

Potential of Rainwater System for Domestic Building in Jakarta

Susy Prajna Sari¹, Suhendri²

^{1,2}Architecture Programme, Institut Teknologi Bandung, Ganesha Street No 10, Bandung, Indonesia

²suhendri.aritb@gmail.com

Abstract. Rainwater harvesting is the process of collecting, storing, and reusing rainwater. Different kinds of rainwater harvesting techniques have been used in developed and developing countries. Singapore, for instances, which has limited land sources and high demand of water, use rainwater harvesting technique on the high-rise buildings' roofs to get an alternative source of water. Also, in Japan, rainwater harvesting technique has been applied to residential areas and able to provide clean water for toilet flushing, firefighter, and water supply in an emergency case. Nonetheless, rainwater management in Jakarta, compared to the countries mentioned above, is obviously left behind. With the high rainfall intensity, buildings in Jakarta are quietly possible to apply the rainwater harvesting technique. This paper is trying to analyse the potential of rainwater harvesting application in Jakarta. Starting from house buildings, the paper uses numerical calculation to study the environmental benefits of the rainwater harvesting implementation. The case study was taken in Gading Griya Residence, North Jakarta. The calculation results show that rainwater harvesting scheme can provide enough water supply for washing, flushing, fire extinguishing, and drinking water.

1. Introduction

Jakarta, with its rapid development, is facing the lack of fresh water supply. The Municipal Office of Water Supply (PAM Jaya) recorded Jakarta's annual water demand is 29.400 L/s. Meanwhile, the PAM Jaya could only supply 60,6% of the demand, and thus left 10.000 L/s deficit [1]. This deficit does not include the population growth which implies the demand growth every year.

On the other hand, Jakarta is hit by flood every year in the heavy rain season, between December to February. Flood that occurs in Jakarta is caused by several factors. One of the factors is the less number of available green open spaces in the city. Green open space acts not only as the source of fresh air supply but also as rainwater catchment areas. Another factor is caused by poor drainage systems [2].

One of the aforementioned problems can be a solution for the other. High precipitation rate in tropical city like Jakarta, should be potential to overcome the fresh water issue. But, the existing condition is quite contradictive. It is more a disaster instead of a blessing. Rainwater management and technologies that have been developed recently may be a solution for this contradictory fact. Rainwater harvesting technology, for example, if used widely, could reduce runoff water, and hence reduce flood risk. Moreover, water collected from it can supply water for household or domestic use. Furumai (2016) argues Although Indonesia is a tropical country with heavy rainfall, the utilization of rainwater itself is still not maximal. For example Jakarta which has high rainfall. Based on data from



Meteorology, Climatology, and Geophysics Council, Jakarta's average rainfall is around 2.500 - 3.000 mm each year [4]. The incapability in utilizing the high rainfall makes it turns into a threat for the city. Thus, this paper is aimed to analyse the potential of rainwater harvesting application in Jakarta, by focusing on the domestic sector.

Rainwater harvesting itself is the process of collecting, storing, and reusing rain water from various surfaces such as rooftops [5]. This technique basically has been implemented for years in many countries such as India, Singapore, China, Germany, Japan, and other countries including Indonesia. Singapore, a developed country which has limited earth surfaces has used rainwater harvesting technology to maintain clean water supply. In Japan, rainwater harvesting technique has been implemented in residential areas and it is able to provide clean water for toilet flushing, firefighting, and drinking water in emergency situation [2]. Benefits of using rainwater harvesting system are:

- economical alternative water supply;
- reduce flood risk;
- increase ground water supply;
- reduce soil erosion;
- overcome drought.

There are six basic components in rainwater harvesting system [6]. It explains as follows.

1.1. Catchment surfaces

Catchment surface represents the amount of rainwater that can be caught by a surface. It depends on the size and texture of the surface. Roof surfaces that made of porous and textured material like clay tiles will hold more rainwater than softer roof surface such as aluminum and metal roof. Roof materials also have a role in cleaning rain water from harmful things. As an example, rain water that is harvested from asphalt, wooden and shingle roof only suitable for irrigation needs.

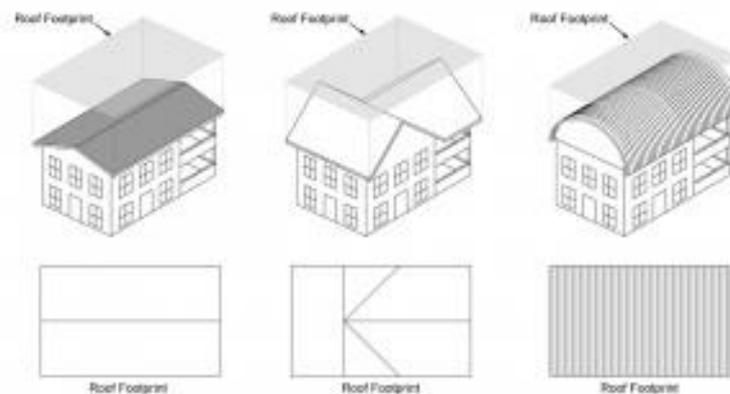


Figure 1. Catchment Surface. Source: rainwaterharvesting.tamu.edu

1.2. Gutters

Gutters serve as waterways for the rainwater. One of the examples is the roof's gutter.



Figure 2. Gutter for roof. Source: thremodeling.com

1.3. Filter

To separate the collected rainwater from its waste, a rainwater harvesting system needs filter. There are various filters which can be used in rainwater harvesting technique. The utilisation of the filter types depends on the amount of the dirt on the roof. Filters can be applied in the gutters to prevent dirt such as leaves, insects, bird's feces, and others into the storage tank.



Figure 3. Rainwater harvesting's filter. Source: pinterest.com

1.4. Storage tank

Storage tank is used for storing the filtered rainwater. It can be made of various materials like fiberglass, polypropylene, concrete, or steel. Storage tank better made of non-reactive materials and it has to be cleaned gradually to remove dirt deposition and prevent moss growth. Storage tank can be put above ground level and below ground level.



Figure 4. Storage tank for rainwater. Source: watertank.com

1.5. Distribution system

Stored rainwater later will be distributed by using a water pump.

1.6. Rainwater care system

Rainwater used for non-drinking water such as irrigation and toilet flushing can be cleaned just by a simple filter. Meanwhile, rainwater used for drinking water need to have further and complex filtration process.

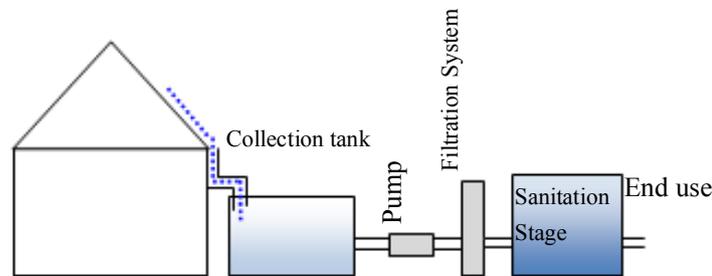


Figure 5. Rainwater harvesting scheme for house

2. Methodology

2.1. Assessment Method

Assessment of the potential of rainwater harvesting is done quantitatively by numerical method. The research identifies monthly average rainfall in Jakarta, as well as the water demand in domestic sector. For the fresh water demand, the data is taken from BPS Jakarta (2016) shows the data from 1999 to 2014. Table 1 shows the water demand data. Further, the average daily water consumption for every household in Jakarta is derived from the water demand data. The formula to calculate the average water consumption (Q_d) is shown by the following formula.

$$Q_d = \frac{\text{Average number of household}}{\text{Average water volume sold}} \tag{1}$$

The formula above gives a value of 1.08 m³ per household per day or 394.52 m³ per year.

Furthermore, numerical method is used to analyse the possibility in rainwater utilisation. In this case, the rainwater harvesting technology calculated is the one that collects rainwater from house roof. The formula used in this analysis is shown as follows.

Average Rainfall per rain days (mm/day):

$$Q_i = \frac{C}{H} \tag{2}$$

where:

C: Monthly Rainfall (mm)

H: Rain days (days)

Water collected from the roof (m³/day)

$$V_j = \left(\frac{Q_i}{1000} \right) \times A \tag{3}$$

where:

A: roof area (m²)

The Equation 3 is then plotted into a table and graph against the daily water consumption.

Table 1. Water demand for domestic sector in Jakarta [7]

Year	Number of Households	Water Sold (m³)
1999	511,548.00	207,629,131.00
2000	562,255.00	228,350,012.00
2001	610,806.00	237,192,219.00
2002	649,429.00	255,161,069.00
2003	690,456.00	274,102,317.00
2004	705,890.00	270,908,257.00
2005	708,919.00	267,080,481.00
2006	725,441.00	266,221,436.00
2007	755,555.00	252,017,908.00
2008	778,044.00	258,939,302.00
2009	795,149.00	266,866,640.00
2010	805,153.00	283,965,498.00
2011	802,636.00	297,819,232.00
2012	800,093.00	310,004,991.00
2013	803,601.00	314,318,816.00
2014	813,356.00	320,883,521.00
Average	719,895.69	269,466,301.88

2.2. Case Study

The house is located at Gading Griya Residence block A3/65. The picture below shows the location map.

**Figure 6.** Case study location

Gading Griya Residence RW 12 is located at Kelurahan Sukapura, Kecamatan Cilincing, North Jakarta. Gading Griya Residence is famous for always flooding when heavy rainfall happens. It happens because of the less ground surfaces and the decreasing of ground level. Gading Griya Residence RW 12 is located at Kelurahan Sukapura, Kecamatan Cilincing, North Jakarta. Gading Griya Residence is famous for always flooding when heavy rainfall happens. It happens because of the less ground surfaces and the decreasing of ground level.



Figure 7. Flood happened in Gading Griya Residence

The average size of the houses in the residence is 9 x 15 meters equal to 135 m². The width of the road is around 3,5 meters and use paving block as the road cover. The residence is always flooding every heavy rainfall and the receding process is very slow although there are a jogging park, empty fields, and fishpond in the residence.



Figure 8. The case study house

3. Results & Discussion

Table 2. Rainfall data and calculation

Month	Rainfall (mm)	Rain days (days)	Rainfall per rain days
Jan	1075	26	41.35
Feb	689	22	31.32
Mar	174	20	8.7
Apr	168	16	10.5
May	47	10	4.7
Jun	174	12	14.5
Jul	214	16	13.38
Aug	39	4	9.75
Sep	0	1	0
Oct	52	4	13
Nov	65	11	5.91
Dec	211	15	14.07
TOTAL	2908	157	

Table 2 displays the monthly rainfall in Jakarta for the most recent year (2014). It contains also the calculation results of rainfall rate for every rain days. From the data, it can be seen that January-February period has the highest rainfall in a year. Total rainfall for a year in Jakarta is 2098 mm. It means, the possible water collected for a year according to Equation 3 is 392.58 m³. Compare to the annual water demand, which is 394.52 m³ the possible water collection could cover almost all of the need (Figure 5). It quite prospective, but a detail analysis is needed to see the real distribution of the rainfall. The more detail analysis is done by calculating the monthly distribution of the rainfall rate and the monthly water demand.

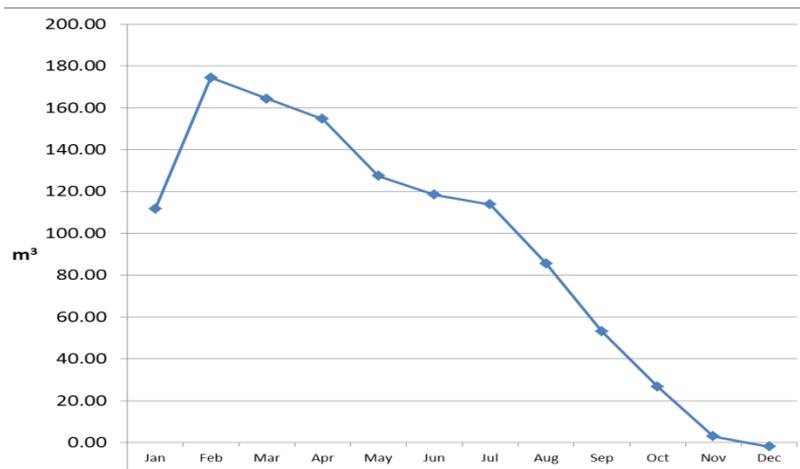


Figure 9. The potential reserved water from the rainwater harvesting after used for the daily needs

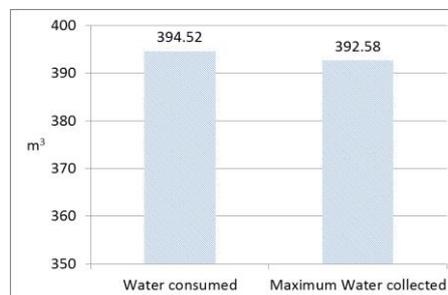


Figure 10. Comparison of water consumed and water collected from the roof

Table 3. Comparison of monthly water collection and consumption

Month	Maximum water collected (m ³)	Water consumed (m ³)	Collected minus Consumed (m ³)
Jan	145.13	33.51	111.62
Feb	93.02	30.26	174.37
Mar	23.49	33.51	164.35
Apr	22.68	32.43	154.61
May	6.35	33.51	127.44
Jun	23.49	32.43	118.51
Jul	28.89	33.51	113.89
Aug	5.27	33.51	85.65
Sep	-	32.43	53.22
Oct	7.02	33.51	26.74
Nov	8.78	32.43	3.08
Dec	28.49	33.51	-1.94

In addition, Table 3 shows the monthly analysis. Along with Figure 6, they display a simulated distribution of water collection and water consumption. The problem is clear after Table 3 plots the distribution. Water demand is constant but the rainfall availability is not. Thus, in order to optimise the rainwater harvesting scheme, a reservoir is needed to conserve the collected water. Figure 6 shows the volume of the reservoir if used.

However, if such a reservoir is used, it needs a large space. The maximum volume to be reserved is 174.37 m³. It equals to a 5m x 5m x 7m box under the yard. Nonetheless, the big reservoir is not quite feasible in the most houses in Jakarta, since they yard is usually limited. If there is a reservoir used, it maybe not as big as the optimum size. And hence it needs to channel the excessive water to the city sewage. Illustration of the reservoir in the case study house is shown by Figure 7.

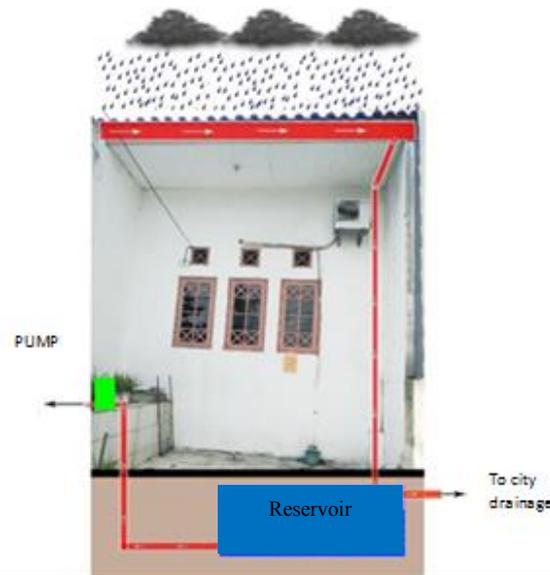


Figure 11. Illustration of the rainwater technology scheme in the case study house

4. Conclusions

The application of rainwater harvesting system aims to reduce run-off from the rainwater that falls to the ground and thus reduce the flood risk. Besides its function to reduce flood risk, rainwater harvesting is also usable for domestic needs. Rainwater harvesting scheme analysed in this study indicates that it is potential to supply almost 100% of an annual household's water demand in Jakarta. However, in order to get that optimum potential, a big volume of reservoir, relative to the site size, is required. Hence, it might be not economically feasible to make a big reservoir for a house. Nevertheless, a small reservoir still benefits the household. In a small volume compare to the daily water demand, the collected rainwater can be used for at least for activities such as car washing, plants watering, toilet flushing, or clean water supply in emergency situation.

Moreover, the large volume reservoir maybe feasible if located below the house building. Yet, it costs higher than under the yard reservoir. On the other hand, if there is a scheme that can manage the rainwater harvesting communally, it might be more feasible to get the optimum potential from the rainfall. A large scale reservoir is easier to get and maintain when it is a communal act.

In terms of sustainability, rainwater harvesting contributes in at least two of three sustainable aspects. It helps environment and economy of the households. For environment, it reduces run-off water and supply "free" fresh water for domestic use. Also, for the economy aspect, houses with rainwater harvesting technology can save money for fresh water, because they have alternative water supply.

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