Water Runoff Quality of Green Roof using Natural Fibres and Recycle Waste Material

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ABSTRACT: This paper investigates the water quality characteristics of green roofs runoff. Parameter included are pH value, total suspended solid (TSS), turbidity and chemical oxygen demand. The data were collected from nine different test bed under simulated rainfall. Three types of recycled waste are selected for each test bed which is rubber crumbs, palm oil shell, and polyfoam. Natural fibres as the filter layer in green roofs are placed on top of the drainage layer. Natural fibres chosen are coconut fibre, palm oil fibre and sugarcanes fibres. Another test bed with waterproofing layer as a control. From the results obtained shows that rubber crumbs are suitable as a drainage layer and, palm oil fibre or coconut fibre are suitable for filter layer of green roofs. A green roofs should be able to neutralised acid rain by stabilizing the pH, reduce the turbidity, total suspended solid (TSS) and chemical oxygen demand (COD).

KEYWORDS: Green roof; Water quality; Simulated rainfall; Drainage layer; Filter layer

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INTRODUCTION

In Malaysia, sustainable issues have become crucial to reduce global warming effect and mitigate urban heat island. Green roof is best management practice for urban stormwater quantity management. Due to some sustainable practices, a recycled waste material for a green roof is introduced as a drainage layer in a green roof system (Asman *et al.,* 2016). However, the system for green roof can be considered as a relatively new concept in Malaysia although it has been implemented widely in the developed countries. More research is required on determining the impacts of green roofs on the stormwater quality. Research by Alsup *et al*. (2010) and Voyde *et al.* (2010) mention that one of the important strategies in sustainable urban drainage systems (SUDS) and Water Sensitive Urban Design (WUSD) systems is the source control of runoff to improve the quality and also to reduce the quantity.

According to Chow *et al.* (2016) in their research mention that green roofs can produce many benefits. The green roof layer for substrate is in the range of 50mm to 150mm and 40mm for drainage layer. Research on using recycled materials utilized for a drainage layer in a green roof are done by some researcher due to some sustainable practices to be applied in a green roof's design (Asman *et al.,* 2015). Several research using rubber crumbs as a drainage layer by focusing on thermal reduction and hydrological performance (Perez *et al*., 2012 & Rincon *et al.* 2014). This recycled waste material can contribute to reducing waste materials production thus lessen the use of raw materials. Shahid *et al.* (2014) also in their research mention that palm oil clinker can be used as the drainage layer because it has an excellent ability to drain the excess water while ensuring not affecting the plant development.

Several studies have investigated the stormwater runoff quality, for example, a study by Beecham & Razzaghmanesh (2015) found that both vegetated and non-vegetated system acted as pollutant sources. Table 1 shows the range of water quality on stormwater, green roof and non-

vegetated roofs. The aim of this paper is to investigate the usage of natural fibres (filter layer) and recycled waste materials (drainage layer) on stormwater runoff quality of green roofs.

Table 1. Runoff water quality (Beecham & Razzaghmanesh, 2015).

Water quality parameter	Stormwater	Green roof (organic mix)	Non-vegetated roof
pH value	7.45-7.55	5.65-8.22	4.5-7.55
Total dissolve solid(mg/L)	2.4-5.9	8.1-220	5.4-380
Turbidity (NTU)	1.3-1.35	1.54-104	1.8-100

METHODOLOGY

In this study, the study are carried out in a laboratory of Faculty of Engineering, Universiti Malaysia Sabah. Test beds are placed under the rainfall simulator as shown in Fig. 1. Table 2 shows nine test bed represent different recycled waste, natural fibres and one test bed as a control bed. The inflow from rainfall simulator are for 15 minutes continuously. The outflow was taken for one hour continuously after the simulator started with five minutes interval.

Figure 1. Testing under rainfall simulator (Asman *et al.*, 2016).

The samples of water quality were collected from each of the test beds. For each selected test bed, 10mL of water samples are taken to be tested in environment laboratory. The samples then analyzed for pH, total suspended solid (TSS), turbidity, and chemical oxygen demand (COD).

Table 2. Materials for each specimen for the test bed.

	Specimen				
	Control	Drainage Layer	Drainage Layer with filter layer		
Materials	Waterproof layer	Palm oil shell	-	-	-
		Rubber crumb	Rubber crumb with sugarcane	Rubber crumb with Coconut fibre	-
		Polyfoam	Polyfoam with sugarcane	Polyfoam with Coconut fibre	Polyfoam with palm oil fibre

RESULT AND DISCUSSION

Three types of drainage layer with the combination of two natural fibres are used in the testing, and nine simulated rainfall has been done. Table 3 show the outflow water quality from the green roofs for each test bed on control, drainage layer and drainage with filter layer.

Table 3. Outflow water quality from the green roofs.

Sample	pH value	Total suspended solid(mg/L)	Turbidity (NTU)	Cod (mg/L)
Control	6.64	3	0.47	13
Polyfoam	6.39	3	0.54	42
Rubber Crump	6.16	5	0.76	3
Palm Oil Shells	6.08	22	6.25	7
Polyfoam + Palm oil fibre	6.17	12	3.79	3
Polyfoam + sugarcane fibre	5.42	17	7.38	38
Polyfoam + coconut fibre	6.00	6	2.30	3
Rubber Crump + sugarcane fibre	5.01	22	10.4	63
Rubber Crump + coconut fibre	6.15	10	3.24	21

PH value

In chemistry, pH can be referred to the negative log of the activity of the hydrogen ion in an aqueous solution. For solutions that having pH value less than 7 known to be acidic while solution that having a pH greater than 7 are basic or alkaline. Pure water has a pH value of 7.

Figure 2 shows the pH value for collected sample. As for the drainage layer, the polyfoam has the lowest reduction from the control with 3.77%, followed by rubber crumb with 7.23% of pH reduction. For the drainage with filter layer, the lowest reduction is polyfoam with palm oil fibre (7.08%), followed by rubber crumb with coconut fibre (7.38%). The pH reduction are increases as filter layer are added onto the green roofs. The most acidic drainage layer is the palm oil shells (8.43%), while for the drainage with filter layer as the highest pH reduction is the palm oil shell with sugar cane fibre (24.55%). This may due to the changes of characteristic of the material itself after react with the water molecule. However, the green roofs that can maintain the pH value for above 7.0, which should protect the downstream receiving waters from acidification.

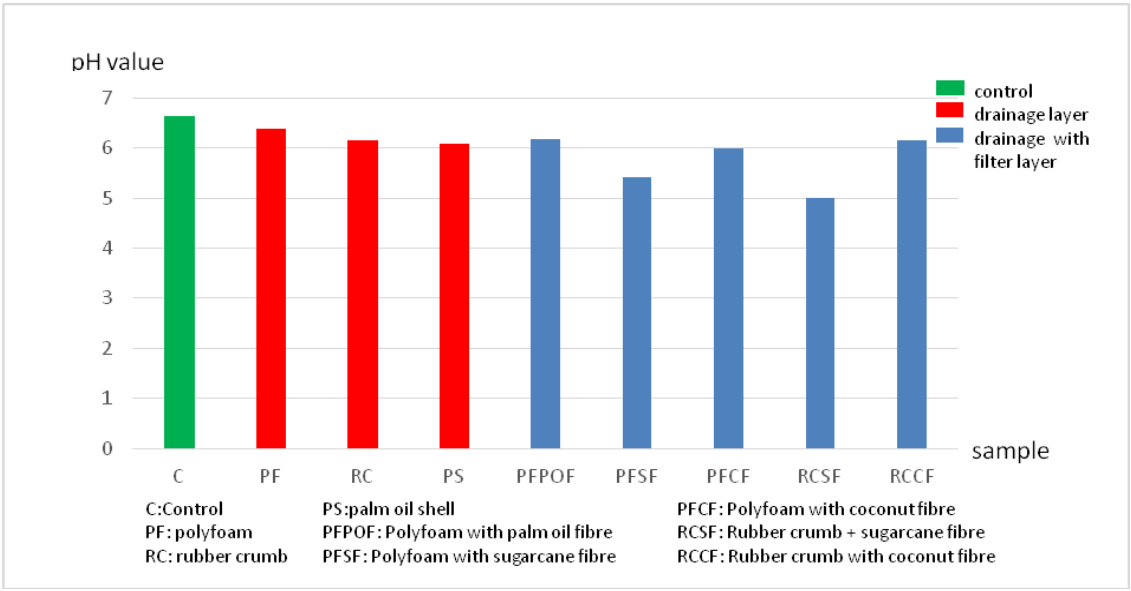

Figure 2. pH value for collected sample.

Total suspended solid

According to the Figure 3, the highest value of TSS for drainage layer was the palm oil shell (22 mg/L) while the filter layer was the sugar cane fibre (22mg/L). The other drainage layer, polyfoam and rubber crumb have the lowest value for their TSS which is 3mg/L and 5mg/L, respectively. On drainage with filter layer, combination of polyfoam and coconut fibres have the lowest TSS value (6mg/L). Water with a TSS concentration less than 20 mg/L are aims to be clear. Meanwhile, water tends to appear cloudy if the TSS levels are between 40 and 80 mg/L, and water with concentrations more than 150 mg/L usually appears dirty. The nature of the particles which comprise the suspended solids may cause these numbers to vary. This may be because their own nature characteristic that gives out the residue.

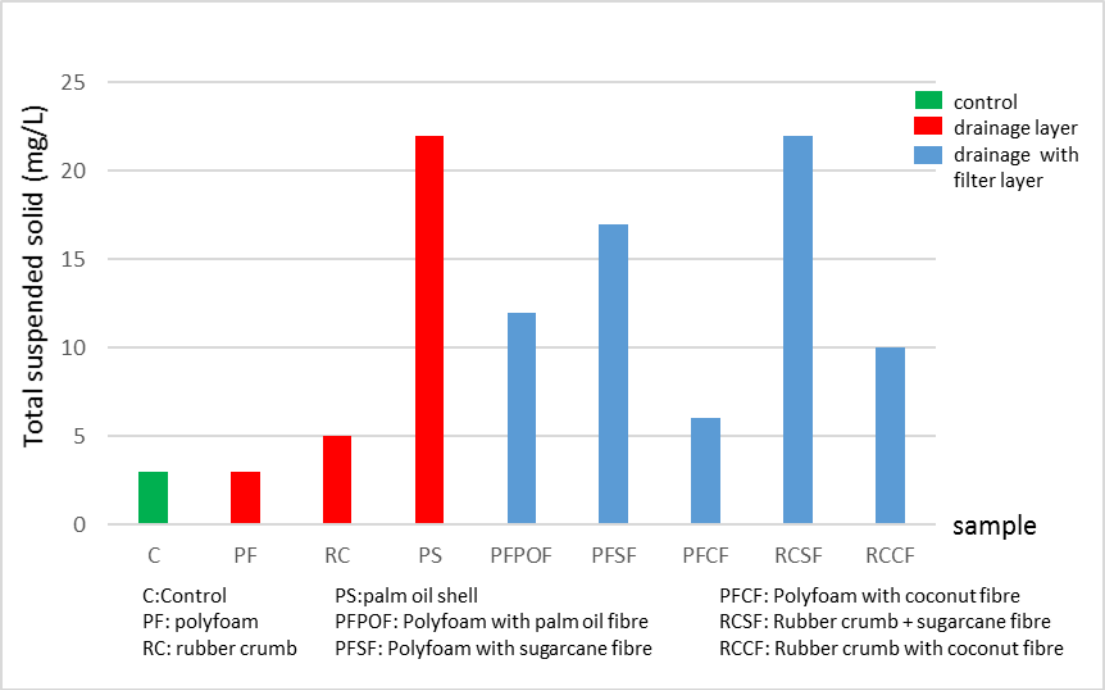

Figure 3. Graph of total suspended solid (TSS) for the collected sample.

Turbidity

Turbidity can be defined as the cloudiness or haziness of a fluid that caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. Fluids can containing suspended solid matter with various size of particles. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand, very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. The small solid particles cause the liquid to appear turbid.

As in Figure 4, the highest turbidity value for drainage was palm oil shell (6.25NTU) while for the drainage with filter layer was palm oil shell with sugarcane fibre (10.4NTU). This indicates that both of the material are showing themselves characteristic as their fibres give out the cloudiness after water passing through it. The suitable materials used for drainage layer with a low turbidity is polyfoam (0.54NTU) while for the filter layer is coconut fibre (PFCF: 2.3NTU).

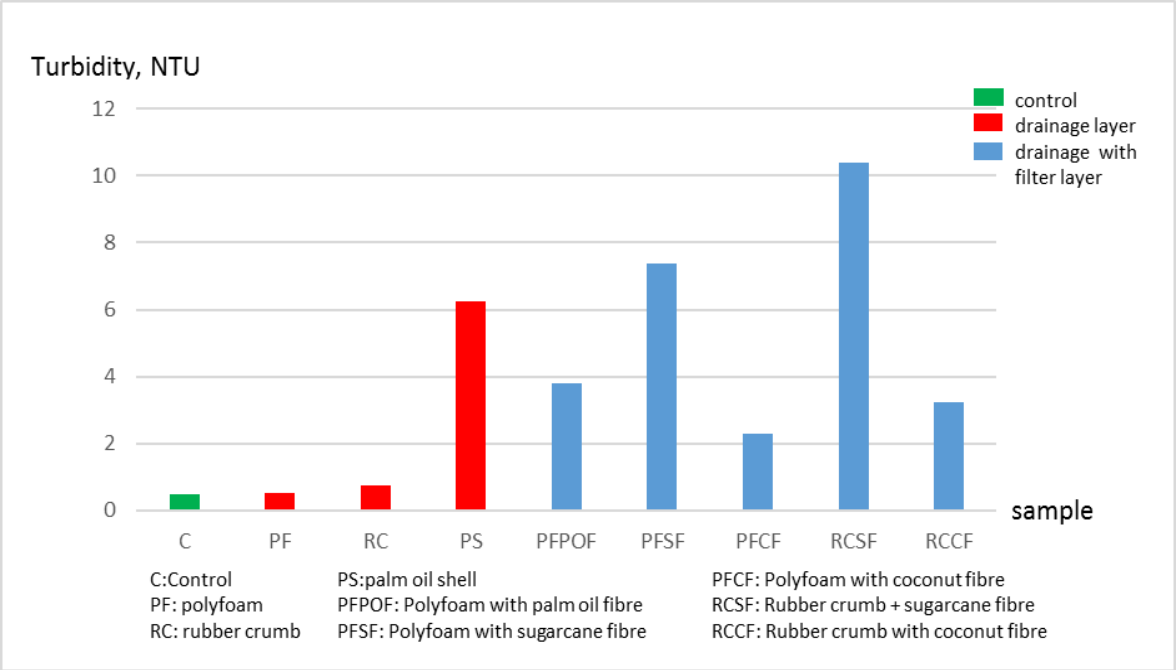

Figure 4. Graph of turbidity for the collected sample.

Chemical oxygen demand test (cod)

According to the laboratory test data as shown in Figure 5, the highest COD value for drainage layer was the polyfoam (42mg/L) and for the filter layer was the palm oil shell with sugarcane fibre (63mg/L). For the drainage layer, rubber crumb has the lowest COD value (3mg/L) then for the filter layer, both polyfoam with coconut fibre and palm oil fibre have the lowest value with COD of 3mg/L.

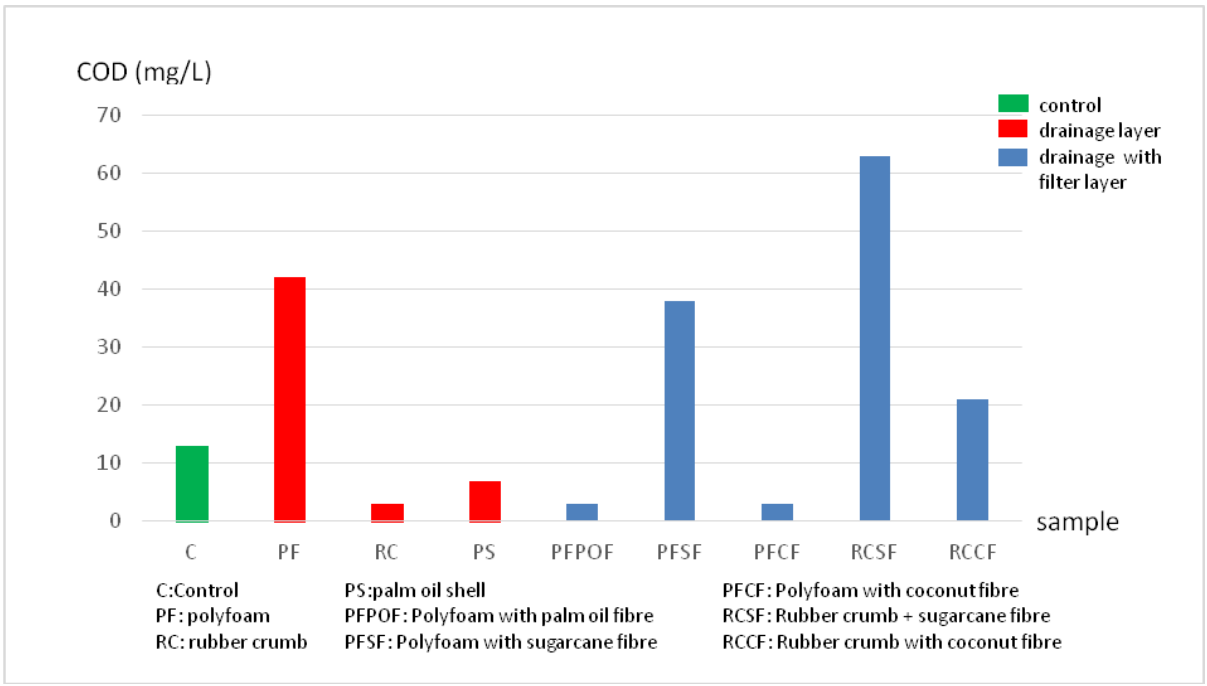

Figure 5. Graph of chemical oxygen demand (COD) for the collected sample.

CONCLUSION

In this study, the water runoff quality from the control, three drainage layer test bed and five combinations of filter and drainage layer were studied. Green roofs should be able to neutralised acid rain to stabilise the pH of the runoff, reduce the turbidity value, total suspended solid and

chemical oxygen demand. Based on the water runoff quality of green roofs, this study found the rubber crumbs suitable as green roof drainage layer. Apart from able to retain water, it also suitable for filtration while ensuring good drainage and aeration of the substrate and roots (Asman *et al.*, 2016), rubber crumb in drainage layer in term of water runoff quality able to reduce the TSS and COD; and almost have the same value (pH and turbidity) with the control. Second wastes material that is suggested for a green roof is polyfoam. Suggested natural fibre should be used in the filter layer of green roof are palm oil fibre and coconut fibre. Both of the fibre almost have same properties where it has the lowest value of water quality for the turbidity, COD and TSS. It also has the lowest value of acidity. However, the outflow water of green roof should not be reused for potable consumption. The emitted contaminant loads are very dependent on the hydrologic behaviour of the roof and thus on soil moisture condition and rain depth. Further details study for the green roofs with a combination of waste materials, natural fibres, substrate and vegetative as a full green roof layer system is needed.

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