RAINWATER HARVESTING AS ALTERNATIVE SOURCE OF SANITATION WATER IN INDONESIAN URBAN AREA (CASE STUDY: BANDAR LAMPUNG CITY)

Gatot Eko Susilo

Lecturer / Civil Engineering Department / University of Lampung
Correspondence e-mail: gatot89@yahoo.ca

ABSTRACT

This paper aims to investigate supporting capacity of rainwater harvesting (RWH) to meet sanitation water needs in the area of Bandar Lampung. Simulation involving rainfall data, house roof data, house dwelling data, and data of domestic water needs per capita is carried out to find optimum supporting capacity of RWH. The simulations show that optimum storage for the RWH in the area of study is 90 m^3. On this design, supporting capacity of RWH for year 2012, 2013, and 2014 is 71.2%, 99.2%, and 99.7%, respectively. Main advantage of RWH is the preservation of groundwater. Others are the reduction of surface drainage discharge and the reduction of electricity consumption for taking groundwater.

Keywords: Capacity, RWH, supporting, sanitation, water

1. INTRODUCTION

The UN World Water Development Report at the World Water Forum in Marseille in 2011 says that water demand will continue to increase in the future. Over-estimated food needs, increasing urbanization, and climate change are the main causes of future water crises. According to the report, by 2050 world food demand will increase by 70%. This will trigger an increase in water demand for agriculture by 19%. Currently the water requirement for agriculture is the most dominant water requirement that is 70% of the total water needs. According to the UN, the world needs to make radical changes in managing water resources in order to meet future water needs. The international community must work together to address the threat of this water crisis. The future water shortage disaster will have a widespread disadvantage for the world community, especially for the poor [1].

Each country has different ways of dealing with water crises for the present and future in its regions. In countries with strong and continuous blowing winds, the windmill is used as a mechanical drive to lift water from the lowland or generate electricity that can be used for water pump machines. In rich Arabic countries, seawater distillation to obtain fresh water is carried out on a large scale. In America, China, and Africa, large dams have been built to house river water and rainwater as a reserve of water in the dry season.

Several countries in southern Asia such as India, Pakistan, Sri Lanka and Bangladesh have developed a method of handling the water crisis by harvesting rainwater. Historically, rainwater harvesting has been carried out in these countries since ancient times and still used until now. In Indonesia, although the annual rainfall is quite high, around 2000 - 3000 mm [2], rainwater harvesting has not been adequately recognized by the community. There are some dry areas and swamp areas that already apply rainwater harvesting to meet domestic water needs. However, these facilities have not been built technically and are still sporadic. So far the application of rainwater harvesting in Indonesia, especially urban areas has not been applied massively.

This paper aims to investigate supporting capacity of rainwater harvesting to meet domestic water needs in the area of Bandar Lampung City. Bandar Lampung is the capital of Lampung Province and a fast growing city. At this time Bandar Lampung is the third largest city in Sumatra after Medan and Palembang. Along with its development, the city will also need a sufficient amount of water in the future. Current water sources are not expected to be able to sustain community water needs as a result of land-use change that reduces the number and capacity of natural water sources. Therefore, the search for new water sources such as rainwater harvesting already needs to be implemented in this city.

2. RAINWATER HARVESTING

In general, rainwater harvesting (RWH) is defined as the activity of collecting and storing rainwater for reuse in daily activities and for groundwater conservation purposes. In this study, RWH is intended as an alternative source of freshwater for the fulfillment of non-potable domestic water needs. RWH for housing, offices, schools, and other settlements is known as Rooftop Rainwater Harvesting (RRWH). This is because rainwater is captured first on the roof of the building before being stored in the reservoir [3]. Basic RWH system consists of several components [4] :

(1) Rooftop for catching rainwater
(2) Gutter for collecting rainwater
(3) Gutter filter for filtering water from gutter
(4) Inlet pipe for sending water from gutter
(5) Tank for storing water from inlet pipe
(6) Pump for taking out water from the tank
(7) Outlet filter for filtering water from the tank
(8) Outlet pipe for sending water from the tank

The illustrations of above components are presented in **Figure 1**.

In the tropical countries, RWH is very suitable to be applied due to their high rainfall and scarcity of clean water sources in the future. At this time, RWH has been carried out by people almost all over the world, especially in dry areas. In Asia, countries in Southern Asia have experienced a lot in the application of rainwater utilization. In China and African countries rainwater harvesting is used as a source of irrigation water. In developed countries such as Australia and North America use rain water for agriculture. On the other hand Japan and European countries harvest rain to meet domestic water needs such as watering plants and flushing toilets.

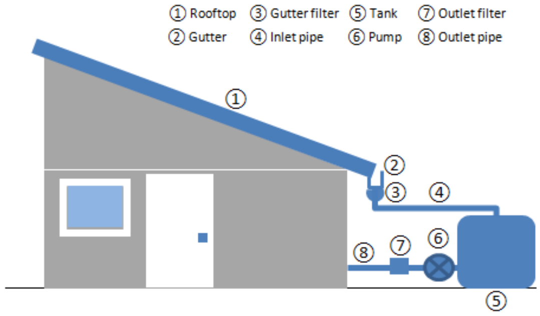

Figure 1. Rainwater harvesting (RWH) system

3. METHODOLOGY

Supporting capacity is the ability of RWH to meet the domestic water needs of a house within a year. To know the supporting capacity of RWH, a simulation involving rainfall data, house roof data, house dwelling data, and data of domestic water needs per capita should be carried out. Supporting capacity is described as the ratio of the number of days whose water requirements can be met by RWH by the number of days in a year. The value of the supporting capacity of RWH is between 0 and 1.

The rainfall data used as the simulation material in this research is the daily rainfall data from Kemiling rain gauge station (PH005). The station is the nearest station from the study location and has sufficiently complete and valid data. The selected data is data from 2012 to represent the dry year, 2013 to represent the wet year, and 2014 to represent the normal year. The annual rainfall for these three stations is 1318 mm, 2900 mm, and 2058 mm, respectively. The manager of this rain data is Mesuji - Sekampung River Organization working under Minister of Public Works and Human Settlements.

Location of this research is Operation and Maintenance Building of Mesuji Sekampung River Basin Organization office in Garuntang, Bandar Lampung. The building has an area of 556.04 m^2 with an effective rooftop area of 80% of the total building area (444.83 m^2). The number of employees in the building is 150 people. On Saturday and Sunday the office is closed, therefore the number of residents at that time is zero.

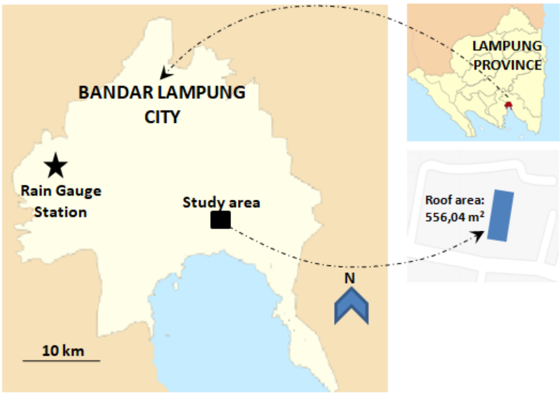

Figure 2. Study area

The simulation to find out the support capacity of RWH applied is basically the water volume fluctuation model stored in the tank. This simulation is based on the principle of water balance model that has been used and modified in previous research [5][10]. The basic equation of the simulation is given as follows:

$$S_t = S_{t-1} + I_t - O_t \qquad (1)$$

where S_t is volume of rainwater in the storage on day *t* (m^3), S_{t-1} is volume of rainwater in the storage on day *t -1* (m^3), I_t is total inflow of rainwater on day *t* (m^3), and O_t is total outflow of rainwater on day t (m^3). If the volume of rainwater in the storage on day *t* (S_t) is greater than maximum storage capacity (S_{max}) then $S_t = S_{max}$ and if (S_t) is lesser than 0 then $S_t = 0$.

Total inflow is the expressed as:

$$I_t = c.R_t.A.1000 \qquad (2)$$

where I_t is total inflow of day *t*, *c* is runoff coefficient for roofs which is assumed to be ranged 0.8 – 1.0 [6], R_t *is* cummulative rainfall on day *t* (mm), and *A* is catchment or rooftop area (m^2). Total outflow is calculated as follows:

$$O_t = nD \qquad (3)$$

where O_t is total outflow of day *t*, n is number of persons live the building. And *D* is water demand per capita per day (m^3).

The simulation is operated for working days. Domestic water demand used in thi simulation is half of total personal sanitation water need which is 30 L/day [7][8]. This is because sanitation water in the office is only needed for flushing toilets, self cleaning, and not for bathing purposes. The runoff coefficient for rooftop is assumed 0.9.

4. RESULTS AND DISCUSSIONS

Daly rainfall data of the year 2012, 2013, and 2014 are presented below. The year of 2012, 2013, and 2014 represents dry, wet, and normal year, respectively. Number of rainfall days each year is 82, 118, and 112 days, respectively. The highest rainfall in the wet season is 120 mm per day.

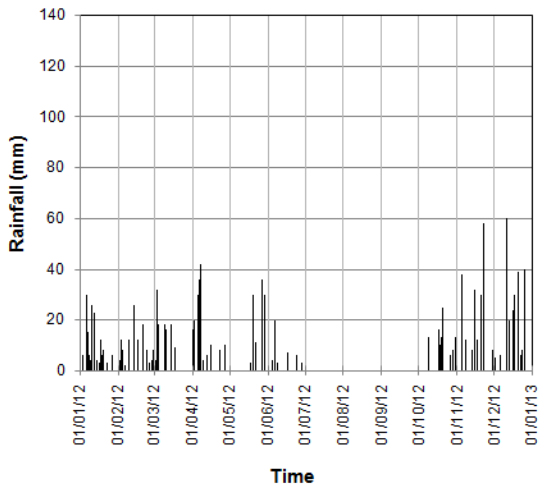

Figure 3. Daily rainfall data of year 2012

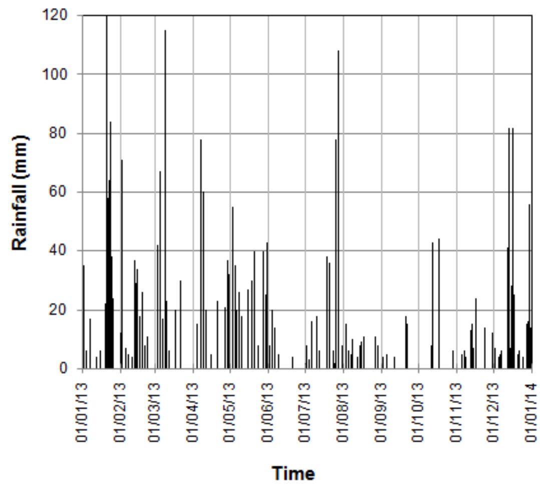

Figure 4. Daily rainfall data of year 2013

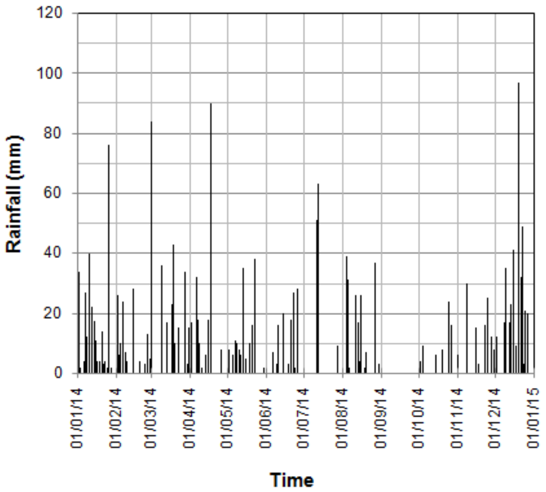

Figure 4. Daily rainfall data of year 2014

Water balance simulation is carried out to find the most effective dimension of rainwater storage by training the value S_{max}. Based on the availability of space for RWH installation, the value of S_{max} used in the simulation ranges between 10 to 150 m^3. Results of simulation for each year are presented in the **table 1** below:

Table 1. Result of water balance simulations

S_{max}	Year		
	2012	2013	2014
10	52.1%	71.0%	71.0%
20	60.8%	82.2%	83.0%
30	64.9%	88.5%	88.2%
40	66.0%	92.6%	91.0%
50	67.7%	94.8%	93.4%
75	71.2%	99.2%	97.3%
100	71.2%	99.2%	99.7%
125	71.2%	99.2%	99.7%
150	71.2%	99.2%	99.7%

Table 1 shows that maximum supporting capacity of RWH for water domestic sanitation demand is on S_{max} of 75 m^3, 75 m^3, and 100 m^3 for dry, wet, and normal year, respectively. The maximum supporting capacity of each year is 71.2%, 99.2%, and 99.7%, respectively. Using graphical illustration, supporting capacity for all years is presented in the **figure 5**. The graph shows that optimum S_{max} for the RWH is 90 m^3. On this value of S_{max} supporting capacity of RWH for year 2012, 2013, and 2014 is 71.2%, 99.2%, and 99.7%, respectively. The graph also shows a significant difference between the result of the simulation in the dry year with the ones of the wet and normal year. This condition indicates that the amount of rainfall and the dimension of the rainwater collection tank are the most important factors to consider in an RWH application. The amount of rainfall is the parameter that cannot be changed in the design of RWH.

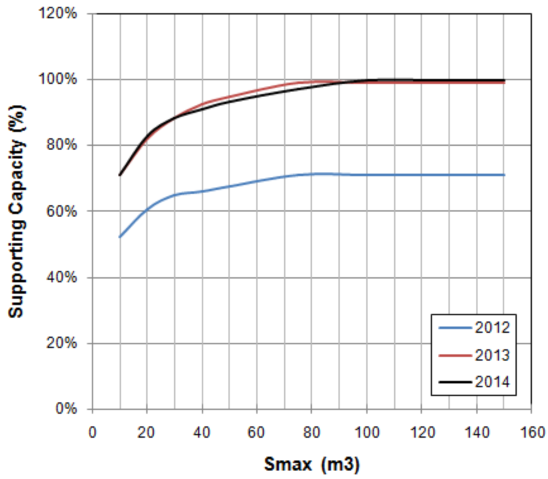

Figure 5. Graphical illustration of balance water simulation results

Based on the optimum S_{max} the fluctuation of water volume in the tank for each year can be identified from the graphs as follows:

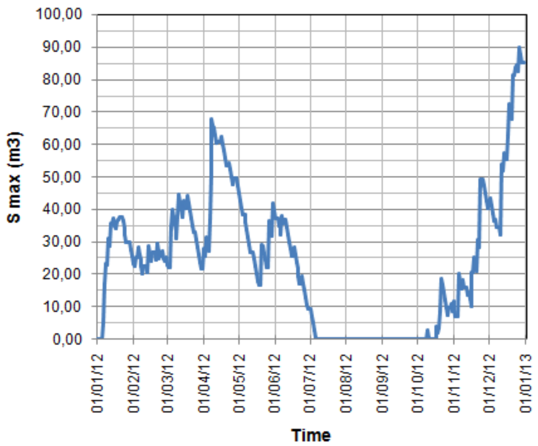

Figure 6. Fluctuation of water volume in the tank in the dry year (2012)

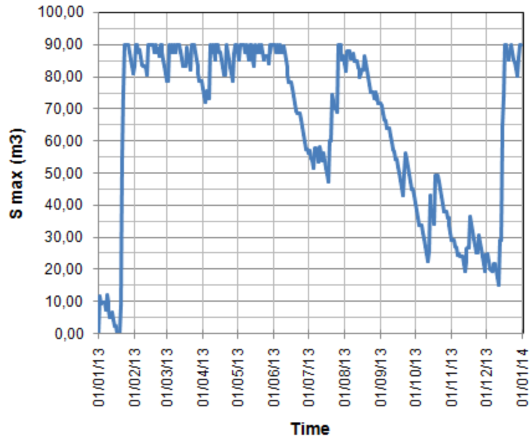

Figure 7. Fluctuation of water volume in the tank in the wet year (2013)

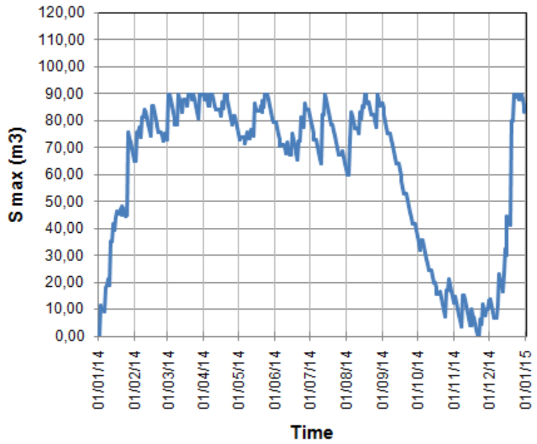

Figure 8. Fluctuation of water volume in the tank in the normal year (2014)

The most frequent problem with RWH implementation is in the dry months like July, August, and September, the amount of rainfall is too small so that the volume of water in the tanks decreases drastically. Under such conditions, the function of RWH becomes interrupted and sanitation water must be obtained from other sources. This kind of problem usually occurs in the application of RWH on the household scale where the water tank is less than 5 m^3 and the rooftop area is less than 50 m^2. Such problems are rarely found in RWH applications that involve large rooftop areas and large storage dimensions, for example in RWH built in office and school areas.

For RWH applied to office and school areas, rainwater tank is recommended to be built below ground level or in the form of ground tanks. Large tank dimension requires a relatively large area for its construction. Therefore, it is expected that the ground above the tank can be used also for other functions such as parking lot or playground. If the ground above the tank will be used as a car parking lot then the ground tank should be designed with reinforced concrete that can hold the weight of the car on it.

In large-scale RWH, ground tank should be equipped with manhole that is easy to open and close for maintenance purposes. Maintenance should be done regularly every three months to ensure continuity of RWH operation. Maintenance on the tank is carried out by sucking the accumulated sediments out from the tanks. Other maintenance is to replace the outlet filter component to ensure the quality of water coming out of the tank. Especially for rooftop, monthly regular maintenance is strongly recommended to prevent the occurrence of clogging at the mouth of the inlet pipe.

RWH can be applied to various scales such as households, offices, schools, industries, hospitals, mosques, and other types of buildings. The buildings mentioned above are buildings that require water in considerable amounts. In the future the water needs will increase and will cause great water crisis. Processing dirty water into clean water is probably one method to get new source of clean water. However, processing dirty water into clean water sometimes cost a lot of money. The application of RWH promises new alternative source of clean water in the future. Rainy season always come every year. And rainwater will be available every year. Because of this, rainwater can be categorized as renewable natural resources.

The main advantage of RWH implementation is the preservation of groundwater. With the application of RWH, the volume of groundwater retrieval can be significantly reduced. Another advantage is the reduction of surface drainage discharge from the roof of the building. Lesser drainage discharge will reduce the risk of flood hazard around the area. The application of RWH not only provides advantages such as the sustainability of groundwater and the reduction of surface drainage discharge, but also can save electricity consumption spent for taking groundwater from deep wells. If groundwater exploitation is implemented intensively then

RWH applications can provide significant benefits by saving electricity costs for pumping operations.

Climatic anomalies such as extreme El Nino event will greatly affect the volume of rain falling to the many areas in Indonesia. Previous research investigating the effect of El Nino in Indonesia had concluded that the inter-annual variability of monthly rainfall in Indonesia is strongly related to the El Nino [9]. Most of the areas affected by the El Nino were Java and Sumatera Island. Another previous study also suggested that El Nino can reduce rainfall volume up to 35% of normal rainfall and reduce supporting capacity of RWH [5].

Some factors that must be considered in designing RWH are the investment cost and the need for routine maintenance. RWH on an office, school, or mosque scale requires substantial investment costs. Large RWH requires extensive land for the construction of water holding tanks. In addition, other infrastructure costs may spend a lot of money. As a tropical country that receives a lot of rain Indonesia should introduce RWH applications more intensively. The socialization of future water supply crisis and the need to find alternative water sources must be implemented from now on in the community. The government should set examples to the community in how to use rainwater for various purposes. RWH development in government offices area is a real example of effective socialization to the community about the importance of RWH.

5. CONCLUSSIONS

The investigation to find the maximum supporting capacity of RWH applied to the office area in Bandar Lampung has been analyzed. Research shows that the maximum supporting capacity of RWH in the study area for the years applied in the simulation is between 70% and 100% with tank volume of 80 m^3 the groundwater requirement for sanitation water in the study area can be saved and replaced by rainwater by 70% to 100%. Maximum supporting capacity of 70% occurs in dry years. In the normal years and wet years the maximum supporting capacity of RWH can reach 100%. This means that in these years all sanitation water needs in the study area can be met by using rainwater.

RWH is heavily influenced by rainfall. The volume of rainfall is a parameter that cannot be changed in the design of a RWH. On the other hand, rainfall is affected by climatic factors such as seasons and climate anomalies such as El Nino and La Nina. Many studies linked El Nino and the decline in rainfall in Indonesia. These studies showed positive correlation between El Nino events and the decrease of rainfall volume in Indonesia, especially in Java Island and Sumatera Island.

6. ACKNOWLEDGEMENT

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7. BIBLIOGRAPHY

[1] Hijauku, 2012, *Pasokan Air Dunia Semakin Menipis*, Situs Hijau Indonesia, http://www.hijauku.com/2012/03/13/pasokan-air-dunia-semakin-menipis/#. 25 January 2018 (21.00 WIB).

[2] Widyanti, E. 2015. *Curah hujan Indonesia*, Pengembangan Media Pembelajaran Geografi. http://eka-widiyanti.blogspot.co.id/2015/04/curah-hujan-indonesia.html. 25 January 2018 (20.30 WIB).

[3] Abdulla, F. A. and A. W. Al-Shareef, A.W. 2008. Roof rainwater harvesting systems for household water supply in Jordan. *Desalination* 243: 195–207.

[4] IRICEN. 2002. *Rain water harvesting*, Indian Railways Institute of Civil Engineering Publication. Pune, India.

[5] Susilo, G. E., K. Yamamoto. and T. Imai. 2011. The identification of rainwater harvesting potency in supporting freshwater availability under the effect of El Nino. *Proceeding of Prosiding of 4th IWA ASPIRE Conference and Exhibition*. International Water Association: Paper 17-4-1.

[6] Fewkes, A. 1999. The use of rainwater for WC flushing: the field testing of a collection system. *Building and Environment*, 34(6): 765–772.

[7] Wulan, A. I. S. 2005. Kualitas air bersih untuk pemenuhan kebutuhan rumah tangga di Desa Pesarean Kecamatan Adiwerna Kabupaten Tegal. *B.Sc Thesis*. Geography Departement, Universitas Negeri Semarang, Indonesia.

[8] Washilatur, R. 2008. Pola konsumsi air untuk kebutuhan domestik di Sukoharjo bagian Utara. *B.Sc Thesis*. Physical Geography Departement, Universitas Muhammadiyah Surakarta, Indonesia.

[9] Hamada, J., M. D. Yamanaka, J. Matsumoto, S. Fukao, P. A. Winarso. and T. Sribimawati. 2002. Spatial and temporal variations of the rainy season over Indonesia and their link to ENSO. *Journal of the Meteorological Society of Japan*. 80:285-310.

[10] Susilo, G.E. 2015. Experience in Rainwater Harvesting Application at Household Scale in Bandar Lampung, Indonesia. *Proceeding of the 1st Young Scientist International Conference of Water Resources Development and Environmental Protection*. *Water Resources Engineering Dept.*, *Brawijaya University of Malang: B – 1*.