Rainwater Harvesting As an Alternative to Conventional Water Supply for Potable Uses

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ABSTRACT

Presently, the Government of Malaysia is supplying treated water to almost all of its citizens. The sources of water are declining in quality and quantity due to urbanization and development works, while the demand of water is exponentially increased. Utilization of rainwater for daily usage, in particular for potable uses can be a viable option to address the future scarcity of water. Research works by different individuals and institutions are discussed to evaluate the future water crisis and the causes. Preliminary test results of the harvested rainwater quality were analyzed to find the suitability of rainwater for domestic uses. This paper suggests that in addition to existing non-potable use, harvested rainwater can be used for domestic potable purposes after minimal treatment process.

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INTRODUCTION

The very low rainfall intensity during the El Nino phenomena in the year 1997/98 resulted in water rationing for 1.8 million residents in southern Kuala Lumpur City, Bangi and Kajang (Shaaban, A.J., K.S. Low, 2003). The drought also hit other areas in Malaysia such as Penang, Kedah, Kelantan, Sarawak and Sabah. This prompted the government to take immediate and active action through the National Water Resource Council. The council, headed by the Prime Minister provides a forum for the planning and management of water resources, including the issues of interstate and interbasin water transfer (Government of Malaysia, 1999). This is to ensure the water security for the people and it has become an important agenda for the government. Besides the coordination among federal and state governments, and water management agencies, instilling the knowledge of water ethics among the consumers will assist in the preservation of water resources (Moorthy, R., G. Jeyabalan, 2012).

Rainwater harvesting is seen as an alternative in facing the challenges of water scarcity, water stress and increasing demand of water supply. Malaysia, in particular is driven towards water security and sustainability, where the component of water efficiency is one of the main component in the assessment of the Green Building Index (GBI). Water collected from rainwater has been successfully used as non-potable purposes such as toilet flushing, car washing and gardening. However, little research, particularly suitable for the tropical climate like in Malaysia has been conducted to investigate the potential of using the harvested rainwater for domestic purposes i.e., washing, ablution or possibly for drinking. This paper aims at the rationale for rainwater harvesting as an alternative of existing water resources and examines its possibility of potable usage.

Water Resources And Its Demand In Malaysia:

In the 1970s, Malaysians used less than 200 litres of water per capita per day (LPD). This value then increased to about 250 LPD in the 1980s and then to more than 300 LPD (Chan, N.W., 2009). In urban areas, however, it has been estimated that a person uses in average 500 LPD. The International Standard for water use recommended by the United Nations is 200 LPD, where average Malaysian usage has exceeded the limit by 50%. Under Malaysian law, water is the subject of control and regulation by both the Federal and State Government. 94.8% of the population is served with potable water that meets international drinking standards. The demand for Selangor and Kuala Lumpur, both with the densest population in Malaysia, in particular has an average increase rate of 6% water usage per year (Subramaniam, V., 2004). It is estimated for the year 2025, the total demand for sectors including the industries, agricultural, irrigation and domestic is 14,504 million cubic

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metre (mcm) compared to 1,622 mcm in 2005. There will be a doubling in the utilization of water resources at the end of each 20 years period and this would lead Malaysia to be dried by the year 2053, unless due care is taken to conserve the water resources (Rahim, N.A., 2004).

There are over 150 river systems in Malaysia (Keizrul, A. and M. Azuhan, 1998). Streams and rivers contribute 98 percent of total water used in Malaysia, whilst the remainder is contributed by groundwater. River flow regimes are irregular and to secure safe yield from surface water sources, storage facilities were constructed. There are 47 single-purpose and 16 multipurpose dams with a total storage capacity of 25 billion m^3. A major portion of household refuse finds its way into drains and rivers. Every day in the Klang Valley, an estimated 80 tons of waste ends up in the river system. River water quality and pollution control need to be addressed urgently since 98 percent of the total water used originates from rivers (Ti, L.H., T. Facon, 2001).

Decline Of Water Resources:

Rivers are the main source for treated water supply but rapid urbanization puts added pressures on the water resources (Chan, N.W., 2004). The water of Selangor River, for example, supplied the raw water to be treated for more than four million people and industries in Kuala Lumpur, Petaling, Gombak, and Hulu Selangor, is facing a decreasing water quality due to unregulated waste discharges (Department of Irrigation and Drainage (DID) Kuala Lumpur, 2007). In 2012, a survey of water quality at 832 monitoring stations within 140 river basins reported, 74 rivers were categorized as clean water (i.e. class I), 54 rivers with slightly polluted water (i.e. class II and III) and 12 rivers with polluted water (i.e. class IV and V) (Department of Statistics Malaysia (DSM) Putrajaya, 2013). Seven of these polluted rivers were located in the industrial area which is the Pinang and Juru Rivers in Penang; River Buloh in Selangor while Danga, Tebrau, Segget and Pasir Gudang Rivers in Johor (Khalit, A.R., 2005). The water quality of Selangor River is classified as unusable quality polluted water due to the presence of microorganisms, excluding the river stretch upstream of Pertak Kuala Kubu Baru until the Sungai Selangor dam (Fulazzaky, M.A., 2009). High organic content was contributed largely by untreated or partially treated sewage and discharges from agro-based and manufacturing industries.

The Berembun study finds that commercial logging resulted in increase in pH, electrical conductivity and hardness (Zulkifli, Y., 1998). In the first year after logging, the suspended solids and turbidity raised up to 12 and nine folds respectively. Additionally, the Malaysian Environmental Quality Report 1998 reported that out of 836 water samples collected from all over the country, 94.5 % did not comply to the standards for oil and grease, 73.7 % did not comply for total suspended solids, and 29.7 % for Escherichia coli (E. coli) (Department of Environment (DOE), 1998). In terms of toxic wastes, the high tariffs charged for treating the industrial wastes have resulted in many factories dumping their wastes illegally.

Malaysia relies heavily on her rivers as the main raw water supply. Not less than 73 man-made lakes have been created for water supply, irrigation, hydropower generation, flood mitigation and others. Nevertheless the water quality of these natural and artificial lakes is experiencing continuous degradation from pollution (Keizrul, A., 2002). These studies show that the current quality of surface water in Malaysia is alarming. This is translated into high consumption of chemicals and increment of treatment cost, which will definitely put a pressure on the water supply.

Rainwater As An Alternative:

Malaysia receives 3000 mm of rain per year which results about 20,000 m^3 of direct precipitation water per capita per year (Chan 2009). Continuous high rainfall intensity provides Malaysia an estimated total annual water resource up to 990 billion cubic meters (Jitender, D.S., 2006). As such it is expected that these abundant water resource can meet the demand from the consumers. Tapping a portion from this annual rainfall can be a viable option to ease the pressure on surface runoff and capacity of dams. Additionally, from the qualitative aspect rainwater usage will decrease the cost of treatment.

The water supply industry is fully dependent on the surface runoff and artificial storage which give a total volume of 591 billion m^3. The usage for water supply however is less than 2.5%. To give an overview of the raw water fraction in Malaysia, Table 1 shows the distribution of the precipitation, obtained from the work of.

Table 1: Precipitation distribution in Malaysia.

Water Resource	Amount
Annual rainfall	900 billion m^3
Surface runoff	566 billion m^3
Evapo-transpiration	360 billion m^3
Groundwater recharge	64 billion m^3
Surface artificial storage (dams)	25 billion m^3
Groundwater storage (aquifers)	5000 billion m^3

Source: Ti & Facon, 2001

Although air pollution threatens the quality of the rainwater, it still can be considered cleaner than the surface water. Droplets of rainwater contain mainly dissolved oxygen (DO), dissolved carbon dioxide, nitrogen

oxides formed by thunder lightening and sulfur dioxide gas from burning of fuels on the ground (Thomas, P. R. and G.R. Greene, 1993). Lead concentration and high levels of turbidity is observed in the industrial area roof catchments. In the city area, lead concentration has reduced significantly after the banning of leaded petrol usage in Malaysia. In comparison to allowable lead concentration in air (1.5 $\mu g/m^3$), the city of Kuala Lumpur recorded a concentration of 0.04 $\mu g/m^3$ lead during the period 2008-2012. Rural area roof catchments, however report a higher concentration of nitrates and a slightly higher pH. The different roof types influence the rainwater quality with zinc concentrations higher in galvanized iron roof catchments, while pH, conductivity and turbidity levels are higher in concrete tile roof catchments (Malaysia Meteorological Services, 2001). The pollution of rainwater collected from the roof catchments is affected by the diffused pollution from atmospheric deposition, and the number of dry days preceding a rainfall event. Upon contact with surfaces such as roofs, gutters etc., the water may pick up soluble and insoluble impurities and microbial contaminants like E. coli from the animal wastes.

Preliminary Rainwater Analysis:
One of the leading universities in Malaysia, University Kebangsaan Malaysia (UKM) has taken a greener approach by introducing the usage of harvested rainwater for toilet flushing. UKM is located at Bandar Baru Bangi, a district in the state of Selangor, 30 km away from the capital, Kuala Lumpur. The study area (i.e. Bandar Baru Bangi) received a well distributed annual rainfall with the average rain of 2700 mm (Meera, V., M. Mansour Ahammed, 2006). The highest rainfall is experienced in October (during monsoon season) with an average of 483 mm and the driest month is January with approximately 120 mm.

Due to its success, the scope to expand the system to potable usage is under positive consideration. A preliminary analysis was conducted at the UKM campus on the rainwater quality, taking the samples from three sites i.e. the collection tank, the storage tank and the toilet flush tank. Results from each tank as shown in Table 2, displays that the parameters pH, DO and TSS are compatible with the A1 category raw surface water quality (according to the Environmental Protection Agency standard). The quasi-neutral of the harvested rainwater suggests that the air quality within the study area is high. That is the presence of harmful toxic substances (that can lead to acid rain) is minimal and gives insignificant impact to the quality of rainwater. It can be expected that there are some microbiological activities presence due to relatively high concentration of nitrogen ammonia in the harvested rainwater. Even so, the values are within the range of 1.5 mg/l and falls under the category A2 waters. Although the parameters BOD, COD are quite high than the recommended limit values, those are not detrimental to non-potable use and can be treated easily. The quantities of E. coli presence in each tank obviously do not favour potable usage, but it is expected that it will be eliminated through disinfection process. Rooftop harvested rainwater is usually contaminated microbiologically by a variety of indicator and pathogenic organisms unless special care is taken during collection and storage of rainwater (Mohammed, T.A., 2012). In general, all physical parameters exhibit a decreasing trend in values from the collection tank to the toilet flush. This indicates a positive possibility for potable uses, with minimal and inexpensive treatment.

Table 2: Rainwater quality in UKM campus.

Parameter	Collection Tank	Class	Storage Tank	Class	Toilet Flush	Class
pH	7.24	I	7.91	I	8.11	I
DO (mg/l)	7.22	I	7.12	I	8.00	I
BOD (mg/l)	6.35	IV	4.87	III	5.88	III
COD (mg/l)	117.09	V	98.11	IV	63.92	IV
TSS (mg/l)	10.33	I	21.89	I	9.22	I
Nitrogen Ammonia (mg/l)	1.68	IV	0.84	III	0.47	III
E. Coli (/100ml)	11.67	II	8.00	I	8.67	I

Source: Nor Bazilah, 2013

The rainwater harvesting system was also installed in the Faculty of Engineering, University Putra Malaysia. The harvested rainwater is slightly acidic and contains small concentration of lead which comes from the automobile emissions (Shaaban, A.J., 2002). National Hydraulics Research Institute of Malaysia (NAHRIM) implemented several pilot projects of rainwater harvesting. Double storey terrace house and mosque complexes were prepared for this purpose and proved a success implementation. Rainwater quality data which was recorded for a three-year period (from 2003 to 2005) and the measured parameters of DO, pH, Sulphate, Ferum, Phosphate, Copper, Ammoniacal Nitrogen, E-Coli, Turbidity and Temperature show that the quality of rainwater was found within the acceptable limit of Malaysian standard except for E. coli (Palmateer, G., 1999).

Prospect of potable use:
In Malaysia, most roofs are built from terracotta or ceramic tiles with a sloping orientation. After the removal of the first flush, the presence of E. coli remains the biggest challenge due to animal wastes for potable usage. In this aspect, slow sand filter is proved to be able to remove the E. coli from the harvested rainwater. The slow sand filter could remove up to 97% of the fecal coliforms present in the raw water.

Based on a roof area of 100 sq m (typical rooftop size of an average dwelling), an approximation of 300 kilolitre (KL) of rainwater falls on the roof in a year. Typically 150 litres of the initial rain needs to be discarded to wash contaminants such as bird droppings, dried leaves, dirt etc. Conservatively it may be assumed that downpour occurs on half the number of days in a calendar year. Thus, an estimated amount of 25 KL of rainfall needs to be discarded annually. Therefore approximately 270 KL of clean rainwater can be collected from a 100 sq. m roof area of a house, providing an average daily supply of 750 litres available water for use. For most households in Malaysia, this constitutes a major part of the water consumed. A research survey, which conducted for double storey terrace houses, has reported that a family of two adults and four children, who uses rainwater for non-potable purpose, saved up to 40% of their monthly bills and save 34% of their total monthly household water use (Palmateer, G., 1999).

Conclusion:

Water resources in Malaysia are facing big challenges due to increasing demand and decreasing water quality. An alternative to the conventional water supply has become necessity. The quality and quantity of harvested rainwater can meet up a major part of domestic nonpotable water demand in Malaysia. Rural houses receive comparatively pure precipitation than those located in urban areas, in particular within the vicinity of highways and industries. Analysis shows positive change in the rainwater quality from the collection tank to the toilet flush tank. With minimal treatment particularly the removal of E.Coli, it is expected the harvested rainwater can be used for potable purposes. A study is undergoing to find the most economical and sustainable in-situ treatment process to extend the usage of harvested rainwater from non-potable to potable. Considering the availability of rainwater in average Malaysian house hold catchment area, it can be a viable alternative to existing water resources. In this way, rainwater harvesting can be a key player in achieving house hold water security for a secure and sustainable future.

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