RAINWATER HARVESTING SYSTEM'S UTILIZATION FOR DOMESTIC WATER NEEDS IN KOBANGO II HAMLET, BANTUL REGENCY

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ABSTRACT Limited groundwater, especially during the dry season, poses a challenge for Kobango II Hamlet Bantul Regency residents to have sufficient clean water supply for their daily needs. Inadequate aquifer conditions and the inability to release enough water are reasons for clean water scarcity. Thus, this study aims to determine the effectiveness of using the rainwater harvesting (RWH) system for domestic water needs in the Kobango II Hamlet Bantul Regency. The method used in this research is conducting a survey, observation, quantitative analysis of secondary data using rainfall data and aquifer conditions and calculating RWH system requirements. The results obtained from this research demonstrated that the required diameter of the vertical gutter for the RWH system is 6.65 cm and the diameter of the gutter is 0.056 cm.

Keywords: *Clean Water, Groundwater, Rainwater Harvesting System, Scarcity, Aquifer*

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1. INTRODUCTION

Clean water is a basic necessity for human survival. In some tropical countries, the population and domestic activities continue to rise, but the clean water supply remains limited, thus, unable to fulfill the increasing demand. Furthermore, an unstable population pose challenges in controlling the losses and degradation of clean water (Wetzel, 1992). Even though water is a renewable energy, good management is vital to ensure sufficient resources to match human needs throughout the year (Kusakana, 2015). Groundwater is one of the most demanded resources by humans due to its availability and quality (Walton, 1970; Todd, 1980; Feter, 1994 in Santosa, 2014). It is well protected from contamination and act as the primary water source for drinking and household use (Zektser, Loáiciga, & Wolf, 2005). Furthermore, groundwater contains geological formations such as the aquifer, which can store and pass large amounts of water.

In recent years, groundwater usage has increased tremendously and exploited at harmful levels in some localities. For instance, environmental problems are rising in the southwestern United States due to overexploitation, i.e. stream flow reduction and decline lake levels, reduction or elimination of vegetation, land subsidence and seawater intrusion into coastal aquifers (Zektser et al., 2005). The constant increase of groundwater abstraction, along with the decreased groundwater recharge, may lead to flooding problems (Permana, Er, Aziz, & Ho, 2015). Groundwater is accessible through dug wells or boreholes; however, its scarcity has become a problem in some areas. For instance, Kobango II Hamlet, Bantul Regency, has been plagued by this issue since July 2019 due to the long dry season in Yogyakarta and inaccessible groundwater sources (Bantul Regional Disaster Management Department, 2019). The government has taken action by delivering a clean water supply for the locals. Nevertheless, this place remains vulnerable to drought and destruction of water catchment areas caused by human activities, hence, classified as a drought-prone zone.

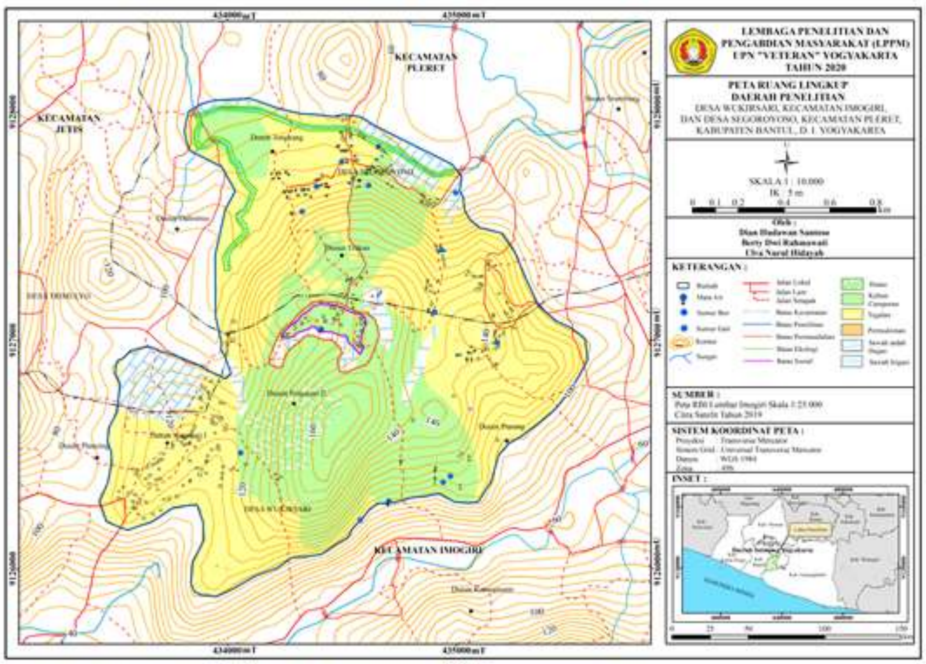

Figure 1. Research location

Kobango II Hamlet is an area with limited groundwater and often experiences drought, especially during the long dry season. In this research, a survey was conducted to assess the current situation in the study area. The findings showed that it is challenging to utilize subsurface water, especially in deep aquifers, to meet the clean water demand. Based on the data collected, groundwater in the deep aquifers is almost impossible to access via drilling wells. Therefore, a good water management technique is vital in maximizing the usage of existing water resources.

A technique that can be used to overcome this hamlet's problems is using the Rainwater Harvesting (RWH) system. Thus, this study aims to utilize rainwater harvesting in meeting the needs of clean water for the residents of Kobango II Hamlet Nogosari II, Wukirsari Village, Imogiri District, Bantul Regency, Yogyakarta. The cost of installation of this is heavily considered since it is the most prevalent factor hampering the new technology application (Olatunji, Raphael, & Yomi, 2018)

2. MATERIAL AND METHODS

Water shortage for domestic needs can be solved using the RWH method made possible by establishing a Rainwater Storage (RWS). RWH is an alternative that can be adopted in areas with limited clean water sources. Collecting rainwater from the roof of a house is a cost-effective means to store water for household use. It is an alternative for other water sources such as dug wells, boreholes and regional water utility companies. There are three purposes for making RWS in the management of water availability which can be adjusted based on environmental conditions: increase water demand, vary the availability of water, and provide a convenient resource for the community. Since the research area lacks accessibility to groundwater, RWS is the most convenient for the community.

2.1 Rainwater Storage Planning

RWS establishment must meet several criteria from a technical and non-technical perspective. A good RWS must follow the following principles:

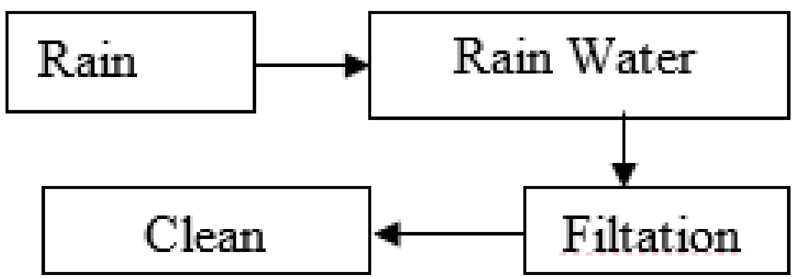

Figure 2. RWS principle

RWS capacity was calculated to determine the rainwater volume that can be obtained at a particular time. The capacity of the RWS storage tank is determined based on the height of the rainfall, catching area, water use, number of dry days and the population.

2.2 Rainwater Storage Components

RWS consists of three basic components as the following:

1. Haul to catch rainwater.
2. Delivery system to transport water from Rooftop to the reservoir.
3. Water reservoirs or tanks for water storage.

Out of the three components, RWH has other components that are more detailed with different functions and uses. Each component of RWH is made based on the calculation of rainwater capacity.

Table 1 RWS components

Component	Function	Note
[A1]W[A2]atershed	Collect rainwater	Roof of houses made of tiles or zinc
Gutters (Horizontal and vertical gutters)	Collecting rainwater that falls on the catchment plane	Gutters are designed to redirect the flow to the reservoir
Filter	Filters rainwater from dirt. The filter media can be sand with gravel as a buffer	Placed on the container
Manhole	Provide access to the reservoir for maintenance and cleaning	Always closed
Collecting tub	Serves as a reservoir to safely collect rainwater during the rainy season or a container for clean water distributed through tank trucks.	Made of ferrous cement, masonry, iron drums, fiberglass reinforced plastic (FRP)
Inlet pipe	Drains water into a reservoir	
Exhaust pipe	Evaporating rainwater that exceeds the holding capacity	Covered with mosquito netting
Water dispenser	To remove or collect water	
Drainpipe	For water passage when draining the tub	
Sewer	To channel wastewater to keep RWH clean and dry	
Air pipe	To remove dissolved gas in rainwater	
Floor	RWH foundation	

Source: Sudarmadji (2014)

2.3 Filter components

Rainwater collected in a storage tank is susceptible to contamination by dirt that flows in the roof or gutter; thus, a filter is required to improve the water quality. Sand and gravel are useful as a filter tubs. The thickness of the sand is 30 - 40 cm with an effective diameter of 0.3 - 1.2 mm, a uniformity coefficient of 1.2 - 1.4 mm and a porosity of 0.4. Meanwhile, the gravel media should be 20 - 35 cm thick with 10 - 40 mm diameter.

2.4 RWS design

Several parameters should be calculated in designing an RWS: water requirements, rainfall, and other components such as roof area/rainwater catchment. These measurements will affect the designed dimensions to ensure effective RWS. In addition, non-technical factors should be considered in the selection of materials used as RWS.

2.5 Domestic water needs

Domestic water needs of rural communities according to SNI 19-6728.1-2002 concerning the compilation of resource balance is 60 liters / day / person (Badan Standardisasi Nasional, 2002). The research area has a population of 115 people.

Water requirement per day = Population x 60 liters / day / person……………………...…(1)
= 115 people x 60 liters / day / person……………..………....(2)
= 6,900 liters / day

Thus, the domestic water demand in the area is 6,900 liters / day.

2.6 RWS Capacity Calculation

To ensure an effective RWS, it is essential to calculate the storage capacity based on the existing rainfall in the study area. The RWS capacity will be used as a reference in determining the dimensions of the reservoir and gutter tanks.

Table 2 Average monthly rainfall (mm)

Month	Average (2009 - 2018)	Month	Average (2009 - 2018)
Jan	241.926	**Jul**	12.872
Feb	197.415	**Aug**	8.216
Mar	211.246	**Sept**	45.15
Apr	142.324	**Oct**	45.279
May	65.649	**Nov**	191.32
Jun	29.228	**Dec**	267.771

The rainfall data were obtained from Balai Besar Wilayah Sungai Serayu-Opak Barongan Station because of its proximity to the study area. Based on the rainfall data, the RWH capacity will be calculated to determine the RWH design for each house, consisting of a roof area of 100 m^2 and five family members.

Figure 3. Urban house

Table 4 RWS capacity

Month	Days	Average rainfall (mm)	Roof Area (m^2)	Rainwater that can be stored (liters)	Water need (liters)	Lack of water (liters)	Excess water (liters)
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Jan	31	241,92	100	24192,6	9300		14892,6
Feb	28	197,41	100	19741,5	8400		11341,5
Mar	31	211,24	100	21124,6	9300		11824,6
Apr	30	142,32	100	14232,4	9000		5232,4
May	31	65,649	100	6564,9	9300	2735,1	
Jun	30	29,228	100	2922,8	9000	6077,2	
Jul	31	12,872	100	1287,2	9300	8012,8	
Aug	31	8,216	100	821,6	9300	8478,4	
Sep	30	45,15	100	4515	9000	4485	
Oct	31	45,279	100	4527,9	9300	4772,1	
Nov	30	191,32	100	19132	9000		10132
Dec	31	267,77	100	26777,1	9300		17477,1
Total		**1458,39**		**145839,6**	**109500**	**34560,6**	**70900,2**

Source: Author (2020)

Where:
(e) = (c) x (d)…………………………………………………………………………………...(3)
(f) = (b) x family member x water need/person/day…………………………………………...(4)

The size of the reservoir is determined based on water consumption and the amount of water availability. First, the ideal tub size is determined by calculating 5% of annual rainwater and 5% of the water requirement of each household (Institution British Standard, 2013). Then, the minimum value between the two is determined as a reference in determining the dimensions of the reservoir.

Potential rainwater = 5% x 145,839.60 liters…………..(5)
= 7,291.98 liters = 7,292 m^3
Water requirement = 5% x 109,500 liters……………………………………………..………(6)
= 5475 liters = 5,475 m^3

Calculations (a) and (b) exhibited that the potential rainwater value is greater than the value of water needs, requiring 5.475 m^3 reservoir volume. Materials needed to make RWS are ferrous cement, masonry and Fiberglass Reinforced Plastic (FRP), the most common being masonry due to its simplicity. Masonry RWS is rectangular with a size based on the calculated reservoir and rainwater volume.

Table 6 Reservoir dimension using a combination of masonry and exhaust pipe

Volume (m^3)	Length (cm)	Width (cm)	Height (cm)	Plaster Thickness (cm)	Wall thickness (cm)	Exhaust pipe (cm)
2	130	130	120	2	14	25
4	180	180	125	2	14	40
6	210	210	140	2,5	15	40
8	225	225	160	2,5	15	50
10	250	250	160	2,5	15	50

According to Table 4, the dimension of the reservoir is 210 cm in length (l), 210 cm in width (w) and 140 cm in height (h). Next, the raw water flow is calculated to find the dimensions of the signposts and vertical gutters. Then, the raw water discharge or the average rainwater flow is obtained from the multiplication of the average rainfall intensity with the roof area divided by the period of rain. The assumption made for this calculation is as the following: catching area = 100 m^2, rainfall intensity = 3.25 mm for five minutes with a velocity of 0.20 m / s and fall height = 3 m.

Calculation:
Average water discharge (rainfall)

$Q = (I \times A) / T$ ……(7)

$Q = ((3.25 / 100)\ m \times 100\ m^2) / (5 \times 60\ s)$ ……(8)

$Q = 0.0011\ m^3 / s$

Calculation of gutter signs

$A = Q / V$ ……(9)

$A = 0.0011 / 0.20 = 0.005\ m^2$ ……(10)

$A = 1 / 2\pi r^2$ ……(11)

$r^2 = A / ((1/2)\ \pi)$ ……(12)

$r^2 = 0.005 / ((1/2)\ \pi)$ ……(13)

$r = 0.056\ m$

Calculation of vertical gutters

$v = \sqrt{2}\ g\ h$ ……(14)

$v = \sqrt{2}\ 9.8 \times 3 = 7.67\ m / s$ ……(15)

$A = Q / v$ ……(16)

$A = (0.0011\ m^3 / s) / (7.67\ m / s)$ ……(17)

$A = 0.0001\ m^2$ ……(18)

$r^2 = A / ((1/2)\ \pi)$ ……(19)

$r^2 = 0.0001 / ((1/2)\ \pi)$ ……(20)

$r = 0.0095\ m$

The diameter of the vertical gutter = 2 x 0.0095 m
= 0.019 m = 1.9 cm.

For safety reasons, the vertical gutter diameter is multiplied by 3.5; thus, the gutter diameter needed is 6.65 cm.

2.7 Operation and maintenance system

It is important to focus not only on the RWH design and development but also on the milling and maintenance system. It is to ensure the quantity and quality of the collected water and maintain the good condition and sustainability of the RWH system.

Table 7 Maintenance operation procedures

Preparation for Operation	Implementation of Operations
• Before filling, the inlet pipe must always be closed while the exhaust pipe remains open • Avoid water in gutters when it rains for the first time after the dry season • When filling the tub, rainwater during the first 5 minutes must be removed to prevent dirt from entering the filter tub	• Use the faucet found on the RWH to get water. • Cover RWH tightly so that it is not contaminated • When the reservoir is full, the water must be stopped immediately by moving the gutter or turning off the faucet to prevent water discharge that can shorten the life of the filter tub. • Flow the wastewater through the drain on the ground floor. • Wash the filter media once a month or as needed • RWH tubs made of masonry should not be left in an empty condition (without water) to prevent cracking due to weather effects • The RWH basin must always be drained at least once every two months at the start of the rainy season by opening the drain valve and cleaning the inner and bottom surface of the walls.

Apart from the operation, RWH system maintenance is conducted following the existing standards to ensure durability. Since clean water is a necessity that is constantly rising with the increase in family members and the general population, RWH system maintenance should be conducted as follows:

i. Clean the gutters from dirt (leaves, soil, other dirt) to avoid clogging.
ii. Clean the ground floor of the reservoir.
iii. Always keep the RWH filled with water at least 10 cm.
iv. Check for any damage to the RWH system (cracks, leaks, or gutter damage).
v. Clean filter media monthly.
vi. Clean all RWH at the beginning of the rainy season.
vii. Clean the plants that grow around the tub.

3. CONCLUSION

In summary, the findings of this study supported the suitability of the RWH system at Kobango II Hamlet. In addition, the required diameter of the vertical gutter is 6.65 cm, and the diameter of the gutter is 0.056.

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