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L O K A

RAINWATER HARVESTING AS AN ALTERNATIVE SOURCE OF DOMESTIC WATER IN LAMPUNG PROVINCE - INDONESIA

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Abstract: Urban areas in Indonesia will experience water crisis in the future due to the rapid population growth. Local water companies will face big problems to meet the water needs of these cities in the future, due to limited water resources and environmental degradation. Efforts to find new alternative water sources are important to undertake to ensure the availability of clean and fresh water in the future. This paper aims to investigate the effectiveness of rainwater harvesting facility and the potential benefits of rainwater harvesting applications in urban areas in Indonesia. The cities that are the object of research are Bandar Lampung, Pringsewu, and Metro City. These three cities are the fastest growing cities in Lampung Province. Simulation to find supporting capacity of RWH is applied for house type 45, which has an effective rooftop area of 30 m2. The maximum capacity of the tanks being tested is 1 m^3 and 2 m^3, and the number of occupants is 5 to 7 people. Research shows that RWH has great potential to meet domestic water demand in major cities in Indonesia. From some analysis and simulation of this research, it is known that the supporting capacity of RWH for domestic water supply in the cities studied is 40% to 50% on average. Research also shows that reservoir size 2 m3 is the most recommended dimension in RWH implementation in Lampung Province cities.

Keywords: Rainwater harvesting, Effectiveness, Domestic water

INTRODUCTION

Indonesia is a tropical country, therefore Indonesia has only two seasons, rainy and dry seasons. As a tropical country, rainfall in Indonesia is quite a lot, about 2500 mm to 3500 mm/year (Susilo, 2015). The wet season generally occurs on the October to March. The islands in Indonesia that have high rainfall are Sumatera Island, Java Island, Borneo Island and Papua Island. Although in general the rainfall in Indonesia is high but there are some regions in Indonesia that have low rain intensity such as Sulawesi and Nusa Tenggara. In Indonesia, rain water can be used for various purposes such as for irrigation, plantation, water domestic, and others. For irrigation and plantations, rainwater is the source of water for rivers or reservoirs. On the other hand, rainwater supplies water for shallow wells that are widely used to meet water domestic for Indonesian people. Unfortunately, with high rainfall in the area, Indonesians have not used rain water more wisely. In general, some of the rainfall becomes the drainage discharge and the cause of the flood.

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In other countries, rainwater harvesting is not new. Countries in South Asia such as India, Pakistan, Sri Lanka, and Bangladesh have been doing it since long ago and still do so until now. In Africa, rainwater harvesting plays an important role in the management of irrigation and domestic water supply (Bruins et al., 1986; Handia et al., 2003; Hatibu et al., 2006). In Taiwan, rainwater harvesting has been used to meet the needs of non-potable water (Chiu et al., 2009), and in China research on rainwater harvesting applications for irrigation supplementation has also been carried out (He et al., 2007). In developed countries such as Japan, Western Europe and North America, rainwater harvesting is already a very important water component to be considered economically and socially.

Problem Identification

Lampung is a one of provinces in Indonesia where located on the southern area of Sumatera Island. This province has area of 35,376.50 km² and consists of 3 cities and 15 regencies. The capital of the province is Bandar Lampung with surrounding cities Pringsewu and Metro. Geographically, Lampung lies between 105°45'-103°48' E and 3°45'-6°45' S. The province is adjacent to the Indian Ocean, Java Sea, South Sumatra Province, and Sunda Strait in the east, west, north, and south, respectively. The western part of Lampung is a hilly coastal area that is part of the Bukit Barisan mountains. The southern part is largely a white sandy beach. The middle and north are lowland areas and the eastern part is coastal area as part of the Malacca Strait and the Java Sea. Average temperature in Lampung is 25° C. The highest and lowest temperature is 33° C and 21° C, respectively. The coldest month is April and the hottest month is January. Average rainfall in Lampung is 160 mm per month with the duration of dry season and rainy season of 6 months, respectively. According to the census of 2017, the population of Lampung Province is 12,904,906 people and consists of various ethnics. The biggest ethnic is Java ethnic with 65.80% of all Lampung population. Number of native people was recorded about 12.80% of whole Lampung population.

Bandar Lampung is the largest city in Lampung and is the third largest city on the island of Sumatera after Medan and Palembang. In 2015, population of Bandar Lampung was 1,166,761 people. This number is followed by ones of two other biggest cities, Pringsewu and Metro. Data showed that the population of Pringsewu and Metro was 386,891 and 161,183 people, respectively. Bandar Lampung, Pringsewu and Metro are urban areas that will experience water crisis in the future due to the rapid population growth. Local water companies will face big problems to meet the water needs of these cities in the future, due to limited water resources and environmental degradation. Therefore, efforts to find new alternative water sources are important to undertake in order to ensure the availability of clean and fresh water in the future.

Rainfall can be used as one of alternatives of fresh water source. Rainfall in Lampung generally ranges from 2,000 mm to 3,000 mm per year with good quality for domestic non-consumption and sanitation water. Rainwater utilization is a potency that must be explored to support domestic water needs in urban areas of the Province. Several places in rural Lampung have used rain as an alternative source of fresh water, although it is implemented in a simple and sporadic way. In urban areas, rainwater harvesting is still something new. In 2017, the Government of Lampung Province has just socialized the use of rain water for the first time. Until now the exact formulation of the most effective shape and dimensions of rainwater harvesting installation in cities in Lampung Province has not been established yet. Therefore, this paper aims to investigate the effectiveness of rainwater harvesting facility and the potential benefits of rainwater harvesting applications in these cities. The cities that are the object of research are Bandar Lampung, Pringsewu, and Metro City.

These three cities are the fastest growing cities in Lampung Province. The main income of these cities is the trade in goods and services. Because of its relatively close proximity to Jakarta, many growing businesses are branch businesses from Jakarta. Its populations, mostly migrants and hard workers, are another reason for the rapid growth of businesses in the three cities.


(adaptation from Google Map with modification)

Figure 1. Bandar Lampung and surrounding cities

Theori of Rainwater Harvesting (RWH)

Basically rainwater harvesting (RWH) is the activity of collecting rainwater and storing it in a reservoir with the aim of utilizing the water for various purposes such as maintaining the sustainability of groundwater or as an alternative source of fresh water. The RWH facility that aims to maintain groundwater preservation is usually infiltration well, while RWH's main facility which aims to fulfill domestic water needs is a water reservoir and its equipment. Water reservoirs can be built either above or below the ground. In this research, RWH is intended for the fulfillment of domestic water needs. This type of RWH consists of several basic components such as: rooftop area, gutter, gutter filter, inlet pipe, water reservoir, outlet pipe, outlet filter, and distribution pump. RWH can be built on a large scale for example for office or school areas. The determination of the reservoir dimension at large-scale RWH depends on the amount of annual rainfall.

However, for RWH on a household scale the size of the reservoir is highly dependent on land availability.

During this time the water from RWH can not be used for drinking water. Although there have been several studies investigating the possibility of rainwater as drinking water but the publication is still very rare. A study in Riau Province noted that rainwater quality was slightly below drinking water quality standards (Anuar et al., 2015). This means that rainwater is safe for sanitation purposes.
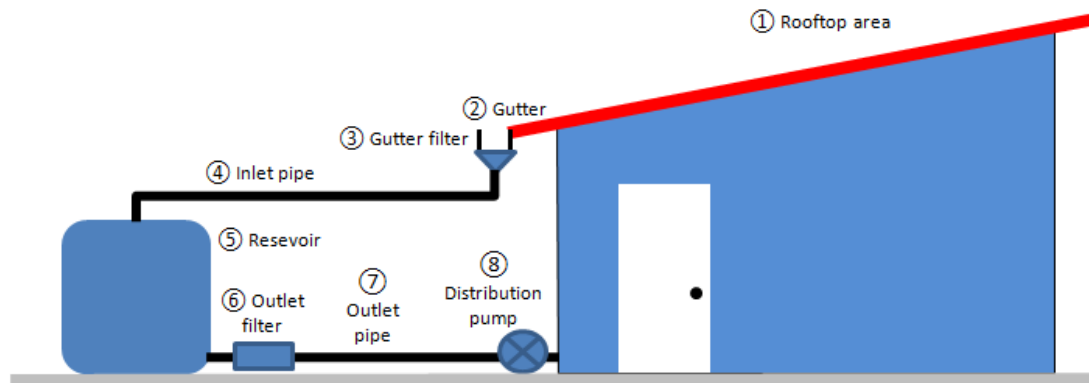
(data source: self illustration)

Figure 2. RWH system

METHOD

In order to determine the optimum dimension of rainwater tank in the RWH facility, it is necessary to calculate inflow and outflow rate coming to and going from the reservoir. Inflow comes from the rainfall caught by rooftop of the house and outflow is the water used by the house inhabitants. The water balance in the tank is calculated using water balance model (Khastagir and Jayasuriya, 2010; Susilo et al., 2011) as follows:

$$S_t = S_{t-1} + Inflow - Outflow \qquad (1)$$

where, S_t is water volume in the tank on day t (m³) and S_{t-1} is water volume in the tank at day $t-1$ (m³). The volume of water in the tank ranges between 0 to maximum capacity of the tank (S_{max}).

Inflow is the function of roof catchment area (A), runoff coefficient of the roof (C), and rainfall (R). C value is taken between 0.8 and 1.0 (Fewkes, 1999). Inflow is calculated as follows:

$$Inflow = R.A.C/1000 \qquad (2)$$

On the other hand, outflow is the function of daily personal water demand (D), and number of people in the house (n) and calculated as follows:

$$Outflow = n.D \qquad (3)$$

Water balance simulation in this research involves daily rainfall data of years 2013, 2014, and 2015. The data are obtained from Mesuji Sekampung River Organization (BBWS Mesuji Sekampung) of Public Work and Human Settlement Ministry. Rainfall data used in simulation for Bandar Lampung, Pringsewu, and Metro is the data from Kemiling (PH005, Fajar Esuk (R006), and Metro Barat (R054) rain gauge stations, respectively. The data are presented below:

(a)

(b)

(c)
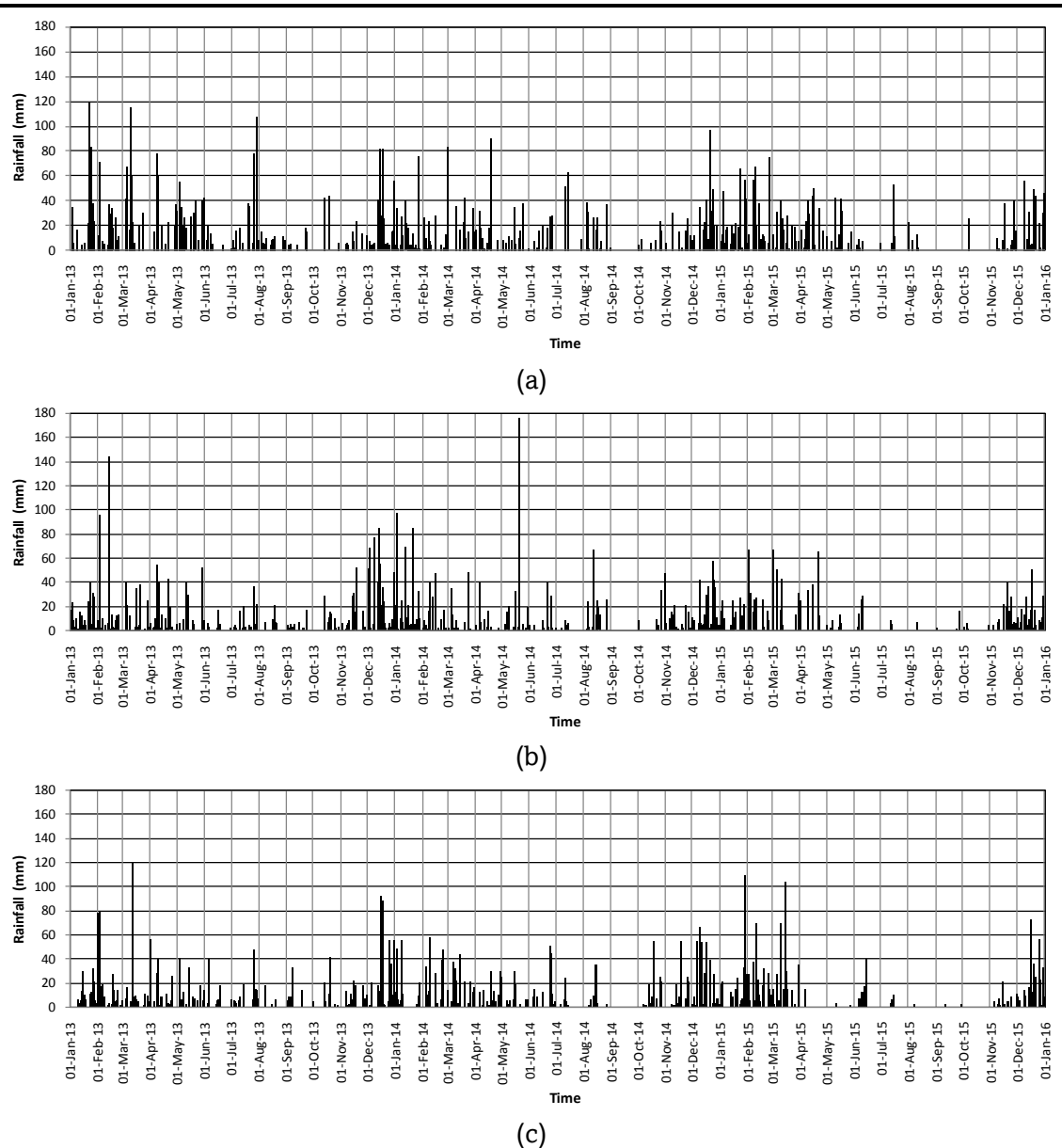
(data source: Mesuji Sekampung River Organization)

Figure 3. Daily rainfall data of study areas: Kemilling (a), Fajar Esuk (b), and Metro Barat (c)

Numerically, data above is presented as follows:

Table 1. Daily rainfall data of study areas

Year	Kemiling Stations for Bandar Lampung City		Fajar Esuk Stations for Pringsewu City		Metro Barat Stations for Metro City	
	Rainfall (mm)	# of Rainy Day	Rainfall (mm)	# of Rainy Day	Rainfall (mm)	# of Rainy Day
2013	2900	118	2391	165	2074	145
2014	2058	112	2049	139	1975	131
2015	2059	106	1419	91	1539	95

Source: Calculation, 2018

Supporting capacity of RWH is the carrying capacity of RWH to replace the use of groundwater for domestic water within 1 year. Supporting capacity of RWH is the ratio of the number of days whose domestic water can be met by RWH with the number of days in a year. Simulation to find supporting capacity of RWH is applied for house type 45, which has an effective rooftop area of 30 m². The maximum capacity of the tanks being tested is 1 m³ and 2 m³, and the number of occupants is 5 to 7 people. Type 45 of house is the most widely used type in the community. Similarly with other variables, the house in Lampung usually consists of 4 to 7 residents. The maximum water reservoir capacity that may be used for household scale is 1 m³ or 2m³ with domestic water needs 50 liters per day (Wulan, 2005; Washilatur, 2008).

RESULTS AND DISCUSSIONS

To find RWH supporting capacity with various parameter values, 48 simulations have been performed for each city. Results of the simulation for each city is presented as follows:

Table 2. RWH Supporting capacity of Bandar Lampung City

Volume of reservoir	n	RWH Supporting capacity			
		2013	2014	2015	Average
1 m³	4	52,9%	55,1%	50,4%	52,8%
	5	43,0%	42,5%	41,6%	42,4%
	6	38,1%	35,1%	34,2%	35,8%
	7	34,0%	29,6%	27,9%	30,5%
2 m³	4	62,5%	62,5%	55,9%	60,3%
	5	53,7%	48,8%	48,8%	50,4%
	6	46,3%	40,5%	41,6%	42,8%
	7	41,1%	34,2%	34,2%	36,5%

Source: Calculation, 2018

Table 3. RWH Supporting capacity of Pringsewu City

Volume of reservoir	n	RWH Supporting capacity			
		2013	2014	2015	Average
1 m³	4	51,5%	46,0%	39,7%	45,8%
	5	40,0%	38,6%	30,7%	36,4%
	6	32,9%	32,6%	26,0%	30,5%
	7	28,2%	27,4%	21,1%	25,6%
2 m³	4	59,5%	52,9%	46,0%	52,8%
	5	47,9%	44,1%	36,2%	42,7%
	6	39,5%	37,0%	28,5%	35,0%
	7	34,0%	32,1%	23,8%	30,0%

Source: Calculation, 2018

With a tank or reservoir of 1 m³, the average of RWH supporting capacity for Bandar Lampung city ranges from 30% to 52%. If the tank size is changed to 2 m³, then the RWH supporting capacity will change to about 36% to 60%.

For Pringsewu City, the average supporting capacity of RWH for tank capacity of 1 m³ and 2 m³ is about 25% to 45% and 30% to 52%, repectively. The complete supporting capacity of RWH for Pringsewu City can be seen in table 3.

For Metro City, the average supporting capacity of RWH for reservoir capacity of 1 m³ and 2 m³ is about 24% to 41% and 27% to 48%, repectively. The supporting capacity of RWH for Metro City is given as follows:

Table 4. RWH Supporting capacity of Metro City

Volume of reservoir	n	RWH Supporting capacity			
		2013	2014	2015	Average
1 m³	4	44,9%	47,4%	32,6%	41,6%
	5	34,8%	37,0%	26,3%	32,7%
	6	29,0%	32,6%	23,3%	28,3%
	7	25,5%	28,2%	19,2%	24,3%
2 m³	4	52,1%	57,0%	36,2%	48,4%
	5	39,7%	44,9%	30,1%	38,3%
	6	32,9%	37,5%	26,6%	32,3%
	7	27,7%	32,3%	21,9%	27,3%

Source: Calculation, 2018

The results above show that the most important component in an RWH application in an area is the amount of rainfall. Rainfall is a parameter that can not be set because it is a natural event that is random. Although the rainy season can be predicted correctly but the date of occurrence and the amount of rainfall is beyond the human ability to predict. If the amount of rainfall becomes large, supporting capacity of RWH value tends to be big. Conversely, if the amount of rainfall becomes less, supporting capacity of RWH value tends to be small. Rainfall determines the maximum capacity of supporting capacity of RWH. Table 2, Table 3, and Table 4 show the year 2015, for each rain gauge station, has the lowest rainfall when compared to other years. This resulted in a small RWH supporting capacity in that year for all cities.

Supporting capacity of RWH is also strongly influenced by climatic factors such as El Nino events. Some studies suggest that areas in western Indonesia are very sensitive to El Nino events (Hamada et al., 2002). El Nino resulted in a decrease in sea surface temperatures around the Western Pacific or the Pacific Ocean around Indonesia. This circumstance encourages the reduction of rain cloud formation so that the rainfall in Indonesia is reduced. Research conducted in 1997 by the Indonesian Meteorological, Climatology, and Geophysical Agency stated that El Nino causes 55% decrease of rainfall from normal rainfall in Indonesia (Kadarsah, 2007).

The effectiveness of supporting capacity of RWH is also determined by the size of the reservoir tank. If the reservoir tank is too small compared to the amount of rainfall it will result in lower supporting capacity of RWH. The volume of wasted rain water will increase and the function of RWH becomes ineffective. Contrarily, if the reservoir tank is too large compared to the amount of rainfall, the optimum supporting capacity of RWH will never be achieved and the investment cost of RWH development becomes greater. The simulation shows that a reservoir of 2 m³ produces a larger RWH supporting capacity when compared to a reservoir of 2 m³. The size of the reservoir that can generate the

maximum RWH support capacity can be found by trial and error. However, the maximum reservoir size for house type 45 is 2 m³. This is because larger reservoir sizes will require considerable space and require substantial investment costs. The placement and size of the reservoir on the RWH system installed at home should be adjusted to the architectural form of the house. Based on the results of this study, reservoirs of 2 m³ can be recommended as standard RWH tank dimensions for Bandar Lampung, Pringsewu and Metro cities. The Water tank of 2m³ capacity is widely available on the market. The dimension of the tank is 163 cm (height) and 136 cm (diameter). This water tank is made of fiber glass material that is durable and available with various brands.

The adoption of RWH, on the other hand, not only makes the use of groundwater less for domestic purposes but also saves electricity to operate water pumps that take water from deep wells. On the scale of households in big cities, the cost of electricity to pump groundwater for domestic water can be quite large. When the ground water well is deep enough then the pump efficiency decreases and the pumping time becomes longer. Automatically the electricity cost will become bigger. If a household applies RWH then it is not necessary to pump water from deep wells. Water is available at ground level and can be distributed by gravity or with a pump that is much smaller in size.

CONCLUSSIONS

The benefits of RWH implementation for household scale in cities in Lampung Province have been analyzed. Research shows that RWH has great potential to meet domestic water demand in major cities in Indonesia. From some analysis and simulation of this research, it is known that the supporting capacity of RWH for domestic water supply in the cities studied is 40% to 50% on average. This means that RWH can supply domestic water for 130 days to 190 days within a year in a household. Research shows that reservoir size 2 m³ is the most recommended dimension in RWH implementation in Lampung Province cities. The reason is because the dimensions match the area of house type 45 and widely available in the market.

The application of RWH on a household scale is not only useful for domestic water supply, preserving groundwater, and reducing flood risk but also providing an economic benefit of reducing the cost of electricity normally used for the operating costs of deep groundwater pumps. In the household scale RWH is quite easy to apply and does not require expensive investment cost. To accelerate the spread of RWH implementation in the household scale, the provincial government of Lampung should provide subsidy for reservoir tank procurement.

ACKNOWLEDGEMENT

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