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FILTRATION OF RAINWATER HARVESTING SYSTEM IN RURAL AREA

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Abstract

This study focuses on the performance of rainwater harvesting filtration system for rural areas. The issue of mosquito breeding in rainwater storage tanks often occurs that caused dengue problem. This issue occurs due to improper rainwater harvesting system. Majority people in rural areas do not apply a proper rainwater harvesting system. A proper rainwater harvesting system should be installed with the filtering system. Filtration should be used for maintaining water quality and to prevent the mosquitoes larvae from entering the storage tanks. In this study, samples are collected from four (4) different rainwater ha rvesting method. Four (4) parameters; water temperature, pH, turbidity and dissolved oxygen (DO) are tested to evaluate the performance of water quality after the filtration then compared with Drinking Water Quality Standard (DWQS), World Health Organization (WHO) and National Water Quality Standard. The results show that the water quality improved and fulfill the water quality standard after the filtration process. Non-woven geotextile fabrics that used as a filter has proven as medium for mosquitoes larvae filtering system. The result shows that the quality of rainwater is acceptable and the uses of filter in rainwater harvesting system is crucial to get a good quality of rainwater.

Keywords: Rainwater harvesting system, Filtration, Non-woven, Larvae mosquitoes, Water quality

1. Introduction

Rainwater is an important source of water supply in rural areas. The demand for rain water supply is increasing due to limited access to clean water, rapid urban expansion, and population growth. Rainwater harvesting systems have been practiced since long time ago, especially in rural areas of Malaysia. The Malaysian government has spent over RM 100 million to provide 40,000 water tanks for rainwater harvesting, particularly in rural areas of Sabah and Sarawak [1].

Nomenclatures

DO	Dissolved oxygen.
NTU	Nephelometric Turbidity Units.

Abbreviations

DWQS	Drinking Water Quality Standard
GRP	Glass-Reinforced Plastic
HDPE	High-Density Polyethylene
NWQS	National Drinking Water Standard
WHO	World Health Organization

Unfortunately, due to the lack of knowledge and information, the use of rainwater harvesting system may cause other problems to the community. Quality of harvested water may decrease due to improper system design or lack of maintenance. Rural populations often implement improper designs for rainwater harvesting systems. Tanks are often placed outside the house to collect the rainwater. Open storage tanks can result in poor water quality and provide mosquitoes breeding sites.

Rural areas of Bangladesh have been storing rainwater since 1989, leading to a national dengue outbreak in 2002. National surveys of dengue cases show that earlier outbreaks had occurred as well [2]. According to Mwami [3], gutters in developing countries are often a weak link in the rainwater harvesting system and installations can be seen with gutters coming away from their mountings, leaking at joints or even sloping the wrong way. Improper installation of gutters will provide areas for mosquito breeding.

Fig.1 shows a typical vernacular rainwater storage system design in rural areas. This improper design uses a white container of recycled material to collect the rainwater and a small PCV pipe to channel the rainwater to the storage tank. This design can be classified as incorrect due to:

i. The open collection of rainwater allows for mosquitoes breeding and could reduce the quality of water by allowing debris, dirt or dust to fall into it;
ii. The size of the PVC pipe is too small, causing wastage of rainwater and reducing the quantity of rainwater in the storage tank;
iii. Although the storage tank is covered, the improper design of the lid could allow mosquitoes to breed inside.

Fig. 1. Rainwater harvesting system in rural area (Kampung Jaya Ria, Serian).

2. Literature review

Rainwater harvesting (RWH) systems have three basic components which are catchment area (roofing, gutter); filtering system; and storage tank [4]. These components are important in order to design a proper harvesting system, better quality of rainwater, and to prevent the breeding of mosquitoes.

The roof is commonly used as a catchment area for RWH systems. Roof material should be considered when designing a rainwater catchment system because the water quality might be affected by the roofing material [5]. Normally, zinc had been chosen as the roofing material for most houses in rural areas. The characteristics of zinc itself make it popular and effective for catchment. Zheng et al.[6] has mentioned that zinc is maintenance-free, has a long life span and is easy to be installed.

The gutter is also one of the components of a catchment area to transport rainwater from the roof to the storage tank, which comes in variety of shapes and materials [7]. Gutters should fall continuously to downpipes to prevent pooling of water that can cause increased accumulation of material, leading to algal growth and providing a place for mosquito breeding [8]. According to Mwami [3] lack of maintenance and improper design inhibits the performance of a rainwater catchment system. He also mentioned inadequate slope for entire system can damage gutters and attract mosquitoes.

Rainwater collected from catchment areas (roof, gutter) usually are contaminated with dirt, leaves, plant debris, silt and other unwanted matter. Due to this condition, rainwater should be filtered before being stored. Filtration can reduce the contaminants and prevent larva, eggs and mosquitos from entering the storage tank. The filter is the most important component in RWH systems to ensure the quality of rainwater. Rural population should be provided with sufficient guidance to ensure proper application of filtration techniques in their RWH systems. There are many techniques to filter rainwater, of which the most appropriate may be geotextile fabrics. Geotextiles are divided into two categories, woven and non-woven. Woven fibers are used in separation and stabilization applications while non-woven fabrics are generally for areas needing increased filtration [9]. The non-

woven fabric has better filtration efficiency than woven filter fabric at lower flow rates. Woven fabric also takes more time for filtration compare to non-woven fabric [10].

Storage tanks are used for collecting rainwater and may be located either above or below the ground [11]. Srinivas [11] describes various types of storage tank such as reinforced concrete, fiberglass, polyethylene, stainless steel, ferro-cement and jars made from mortar or earthen materials. However, plastic tanks made from high-density polyethylene (HDPE) or glass-reinforced plastic (GRP) are more efficient and popular in developed countries. HDPE tanks are considered top-ranked because their lightweight and sustainable characteristics, large storage capacity, easy to clean and have many openings which can fit into the connection pipes [11].

Meanwhile, rainwater tanks can provide excellent habitat for mosquito breeding [12] and have been identified as potential breeding sites for mosquitoes, the vector for the dengue virus. Mosquitoes live and breed in streams, ponds, puddles or any other place that contains water [13]. Any water source has potentials for breeding of mosquitoes, therefore some precautions should be taken in designing rainwater harvesting storage systems. The study on rainwater harvesting in Nova Scotia, Canada and Bermuda, stated that if the storage tank is not covered, open storage may provide a breeding place for mosquitoes [14]. The presence of mosquito larvae have also been detected in rainwater tanks due to openings through which female mosquitoes can enter and lay eggs in ponded water collected in roof gutters [12].

Rainwater quality can vary depending on atmospheric pollution and storage method while some rainwater catchment systems are open to environmental hazards due to nature of catchment area [2]. In addition, chemical contamination may dissolve into rainwater during precipitation. Poor collection, storage design and other factors such as bird dropping can cause microbial risks. The main concern on the quality of RWH is in rural areas where they usually use the rainwater for drinking and cooking without focusing on the level of water quality required. Drinking water guidelines were first published as International Standards in 1958 [15]. There are few of water quality guidelines such as World Health Organization (WHO), Drinking Water Quality Standard (DWQS) and National Drinking Water Standard (NWQS).

3. Data Collection Methods

Four (4) samples of rainwater from each of the four (4) different RWH storage tanks with a total 16 samples were collected and analysed. The parameters of rainwater quality are determined before and after filtration to identify the changes of rainwater quality for each sample. Samples were collected three times for several days.

Four (4) parameters; water temperature, pH, turbidity and dissolved oxygen(DO) were tested on site for accuracy. Water temperature measured using digital thermometer, pH meter had been used to measure pH level, water turbidity measured using turbidity meter and DO meter had been used to measure dissolved oxygen. In addition, non-woven filter fabric were used to filter the mosquitoes larvae. Table 1 shows the types of rainwater collected for this study.

Table 1. Rainwater samples collected from different tanks.

Tank	Description
Tank 1 	Rainwater sample is collected in a closed storage tank and the rainwater is from catchment area (roof) and flow directly from gutter to the storage tank.
Tank 2 	Rainwater sample is collected from an open tank where the rainwater falls directly into the tank without any rainwater harvesting system components for an example catchment area. It shows that rainwater contaminated by dust, leaf, and dirt etc.
Tanks 3 	Rainwater sample is collected from an open tank and zinc is used as a gutter. Mosquitoes larvae are found during sample collection.
Tank 4 	Rainwater sample is collected from the open tank. This tank is located near with tree/plants.

The filtration concept is designed based on Vieira et al., [16] using 2.5" PVC pipe. The filtration concept (Fig. 2) allows rainwater from the gutter to enter the inlet pipe and pass through the non-woven fabric, then flow into the treated water outlet (storage tank). The treated water will directly wash the non-woven filter when the pressure of rainwater becomes low and water flows into the downpipe. Then, the valve outlet is designed to drain out the untreated rainwater after the pressure of rainwater becomes lower and unable to enter the treated water outlet. Valve outlet must be opened manually after the rain stops. TS20 nonwoven fabrics (TenCate Polyfelt) is used as the filter fabric.

Vieira et al., [16] used a magnetic backwash valve to open and close the valve automatically without any equipment to drain out untreated rainwater. This backwash works by considering the hydraulic pressure of water level from storage tank. However, for this study, manual valve was used to drain out because the storage tank provided by the government has high water capacity and the magnetic backwash valve is not practical to be applied into this study.

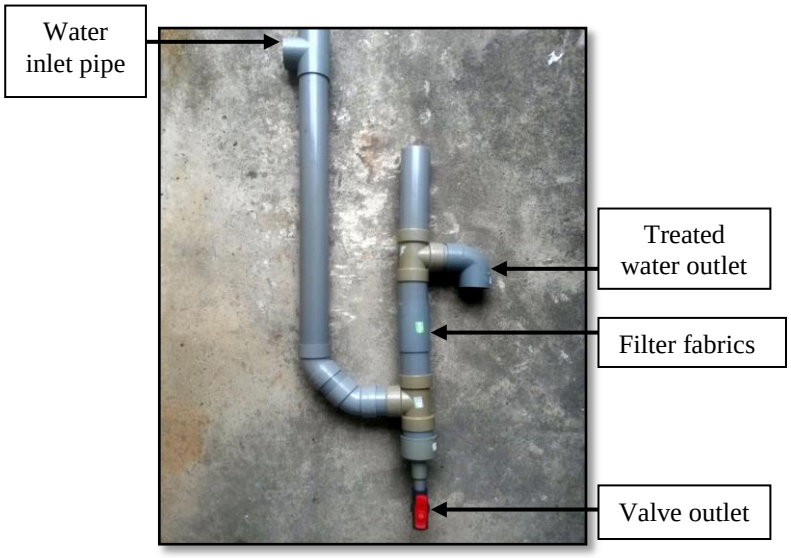

Fig. 2. Rainwater harvesting filtration.

4. Results and Discussion

A few observations were carried out in order to determine the performance of non-woven geotextile as a filter medium for mosquito larvae. The filtering tests on mosquito larvae were done many times with existing mosquito larvae found in storage tanks, in order to check the possibility for larvae to passing through the filter.

After the filtration of larvae, the result shows that the rainwater is free from larvae, which means the larvae could not pass through the non-woven fabric. Fig. 3 and Fig. 4 show the rainwater before and after filtration using non-woven fabric.

Fig. 3. Before filtration of rainwater on mosquitoes larvae.

Fig. 4. After filtration of rainwater on mosquitoes larvae.

4.1. Data analysis and discussion

As shown in Fig. 5, the water temperature decreased after the filtration process. The changes of water temperature can be related with microorganisms (bacteria) growth in rainwater. Water temperatures of rainwater were decreased after filtration due to the reduction of total organic during the filtration.

In terms of bacterial growth, the decreasing of temperature means reduction of bacterial growth in rainwater. The water temperatures obtained in this study are in the range of 28°C to 34°C, where the water temperature above 20°C can enhance the growth of microorganisms in rainwater [17].

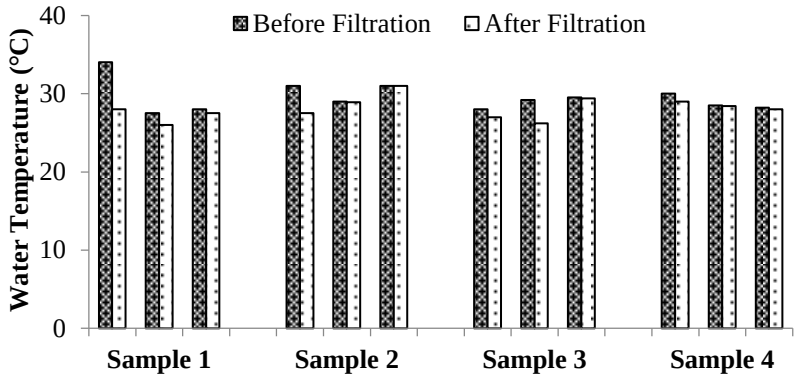

Fig. 5. Water temperature.

Abbott et al. [18], bacterial growth may occur when the water in the rainwater storage tanks is dirty and the bacteria have sufficient nutrients to multiply in the tanks. They also mentioned that bacterias require high temperature for re-growth especially in the countries with warm climate. In Malaysia, bacteria can grow in storage tanks as the country has warm climate and storage tanks are also placed outside of the house, and these lead to the rapid re-growth of bacteria to occur.

Fig. 6 shows the pH level for all of the samples. Changes in pH are common due to the amount of metal content in rain water. Metal usually comes from the catchment areas, such as roof. Filtration can prevent or reduce metal, such as copper, iron, lead and zinc, from passing through the pipes [19].

The result shows improvement even though not all pH results achieved the rainwater quality standard of 6.5 to 9.0 for Drinking Water Quality Standard and 6.5 to 8.5 for World Health Organization.

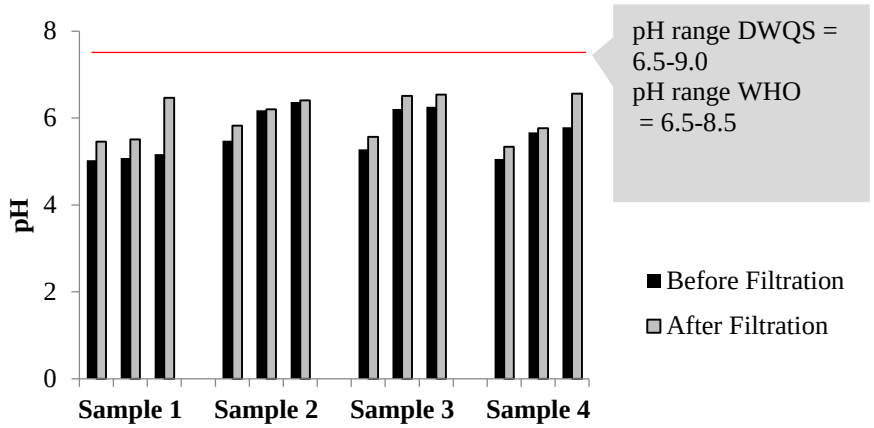

Fig. 6. pH.

The turbidity levels before and after being filtered through non-woven fabric were taken and recorded. The result of turbidity analysis shown in Fig. 7, depicts that the turbidity level decreases after the filtration. Based on Drinking Water Quality Standard and World Health Organization, turbidity must be below 5 Nephelometric Turbidity Units (NTU). From the turbidity level result recorded, all samples are still below 5 NTU and the turbidity level decreases after filtration. However, ideally turbidity is below 1 NTU [20].

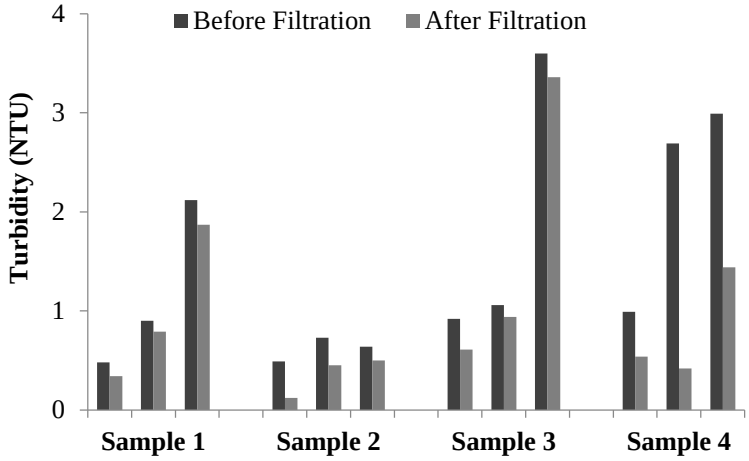

Fig. 7. Turbidity.

As shown in Fig.8, Dissolved Oxygen (DO) results indicate the improvement of rainwater quality after filtration. Dissolved oxygen (DO) values were increasing for all samples after filtration and meet the water quality standards.

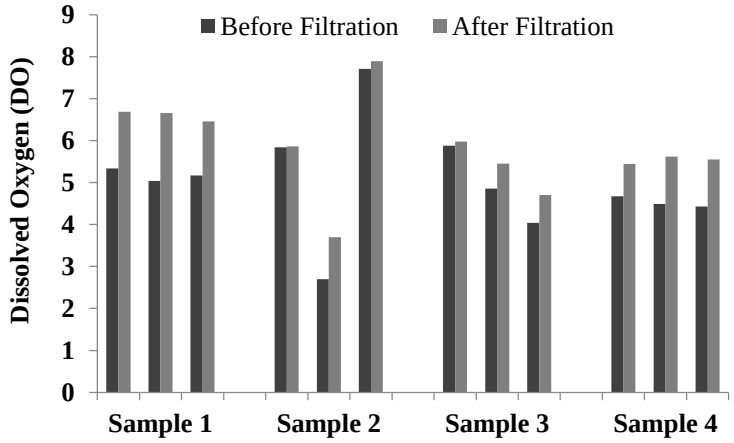

Fig. 8. Dissolved oxygen (DO).

The increasing of dissolved oxygen shows the reduction of microorganism in rainwater. Temperature is one of the factors that can reduce the concentration of dissolved oxygen. Nutrients in rainwater are food for algae. Rainwater with high amount of nutrients can produce algae in large quantities. When the algae dies, bacterias decompose them and use up the oxygen in rainwater [21]. Bacterias also need oxygen to live in rainwater. Because of this, dissolved oxygen in rainwater decreases.

5. Conclusions

As a conclusion, filtration has proven that it can solve the problem of mosquito breeding and improve the quality of rainwater. Non-woven geotextile fabric could be used as a filter in RWH system and make the rainwater quality better. Non-woven geotextile successfully excluded mosquito larvae from going into the storage tank. Filtration process is effective to filter mosquito larvae and contaminants before rainwater enters the storage tank. The characteristics of the filtration concept design are easy to conduct and give benefits to the user compared with the RWH system without any filtration. Besides that, the filtration concept is low maintenance, requires no energy and does not adversely affect the environment.

Rural populations should learn and gain more knowledge about filtration systems and how to properly design their RWH system. This knowledge could be delivered to the community by campaign or talk so that they would realize the importance of designing proper rainwater harvesting systems. Further research on the filtration concept should be carried out by using other types of filter fabric. Evaluate the performance on site with full scale of rainwater harvesting system.

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