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Brownification Effects from Surface Water Sources to Intelligent Rainwater Harvesting System

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Abstract: Rainwater harvesting (RWH) system has gained recognition as a sustainable means to cope with water crisis in the future. This study was to evaluate RWH system in Tun Dr Ismail (TDI) College, Universiti Tun Hussein Onn Malaysia (UTHM). Since being launched at 2007, the system emerged needing of improvisation due to rusty water and incomplete system installed. Main focused was on system effectiveness to supply non-potable water (toilet flushing) and brownification factors. Three samples were collected to analyse its concentration of iron (Fe) and pH. Rainfall data from Research Centre of Soft Soil Malaysia (RECESS), UTHM and Department of Irrigation and Drainage Malaysia (DID) used to estimate capacity effectiveness of the system. Result indicated Fe does contribute to brownification process. 20 feet pipe had highest concentration of Fe at 2.25 mg/l, while a projection at week 8 could reach until 3.25 mg/l. Growth of Fe over time would cause harm to residents. As for capacity, RWH system could cover 20 days toilet usage and save up to minimum 840 MYR monthly bills, which showed great potential to be considered as alternative water supply.

Keywords: Rainwater harvesting, Fe concentration, brownification

1. Introduction

Malaysia receives approximately 990 billion cubic meter of rainfall every year and has an average annual rainfall of 3000 mm [1]. From the total volume of rainfall, 566 billion cubic meters becomes surface runoff 360 billion cubic meters evaporated to the sky, and 64 billion cubic meters are discharged as ground water. In year 2000, water consumption for the country is 12.5 billion meter cubic where it is only 2.2% of the surface runoff. However, Malaysia

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still facing the problem of water disruption, indicated by the case in 1998 where drought brought unpleasant water supply disruption to 1.8 million residents of Klang Valley [2].

Despite abundant rainfall and water resources, Malaysia has its fair share of water crisis and this problem lead to the introduction of rainwater harvesting in the country. National Hydraulic Research Institute of Malaysia (NAHRIM) through collaboration with DID and UTHM have constructed RWH system located at TDI College as shown in Fig.1 since 2007. Contaminated water (rusty), and incomplete components installed to the system emerged as the main setback, needing of improvisation for better usage in the future.

This study examines Fe as one of the factor that contributed rusty to harvested water. Studied by [3] stated that water colour was increasing in many lakes and running waters, due to Fe presented in the water. According to [2] mentioned that the hydrostatic pressure increased Fe concentrations in standing water. Effectiveness of the system to supply non-potable water was also determined. Previous study by [3] was concluded that terrace house located at Taman Wangsa Melawati was able to save up to 34% of public water use. Studied by [4] stated that implementation of RWH in Raub DID has reduced 23% of annual water bills.

(a)

(b)

Fig. – (a) 1 RWH system in UTHM (b) dried pond after pumping

2. Application Rainwater Harvesting System in TDI

All of water problems lead to the introduction of rainwater harvesting. Soon after water shortage in April 1998, Malaysia Government announced interested on rainwater harvesting. By 23 June 1998, initial guidelines produce by Housing and Local Government , Installing a Rainwater Collection and Utilisation System [5].

Then, cabinet paper released to encourage government and federal building need to install rainwater harvesting in October 2004. 2006 is the most important moments toward conserving water. Town of Country Planning and Development had produce national Urbanization Policy stress the need to improve water management efficiency by emphasizing the use of rainwater harvesting. Besides, the police state it is mandatory to large building such as factories and school to install rainwater harvesting [6].

This system comprised of catchment area which runoff were collected, reservoir, filter, and conveyance system which shown in Fig. 2. As the rainfall to catchment surface (rooftop), water collected via system of gutters feeding into down pipes and from there into the pond (reservoir). The design of pond was based on Bio-Ecology Drainage System (BIOECODS) application introduced by DID, which proved more environmental friendly and sustainable. A single layer of hydro net used to act as a filter, which prevent any movement of particle soil into the reservoir. Harvested water is pumped into collection pipe and then direct bypass public water supply to the point of use (non-potable water).

Series of initial investigation was conducted to identify the problems and overall condition of rainwater harvesting system. The components included pumps, electrical system, plumbing system, filtration system and overflow system, flushing and storage system. However, since the project was known as pilot project, the whole components that being installed were enough to provide sufficient water to TDI college. But, it showed that the possibility of harvested rainwater to suffer brownification process was high and water that being used for toilet flush was rusty.This pilot project was collected water from direct surface water from runoff of catchment and some of roof top from TDI college. After the preliminary investigation, three main data consist of hydrological data, water demand and water quality. For this study, water consumption was 216 litres per person per day. Thus, average water usage in Malaysia for toilet flushing was 26 per cent only. This important data was considered total water demand for TDI college.

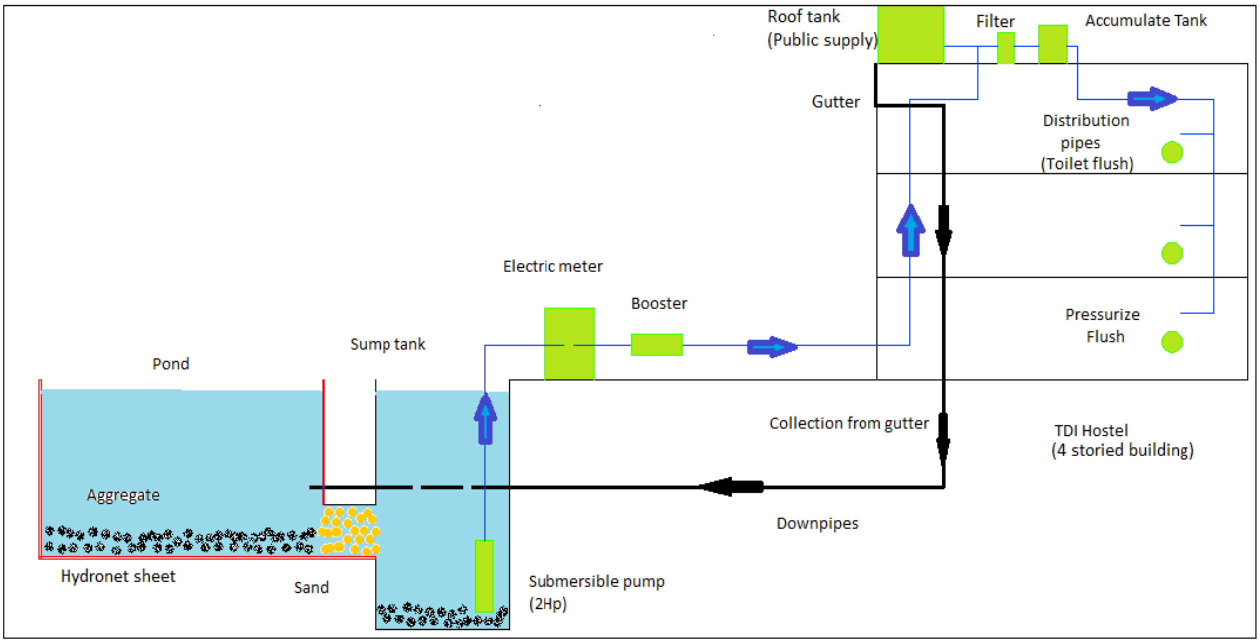


Fig. - 2 Layout of RWH system in TDI college.

3. Water Quality

Initial water quality test shown harvested rainwater in TDI had higher concentration of Fe while for pH, in standard range. Simulation of plumbing system (Fig. 3) with different height made to check Fe growth over time. The concept applied was adapted from hydrostatic pressure theory. Two samples from the system and one for control inserted in each pipe and tested every week for 5 weeks period. Fe concentration then were analysed using Spectrophotometer, DR 5000.

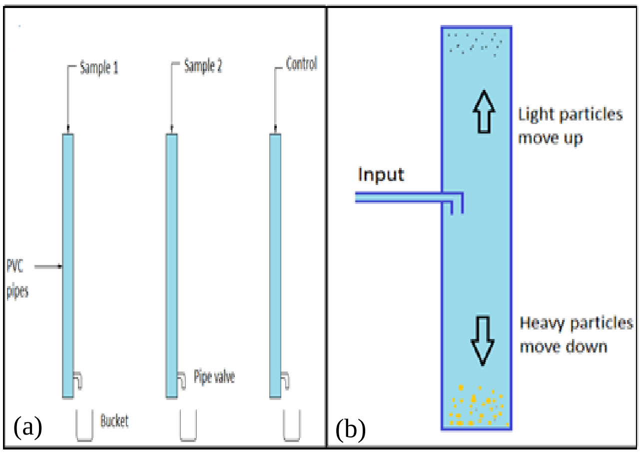


Fig. 3- (a) Fe concentration test and (b) hydrostatic clarifying.

4. Capacity of Harvested Rainwater

Reservoir (pond) firstly dried out by using petrol and electric pump. Then, an observation made on the day pond filled with maximum volume. Rainfall data from RECESS, UTHM and DID used to estimate Average Recurrence Intensity (ARI). Daily water consumption calculated to estimate water demand (non-potable water) for the college.

The result indicated such high water pressure for water supplied at the college. The 1st floor recorded the highest water pressure at 167.80×10^3 N/m^2 and 4th floor was the lowest at 257.50×10^3 N/m^2. The different of water pressure at each floor were due to different distance from the accumulate tank. High water pressure would increase accumulated Fe in pipe, caused clogging. On the long term, clogging pipe would cause water pressure became low as it reduced the flow of water as shown in Fig. 4.

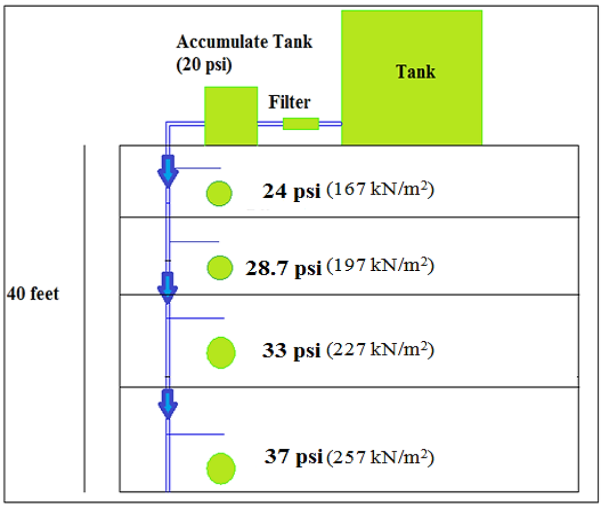
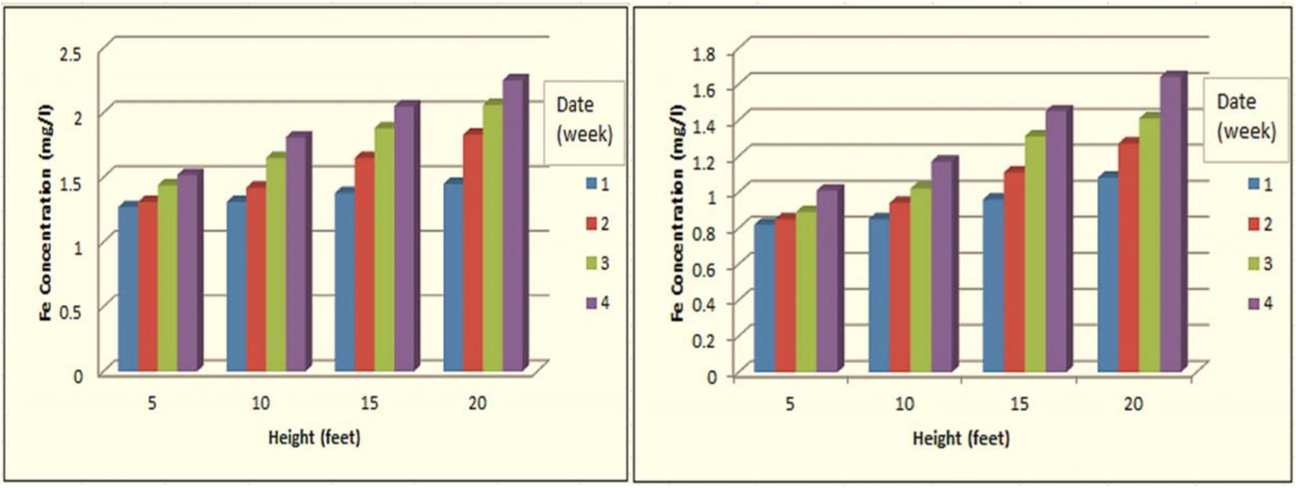


Fig. 4- Water pressure for RWH system

5. Results

For water quality, Fig. 5 clarified Fe concentrations increased over time. However, the increment was depended variably on pipe height. The longest pipe (20 feet) had the highest Fe concentrations for both sample 1 and sample 2 (2.25mg/l and 1.64mg/l). Prediction of both samples found it could reach up to 3.25mg/l for sample 1 and 2.5mg/l for sample 2. Meanwhile the shortest pipe (5 feet) produced lowest Fe concentrations (1.45mg/l for sample 1 and 1.08mg/l for sample 2). High water pressure might increase precipitation of Fe at the bottom of pipe to cause brownification process occurred [7]. However, for water control, the increment was nearly to zero, possibly due to proper treatment and filtration by DID [8].



(a) **(b)**

Fig. 5 – (a) Sample 1, Fe concentration; (b) Sample 2, Fe concentration

As for capacity, there were three times recorded in 30 days observation where rainfall has caused the reservoir filled with maximum volume. Fig. 6 indicated 2 years ARI estimated for 30 March and 7 April 2013 while 10 years ARI for 16 April 2013. ARI estimated for the events mean TDI hostel could reduce dependence on public water supply for non-potable water. Water demand for the college estimated at 14376 L/day, while the reservoir could store up to 3000000 L/day. It mean RWH system could cover 20 days toilet water supply and save up to minimum 840 MYR monthly bills for every rainfall event that yield maximum volume of reservoir.

According to water quality data, high concentration of Fe does contribute to brownification process of harvested rainwater. This problem would be worse for college residents, especially during semester break, when they were given 2-3 month holiday. As a result, the growth of Fe over time in standing water can cause a lot of problems to the residents. Annually the student will have 2 month semester breaks for 2 times, which can increase more of Fe precipitate in water. A roof tank (Fig. 7) provides with ion exchange would decrease Fe concentration in water. As for capacity data indicated the system could reduce dependence on public water supply. However, RWH system with larger catchment area (Fig. 8) is recommended to increase its reliability.

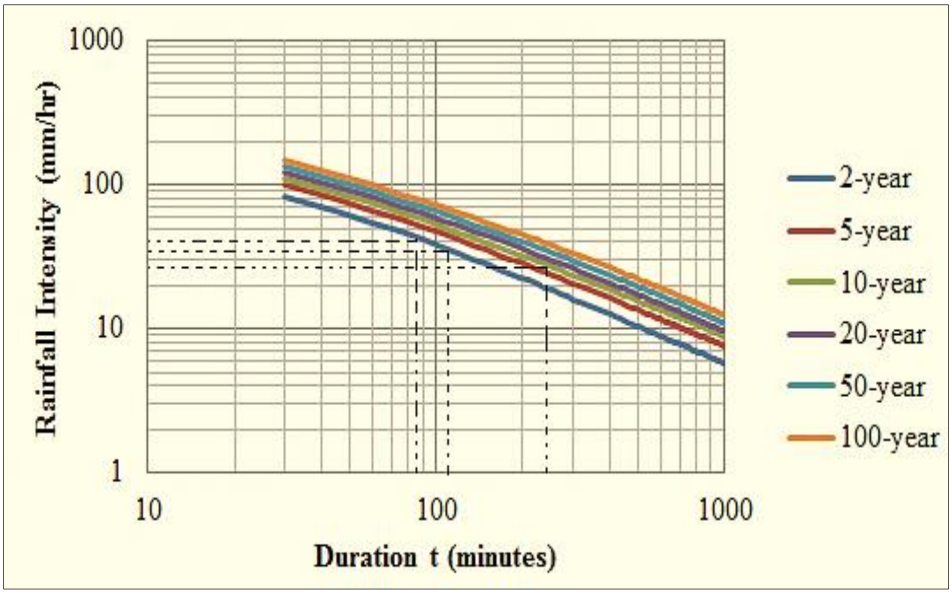


Fig. 6 - ARI estimation for maximum rainfall intensity for IDF Batu Pahat.

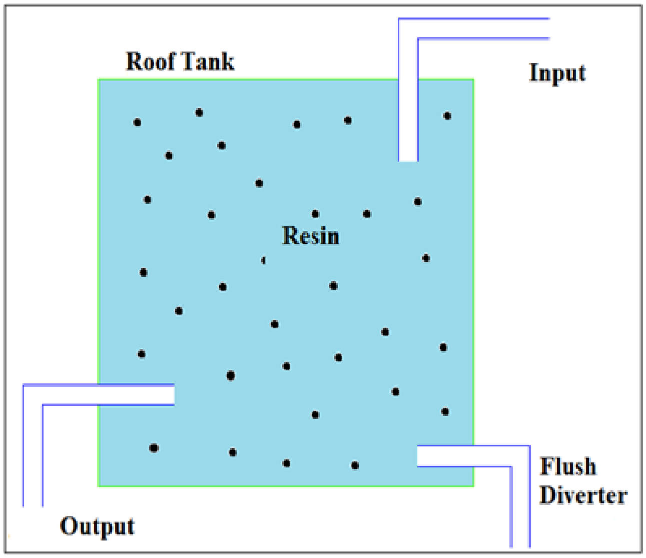


Fig. 7 - Roof tank condition.

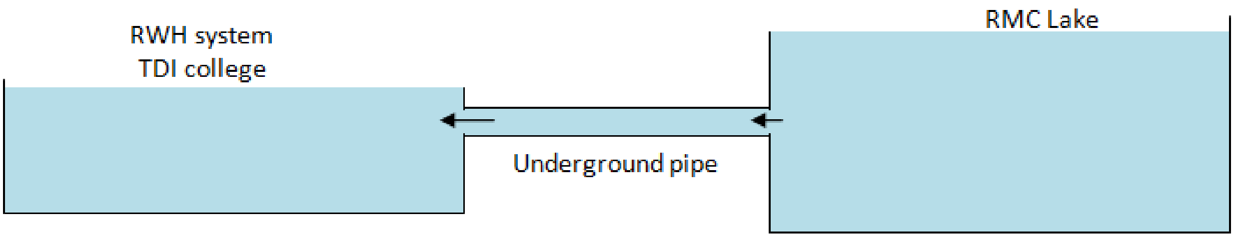


Fig. 8- RMC lake provide bigger catchment.

At the low level of Fe, it does not present a health hazard. As matter of facts, Fe is an essential nutrient for good health (Fe below 2 mg/l). It is a major component of hemoglobin, which is used to transport oxygen and carbon dioxide in the blood. Fe deficiency can enhance lead absorption and toxicity.

For capacity of harvested rainwater indicated the college could not depend entirely to RWH system for non-potable water supply. According to average recurrence interval (ARI) design for rainfall event to cause maximum volume of reservoir, it is far beyond the capability of RWH system to supply non-potable water. However, the system still could reduce dependence on public water. The reservoir estimated to store 6 times water demand for non-potable use on maximum rainfall intensity, indicating such promised to exploit primary source of water the best way as possible.

6. Conclusion

According to analysis made on harvested rainwater quality, found Fe ion was the main factor behind brownification process. This result has proved the role of Fe to harvested rainwater in TDI. The Fe ion complexity has caused difficulty to deal with. Even filtration system provided at reservoir and rooftop, it only to prevent precipitate of Fe but not dissolved Fe. At Reservoir, Fe ion will oxidize once expose to air and go to ferric state. The same situation occurs at filtration at rooftop, as Fe ion will undergo oxygenation process when mixed together with water from public water supply. Over time, Fe would precipitate more and brown color of water can be seen clearly. Besides, the role of Fe to cause brownification process has proved by hydrostatic pressure theory. High pressure in water supply will allow precipitation of Fe occur rapidly. However, this sediment of Fe can clog pipes and valves at plumbing system. This will reduce the available quantity and pressure of water supply.

However, a number of important limitations need to be considered. As for factors contribute to brownification process, this current study only examine Fe as the main factor contribute to rusty water of harvested rainwater. The fact that Fe is generally correlated to concentrations of dissolved organic matter (OM), which OM concentration may also contribute to rusty water. Besides, other factors behind this trend, may also cause by hydrological factors, climate change (increase in temperature), and changes in land-use and reduced acid deposition.

For the capacity of harvested rainwater, the finding of the study only base on one month observation of rainfall event. This observation does not enough to reflect rainfall event for the whole year. The occurrence of extreme event such as El Nino (flood and droughts) could easily distract the analysis on the capacity of harvested rainwater. Besides, the variability of climate also is not considered, as location this study is influenced by southwest monsoon which commences in May and usually lasts between 3-4 months up to August.

Further work needs to be done in order to establish the RWH system as the main water supply for non-potable water in the future. Electric meter for RWH system should been repair as soon as possible, therefore the capacity of harvested rainwater can be determined more effectively. The electric meter can detect every water usage by the residents, and importantly the cost estimation of water supply could be more accurate. Furthermore, detail investigation on factor correlates to rusty water must be carried out.

Finally, as water crisis looming over the years, RWH system could be the best solution to deal with. As water demand dramatically increases, the government should promote with more aggressive and determined RWH system to people. On the other side, people should be aware and show more appreciation towards availability of water resources.

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