COMPARATIVE STUDY ON THE EFFECTIVENESS OF RWH SYSTEM IN DIFFERENT TYPES OF BUILDING

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ABSTRACT

RWH system is a norm practice in village and rural areas. It is done by collecting rainwater from rooftop and stored for domestic usage, such as washing and bathing. Since Malaysia received a stable rainfall throughout the year, the government realized that the RWH system can be used to resolve water shortage issue. Hence, the government provides a suitable guideline toward this issue. This paper will cover the effectiveness of the RWH system in different types of building such as office building, houses, HT Presswork Factory, commercial building, SJK Chung Hua 2 and Bukit Indah Mosque. There are few factors that influenced the effectiveness of the RWH system such as roof area, building function and location of buildings. Another factor that affects effectiveness is the number of, user or employee, size and capacity of the tank and lastly cost of the system. From the study, the most effective RWH system is on office building because the number of employee and demand are small. The capital cost is also considerably low due to the location factor where the office building is located in a rural area but still have a higher percentage of water saving with low capital cost. Contrarily, this system is not economically for the HT Presswork Factory buildings as its installation cost is higher compared to the percentage of water savings.

ABSTRAK

Penuaian air hujan adalah amalan normal di kawasan kampung dan juga luar bandar. Ia dilakukan dengan cara mengumpul air hujan dari bumbung dan disimpan untuk kegunaan harian seperti membasuh dan mandi. Memandangkan Malaysia menerima hujan yang stabil sepanjang tahun, kerajaan menyedari kepentingannya dalam menyelesaikan masalah kekurangan air. Oleh itu, kerajaan menyediakan garis panduan yang sesuai ke arah memperkenalkan sistem ini. Kajian yang dilakukan ini meliputi keberkesanan sistem penuaian air hujan di dalam pelbagai jenis bangunan seperti bangunan pejabat, rumah, kilang, bangunan komersial, sekolah dan masjid. Terdapat beberapa faktor yang mempengaruhi keberkesanan sistem penuaian air hujan seperti keluasan kawasan bumbung, fungsi bangunan dan lokasi bangunan. Faktor lain yang mempengaruhi keberkesanan ialah bilangan pengguna atau pekerja, saiz dan kapasiti tangki dan kos pemasangan sistem. Dari kajian ini, penggunaan sistem penuaian air hujan yang paling berkesan adalah di bangunan pejabat kerana jumlah pekerja dan permintaan terhadap bekalan air adalah kecil. Manakala, kos dan modal permulaan adalah kecil disebabkan oleh faktor lokasi di mana bangunan pejabat ini yang terletak di kawasan luar bandar tetapi masih mempunyai peratusan penjimatan air yang paling tinggi. Selain itu, sistem ini tidak ekonomik digunakan di bangunan kilang kerana kos pemasangannya lebih tinggi berbanding dengan peratusan penjimatan air yang diperolehi

TABLE OF CONTENT

CHAPTER 2 LITERATURE REVIEW

CHAPTER 3 METHODOLOGY

CHAPTER 4 RESULT AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

RWH	Rainwater Harvesting
DID	Department of Drainage and Irrigation
KETTHA	Ministry of Energy, Green Technology and Water
NAHRIM	Natural Hydraulic Research Institute of Malaysia
MHLG	Minister of Housing and Local Government
AGWF	Australian Government Water Fund
PCRWR	Pakistan Council of Research in Water Resources
NWQS	National Water Quality Standard

CHAPTER 1

INTRODUCTION

1.1. INTRODUCTION

Water is an important natural resource for all creatures on this earth. Humans, animals and plants need water in their daily life. Without water, living thing can not only survive, but also the development and the industry could not operate. This is because, water plays a big part in the growth of the community as a permanent water supply system is a prerequisite to building a permanent community. Unlike other raw materials, there are no materials that can replace the water because it cannot be created or replaced. There are a few natural water sources such as rivers, ground water, dew, snow and rain. However, too rapid technological advances today allow re-use of rainwater in an effort to alleviate the shortage of clean water supply and water pollution issues.

One of the most significant current discussions in legal and current philosophy is green building which is based on saving concept such as less energy, supply the best air quality, emit less waste, water and natural resources and can be treated as sustainable development enhanced homeowners' lifestyle. (Alias, Sin & Aziz, 2010). The Malaysian government is also aware of the importance of green building philosophy in maintaining harmony between humans and the environment. This concept has just started through the development of the luxury Green Home at Taman Tun Dr Ismail (TTDI), Ampang, and Selangor, Malaysia. (Andrew, 2007). This is because green buildings can help to reduce

Polluting the environment, while reducing carbon dioxide emissions into the atmosphere. However, environmental friendly house construction requires a very high cost of construction materials which are scarce and the materials normally are imported from abroad. The majority of the homeowners cannot afford to pay extra money to buy green building. Indirectly, this is the reason of demand for it become remains lower and harder to sell compared to conventional houses. (Alias, Sin & Aziz, 2010). High construction cost is the factor that affects the usage of this system and unfortunately makes environmental friendly house concept unappealing among homeowner.

Rainwater Harvesting system (RWH) is an important component in the green building system and plays a key role in environmental impact studies. RWH system can be defined as an action to collect and stored the rainfall that fall onto the catchment area or roof. Athavale (2003) also agreed that the RWH system was described as an action of collecting and storing of natural precipitation and prevent of losses through all hydrological activities. Debates continues about the best strategies for the management of the RWH system mainly for both potable and non potable usage such as drinking and landscaping. Rainwater management may include all the relevant idea to purify the water and also a distribution method, in order to ensure the objective are achievable.

One major theoretical issue that has dominated the field for many years concern that quality of rainwater is poor and none suitable for potable use. However, through scientific studies on the quality of rainwater, it is proven that rainwater has met the water quality standard and safe to be used. Since rainwater is practically economical, government is intensifying the efforts to convince the community to use the RWH system in their daily use. One of the methods used to implement this system is by installing RWH system systems in government buildings such as offices of Department of Drainage and Irrigation (DID) Bera and several other buildings. Natural Hydraulic Research Institute of Malaysia (NAHRIM) through their policies has been conducted pilot projects which consist of the Bukit Indah Mosque, government housing projects and schools that are built with RWH systems.

1.2. BACKGROUND OF STUDY

A valuable and sufficient water resource can be achieved by conducting an appropriate application of RWH system. This is including by applying this RWH system on several types of building. Currently, there are several buildings that already incorporate the RWH system as a main part in their water supply. This research are focused on post construction of building construction which is mainly concentrated on economically aspect such as cost for installation. With the lower capital cost of construction and installing the RWH system, the system should conserve water usage.

As already proven by certain researcher, rainwater is quite safe for domestic and also commercial use. This is can only be achieved if the RWH system appropriately collected and stored in suitable tank. The system design plays an important role in ensuring the success of this system to function correctly. If this can be endured well, it will becoming the best choices for individual and residential houses area. This is so, because this system is said as a source of safe and adequate water lacking specially those located along a coastal area.

Research is carried out by launching a visit to related building such as DID (Bera) office building, HT Presswork Factory and office building of the Energy Commission (Putrajaya). The data also were collected from these three agencies and supported by another agency such as NAHRIM. The study begun with the research concept by determining the overview of RWH in Malaysia, research question and objectives of the study. It was then briefly explained the methodological approach in visualizing the framework which included the research scope, data collection and analysis technique, before summarizing the entire points research outline.

1.3. PROBLEM STATEMENT

RWH system concept is similar to the dam where the water collected is intended to be supplied to the user and prevent flooding. Among the factors that cause the flooding is due to the high rainfall and the river's ability to hold water is not sufficient. DID research shows that rainwater system can reduce the percentage of flash floods that

occurred in Malaysia in addition be used for agricultural purposes and for other non-potable use. Indirectly, government does not have to spend more to do the work of digging trenches to prevent flooding.

Unfortunately, the RWH system looks likely still a new phenomenon in Malaysia. (Othman et al., 2007). So far, this method or RWH system only been applied to government building due to high construction cost. Due to this circumstance, the government takes a various way to promote this system to the community. However, the cost of green building construction is higher than conventional building. This is the main reason why people shy away from this kind of building. Regarding to this problem, the research aims to investigate the effectiveness of using the RWH system in different types of building for long term goal such as the return period and percentage of water savings. This includes the cost saving and also reduce the pollution.

Problems may also arise due to the absence of complete guidelines on the procedure to implement and maintaining RWH systems. This may resulted in term of incompetent of overall RWH system performance. At the same time, if the RWH system is failing to conduct efficiently in good manner, it will contribute to waste of existing resources. Rain water is a good alternative to use as it is free from toxic solution as there is no running water in the basement. Among the types of toxic solvent that may be contained in runoff water is arsenic, cadmium and nitrate can give a negative impact on consumers. The effectiveness of the RWH system depends on several factors such as the number of users, the demand for water supply, the number of toilets, catchment area (roof area), initial capital and also the unit cost of the system. Directly, the percentage of water-saving rate is known.

1.4. RESEARCH OBJECTIVE

The research objectives for this study are as follows

i) To compare the effectiveness of using the RWH system for different types of building.

ii) To determine the factor affecting the effectiveness of the RWH system in each type of building

1.5. SCOPE OF STUDY

This study has been divided into two parts. The first part dealt with collecting data from the parties involved that is from DID Bera as well as for a Double Terrace house, Bukit Indah Mosque, HT Presswork Factory, Diamond building and SJK Chung Hua 2 building. The scope of this research consists of research on the use of rainwater for toilet flushing where comparison was conducted on these types of buildings with different size scales. For buildings with large scale represented by the Diamond Building, Energy Commission and HT Presswork Factory whereas for building small scalar represented by the DID Bera Office building, double terrace house and Bukit Indah Mosque. These buildings were chosen because they are using RWH systems as toilet flushing instead of using treated water.

In addition, this study includes data collection work. Specific required data needs from these buildings are the size and capacity of the rainwater for each tank. Other than that, the way to describe and design the size of the tank also must be known. On the other hand, each consideration factor must be determined so that the tank is sufficient for sustaining the usage if there are any contingencies that occur. In addition, the number of toilets and the number of users is also taken into account to ensure that rain water tank capacity is able to accommodate the number of toilets. The most important data needed in this study is the percentage rate of successful water conservation was recorded where it recorded a reduction in the use of the treated water system. Thus it is proven can reduce costs for the building.

The second part dealt with data analyzing by comparing these types of building. This study are critically traces the comparison of building area, size of user, number of toilets, capacity of rainwater needed and the most important one is financial statement that will be prove whether the study is success or otherwise.

1.6. EXPECTED OUTCOME

At the end of this study, after visiting the building, size of tank would be determined for each type of building and hence the capacity of rainwater needed also can

be identified. Before that, the design concept would be established first where looking for few consideration factors that must be taken into account when designing a rainwater tank. This is important to ensure tank can be sufficient to sustain rainwater. These factors are included rainfall and maximum rainfall received by the state of a place. The other data also can be known as well such as number of user and number of toilets. This data then gathered together for second step which is analyzing the process.

After that, all the data were analyzed by using charts and graph. All the involved buildings data collected were compared on each element. The comparison was based on several factors such as the capacity of employees and visitors, the number of toilets and rain water capacity itself. Variables are very important in determining the operational efficiency of rain water harvesting system on either sufficient or not to accommodate the number of users at a time. Comparisons were also made for the cost of construction of the two buildings.

In addition, the use of the treated water supply system of monthly water bill has also played an important role in proving that the rate of consumption of treated water would be reduced when using RWH systems. Comparing the effectiveness of RWH system implementation in all buildings in term of energy and water saving was also conducted. The result shows up in decreasing of treated water usage for toilet flushing in both buildings.

1.7. SIGNIFICANT OF STUDY

Rainwater has a variety of uses for local residents since tens of years ago. Among its uses is as a source of water supply for drinking water, cooking, washing and so on. However, the increase in air pollution limits the use of rainwater as drinking water for fear of harmful toxins. Therefore, the use of rain water has started to be commercialized in the toilet flushing system for certain buildings. In recent years, there has been an increasing interest in the RWH system concept in Malaysia. However, these rapid changes are having a serious effect on the environmental impact. This study is essential in generating new innovation in green building technology since it has gained more attention in the community nowadays.

From the research, the RWH system can provide many benefits to the government, consumers and also the environment. For consumers, the benefits that can be obtained are that from an economic point of use water-saving way of treated water supply system. This is because the costs incurred were only on the installation of a rainwater reservoir and canal systems into homes. As rain water is free, this will indirectly lead to lower costs allocated to water consumption for each household based on the water meter. The installation of RWH systems technology is simple and its maintenance cost is also cheap. By using the RWH system in toilet flushing in the building would eventually increase the rate of water consumption savings.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

A water shortage has hit the world and many environmental incidents have taken over the future of water security. There are so many countries around the world are facing water shortage problems. A various precaution method is taken to solve this issue. One of the precaution takes is by optimizing and conserving the water usage. Besides that, to overcome this problem natural water sources also can be used such as rainwater. In general, rainwater can be used for both potable and non-potable uses such as drinking, bathing, and cooking and washing for potable use. However, for this purpose, rainwater need to be treated in kill the contaminant but for non-potable use such as toilet flushing and gardening, there is no need to treat the rainwater. (Mohammed, et al., 2008).

Global climate change is a major threat to the entire population of the earth. Due to this, people began to realize the importance of preserving nature. Thus, it generates new creative ideas of green building concept which is being developed throughout the world. This concept highlights environmentally friendly building issues which involve the entire development process, from the planning stage up to over the life cycle of the building. In fact, many benefits can be derived from the concept of green buildings as more economical and also ensured the health of human beings is always satisfying. Ali and Nsairat (2009) demonstrate that, this concept has been successfully catalyzed the development of a more stable and robust system, which was able to maintain a satisfactory level environment as well as long-term economic cost.

Green building has highlighted the usage of some natural resources in the main building to replace existing sources such as solar energy to replace the use of electricity, the RWH system to replace the treated water and the construction of a mini-wetland wastewater treatment area. In summary, Alias, Sin, Aziz (2010) claimed that green building can reduce a large amount of the costs incurred for the construction as well as the source of energy. Indirectly, this is what makes this green building environmentally friendly and creates a conducive to work. With the full utilization of natural resources in a building, operating costs are reduced, increase employee productivity while creating a more comfortable atmosphere.

The global change in weather patterns affecting rainwater distribution to human in in the short term and long term. However, the application of the RWH system has certainly been specified and extra measurement and method toward an integrated sustainable development innovative. The rainfall from the roof is measured and the non-potable water use of the building occupants is also metered. Sizing of the storage tank is influenced by the reliability of the delivered water, roof catchment area and space constraints in the house compound. The economic aspect of the system such as unit cost of rainwater is also determined.

By using the RWH system for current and forthcoming use on-site would definitely help to increase city public water supply and perhaps substituting the non-potable used even as to minimize the possibilities of urban flash floods through reduction of peak storm runoff. There are many activities in our building that can use rainwater. These include flushing and cleaning toilets, washing cars and other vehicles and watering plants. The government is also intensifying their efforts to create awareness about the importance of RWH systems to all levels of society. Various policies and guidelines were first introduced to prove the seriousness of the government in developing the RWH system.

2.2. HISTORY OF RWH SYSTEM

Actually methods of the RWH system have long been practiced by the local people, especially in rural areas. This is so because, at that particular period, the supply

of clean water is scarce to come by. Thus, people take the initiative as a means to make ends meet. The beginning of RWH appearance, it used simple equipment's just to ensure the system works and can be used. Currently, various additives and improvement has been done not only to make sure it works well, but also to ensure the safety and health of consumers not to be disturbed.

In the past, these systems were used merely to fulfill the need for a water supply system, but now, the use of RWH systems have been able to increase the standard of living and socioeconomic. By using RWH system, basically there are four main objectives that can be achieved in term of money saving, water and energy conservation. It also includes environmental quality such as preventing erosion and storm water runoff which eventually increase water quality.

In order to save cost, precaution can be taken by preventing the economic redundancy and also reducing the cost of purchasing treated water from the treatment water plant. In general, the operating cost of RWH system is much lower than the cost to purchase a treated water. By reducing water usage, energy that is needed in pumping system to move water from the treatment plant to the service area can also be lowered too. By doing that, total number of new treatment plants also can be reduced as well. RWH also can help to lower the demand of ground water sources as a result of centralized water systems and wells pull from the water table.

The most important benefit that can be achieved by implementing the RWH system is reducing the erosion. By harvesting rainwater that fall onto the roof, it reduces the flash flood and hence reduces storm water runoff. Directly, less storm water runoff may lower the amount of storm water collection fee of the household and will definitely improve the health, quality and also biodiversity of our watersheds.

2.2.1. Background of RWH

Rapid development gives a negative impact on the population and the environment. Efforts were taken by the government to reduce the impact of this industry without compromising the development of the urban system thus retard economic growth.

Therefore, the government began to introduce green building technology that has been proven to reduce the environmental pollution problems as well as help preserve the environment. The green technology is the use of photovoltaic intended to reduce energy consumption and harvesting rainwater to reduce the demand for potable water and also as a moment of emergency assistance.

One of the technologies applied in green building is the use of rainwater which would be harvested to be used for another purpose. One of the focused on the RWH system is on operating and maintaining the system (Nicholson, et al., 2010). In Malaysia, which generally received an average rainfall of 2400mm per annum, the implementing of RWH system seems possible.

By using RWH, many advantages can be obtained. Gold, Goo, Hair, & Arazan (2010) has proven that rainwater can reduce pollutant discharge into the surface that can also reduce the demand on potable surface other than reduced the gas emission from building itself. According to Philic (2010) in his seminar article also said that RWH system are capable to reduce overall cost for management by providing conservation and mitigation. Concurrently, the RWH system can also reduce the utility bill for drinking water, and contribute to energy efficiency. So that RWH is proven to reduce overall cost such as treatment water cost, energy cost and also reduced the emission to the environment.

It is clear that many researchers have shown that the use of RWH systems is a good initiative in controlling the level of environmental pollution also involves the entire life cycle. Not only focus in Malaysia, but this system has been widely used almost throughout the world. Directly, it proves that people began to realize the importance of using new resources in place of the existing resources in the process of adding the quality of life. So should everyone not only the government, but also the people should welcome this move to also use the rain water harvesting system in their homes.

2.3. ELEMENT IN RWH SYSTEM

The RWH system has been accepted and widely used in many countries of the world such as Canada and the USA. The uses of this system are to overcome with water demand issues that already risen in recent year. In this study, RWH system is the main materials used to commensurate with green building concepts which is rainwater are used in toilet flushing. In order to apply this concept, harvested rainwater will be stored in a water tank after rainwater transported into the tank by the rain barrel. The size of the rain barrels and cisterns hereafter referred to as storage units need to commensurate the area of the roof and the desired water use rate. (Yiping Guo, Brian W. Baetz, 2007). There are six main elements in a RWH system such as catchment area, gutter and downspout, filtration system, storage system, delivery system and treatment.

2.3.1. Catchment Area/ Roof Area

The area of a roof will affect the volume of the harvested rainwater roof which serves as a catchment area. Increasing in area of the roof means more and more volume of rainwater that can be harvested. RWH can be done by installing a rain barrel round the roof. Rain water is then discharged into the tank for storage. The slope of the roof surface should also be considered so that water can be drained quickly into the tank. The slow movement of rain water or too slow can cause rain water to evaporate into the atmosphere. Over time, the volume of rainwater stored in the tank will drop and cause existing volumes are no longer sufficient to accommodate the volume of water needed to spray the entire roof area. Thus, water must be supplied from a service pipe to the storage tank.

The catchment surface of a RWH is the surface which receives rainfall directly (Lung, 2010). Obviously the roof of a building is the first choice for catchment surface. However, the roof surfaces must be chemically inert materials, such as concrete tiles, metal deck or any other material. This is an important consideration in order to avoid adverse effects on water quality.

2.3.2. Gutter/Downspout

The most important element in the RWH system is gutter and downspout. This system includes the down pipes and gutter that carry rainwater from the roof to the tank. Down pipes and gutter may contain any material like polyvinyl chloride (PVC), asbestos or galvanized iron (GI). The main thing that must be good enough is when using the roof of a building as catchment surface, it is important to consider about size of roof, slope of the roofs, and intensity of rainfall. The location and size of the gutter and down pipes should be able to capture all the water at that point. All these items shall be determined to be in line with each other.

Usually, these gutters are manufactured with the correct size to facilitate the flow of water. So that, gutters should are installed with the slope towards the down pipes also the outside face of the gutter are being lower than the inside face to encourage drainage away from the building wall (Fayez, A.A. & Amani, A.S., 2006). As a precaution, the debris and leaves inside the gutter need to be cleaned periodically to prevent it from clogging. In addition, gutters should be made up of chemically inert materials (Texas Water Development Board, 2005). The example of material that are suitable to use is UPVC, galvanized iron. This is important in order to avoid adverse effects on water quality.

2.3.3. Filtration Process

A roof is a main medium in a RWH system that act as a catchment area. Not only collect rainwater, but most of the time, roof collect a certain types of natural waste such as leaves, dust, debris and also insert bodies (Texas Water Development Board, 2005). In order to prevent all this thing from being part of the system, filtration part seems to be very important. Usually, filtration will be located in the down pipe and also rainwater storage. So that, all the waste can be separated and removed before clogging occur. But sometime, the rain gutter needs to be close first in order to prevent waste from being transported along together with rainwater.

2.3.4. Storage

There are suitable methods that are used for calculating rainwater storage such as Hanson L. S., Vogel, Kirshen and Shanahan, (2009) suggested that a variety in Storage Reliability Yield (SRY) is possible to generalize a regression model which is it is capable to determine the storage needed in the RWH system study area. Furthermore, Hanson (2010) also suggests the Storage-Reliability-yield because it is more convenient and rapid method to investigate the potential impact and the amount of storage of RWH system. McMahon, Vogel, Pegram, Peel and Etkin, (2007) said that, storage decides be determined based on annual stream flow by using an algorithm. So, it can conclude that, The Storage Reliability Yield is most suitable method to determine the storage needed for RWH system. Typically, an area of the tank must be sufficient to accommodate the maximum rainfall received by an area. So that people can take full advantage of RWH system.

2.3.5. Delivery System

The delivery system is a system acts to deliver the collected rainwater to water taps for daily use, such as toilet flushing, vehicle washing, garden watering and others (Lung, 2010). Type and location of cistern, conveyance and distribution system are the main consideration in RWH system. In choosing the suitable type of cistern, sizing is the one important factor that must be considered which is the size of the cistern depends on the amount of water to be collected. At the same time, all cisterns should be watertight, durable, and have a clean, smooth interior. The cover also should tightly fit to avoid evaporation (Sehgal, 2005). Cistern also must be located in high point on the roof. However, cistern also can be located above and below ground cisterns. While the conveyance system should be installed one quarter inch wire mesh in a metal frame to prevent debris from entering the system

2.4. OVERVIEW OF RWH SYSTEM IN MALAYSIA

Malaysia is a country located near the equator, where Malaysia receives weather is hot and humid all year round. Through this climate, Salmah & Rafidah (1999) identify