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A Case Study on Application of Rainwater Harvesting System for Different Towns as an Alternative Water Supply

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Abstract: Rainwater Harvesting System (RWHS) is a reliable method used to collect rainwater into the defined catchment area. As water scarcity and flood problem sometimes hit the community, thus this system will act as one of the alternative methods in order to reduce the stated problems. Rainwater that precipitates will not be let to runoff on the ground surface instead we store it for emergency usages. Hence, the objectives of this research are to determine the capacity of rainwater collected through RWHS as an alternative resource for water supply and to analyze the performance of harvested rainwater over water demand for different towns based on existing data. In order to achieve the objectives, some assessments and data extracted from previous research have been done such as rainfall data and water consumption for domestic usage. As a result, this study found that few towns which is Alor Star, Johor Bahru, Klang and Kota Bharu were able to harvest 124 m^3, 154 m^3, 128.4 m^3 and 114 m^3 of water per year respectively while for performance of the system, harvested rainwater were able to contribute 20-30 percent for the domestic water demand. As a conclusion, this method could somehow give positive impact to the water consumers and thus efforts in increasing awareness and give more information on this system must be widen.

Keywords: Rainwater Harvesting, Water Scarcity, Water Supply, Domestic Water Demand

1. Introduction

Our lives, civilization and other development will not be developed properly without the existence of water [1]. Direct and indirectly contribution of water is needed as the factor of production to economic activities including all sectors and areas of global economy [2]. However, it is being threatened more and more by several factors such as human activity and climate change. Thus, many studies have found that water shortage will escalate severely for the upcoming decades and resulting difficulties in food security, environmental sustainability and economic development as well. Besides, the increasing number in human population will increase the water demand to fulfil their lives' need.

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Thus, RWHS will be introduced in this research in order to aid the consumers in saving water as for emergency preparation and alternative resource for water supply. RWHS is a proposed method to overcome water problem such as water deterioration, drought season and flood from happening. It is a system where rainwater is being collected by appropriate ways instead of letting the rainwater to runoff freely onto the ground. Most of the countries with inadequate water supply has starting to have awareness on this alternative method. This method is presented as a sustainable policy to be included especially for urban water cycle management [3].

In order to overcome water difficulties, thus this research have been conducted by determining the capacity of rainwater collected through RWHS as an alternative water supply and analyzed the performance of harvested rainwater over domestic water demand for different towns based on existing data. Selected towns for this research were based on coastal regions in Malaysia which are Alor Star, Johor Bahru, Klang and Kota Bharu residential areas. It has been chosen due to the differences in the rainfall event as the latitude and longitude of these four states are a bit further to one another.

2. Literature Review

2.1 Water Supply Issues

Recently, both rural and urban areas have experienced water supply scarcity due to several problems that occurred within the regions. Severe problem named water scarcity has threatened numerous numbers of families and more than 1 billion mankind all over the world with insufficient good quality of water supply and unsafe drinking water [4]. From previous study, it was stated that Malaysia is the country which undergo climate change and uttermost weather at certain time due to the El Nino Southern Oscillation (ENSO) phenomenon and Indian Ocean Dipole (IOD). Addition to this, Malaysia's rainfalls are dispersed unequally thus causes some regions to be dry or drought while other regions experience flood [5]. Hence, RWHS is one of the methods that can be applied in order to overcome water problems and could be able to support the water demand.

2.2 Application of RWHS

Most consumers use the harvested rainwater for the purposes of toilet flushing, car washing and lawn irrigation. RWHS have been implemented widely over the world such as in Greek, Roman, Indian and Middle Eastern [6]. In Malaysia, mathematical model has been introduced in Nusajaya, Johor Bahru for maximizing the water collection and water consumption supply for RWHS by using daily rainfall data analysis [7].

2.3 Rainfall Event

Hydrological cycles are expected to experience great changes and cause global shifts in rainfall distributions patterns and thus the frequency and severity of extreme events will arise. For every region, the rainwater capacity, annual weather, and temperature varies among each other. It depends on the monsoon area and climate changes of the particular locations [8]. Rainfall distribution in Malaysia has increased as the climate changes. According to the research, the rainfall time series can be classified as stationary and non-stationary based on the amount of rainfall distribution over period of time. Stationary means the means and variances of rainfall reading are significantly same and do not has any critical changes while non-stationary in time series means there are changes in the terms of the variances and the means of rainfall distribution [9].

2.3 Advantages of RWHS

RWHS has its own advantages to many sectors such as agriculture, domestic and industrial. The advantages are as stated below:

- Able to minimize potable water demands on the centralized water supply system they provided [6].

- Water-related energy consumption literally could be controlled and the greenhouse gas emissions could be reduced if in situ harvested rainwater is being applied in order to satisfy non-potable water demands [6].
- Control the flooding event, improve the quality of storm water and reduce influx of storm water into sewer system [10].
- Decrease the annual water bill by the consumers from local water authorities as rainwater acts as additional source of water supply [3].
- Users are enabled to conserve the water when applying this RWHS [11].

2.4 Disadvantages of RWHS

In few circumstances, RWHS might cause few effects as below.

- The water might contain chemical from roof seepage. This is due to the roof coverings or tiles will excrete chemicals and thus flow it to the discharge point and it is harmful to be used for life sustainability [12].
- Water quality of this harvested rainwater will be affected or disturbed by air pollution, animal droppings, insects or other organic matter. Thus, for the sake of the safeness, this system required regular and right maintenance such as, consistent inspection, cleaning and occasional repairs [12].
- The harvested rainwater might consist of metal due to the roof materials such as lead and iron. These elements will react with dissolved sulfide in the formation of sulfide precipitations which will result in pipe corrosion [10].
- Rainwater might also consist of acid rain which resulting in reduction of pH levels especially in the regions characterized by high vehicle traffic volumes, industrial and high density of residential development [11].

3. Methodology

These are the crucial steps to be planned in order to achieve the objectives and aims of this writing. Research methodology is a way to enable the researcher to define their solutions to the problem statement. The steps of this study will be recognized in details which will include the data collecting methods, resources of data and few analyzations in other to determine the capacity of rainwater collected and also the performance of the system upon implemented as alternative source of water supply.

3.1 Data Collection

Data and information for this research has been determined by using previous research and existing data. Required data are as follows:

- Number of populations at those particular areas
- Average number of residents per house
- Demand or average consumption of water per person
- Range of uses (indoor and outdoor)
- Rainfall data for the selected towns
- Tank size that equivalents to the catchment area

The information above have been obtained from few sources which include Department of Statistics Malaysia (DOSM), Manual Saliran Mesra Alam (MSMA) 2nd Edition, Department of Irrigation and Drainage (DID).

3.2 Data Analyzing

The data and information that has been obtained from related resources has been specified to residential areas in Malaysia. Selected towns that will be analyzed consist of Alor Star, Johor Bahru, Klang and Kota Bharu which are Northern region, Southern region, West Coast and East Coast respectively.

As mentioned earlier, the number of populations at those particular areas were obtained from DOSM by referring to the statistics of residents in 2010. As all the data such as total number of living quarters, populations and households collected, then the average of households will be calculated by using the formula provided by DOSM. By referring to the standards and manual from MSMA, the water demand and the volume of harvested rainwater then being calculated based on rainfall data and tank size that equivalents to the catchment areas.

4. Results and Discussion

The data obtained in order to achieve the objectives of this study are average size of households, rooftop catchment area, rainwater demand for domestic application, rainfall yielding capacity and average annual rainwater yield.

All of the towns are listed under urban areas as the number of populations exceed 10,000. The average number of residents per house was to be counted as 5 persons while the estimated average area of house of 900 sq ft are based on Malaysia standards of house development in residential areas for an affordable and reasonable cost where it usually be equipped with 3 bedrooms and 2 toilets per house. Hence, common rooftop catchment area of 120 m^2 as shown in table below.

Table 1: Average size of households per towns

No.	Name of Towns	Total Number of Living Quarters	Total Number of Populations	Total Number of Households	Average Size of Households	Rooftop Catchment Area (m^3)
1	Alor Star	93,190	357,176	86,456	5	120
2	Johor Bahru	389,145	1,334,188	331,221	5	120
3	Klang	234,039	842,146	201,994	5	120
4	Kota Bharu	105,803	468,438	96,278	5	120

Table below shows the average annual rainwater yield among towns in Malaysia which have been extracted from MSMA 2nd Edition. It had been considered for volume of 1 m^3 tank size and 100 m^2 catchment area regardless Malaysia standards.

Table 2: Average Annual Rainwater Yield (AARY)

No.	Name of Towns	Average Annual Rainwater Yield (m^3)
1	Alor Star	103
2	Johor Bahru	128
3	Klang	107
4	Kota Bharu	95

The capacity of harvested rainwater for specified tank storage among four towns have been listed in the table below regarding to the AARY for each of the towns.

Table 3: Capacity of harvested rainwater

No.	Name of Towns	Capacity of Harvested Rainwater (m^3)
1	Alor Star	124
2	Johor Bahru	154
3	Klang	128.4
4	Kota Bharu	114

Table below shows the comparison of rainwater performance over domestic water demand among towns which have been calculated based on the water demand for domestic application and water per consumption per capita.

Table 4: Comparison of rainwater performance over domestic water demand among towns

No.	Name of Towns	Percentage of Rainwater Performance (%)
1	Alor Star	24.70
2	Johor Bahru	30.68
3	Klang	25.58
4	Kota Bharu	22.71

From the results, it was found that different rainfall intensity of residential areas among towns will contribute different capacity of rainwater for each of them. Although the size of the tanks for all residential areas in these four towns are same, however there are differences in volume of water yield and percentage of harvested rainwater over domestic water demand. From the result, it shows that Johor Bahru collects the highest amount of water (154 m^3) while the amount for Kota Bharu is the lowest (114 m^3). Thus, the percentage of harvested rainwater that are able to contribute to domestic water demand also shows the same trend as the capacity of water collected. From the previous data, rainfall precipitation of Johor Bahru is the largest value compared to other towns which means that the higher the rainfall precipitation, the higher the capacity of water collected and the greater harvested rainwater could contribute to domestic water demand.

5. Conclusion

As a conclusion, the objectives of this study were achieved. Capacity and the performance of rainwater that could support domestic water demand have been analyzed for four selected towns in Malaysia. It shows that this system could somehow contribute positive impact to the consumers especially during emergency condition and also could reduce the usage of water pipes.

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