ROOFTOP RAINWATER COLLECTION, A SMALL SCALE WATER SUPPLY FOR DOMESTIC WATER USE

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ABSTRACT

Indonesia is a tropical country which has two seasons, i.e., wet and dry season. During wet season, some regions get flooded, such as Jakarta, Tangerang, Gresik, Jember, and Semarang. On the other hand, during dry season, some regions get drought. These two contrast situation happen annually. In Tangerang, for example, some communities have to pay about Rp. 450,000.00 per month for water they buy from water vendor, because they are not serviced by public water utilities (PDAM) and their own well get dry. In fact, the rainfall pattern in Indonesia, especially in Java Island is suitable for rainwater harvesting. Rainwater harvesting/collection has been practised in some places in the world to supply the water demand for domestic purposes, agriculture, as well as for livestock. Rainwater harvesting is a simple method in water source development which give some advantages such as supply the water demand for household and reduce the risk of flood caused by high rainfall intensity during wet season. In addition, rainwater harvesting might be appropriate in some places in Indonesia for small scale water supply. However, some considerations should be taken into account to apply rainwater harvesting, such as evaporation rate, rainfall pattern, and community affordability.

Keywords *: rainwater harvesting/collection, small scale water supply, water source development.*

INTRODUCTION

From January to March, the precipitation intensity in Indonesia, especially Java Island tends to be high. Recently, according to mass media report, there have been some regions which get flooded such as Jember, Gresik, South Sumatra and Jakarta, as an impact of high precipitation intensity and human activities. In fact, rainwater gives advantages and disadvantages for humankind. The advantages, for instance, is as a water source for many purposes such as for domestic use, agriculture and livestock.

According to Skinner (p 3.6., 2004), in a number of places in the world some communities have traditionally practised rainwater collection. In addition, rainwater collection is not only an appropriate technology for some developing countries but also is promoted in some developed countries such as Australia.

WHEN IS RAINWATER COLLECTION APPROPRIATE?

According to Skinner (p 3.6., 2004), rainwater collection is appropriate when :

- There is suitable rainfall pattern.
- The householder or community want to use rainwater.
- The rainwater collection system is affordable.
- The other sources of water are not available or only seasonally available, polluted, inconveniently located, or unreliable.

Furthermore, Skinner (p 3.6., 2004) reported that in general, it would seem that regions with annual rainfall between 200 and 1000 mm are particularly appropriate for some form of rainwater harvesting. The length of dry season also affects the appropriateness of rainwater collection since enough water to meet the demand during dry season has to be collected and stored during the wet season.

TYPES OF RAINWATER COLLECTION

According to Skinner (p 3.10., 2004), there are several types of rainwater collection which can be categorised into four main types, i.e. :

1. Artificial raised surfaces
2. Natural land surfaces
3. Improved natural land surfaces
4. Artificial ground surfaces

1. Artificial raised surfaces

The roof of a building is the commonest form of artificial raised catchment, and the advantages of such is that the expense of the catchment has already been paid for. However, the gutters and downpipes needed to collect the water properly can be quite expensive.

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Roofing materials come in several different types such as mud, thatch, tiles, or sheets, which has different characteristic and runoff coefficient. According to Skinner (p 3.14, 2004), the advantages and disadvantages of artificial raised surfaces catchment are as follows:

Advantages :

- It is less likely to become contaminated
- It can be used to fill above ground tanks which can deliver water via taps
- In the case of roofs, the catchments are fairly impermeable and are already in existence on dwellings at the point of use of water for domestic purposes

Disadvantages :

- The area of raised catchment is usually small
- They are expensive to construct if they do not already exist

2. Natural land surfaces

According to Skinner (p. 3.15., 2004), undoubtedly the best natural land surface for a catchment is a smooth sloping surface of impermeable rock. Soils with high clay content, especially ones on which a natural impermeable crust forms are the next best type. The proportion of runoff which can be collected from a natural catchment will not only depend on the type of rock or soil forming the catchment, but also on the slope and shape of the land.

3. Improved natural land surfaces

A number of techniques can be used to improve the very low runoff coefficients of natural land surfaces including the addition of cement, lime, clays or chemical to the soil (Skinner, p. 3.16., 2004). The simplest method is to smooth and compact the soil, which will give a good improvement especially in soils with at least 10% clay or silt. However, in many developing countries the use of chemical or mechanical plant will often not be possible.

4. Artificial ground surfaces

According to Skinner (p. 3.17., 2004), numerous artificial ground coverings have been used in developed countries for rainwater catchments based on a layer of impermeable material applied to the surface such as concrete, bitumen, etc., or sheets of flexible membrane laid over the surface such as PVC, butyl rubber, etc. However, the coverings are very rarely appropriate in developing countries because of their high cost.

RAINWATER COLLECTION SYSTEM CALCULATION

According to Skinner (p 3.18., 2004), there are five important considerations in rainwater collection planning, i.e. :

1. The quantity of water required and when it is required
2. The water losses from the system
3. The rainfall pattern
4. The volume of storage required
5. The best way of storing the water

1. The quantity of water required

The water demands for domestic purposes can include drinking water, food preparation, cooking, personal hygiene, washing pots and pans, washing clothes and cleaning the home. In addition, Skinner (p. 3.18., 2004) noted that the amount of water which can be provided from a rainwater scheme will often be limited by the size of the roof and/or the size of storage tank which can be afforded. What can be afforded may not be sufficient to capture and store enough water for all dry season demands.

2. The water losses from the system

According to Skinner (p. 3.19., 2004), water losses can take place at four points, i.e. from the catchment, from the collection system, from the reservoir, and from wastage when users draw the water.

a. Losses from the catchment

According to Skinner (p. 3.19., 2004), when the size of a catchment is known, then the total volume of water which can be captured during any period is found from :

$$V = C \times A \times d \qquad (1)$$

where :

V = the volume of runoff during a period in litres
A = the area of the catchment in m^2
d = the depth of the rainfall during the period in mm
C = the runoff coefficient

Skinner (p. 3.19., 2004) noted that the runoff coefficient (C) is usually less than 1.0, since some of the rainwater is lost when particularly in the case of ground-level catchment, it soaks into the catchment or is trapped in depressions on the surface. In addition, in the case of elevated catchments rainwater can also splash off, or be blown off, the catchment surface. With thatched roofs, water is retained in the thatching material. If a catchment surface, such as a sheet metal roof, is hot when the rain starts then a small amount of the water is lost by evaporation.

b. Losses from the gutters or channels

According to Skinner (p. 3.19., 2004), if roof gutters (or channels carrying water from ground-level catchments) are too small to carry the peak flow of rainwater during an intense storm they will overflow. If they are poorly constructed they will leak whenever it rains. Both situations reduce the amount of water entering storage so efforts should be made to reduce these losses to a minimum.

c. Losses from the reservoir

According to Skinner (p. 3.20., 2004), losses from the reservoir can be leakage, evaporation or wastage. The amount of leakage from a tank constructed from building materials plastered with cement mortar should be low and no allowance for leakage usually needs to be made.

Skinner (p. 3.20., 2004) noted that evaporation rates in many places are quite high, often over 1200 mm and sometimes more than 2000 mm per year. The resulting losses from open reservoirs are appreciable (equal to the volume found from multiplying the surface area of the reservoir by the depth of evaporation), so wherever possible reservoirs should be covered. Where this is not possible, the evaporation losses from the surface area of an open reservoir need to be calculated for each month throughout a year so that the theoretical volume of rainwater remaining in it can be appropriately reduced. According to Skinner (p. 3.20., 2004), one of the ways of making this allowance in storage calculation is to add to the monthly demand figure the volume lost by evaporation in each month.

Wastage will occur, for example, when water is drawn from a reservoir using a bucket, or when children play with the taps.

3. The rainfall pattern

According to Skinner (p. 3.22., 2004), to find the minimum volume of storage required by a rainwater collection system we need to know the demand on the system, the losses from the system and the supply of water from the rainfall. Skinner (p. 3.22., 2004) noted that records of rainfall over as long a period as possible is necessary to design a rainwater collection system properly. In addition, in some parts of the world rainfall patterns are changing, so recent records are important as well as the historic ones. It is unlikely that a rainfall gauging station will be very near to any proposed rainwater collection site so records from the nearest station(s) will have to be used.

Furthermore, if rainfall gauges do not already exist, they should be set up in a project area as soon as a rainwater catchment system is being considered. Records from these can be compared with any nearby existing stations to see if they are comparable.

In the author opinion, the rainfall pattern in Java Island is suitable for practising rainwater collection scheme.

4. The volume of storage required

There are some different methods to calculate the minimum amount of storage necessary using the rainfall data, such as using a particular year from the rainfall records, construct a design year rainfall pattern, or using mass curve analysis (World Bank, 1985).

In addition, Pacey & Cullis (1986, cited from Skinner, 2004) consider that when calculating the volume of storage required for a collection system, the use of detailed analysis methods are only rarely warranted. It can be justified since for a particular scheme the monthly rainfall depths and runoff coefficient are only estimates. In addition, the accuracy with which the demand pattern can be predicted is usually poor, so the figure assumed for it in the storage calculation will affect the accuracy of the result. Also, in domestic system, roof sizes and demand will vary from house to house, and the roof area and demand assumed in the more accurate complicated analysis will only strictly apply to a few situations.

Example of calculation

The calculation below is an example of calculation for rooftop rainwater collection system.

a. Rainfall data can be seen on the table below.

Table 1 Rainfall data for example calculation

Month	Precipitation (mm)
January	275.0
February	262.5
March	37.5
April	5.0
May	0.0
June	0.0
July	0.0
August	10.0
September	30.0
October	87.5
November	130.0
December	200.0
Annual	1,037.5

b. Check maximum volume of water available in a year.

Assume that the roof of the dwelling is a corrugated iron roof which has an area (A) of 36 m^2, and it is equipped with a good gutter system with runoff coefficient (C) about 0.9. Hence, if storage were no problem, the maximum possible volume of water (V) which can be collected from the roof is :

$$V = C \times A \times d = 0.9 \times 36 \times 1{,}037.5 = 33{,}615.0 \text{ (litres)}$$

c. Check maximum supply against total demand.

Assume that there will be 5 people living in the house with water demand is 15 litres per person per day (15 l/p/d). So, the total demand per year of this family is :

$$5 \times 15 \times 365 = 27{,}375.00 \text{ (litres)}$$

d. Finding the minimum size of tank using the tabular method.

Table 2 shows the calculation to find the minimum size of storage tank. It should be born in mind that we have to choose the right month to start the cycle of calculation to avoid negative figures in column F. In this example, the cycle of calculation started from December.

Table 2 Tabular method to calculate the minimum size of storage.

Month	Rainfall (P) (mm) (A)	Amount captured from the roof (litres) (B)	Cummulative of column (B) (litres) (C)	Volume demanded in month (litres) (D)	Cummulative of column (D) (litres) (E)	Total amount stored [(C) - (E)] (litres) (F)	Deficit/surplus for month [(B) - (D)] (litres) (G)
Dec	200.0	6,480.0	6,480.0	2,281.3	2,281.3	4,198.8	4,198.8
Jan	275.0	8,910.0	15,390.0	2,281.3	4,562.5	10,827.5	6,628.8
Febr	262.5	8,505.0	23,895.0	2,281.3	6,843.8	17,051.3	6,223.8
Mar	37.5	1,215.0	25,110.0	2,281.3	9,125.0	15,985.0	-1,066.3
Apr	5.0	162.0	25,272.0	2,281.3	11,406.3	13,865.8	-2,119.3
May	0.0	0.0	25,272.0	2,281.3	13,687.5	11,584.5	-2,281.3
June	0.0	0.0	25,272.0	2,281.3	15,968.8	9,303.3	-2,281.3
July	0.0	0.0	25,272.0	2,281.3	18,250.0	7,022.0	-2,281.3
August	10.0	324.0	25,596.0	2,281.3	20,531.3	5,064.8	-1,957.3
Sept	30.0	972.0	26,568.0	2,281.3	22,812.5	3,755.5	-1,309.3
Oct	87.5	2,835.0	29,403.0	2,281.3	25,093.8	4,309.3	553.8
Nov	130.0	4,212.0	33,615.0	2,281.3	27,375.0	6,240.0	1,930.8
Annual	837.5	27,135.0	33,615.0	27,375.0	Max storage =	17,051.3	
						Total surplus =	6,240.0

(source : Pudyastuti, 2005, adapted from Skinner, 2004)

From the table above (column (F)), it can be said that the minimum volume required to prevent any overflow is 17,051.3 litres or 17.05 m^3, hence the capacity of the tank will need to be larger than this to allow for the dead storage space below the outlet and any air space above the overflow to the tank. Furthermore, according to Skinner (p 3.27, 2004), if affordable it is wise to supply more storage than is indicated by the calculations to allow for unexpected variations in the pattern of rainfall and the pattern of the demand.

5. The best way of storing the water

The water storage is expensive, hence the most cost-effective solution to suit the local situation is required. Skinner (p 3.36., 2004) reported that one idea to make storage more affordable is to promote the use of incremental construction of storage.

MAINTENANCE AND IMPROVEMENT OF COLLECTED RAINWATER QUALITY

According to Skinner (p 3.36, 2004) and Harvey (2005), clean rainwater can be contaminated :

- as it passes through the atmosphere
- as it flows over the catchment surface
- while it is being stored or during collection from storage
- in the home
- during maintenance

As the impact of industry activities and carbon emission from transportation, the atmosphere becomes polluted. Furthermore, downwind of pollutants in the air can be adsorbed by raindrops, resulting in some pollutants being present in the collected rainwater. Besides that, wind-borne dust can also be picked-up by raindrops. However, this is not usually a major problem.

According to Skinner (p 3.37., 2004), if the water is carefully collected and stored before consumption, the quality of the water often improves because after a few days many of the bacteria die-off in the tank.

In addition, Skinner (p 3.37., 2004) reported that systems to remove the first flush of water from the catchment, or to settle or filter our contaminants can prevent larger solids from entering the storage. Deposits of dust and debris often build up on roofs and in gutters during the dry season and these are likely to be washed off the next time it rains. The provision of a device to divert the first flow (first flush) away from the storage tank can dispose of most of these deposits.

Furthermore, the removal of organic pollutant is advantageous since their presence aids the survival of bacteria in the storage tank and may add unpleasant odours or taste to the water.

In addition, according to Skinner (p 3.41., 2004), unpolluted water which enters a storage tank or reservoir can be contaminated during storage. Open tanks and reservoirs are easily contaminated by wind-blown debris, birds, small animals or amphibians. Hence, the tanks or reservoirs need to be fenced off and provision should be made to divert polluted surface water away from the tank. The roof to a covered tank needs to be of a good standard to exclude small animals, amphibians, and dust.

In addition, Skinner (p 3.41., 2004) noted that a filter constructed on the base of the tank and connected to a handpump is a good method of improving the quality of the water if the handpump and filter can be properly maintained.

Furthermore, there are some methods to produce good quality drinking water from rainwater by purifying the water after it has been collected, for instance, small scale domestic sand filtration, ceramic filters, solar disinfection, chlorination and boiling.

In addition, tanks and reservoirs need to be cleaned and de-silted periodically as well as monitoring for leaks.

POSSIBILITY OF THE APPLICATION OF ROOFTOP RAINWATER COLLECTION

Based on a personal communication with the communities living in Karawaci (Tangerang), they said that they have to pay about Rp. 450,000.00 per month to water vendor to buy the water for their domestic use. On the other hand, during the wet season, there is too much water from precipitation. According to some mass media reports, the groundwater source in Tangerang and Jakarta has been contaminated, either by E. coli bacteria or seawater intrusion. Hence, in the author opinion, rainwater is a suitable water source to supply the water demand. In addition, rainwater collection is an advantageous method to store the rainwater during the wet season which can give benefits such as supply the domestic water demand, and reduce the risk of flood.

Other example is Gunungkidul Regency. Gunungkidul Regency is a dry region, and it always get drought during dry season. Some communities in Gunungkidul have got rainwater collection tank made from mortar cement which give enough supply for their domestic water use. However, numbers of communities still have problem to supply their domestic water demand due to several aspects such as affordability to construct the water tank.

CONCLUSIONS

According to the explanation above, it can be concluded that rainwater could be a suitable water source when the other water sources is polluted or not available. In addition, the rainwater collection is a simple method in water source development to supply the water demand, especially for small scale purpose. The rainwater collection also give benefits such as supply the domestic water demand and reduce the risk of flood during wet season.

However, further research should be done to find whether the rainwater harvesting is feasible or not to be practised. In addition, to apply the rainwater collection systems, some considerations should be taken into account, such as rainfall pattern, evaporation rate, and communities' affordability.

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