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Potential of rainwater harvesting in wilayah persekutuan Malaysia

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Abstract

Although Malaysia has abundant water resources, some parts of Malaysia are currently facing water shortage problems. The increasing demand for water has sparked initiatives to seek alternative water supplies. Rainwater harvesting has been proposed by governments as part of the solution to alleviate the problem of water scarcity. Literature related to rainwater harvesting is available from a variety of sources. In this study, rainfall was analysed as a crucial factor affecting RWHS efficiency, rainwater potential at different zones for residential, industrial, and commercial. In addition, the study evaluated the rainwater quality that obtain fresh rainfall and roof rainfall. Furthermore, potential of treatment technology for rainwater was suggested to optimate rainwater harvesting.

Keyword :
Rainwater harvesting, rainwater technology, RWH system, rainwater assessing, rainwater quality

1 Introduction

Climate change and population growth have resulted in serious water shortages in certain locations. Approximately 90% of the world's water supplies were drawn from forest catchments in arid and semi-arid mountainous areas (Zheng et al., 2018). As a result, researchers are increasingly suggesting rainwater collection employing ecosystem vegetation, the creation of rainwater collection systems, and a rise in the production of accessible water resources (Cosgrove and Loucks, 2015).

Water crises, on the other hand, have become more prevalent as forest acreage and density have increased, owing mostly to the loss of precipitation through canopy interception and evapotranspiration (Zhang et al., 2019). Water supply is limited throughout the summer due to substantial changes in precipitation and poor storage capabilities, even in places with high rainfall and low evapotranspiration (Kuppel et al., 2015). In semi-arid environments, rainfall, topography, soil type, land use, runoff characteristics, and other variables have been utilized to identify possible RWH sites (Matomela et al., 2020). One of the most essential elements for predicting possible RWH locations is runoff (Rajasekhar et al., 2020).

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However, high surface runoff can lead to soil erosion, the loss of soil and its nutrients, and the formation of a layer of mud at the bottom of reservoirs, thereby degrading water quality (Lal, 2015). Therefore, in areas at high risk of soil erosion, vegetation is often used to increase infiltration, reduce surface runoff, and enhance the ecosystem's ability to store and retain rainwater rather than release and absorb surface runoff (Zhang et al., 2015). Protective or engineering measures are required. In Malaysia, in 1999 the government started promoting the use of the RWH system (Lee et al., 2016). Thus, we present rainfall analysis as a crucial factor affecting RWHS efficiency, rainwater potential at different zones for residential, industrial, and commercial. In addition, the study evaluated the rainwater quality that obtain fresh rainfall and roof rainfall. Furthermore, potential of treatment technology for rainwater was suggested to optimate rainwater harvesting.

2 Rainfall characteristics

Rainfall characteristic is a crucial factor affecting the efficiency of RWHS. Several investigations have been carried out to verify the effects of rainfall pattern on RWHS performance (Hajani and Rahman, 2014; Palla et al., 2012; Rahman et al., 2012). In the current work, yearly rainfall data from 1975 to 2008 obtained from the JPS Wilayah Persekutuan rainfall station are shown in Figure 1. It is useful to note that the average and maximum yearly rainfall were 2588 mm and 3612 mm, respectively.

It is obvious that the annual rainfall at JPS Wilayah Persekutuan rainfall station ranges from 1763 to 3612 mm. The maximum and minimum annual rainfall occurred in 2005 and 2008, respectively. Globally, the rainfall is considered very high with only three observation years recorded annual rainfall below 2000 mm (1986, 1990, and 2005). It is evidenced in scholarly literature that the annual rainfall in Malaysia varies over time and space. Rainfall in the

Peninsular Malaysia can be categorized into five regions, namely, the northwest, west, east, southwest, and central (Suhaila and Yusop, 2017). It was observed from the study that two rainfall peaks were observed for the northwest, west, southwest, and central regions where the second peak was larger than the first peak.

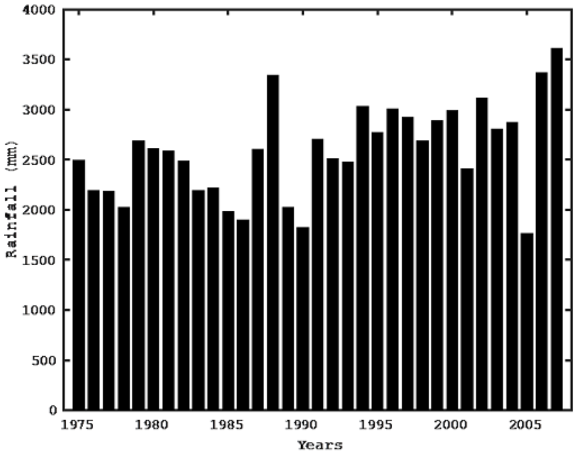

Figure 1 Annual rainfall at JPS Wilayah Persekutuan rainfall station from 1975-2008

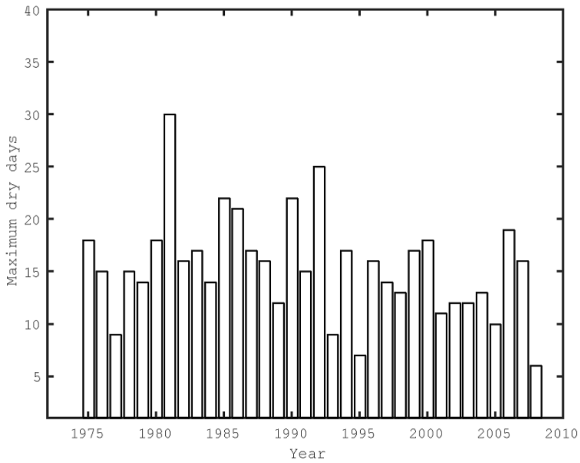

Figure 2 Annual maximum dry days at JPS Wilayah Persekutuan rainfall station from 1975-2008

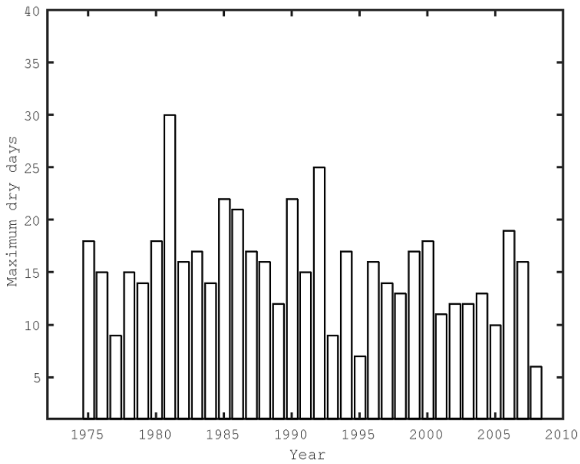

Figure 3 Continuous dry days at JPS Wilayah Persekutuan rainfall station from 1975-2008

As observed in Figure 1, it shows consistent rainfall pattern throughout the year. Thus, the region is highly promising for the implementation of RWHS. It is also supported by this study as presented in Figure 2 that the number of maximum dry days ranges from 6 to 30 days with an average of 15 days and very high annual rainfall. Successful implementation of RWHS has been reported in countries with high annual rainfall such as in Singapore (Alexander et al., 2006) and in Indonesia (As-syakur et al., 2013).

The number of continuous dry days is useful in designing the storage tank for the commercial building. Figure 3 shows the number of continous dry days at JPS Wilayah Persekutuan rainfall station from 1975 to 2008. The results suggest that one day dry period shows the highest frequency with 1062 events, which is about 8.6% of the total observation day (12388 days).

In the context for RWHS, rainfall is the most important parameter affecting the performance of the system. For instance, the water-savings potential, reliability of water supply, financial benefits, and government subsidy for RWHS at ten different locations in Greater Sydney, Australia, were investigated by Rahman et al. (2012). Their study confirmed that the average annual water-saving of the system was strongly correlated with the average annual rainfall. Moreover, the reliability of RWHS was also evaluated for different locations in Australia during the wettest and driest periods (Hajani and Rahman, 2014). It was found from the study that the reliability was 99% in the wettest year when the system was implemented for toilet and laundry use only while for the driest year, the reliability reduced to 69%. In addition, when the proposed system was implemented for irrigation use only, the reliabilities were 96% and 66% for the wettest and driest years, respectively. Moreover, when system was implemented for combined uses such as irrigation, toilet, and laundry, the reliabilities were 95% and 63% during the wettest and driest years, respectively.

3 Rainwater harvesting potential

Table 1 lists the total collecting area at all selected zones for different buildings, namely, residential, industrial, and commercial. This study showed that the collecting area (roof area) varied depending on the building types and zones. By proposing the roof coefficient is 0.9, the rainwater harvesting potential for the residential building is listed in Table 1. It is then proposed the correction factor for all buildings by 52%, 71%, and 60% for residential, industrial, and commercial buildings, respectively. It is noted that the estimated rainwater harvesting potential is the potential by assuming the rainwater collector (roof) can be all connected at each considered location (Abdulla, 2020).

Table 1 Rainwater harvesting potential for different zones for residential, industrial, and commercial

Zone	Building type	Roof area (m2)	Annual rainfall (m)	Rainwater potential (Mm3)	Corrected rainwater potential (Mm3)
1	Residential	8076743.85	2.58	20.84	10.84
	Industrial	1128356.40	2.58	2.91	2.07
	Commercial	6710670.36	2.58	17.31	10.39
2	Residential	5603924.25	2.58	14.46	7.52
	Industrial	4654929.76	2.58	12.01	8.53
	Commercial	12449945.81	2.58	32.12	19.27
3	Residential	15114463.61	.58	39.00	20.28
	Industrial	968926.71	2.58	2.50	1.77
	Commercial	14348452.40	2.58	37.02	22.21
4	Residential	6292526.02	2.58	16.23	8.44
	Industrial	5206762.00	2.58	13.43	9.54
	Commercial	14735591.56	2.58	38.02	22.81
5	Residential	8273549.36	2.58	21.35	11.10
	Industrial	2123316.86	2.58	5.48	3.89
	Commercial	13824172.34	2.58	35.67	21.40
6	Residential	15023321.93	2.58	38.76	20.16
	Industrial	1479855.29	2.58	3.82	2.71
	Commercial	6954826.75	2.58	17.94	10.77

4 Rainwater quality

The quality of the harvested rainwater not only depends on the characteristics of the considered area, the weather conditions, the proximity to pollution sources, management of the water but also the type of the catchment area (Sánchez et al., 2015). Table 2 lists the rainwater quality in Malaysia and some parameters come from the rainfall study observed at nearest location at Setapak (Khoon et al., 2011). In addition, legend b denotes the additional rainwater quality measured at humid tropic center (HTC) (Sultana et al., 2016). In some parameters, the quality of rainwater is in the range of the allowable limit permitted for raw water standard (Islam et al., 2019). For example, pH for the rainwater ranges from 5.2 to 7.5, which is in the range of the allowable limit permitted for raw water standard (5.5-9.0). In addition, the sulphate concentration is far below the allowable limit for raw water standard, which is less than 250 mg/L. Table 2. Rainwater quality in Malaysia and some parameters come from the rainfall observed at near the center Zone 2 Potential low-cost treatment technology for rainwater harvesting

Table 2 Rainwater quality in Malaysia and some parameters come from the rainfall observed at near the center Zone 2

Parameters	Rainwater	Roof water
pH	5.6	5.2 to 7.5b
Dissolved oxygen (mg/L)	-	3.6 to 6.5b
EC (uS/cm)	21.53	48 to 116b
Turbidity (NTU)	1.75	2.80
TSS (mg/L)	2.593	3.033
Sulphate (mg/L)	0.39 to 3.26	2.000
Phosphate(mg/L)	0.033	0.187
Chloride (mg/L)	0.700	0.757
Ammoniacal-N (mg/L)	0.41 to 3.32	0.575
Nitrate-N(mg/L)	0.267	0.567
Total Organic Carbon (mg/L)	19.8	11.3
Cu (mg/L)	0.013	0.014
Pb (mg/L)	0.080	0.085
Fe (mg/L)	0.059	0.085

5 Potential low-cost treatment technology for rainwater harvesting

Rainwater harvesting must undergo several steps of treatment including sterilization and filtration before it can be used for potable consumption as shown in Figure 4. Two primary treatment options are available for rainwater such as chlorine and ultraviolet light treatments. Chlorine (CL) is an excellent solution when large amounts of water will be stored for later use (Zhang et al., 2020). Alternatively, ultraviolet light (UV) treatment is commonly used when smaller amounts of stored water are required for a shorter time period and is a great alternative for industrial applications sensitive to corrosion from chlorine exposure (Chen et al., 2022).

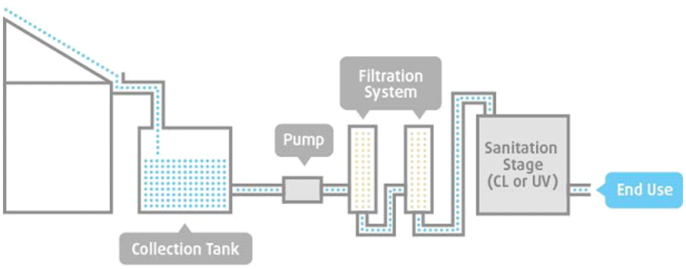

Figure 4 Treatment technology design for rainwater harvesting

The use of chlorine to water is a simple and effective procedure to sterilize filtered rainwater. The Victorian Government Department of Human Services recommends the use of chlorine dosage and concentration as follows. The initial dosage to be a minimum of 5 mg of chlorine per litre of rainwater to be treated. After 30 mins, a concentration of 0.5 mg of chlorine for every 1 litre of rainwater must be maintained. For example, for a 50L tank of rainwater, a total of 250 mg of chlorine is needed for sterilization. Then 30 minutes after the initial dose, the concentration must be maintained at 25 mg of chlorine per litre.

Alternatively, ultraviolet light is also potential method of sterilization. It works by disrupting and damaging pathogens' cells. UV light sterilization requires rainwater to be virtually free of any large sediment. If the rainwater has not been filtered, 'shadowing' can occur, whereby sediment blocks the UV light rays, reducing the effectiveness of sterilization.

6 Conclusion

The implementation of rainwater harvesting in the proposed zone is promising because of high rainfall intensity, relatively available throughout the year with average maximum dry day of 15 d, and relatively free from contaminants. In the proposed zone, residential area provides the highest rainwater harvesting potential and followed by industrial, and commercial. In this study, rainfall analysis was presented as a crucial factor affecting RWHS efficiency, rainwater potential at different zones for residential, industrial, and commercial. In addition, the study evaluated the rainwater quality that obtain fresh rainfall and roof rainfall. Furthermore, simple and low-cost treatment technology such as chlorine and ultraviolet light treatments are promising for rainwater harvesting before it uses for portable consumptions.

Declaration of competing interest

The authors declare no known competing interests that could have influenced the work reported in this paper.

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