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RAINWATER HARVESTING APPLICATION IN YOGYAKARTA

Alva Dian Fadhila[1], Widodo Brontowiyono[1], Any Juliani[1*]

[1] *Department of Environmental Engineering, Universitas Islam Indonesia, Yogyakarta, Indonesia*

ABSTRACT

The increasing number of population and variation of human activities are some of the causes of land conversion from open space into settlement. One of the impacts of this land use change is the decreasing quantity of rainwater infiltration into aquifer which furthermore will reduce the water carrying capacity of the area. Green settlement is proposed to answer the problem. Water carrying capacity issue is addressed by the application of rainwater harvesting at supply and demand side of measures. This study was aimed to assess the potency of rainwater harvesting in Yogyakarta, where the problem is becoming more prominent. The assessment included the quantity and quality aspect of rainwater to meet daily water need at domestic level. To assess the quality, samples of rainwater were taken and analyzed to compare to the standard of PERMENKES No. 416/MENKES/PER/IX/1990. Meanwhile, hydrological analysis of rainfall data from the surrounding stations was conducted to assess the quantity aspect. The perspective of the community in regards to the application of rainwater harvesting was also assessed by questionnaire distribution. The result of this study showed that rainwater harvesting can fulfil 37 – 45 % of daily water need. According to the result of the questionnaire distribution, other proposed models of rainwater harvesting include recharge well, biopore and retention pond.

Keywords: Green Settlement; Rainwater Harvesting; Yogyakarta City

1. INTRODUCTION

An increasing population is a cause of several problems especially in urban area. One of those problems is the increasing rate of land conversion from open space into settlements. Yogyakarta City experiences similar problem. In 2015, this city was inhabited by 412.718 persons. With an area of only 32.5 km^2, the population density in this city reached 12.699 persons/km^2 (BPS DIY, 2016). It is among the 10 most densely populated cities in Indonesia. Logical consequence of this condition is rapid land conversion from agricultural land into settlements. In 2016, the remaining agricultural land in Yogyakarta City covered only 56 ha or 2% of the total area, while there were still some 56.538 ha of agricultural land in 2010 (Tribun Jogja, 2016 and Prihatin, 2015).

Land conversion into relatively more impervious land covering reduces its infiltration capacity, thus also reducing the groundwater recharge in the area. As one of the most important sources of water, this condition will decrease the water carrying capacity of the area. Green settlement is proposed to answer this problem. It is a concept of settlement development with sufficient consideration of environmental issues during its establishment. To implement green settlement concept at a practical level, rainwater

* Corresponding author's email: joellyan@gmail.com

harvesting is proposed to address the above-mentioned problem in Yogyakarta City. Rainwater harvesting addresses mainly endeavor at supply side measures to deal with water problem. Consumption of harvested rainwater for daily water use would reduce dependence on conventional water sources such as groundwater or piped water. On the other hand, it can be maintained to infiltrate to the aquifer and perform water conservation. However, the implementation is facing some challenges so that a feasibility study should be conducted prior to its implementation. This paper will discuss to what extent rainwater harvesting can be implemented to answer water problem in Yogyakarta City. It covers the potency of rainwater harvesting to fulfil daily water need while on the other hand address people aspiration on the most fit Rain Water Harvesting purpose to implement in Yogyakarta City Area.

2. METHODOLOGY

This study covered two main parts: firstly, to estimate the potency of harvested rainwater to fulfil daily water need; secondly, to assess the existing rainwater harvesting practice and to explain people's general perception on its future application to address the water problems in Yogyakarta City.

a. Assessment of the existing rainwater harvesting practice and people's general perception

An assessment of the existing rainwater harvesting practice and people's general perception was conducted by observation and questionnaire distribution. Samples were taken from 14 districts of Yogyakarta City and selected according to proportional cluster random sampling. Housing estate and non-housing estate groups were used as two (2) population categories for the questionnaire distribution. A more detailed sub groups of both categories is presented in Table 1.

Table 1. Criteria of group samples

Housing estate criteria		Non-housing estate criteria	
Group	**Property price (rupiahs)**	**Group**	**Criteria (number of population)**
High class	800 million – 2 billion	High populated	> 30.000
Medium	400 – 800 million	Moderate	11.000-30.000
Low cost	80 – 400 million	Less populated	1000-11.000

The questionnaire addressed the existing rainwater harvesting practices in Yogyakarta City and general knowledge on the various purposes and models of rainwater harvesting.

b. Potency of harvested rainwater to fulfill daily water need

Hydrological analysis was conducted to estimate the potency of rainfall to harvest. Rainfall data series from 2006 – 2015 from 3 rain-gauge stations surrounding Yogyakarta City were used for the analysis. The following method and equations were used in the analysis:

- To estimate the average areal precipitation, Thiessen Polygons method was used.
- To estimate the distribution of daily maximum rainfall was by comparing three methods; Gumbel, Log Pearson, and Iway Kadoya Method (Suripin, 2004).

- To analysis the rainfall intensity, Hasper der Weduwen Method was used.
- To define the most appropriate rainfall intensity was by comparing the results of three methods; Talbot, Sherman and Ishiguro Method.

The rainfall intensity for 2-year return period was selected to estimate the amount of the runoff to be harvested by using Rational Equation. Runoff coefficient C and area A which were used in the calculation refer to the rooftop characteristics of houses and buildings where rainwater harvesting was about to be applied (Triatmojo, 2008). The amount of the harvested rainwater was then compared to the daily water need of one household or building and capacity of commonly used storage tanks. It was assumed that the average daily water need is 120 litre/capita/day, while the average number of persons in one household is 5 persons.

$$Q = 0.278.C.I.A \quad (1)$$
$$Q = 5 \text{ person X } 120 \text{ litre/capita/day} = 600 \text{ litre/day} \quad (2)$$

The assumption for C and A value for each group sample is presented in the following table.

Table 2. Value of C and A used for peak discharge calculation

Housing estate			Non-housing estate		
Group	**C**	**A (m^2)**	**Group**	**C**	**A (m^2)**
High class	0,8	77	Highly populated	0,75	42
Medium	0,8	56	Moderate	0,75	48,75
Low cost	0,8	30	Less populated	0,75	56

The suitability of the harvested rainwater to fulfil the daily water need was also assessed on its quality aspect. The samples of the harvested rainwater were collected from 2 sources; directly collected rainfall and taken from the existing rainwater storage tank. The laboratory analyses of these samples were then compared to Indonesian Standard for drinking water quality (PERMENKES No.416/MENKES/PER/IX/1990) as well as quality standard for raw water source for various purposes (Regulation of Governor of Yogyakarta Special Region No. 20 of 2008 Class I and II).

3. RESULTS

The result of the laboratory analysis of the samples is presented in Table 2. Compared with the available standard for drinking water as well as for raw water, this result shows that rainwater meets these particular parameters of standard quality.

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Table 3. Rainwater Quality Laboratory Analysis

No	Parameter	**Unit**	**Sample**			**Standard**		
			1	**2**	**3***	**1**	**2**	**3**
1	TDS**	mg/L	38	37	-	1000	1000	1000
2	pH	-	7,58	7,48	6,21	6-8,5	6-8,5	-
3	TSS	mg/L	2	5	-	0	50	-
4	Free Ammonia (NH_3-N)	mg/L	< 0,006	0,008	0,34	0,5	-	-
5	Nitrate (NO_3-N)	mg/L	0,174	0,048	2,7	10	10	10

) BLH, 2012

Sample 1 : from storage tank
Sample 2 : direct rainfall
Sample 3 : direct rainfall
Standard 1 : Governor Regulation No. 20/2008 (Class 1 Category)
Standard 2 : Governor Regulation No. 20/2008 (Class 2 Category)
Standard 3 : Regulation of Ministry of Health No.416/1990 (drinking water standard)

An estimation of the quantity of the harvested rainwater was acquired through hydrological analysis which is presented in the following tables.

Table 4. Average Areal Precipitation by Thiessen Polygon Method

Year	Average areal precipitation (mm/day)	Year	Average areal precipitation (mm/day)
2006	265	2011	238
2007	388	2012	271
2008	441	2013	363
2009	214	2014	344
2010	267	2015	315

To determine the maximum daily rainfall, 3 distribution models were compared: Gumbel, Kadoya Iwai and Log Pearson III (Suripin, 2004). Iway Kadoya Distribution was then selected since it gave the highest value. The calculation of the rainfall distribution was conducted with Hasper Weduwen Method. And then to calculate the rainfall distribution curve, Talbot, Sherman and Ishiguro were compared. The smallest deviation from these 3 methods to that calculated by Hasper Weduwen Equation was then selected to calculate the rainfall intensity. Talbot Equation was selected through these steps.

Table 5. Comparison of maximum daily rainfall for 2-year return period

Return Period (Year)	Maximum Rainfall (mm/hour)		
	Gumbel	Log Person	Iwai Kadoya
2	299	286	303

Table 6. Comparison of 2-year return period rainfall intensity

Duration (minute)	Rainfall Intensity (mm/hour)			
	Hasper Weduwen	Talbot	Sherman	Ishiguro
5	261,76	267.34	301.55	300.21
10	245,05	250.41	247.64	256.09
20	223,51	222.27	203.36	212.02
30	203,17	199.81	181.23	187.29
40	185,84	181.47	167.00	170.52
60	158,77	153.33	148.83	148.25
80	132,47	132.74	137.14	133.55
120	100,71	104.64	122.22	114.50

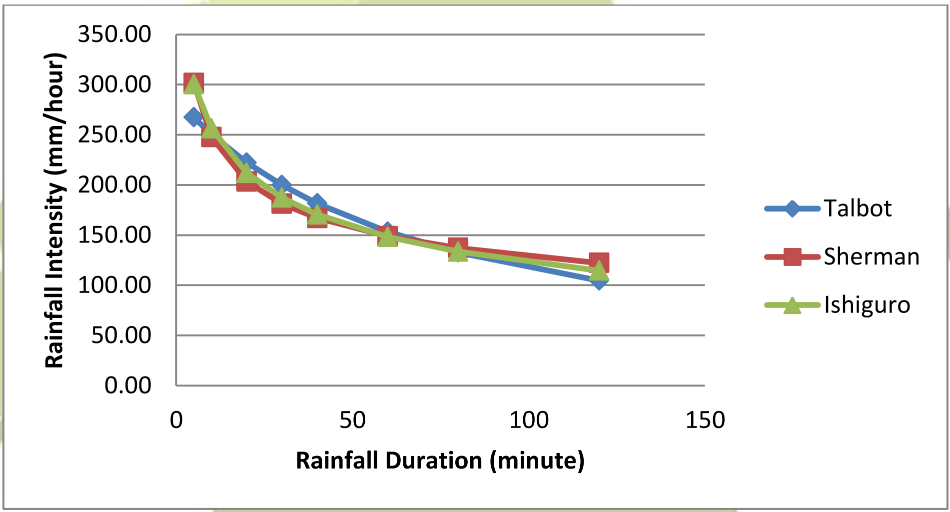

Figure 1. Intensity Duration Frequency (IDF) Curves of 2-year Return Period

Using Talbot Equation for the assumption of the rainfall duration of 20 minutes gave a rainfall intensity of 222 mm/hour. This value was used in rational equation (equation 1) to calculate the peak discharge for a given rainfall intensity and runoff coefficient as well as rooftop area given in Table 2. The result is presented in Table 7.

Table 7. Amount of harvested rainwater for each group sample

Housing estate		Non-housing estate	
Group	Q (litre/day)	Group	Q (litre/day)
High class	378	Highly populated	194
Medium	276	Moderate	226
Low cost	148	Less populated	259
Average	268	Average	227

The comparison of the average amount with equation (2) shows that 37.8 % and 45 % of daily water need could be fulfilled by harvested rainwater in non-housing estate households and housing estate households respectively.

In addition to its significant potency as a source of water for domestic needs, the implementation of rainwater harvesting practice depends on people's willingness to apply it. The result is presented in the following figures.

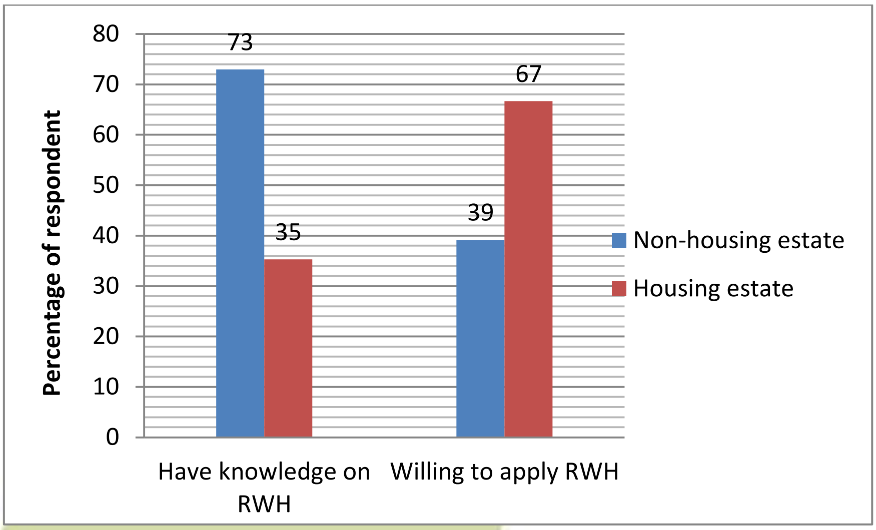

Figure 2. Knowledge of RWH and willingness to apply RWH among respondents of housing and non-housing estate

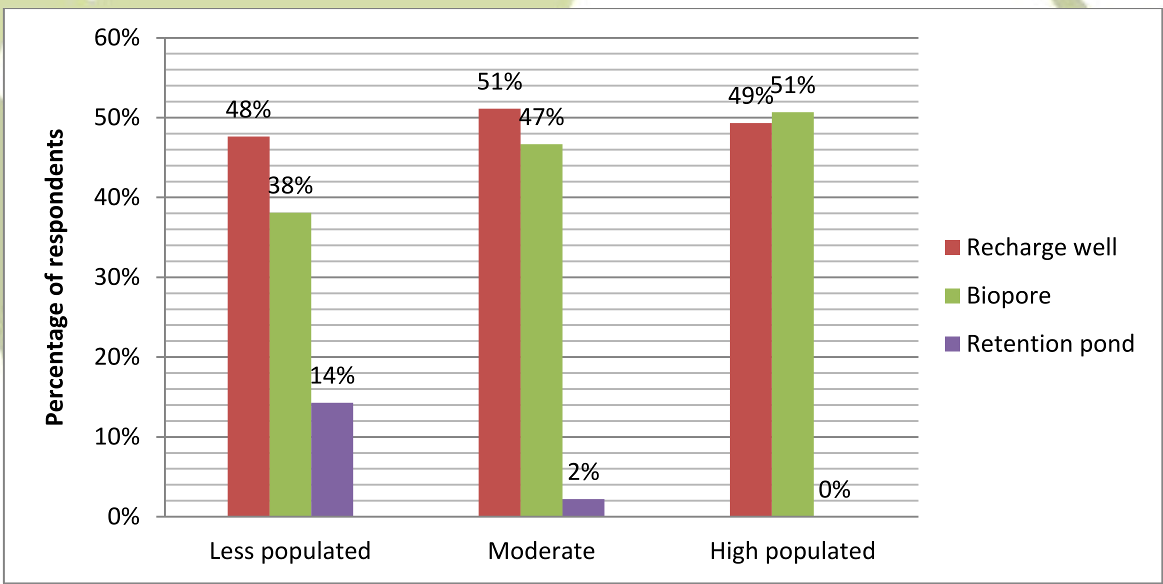

Figure 3. RWH model suitable to apply in Yogyakarta City according to respondents in non-housing estate group

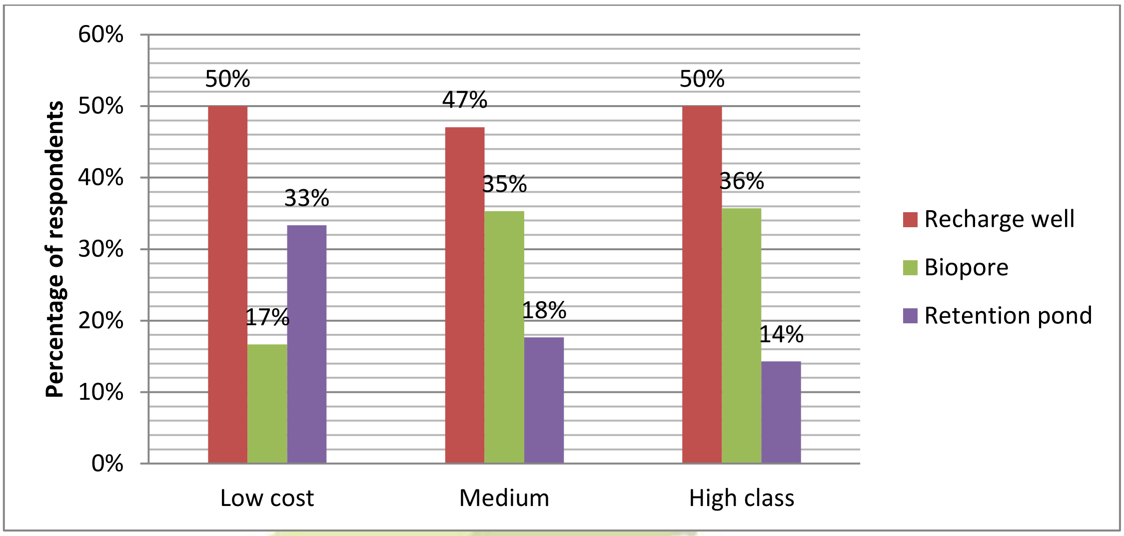

Figure 4. RWH model suitable to apply in Yogyakarta City according to respondents in non-housing estate group

4. DISCUSSION

Yogyakarta City experiences a water problem due to massive urban development. Green settlement is proposed to answer this problem. It is a concept of settlement development with sufficient consideration of environmental issues during its establishment including ones related to water issue. At the practical level, rainwater harvesting is proposed to answer the problem. The study shows that rainwater harvesting can fulfil 37 – 45 % domestic daily water need. The implementation of domestic rainwater harvesting can significantly reduce the magnitude of groundwater extraction since it is the most common source of water in Yogyakarta City. The service area coverage of piped water operated by Yogyakarta Municipality Water Company (PDAM) was only 45 % in 2015 (BPPSPAM, 2015). Of this number, as much as – 38.6% in 2014 which increased to 40.11% in 2015- of its raw water source was still from groundwater/deep well (KRJogja, 2016). A reduction of dependence on groundwater source can prevent further groundwater depletion. Yogyakarta area has experienced groundwater depletion of 30 cm per year since 2011 (UGM, 2016). This figure would be worse concerning the massive development of hotels and apartment in the area within the last 5 years. Some measures should be taken to prevent further deterioration. It is more common to take supply side measure to cope with water supply requirement. Nonetheless, it would be more sustainable to cope with supply by controlling demand. Rainwater harvesting answers this problem at demand side of measures.

However, some problems related to social aspect are still becoming constraint to the implementation of rainwater harvesting at practical level. The questionnaire distribution gave figure on this aspect. In non-housing estate group, a higher percentage of respondents already had knowledge on RWH but their willingness to apply was much lower than those from housing estate group. People are still reluctant to use harvested rainwater to fulfil daily water need. It is shown in figure 3 and 4 in which they prefer rainwater harvesting model for non-consumptive purposes, whereas its quality actually is sufficient for daily consumption with prior treatment as shown in Table 3. Therefore, rainwater harvesting still needs some endorsement and promotion through following aspects (UNEP, 2016):

a. A systematic approach to incorporate rainwater utilization into regulation together with water conservation and wastewater reclamation
b. Implementation policy to put rainwater utilization and other measures as a part of social system
c. Technology development and training to address human resources and the development of efficient and affordable devices and facilities to use rainwater
d. Networking which involve government, citizens, engineers, plumbers and representatives of equipment manufacturers.

5. CONCLUSION

Some concluding remarks of this study are:

a. Rainwater harvesting can fulfil up to 37 – 45 % of the daily domestic water need.
b. Respondents proposed other models of rainwater harvesting which include recharge well, biopore and retention pond.
c. The promotion of rainwater harvesting application involves some aspects including regulation, implementation policy, technological development and training, and networking

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