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Original Research Article

Water quality of roof runoff in sub-urban Malaysia

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Abstract

The purpose of this study is to investigate the composition of roof runoff pollutants and to determine the relationships between pollutants and seasons (wet and dry) from two commonly used roof types in Jengka, Pahang. Rainwater was collected from galvanized and ceramic roof runoff. The sampling regime was done in two different seasons; between November 2014- February 2015 (wet) and March-May 2015 (dry). A total of 60 rainwater samples were analysed for temperature, pH, EC, DO and selected heavy metals (Fe and Zn). Zn and Fe are higher in galvanized roof (Zn: 0.05 ± 0.11 mg/L, Fe: 0.06 ± 0.13 mg/L) compare to those in ceramic roof (Zn: 0.001 ± 0.00 mg/L, Fe: 0.01 ± 0.02 mg/L). There were no significant differences of metal elements found between wet and dry seasons (p>0.05). The concentrations of metal elements in the harvested rainwater are lower than the permitted heavy metal concentration limitation if to be used as drinking water. All water quality parameters from galvanized and ceramic roofs runoff in this study matched the drinking water guidelines proposed by the Ministry of Health, Malaysia and safe to be used for the domestic purposes.

Keywords: Harvested rainwater, Water quality, Heavy metal, Runoff water

Introduction

The water shortage issue in Malaysia does not only influence the development of the country but also affect the residents' life. Due to the increasing of the water demands in Malaysia, the government introduced the rainwater harvesting system in 1998 and launched the "Guidelines for Installing a Rainwater Collection and Utilization system" in 1999 (Che-Ani et al., 2009).

The chemical, physical and biological parameters of rainwater need to be considered ensuring the safe water sources. The concentration of roof runoff pollutants maybe higher in dry seasons than those in wet seasons. This could be related to the accumulation of pollutants on the roof surface during the dry season (Zhang et al., 2014). Previous studies reported that the catchment area i.e. roof is considered as a non-point source of water pollution (Sulaiman et al., 2009; Sulaiman et al., 2016; Wang et al., 2017). Thus, different roofing material and different seasons may lead to accumulation of different pollutants in the roof runoff.

University Teknologi MARA (UiTM) Cawangan Pahang in Jengka, Pahang has been chosen as the sampling site because water supply shortage continuously occurs within this area. Therefore, it is vital for an alternative source of water supply. This study aims to analyse the physical and chemical compositions of roof runoff and to compare them with the drinking water quality standard set by Ministry of Health Malaysia (MMOH, 2010). The relationship between the runoff composition and different seasons will also be determined.

Materials and Methods

Site description

Jengka is a sub-urban area located in Pahang state in the east coast region of Peninsular Malaysia. It has a humid tropical climate with an annual mean temperature of 21 °C to 32 °C (Wong et al., 2009). It has two different seasons which are wet and dry seasons.

Sample collection and analysis

A total of 60 rainwater samples were collected in two different seasons (dry and wet) on monthly basis from October 2014 to May 2015. Samples were collected from two types of roofs; namely, galvanized and ceramic type. Rainwater sample also collected as the control sample. For in situ parameters, the collected rainwater was analysed directly within 24 hours using multiparameter YSI meter (YSI 556 MPH). For metal analysis, the water sample was determined by Atomic Absorption Spectroscopy (AAS).

Statistical Analyses

In this study, statistical analyses were performed using IBM SPSS Statistic 21. One-way analysis of variance (ANOVA) and Bivariate correlation were applied. The one-way ANOVA was employed to determine any presence of significant differences between the parameters of water quality and seasons as well as between water quality parameter and roof types. The Bivariate correlation was applied to understand the relationships between parameters.

Results

pH, EC, DO, and Temperature

The analysis of the pH variation over the catchment area using one-way ANOVA showed significant differences with $p<0.05$ (Table 1). The harvested rainwater from ceramic roof showed the highest pH values (7.08 ± 0.32) compare to the galvanized roof (6.70 ± 0.32) and control (6.71 ± 0.29). The runoff pH also showed significant differences between seasons (Table 2). The mean of pH from wet and dry seasons were 6.73 ± 0.29 and 6.94 ± 0.38, respectively. The range of pH value was higher in the ceramic roof runoff (6.58-7.73). The pH of galvanized roof runoff was similar with the pH for control water samples. Dry season showed higher pH value than the wet season. Yet, all pH values are still in the range of permitted level (6.50-9.00).

The mean of conductivity values (EC) for roof types and seasons were similar (Table 1 and Table 2) with galvanized roof (0.01 ± 0.01 µS/cm), ceramic roof (0.02 ± 0.02 µS/cm), control (0.01 ± 0.01 µS/cm), wet season (0.01± 0.01 µS/cm) and dry season (0.02 ± 0.02 µS/cm). The range of EC value in the ceramic roof (0.009-0.074 µS/cm) runoff water samples were higher than in galvanized roof (0.001-0.031 µS/cm). The one-way ANOVA analysis showed significant differences for both types of roof and seasons.

Means of dissolved oxygen (DO) concentration from galvanized roof (0.25 ± 0.21 mg/L), ceramic roof (0.26 ± 0.23 mg/L) and control (0.24 ± 0.018 mg/L) are as shown in Table 1. DO level for wet seasons (0.10 ± 0.05 mg/L) and dry seasons (0.40 ± 0.19 mg/L) are presented in Table 2. The ANOVA showed there were no significant differences for DO in different types of roof. However, there was a significant difference between two seasons, as DO value in dry season is higher than the value in wet season.

The mean temperatures of runoff water were as follows; galvanized roof (25.47 ± 1.55 ºC), ceramic roof (25.58 ± 1.34 ºC) and control (25.47 ± 1.47 ºC). The mean temperature of roof runoff in the wet season (25.45 ± 1.37 ºC) and dry season (25.56 ± 1.51 ºC) seems not much changed. The ANOVA analysis for roof runoff temperature showed no significant difference. Nevertheless, the mean temperature values of water sample were slightly higher during the dry season compare to the wet season.

Correlations analyses between water quality parameters are displayed in Table 3. Moderate relations of pH-EC (r=0.351), pH-temperature (r=0.407) and pH-DO (r=0.462) were identified. These moderate correlations suggesting pH value may have been influenced by temperature, EC and DO. A weak link revealed for Zn-EC (r=0.288). There was no correlation observed for other pairs of parameters.

Table 1: ANOVA analysis for parameters in different roof type

	Sample	Mean ± SD	*p*-value
pH	C	6.71 ± 0.29	0.00*
	GR	6.70 ± 0.32	
	CR	7.08 ± 0.32	
EC (µS/cm)	C	0.01 ± 0.01	0.00*
	GR	0.01 ± 0.01	
	CR	0.02 ± 0.02	
Temp. (º C)	C	25.47± 1.47	0.96
	GR	25.47± 1.55	
	CR	25.58± 1.34	
DO (mg/L)	C	0.24 ± 0.18	0.96
	GR	0.25 ± 0.21	
	CR	0.26 ± 0.23	
Fe (mg/L)	C	0.02 ± 0.09	0.17
	GR	0.06 ± 0.13	
	CR	0.01 ± 0.02	
Zn (mg/l)	C	0.001± 0.00	0.04*
	GR	0.05 ± 0.11	
	CR	0.001± 0.00	

*$p<0.05$, C-Control, CR- Ceramic roof, GR-Galvanize roof, SD-standard deviation

Table 2: ANOVA analysis for parameters in different seasons

	Seasons	Mean ± SD	*p*-value
pH	Wet	6.73 ± 0.29	0.02*
	Dry	6.94 ± 0.38	
EC (µS/cm)	Wet	0.01 ± 0.01	0.00*
	Dry	0.02 ± 0.02	
Temp. (º C)	Wet	25.45 ± 1.37	0.77
	Dry	25.56 ± 1.51	
DO (mg/L)	Wet	0.10 ± 0.05	0.00*
	Dry	0.40 ± 0.19	
Fe (mg/L)	Wet	0.04 ± 0.08	0.68
	Dry	0.03 ± 0.10	
Zn (mg/L)	Wet	0.002 ± 0.005	0.103
	Dry	0.03±0.09	

SD-standard deviation

Table 3: Correlations matrix between parameter

	pH	EC	Temp.	DO	Fe	Zn
pH	1	**0.351****	**0.407****	**0.462****	-0.049	0.029
EC		1	-0.035	0.219	-0.206	**0.288***
Temp.			1	0.105	0.057	-0.191
Do				1	0.124	0.026
Fe					1	-0.059
Zn						1

** $p<0.01$, * $p<0.05$

Heavy metals

Table 1 showed the existence of Fe and Zn in roof runoff samples. The concentration of Fe and Zn were higher in galvanized roof compare to those in the ceramic roof. The analysis of selected heavy metal over different catchment areas using ANOVA showed that there were no significant differences for Fe. However, significant differences were determined for Zn. Both Fe and Zn showed insignificant differences between seasons. The concentration of Fe was slightly higher during the wet season than in the dry season. Nevertheless, the concentrations of Fe and Zn in roof runoff samples were within the range of permitted value in drinking water guidelines set by the Ministry of Health, Malaysia.

Discussion

Both runoff water samples from ceramic and galvanized roof were found relatively clean because there were no significant human activities in the sampling area. Hence, the sampling area in this study was chosen far from the main road and trees to reduce the possibility of leaves, and other pollutants affecting the roof runoff water quality. Two main issues influenced the roof runoff quality; meteorological factors and roofing material. Meteorological parameters include the atmospheric deposition (dry or wet seasons), temperature, pH, and atmospheric compositions while roofing material factors include the types, age and slope of roof used. All these parameters were considered during the analysis.

Previous studies found that seasons affecting the harvested rainwater quality (Gwenzi et al., 2015). Nevertheless, this study found that appearance of different seasons did not affect the concentration of Zn in the collected roof runoff samples. However, the concentration of Fe was slightly higher during the wet season which contradicts with most of the previous findings by Farreny et al. (2011) and Zhang et al. (2014).

The seasons also affect the values of pH, EC and DO. These three parameters' values were higher during dry season than those in the wet season. Although there were differences in concentration of the parameters, the readings fit well with the drinking water guidelines permitted by the Ministry of Health, Malaysia.

The seasonal trends in water quality parameters have implication for the treatment and utilization of roof runoff. In this study, the mean concentration for most of the water quality parameters in the wet season was

lower than those in the dry season, except for Fe concentration. Perhaps the high volume of rainwater dilutes pollutants from the surface of the roof, especially in the wet season. The higher the volume of rainfall indicates the lesser amount of pollutant level in runoff samples (Huston et al., 2009; Razzaghmanesh et al., 2014). Thus, the roof runoff in rainy season would be cleaner than those in the dry season. Therefore, it is beneficial to harvest and utilize rainwater during the wet season.

Conclusion

The roof runoff quality from two types of roofing material in Jengka Pahang was examined to determine the suitability for domestic purposes in term of pH, EC, DO, temperature, Fe and Zn. The ceramic roof was found to be the most suitable for rainwater collection due to the lowest concentration of Fe and Zn. Even though other parameters (pH, EC, DO and temperature) were slightly higher in ceramic roof runoff, but maximum value for each parameter was still in the range of permitted value by the drinking water guidelines. There were no significant differences of Fe and Zn between the seasons. All water quality parameter from galvanized and ceramic roofs runoff in this study were below the guidelines value set by the Ministry of Health, Malaysia and therefore, safe to be used. Nonetheless, more analyses such as toxic metal composition (e.g. Pb, As, and Cd) as well as biological parameter (e.g. *E. Coli* sp.) in the roof runoff are crucial to be considered in maintaining the clean and safe level of alternative water source.

Ethical Considerations

The research was approved by Human Research Ethic Committee (HREC) UPM SERDANG with FPSK (Exp15) P060.

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