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Water Filtration Design for Rainwater Harvesting System in Faculty of Civil Engineering and Built Environment, UTHM

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Abstract: Rainwater harvesting system is an integrated environment friendly system that reduce the surface runoff which involve in the process of sustainable urban water resources development. One of the rainwater harvesting system component is water filtration system which able to ensure a good quality of harvested rainwater produced. Collected rainwater were expose to the atmosphere that may contain contaminants which may affect human health as it contribute direct contact with human skin. This study aims to propose a suitable media filter for the installed water filtration system at Faculty of Civil Engineering and Built Environment (FKAAB) building. Besides, harvested rainwater quality were measured to identify the class of water based on the National Water Quality Standard for Malaysia through sampling and testing process. Results showed that RWHS in FKAAB building utilized a mineral tank for water filtration system which required various layers of media filter. 2 parameters which were pH and temperature harvested rainwater were classified under Water Class 3. Therefore, five layers of filter media were proposed consisting of natural material such as gravel, sand, charcoal, clam shell and peat soil that able to filtrate any large and small debris, remove odour and taste, filtrate heavy metal and decompose any organic compound content in water.

Keywords: Water Filter, Rainwater Harvesting, Water Filter Media

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1. Introduction

Rainwater harvesting system (RWH) is an alternative method that helps to store rainwater for other usages. It is defined as the process of accumulating and store rainwater for drinking, livestock, and irrigation. It is a system that accumulates rainwater from various surfaces and platforms and then reserves it for future use. The water can be obtained from different surfaces and platforms and then kept for future use. The most common method to collect water was from roofs and impermeable surfaces. Besides that, it is known that RWHS has many advantages in numerous aspects such as the economy, environment, technology, and society [1]. The installation of a Rainwater Harvesting System in a building may change the rainwater flow path, from the roof gutter to the storage tank where it will be kept for household use [2]. The collected rainwater can be utilized as the toilet flush, gardening and cleaning or small scale activities.

However, rainwater quality could affected by the polluted air and roof surfaces where polluted air contain small particles such as dust combining with the corroded roof material would lead to residue formation in the storage tank [3]. In addition, physical contaminant such as mosquito larvae, pupae and dirt from roof also found in the stored rainwater [4]. Rainwater were natural water dropped from the open wide airspace which content less pollution unless the atmosphere were polluted.

Contaminant may be resourced from any environment and compartment of the rainwater harvesting system that unable to be controlled and protected. Any contaminant in rainwater obtained right after alighted on the roof surface or catchment area and flowed through the gutter comprise pathogenic organisms which accommodate with organic material, animal feces and material of surfaces [5,6]. Hygiene and cleanliness of the rainwater harvesting system compartment should be regularly conducted to ensure a good quality of harvested rainwater [7]. Poor quality of harvested rainwater may due to water directly contact with roof catchment that contain contamination [8].

The RWH might contain high contaminant from the rooftop and storage tank. The material of catchment area played a main role in the quality of harvested rainwater such as steel, metal and paint. Other than that, the storage tank might produce algae and moss at the wall of the storage tank. Those compartments might have effect on the water quality of the harvested rainwater. In order to provide safe and clean water that contact to our body, a water filtration should be installed. Installation of the water filtration would reduce the pollution level content in harvested rainwater.

This study contribute two objectives as the aim and goal for achieving the expected outcomes. Those objectives were to identify the quality of collected rainwater based on the parameter which are pH and temperature by following the guideline from National Water Quality Standard for Malaysia and to propose media filter that suitable for the water filtration system in rainwater harvesting system.

2. Material and Method

The important of water filtration system is to harvest rainwater from those pollutant and ensured a good quality of harvested rainwater to be produced. Therefore, a proper design of rainwater harvesting system should be implemented. In general, purification consist of various type of system such as disinfectant, filtration and water polishing depend on the intended use whether potable or non-potable. Water filtration were able to trap and clear all the suspended solid content in harvested rainwater.

2.1 RWHS in FKAAB Building

To conduct this research, a rainwater harvesting system was installed at the back of South Tower in the Faculty of Civil Engineering and Built Environment (FKAAB) building. In details, the rainwater harvesting system consists of several elements such as catchment area, outflow pipe, storage tank and water filtration tank. Arrow in Figure 1 illustrated the flow of rainwater.

Figure 1(a) Figure 1(b) Figure 1(c)

Figure 1: Component of rainwater harvesting system

Based on Figure 1(a), the rainwater was initiated from the peak of the pitch roof and running off towards the small drain. The small drain connected to the outflow pipe at the corner of the rooftop area. Outflow pipe as circled in red in Figure 1(a). Figure 1(b) shows, an outflow pipe connected to the newly installed storage tank near the emergency stairs of South Tower and the collected rainwater will be stored in the storage tank. Storage tank was linked with main outlet of the rainwater harvesting system which faucet located at the Ground Level of the South Tower. Figure 1(c) show the location of the faucet and filter tank at the outside of laboratory building between the Geological Laboratory and Geotechnical Laboratory. Water flow from the distribution pipe was entered the filter tank then filtrate through each of media filter and flow out from the filter tank to the main faucet.

2.2 Filter Media Material

Water filtration system were widely utilised and varies with types of material used to filter all the unneeded content in harvested rainwater. Table 1 shows the various type of material and its function based on the previous researchers.

Table 1: Filter media material for water filtration system and their benefits

Source	Country	Media filter	Benefits
Ceramic membrane based on TiO2 – modified kaolinite as a low-cost material for water filtration [11]	Indonesia	Modified kaolinite mineral as ceramic membrane coating	Reduce metal and bacteria content in water Reduce total suspended solid and chemical oxygen demand
Feasibility of the direct filtration over peat filter media for bathroom greywater treatment [12]	Malaysia	Peat soil	Decompose organic compound content in water Reduce Biological Oxygen Demand in water

Surface water filtration using granular media and membranes: A review [13]	Greece	Granular activated carbon such as nutshell, wood, coal and petroleum	Adsorb organic compound, taste and odour
		Sand filtration	Remove inorganic substances such as iron and manganese
Development of Innovative Filtration System Natural Water Treatment in the Chechen Republic [14]	Russia	Bentonite from the Dash-Salakhly deposit combine with brucite-based sorbent	Adsorb heavy metal ions
Enhanced rooftop rainwater harvesting quality through filtration using zeolite and activated carbon [15]	Indonesia	Combination of zeolite and activated carbon	Reduce the total dissolved solid (TDS) Filter large molecule such as heavy metal Reduce the number of coliform bacteria
Denitrifying woodchip bioreactor and phosphorus filter paring to minimize pollution [16]	United State of America	Paring woodchip bioreactor with phophorus-sorbing filters	Increase the pH values Remove phosphorus and nitrogen content in water
Ensuring water security by utilizing roof-harvested rainwater and lake water treated with a low-cost integrated adsorption	Malaysia	Coconut shell acted as activated carbon combined with sand filtration	Increase pH value Reduce BOD, TSS and ammonium content Fecal coliform E. Coli removed

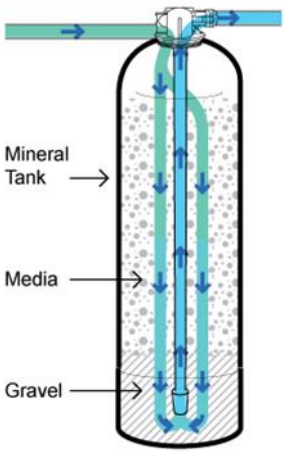

Figure 2: Flow of harvested rainwater inside the mineral tank

Figure 2 shows, the blue arrow indicates the water pathway. The order of media filter layers was arranged according to the material density where higher dense material was positioned at the bottom while lesser dense material was positioned at the top of the mineral tank.

2.3 Methodology

Generally according to literature review, the process of identifying harvested rain water quality might contribute the sampling action, installation of water filtration medium and rainwater quality testing. Figure 3 shows the flow of identification of harvested rainwater quality process in general.

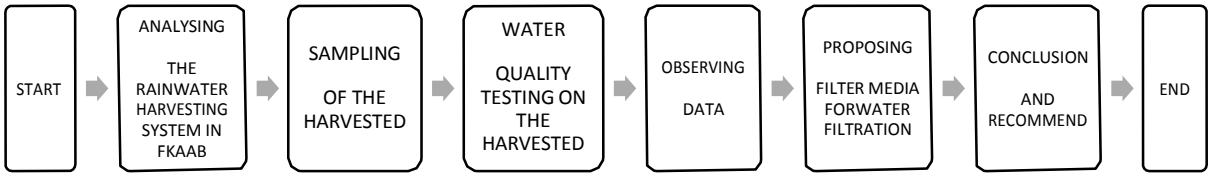

Figure 3: Methodology framework

RWHS in FKAAB building was installed during the research being conducted. The concept of the RWHS installed was analysed based on its component, rainwater distribution flow and water filtration tank utilized. Based on the analyse process, the overall concept obtained including the water filtration system installed in the RHWS. Sampling of the harvested rainwater was used for the water quality testing. Water sample was taken directly from the water storage tank of rainwater harvesting system. Then, the sample was tested for water quality at the Micro Pollutant Research Center (MPRC) laboratory. Its was to ensure the efficiency of the natural water filter that was installed previously. The main parameters considered were pH value, turbidity and water temperature. Data from all tests will be tabulated separately for each tests in different tables to ease the observation process for comparing both of the sample's result. The finalised result only used the average value for each of the test to be plotted. Based on the data obtained, National Water Quality Standard for Malaysia would be referred in order for comparison purposed to identify the water classification for harvested rainwater.

3. Result and Discussion

The observation data required sample from every rainfall event occur within a month, however only a sample from a rainfall event had been observed due to impediment of laboratory usage that had consequences towards the Pandemic of Corona Virus outbreak. These situations had effect the data observation process and the final result of this research.

3.1 Rainfall event

Estimated that March were the month that has higher occurrence of rainfall event, the maximum data collect was based on five rainfall events. Unfortunately, due to the several obstacles regarding the Restriction Movement Order by the Government of Malaysia, only one rainfall data was observed. Table 2 below shows the information of the rainfall event. The sample taken was kept and tested at MPRC.

Table 2: Rainfall event information

Sample No.	Location	Date of rainfall event	Time of rainfall event	Duration of rainfall event
0403	Universiti Tun Hussein Onn Malaysia	4th of March 2020	5:00 p.m. until 6:30 p.m.	1 hour 30 minutes

3.2 Water Quality of Harvested Rainwater

The Sample of harvested rainwater was collected based on the details of location, date and time. Test was conducted as soon as possible to avoid any changes of the sample physically and chemically. The data shown in Table where only a sample that able to be tested due to the outbreak.

Table 3: Water quality of harvested rainwater

Sample No.	Testing		
	pH value	Turbidity (NTU)	Temperature (°C)
0403	6.64	17.88	27.7

3.3 National Water Quality Standard

Table 4 show the details of water quality parameter based on the Malaysia National Water Quality Standard.

Table 4: Malaysia National Water Quality Standard (Official Portal of Malaysia Department of Environment, 2019)

Parameter	Unit	Value
pH		5 - 9
Turbidity	NTU	-
Temperature	°C	Normal + 2°C

Normal temperature of the sample was 25.9°C which was measured during the sample collection process. While the temperature required for the sampling works was ranged from 25.9°C to 27.9°C. Required pH value show that the rainwater should in alkaline composition to make sure its safe when contact with skin.

3.4 Filter Media for Water Filtration System

Water filtration system proposed is based on the filtration tank that used in the rainwater harvesting system. A mineral tank which cylindrical in shape with 1.5 meter height and 0.4 meter diameter was utilized in this filtration system. Five layers of different filter media were installed in the filter tank and each of the layer has its own functions and advantages. Therefore, five different materials would be proposed for the water filtration system. Table 5 show the proposed material that suitable for the water filtration system based on the past study.

Table 5: Filter media for water filtration system

Layer	Filter Material	Filter Production	Function
1	Carbon	Crashed charcoal	Adsorb organic compound, remove taste and odour.
2	Peat soil	Molded peat soil	Decompose organic compound and reduce Biological Oxygen Demand (BOD) in water
3	Clam shell	Shattered clam shell	Reduce metal, total suspended solid and Chemical Oxygen Demand (COD) concentration in water
4	Fine grained sand	1mm particle size of sand	Remove inorganic substances and small particle of contaminant
5	Coarse grained gravel	4mm particle size of gravel	Remove large particle of contaminant

Layer 1 indicates top layer of the filtration tank while layer 5 position at bottom of mineral tank. Harvested rainwater would enter from the top of water filtration tank then flow through each of the filter media layers and withdrawal from mineral tank through a distributor tube. Figure 3 show harvested rainwater flow inside the mineral tank.

4.0 Conclusion

Quality of harvested rainwater was classified as Class 3 from the water classification table based on the National Water Quality Standard for Malaysia. Therefore, the harvested rainwater suitable to be used as the secondary water supply for general cleaning and external usage purpose only. The pH value for the tested sample fall into the range of pH value required and turbidity data also in the range of standard requirement. While the harvested rainwater sample were tested, the temperature of the sample were 27.7°C which in the range of temperature standard requirement. All the parameters selected were considered meet the standard requirement for National Water Quality Standard for Malaysia. Media filter were suggested based on the past study made. Water filtration system concept were multi-layer media filter comprise of natural elements which are charcoal layer, peat soil layer, clam shell layer, sandy layer and lastly the gravel layer. Water filtration tank that utilised in this system were mineral tank. This mineral tank were connected in between the main faucet and storage tank. Harvested rainwater flow out from the storage tank through distribution pipe would insert into the mineral tank then passing through the five layers of media filter and flow out to the main faucet.

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