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Utilization of Karst Water Resources by Residents in the Gremeng Cave Spring

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***Abstract*— Karst landscapes are formed by soluble rock, resulting in a high level of susceptibility of the landscape. Gremeng cave spring is a karst spring that is perennial. Preservation of these springs requires a proper understanding of both human factors and physical conditions. This study aims to understand (1) the form of utilization and the amount of water needed by residents around the spring, and (2) the availability of water both in terms of quality and quantity. The study was conducted in the karst spring catchment area of Gremeng cave and its surroundings. The samples used are population samples and water samples. Data is collected through in-depth interviews with respondents, observations, and direct measurements as well as laboratories. The results showed that the water needs of residents around the Gremeng cave spring was 71.23 l / person / day. Water is used for bathing, drinking, cooking and washing. The Gremeng cave spring has an average discharge of 5.2 l / sec in the dry season and 1739.12 l / sec in the rainy season. This spring can be used to meet the water needs of more than 6,308 people per day. The Gremeng cave spring has a high sensitivity to rain that occurs in the catchment area**

Keywords*— *Utilization of karst water, water availability, Gremeng cave springs

I. INTRODUCTION

Karst landscapes are formed by soluble rock so that cracks, holes and conduit flows are formed [1][2]. Vertical holes result from dissolution, lead surface water entering the subsurface tunnel quickly. This condition triggers surface water scarcity, but there are many subsurface water [3][4][5]. However, on a global scale the karst landscape covers a vast area and is a water buffer zone for nearly a quarter of the world's population [2][6]. Gunungsewu is an example of karst landscape in Indonesia which has been inhabited by many residents.

Surface water scarcity is often a major problem for residents in the Gunungsewu karst region. Meeting the household water needs of residents in the Gunungsewu karst area in the past relies on three sources namely rainwater, springs, and ponds [7]. In the dry season the availability of rainwater and lake water becomes very limited. Utilization of rainwater is carried out by way of collecting it in a rainwater reservoir. The rainwater supply at rainwater reservoir only provides reserves for a short time. The next source of water is stacked on karst lake water. Before the presence of the PDAM pipeline network, nearly 80% of the population in the Gunungsewu karst area utilized this karst lake water for household needs [7][8]. Until now, most of the ponds have experienced drought and decreased water quality. This was explained by [8] because (1) the reduction in the capacity of the lake due to erosion and sedimentation factors, (2) the existence of a leakage of the lake that resulted in rapid water loss, (3) a decrease in the quality of the lake water due to the direct utilization and disposal of waste in the lake water. In line with the reduction in the number of perennial ponds, there has been a change in the pattern of lake water use. Reference [7] states that the current use of lake water is only to meet the needs of washing, drinking water and livestock bathing, and fish farming. Karst springs are another alternatives that is widely used by residents in the Gunungsewu karst region. The potential availability of water in these karst springs depends on the nature of the springs. However, the availability of water and the quality of karst springs in general are better than lake water.

The quality of karstic springs is largely influenced by land use activities in the catchment area [9][10]. High porosity in karst rocks makes it easy to move pollutants from the surface into underground water. Reference [11] found that there was a high concentration of nitrate in springs with catchment areas in the form of agricultural land. Nitrate is a mineral that is found in agricultural lands as a result of fertilizing activities. The low filtration ability of karst land increasingly triggers a decrease in the quality of karstic springs. Findings from [1] show that there are similarities in the concentration of pesticide pollutants in karst spring discharges with their input points. This shows the small

reduction and decomposition of pollutants during the karst underground water flow system.

Most of the karst spring catchment area in the Gunungsewu karst area has a high level of vulnerability to the danger of pollution [11][12]. Thus to preserve the sustainability and quality of water in the karst springs in the karst region of Gunungsewu, the appropriateness of the land use is considered. This is especially true in various karst springs in Gunungsewu which are perennial such as the Gremeng cave spring. Considering the importance of this, this study was conducted to examine several things, namely (1) the form of utilization and the amount of water needs of the population around the spring, (2) the availability of water in quantity and quality. The results of the study were aimed at identifying the characteristics and potential of Gremeng cave springs.

II. METHOD

A. Research Site

This research was conducted in the catchment area of Gremeng cave and its surroundings. Administratively the research location is included in Umbulrejo Village, Ponjong District, Gunungkidul Regency. Map of the research location can be seen in Figure 1 below.

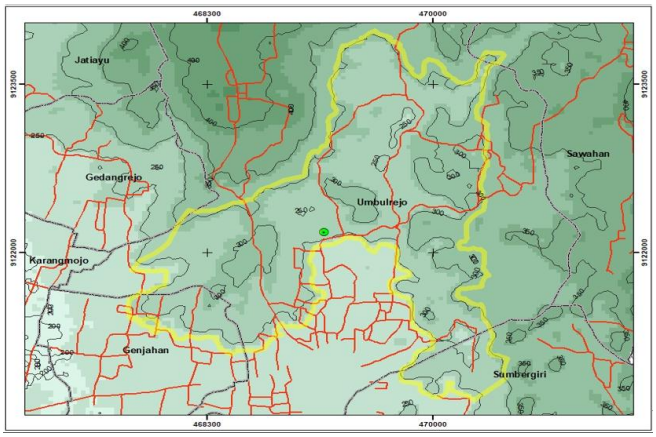


Fig. 1. Research site (source : image processing, 2018)

In accordance with Figure 1 above, the research location is included in the Gunungsewu karst region. In general, It is a karst hilly area with the location of the spring facing to Wonosari basin. Land use is mainly in the form of teak land and some agricultural land areas. The slope gradient is sloping to steep. Soil covers varies in thickness between 5 and 30 cm. There are many limestone outcrops, especially in the upper area of the spring. Settlements form groups that are scattered in the spring catchment area. Accessibility between these settlements is difficult with rocky road conditions. The number of residents between settlements is not the same as the highest density in the Blimbing hamlet, which is located in an area near the Gremeng cave spring.

B. Sampel

The sample in this study is in the form of population and water samples. The population sample is used to determine the form of water use and the amount of its needs. Water samples are used to determine the condition of the quality of the Gremeng cave spring water. The population sampled are residents who live in the catchment area of the spring and its surroundings. The sample selection is done randomly by paying attention to the location of the residence. The number of samples is determined at least 50 people. This number considers the representation of the total population around the spring. Data collection was carried out using interview techniques assisted by questionnaires. Observations were carried out to determine the condition of water use by the daily population.

Water samples are taken during the rainy and dry seasons. Samples were taken 5 times with a range of one day in the dry season, and 10 times in the rainy season. Water samples were taken at the mouth of Gremeng Cave using two-liter cans for each collection. This water sample was then tested at the BBTKL laboratory of the Yogyakarta Province Health Office. The parameters measured in the sample are turbidity, nitrate, and CaCO3. Other parameters namely pH, water temperature, and DO are measured directly in the field. PH and temperature parameters were measured using OHAUS ST21. Whereas DO is measured using DO Meters.

Calculation of discharge in the rainy season is done using the floating method. The tools used for data retrieval are buoys, meter rollers, and stopwatches. In the dry season the calculations are done using a bucket and stopwatch. This is considering the small flow of water in the spring so it is not possible to do measurements using the floating method. In this method, the dammed water flow is directed using a pipe. The water that comes out of the pipe is collected in a bucket which volume has been measured. The time interval for water to be filled to the full is measured using a stopwatch.

III. RESULT AND DISCUSSION

A. Result

Residents in Blimbing, Dlisen and Plalar hamlets are the closest communities to the Gremeng cave spring. Dlisen and Plalar Hamlet residents are scattered in the spring catchment area. Blimbing Hamlet residents are scattered around springs that are partly not in the spring catchment area, however they have the easiest access to the springs. The total number of family heads from the three hamlets is 532 households with a total of 1648 inhabitants.

Based on interviews and observations during the research, it is known the forms of water usage from the Gremeng cave spring by residents in the three hamlets. This form of water use is for bathing and washing clothes. Bathing and washing activities are carried out directly on the flow of water that comes out of the mouth of the cave. This is especially done in the dry season. In the rainy season the population has a water supply from other sources such as water from rain water reservoir and well water. Activities carried out directly on the Gremeng cave water body often result in contamination of water from these springs. The remaining water from bathing activities returns to the body of water that becomes a surface flow. Meeting other household needs, namely for drinking and cooking, generally

taken from other sources such as rainwater reservoir, well water, or buying.

The amount of water needed in the population in the study area is calculated based on samples taken from the three hamlets. The general form of water needs is water for drinking, cooking, bathing, and washing. In-depth interviews found the amount of each of these needs. The following table shows the number of water needs of the population around the Gremeng cave karst spring.

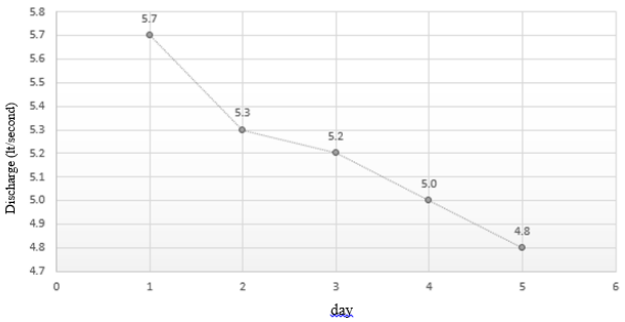
TABLE I. REQUIRED WATER (L/DAY)

banth	*drink*	*cook*	*wash*	*Total*
30,88	2,30	9,09	28,96	71,23

Source : calculation result, 2018

Based on Table 1 it is known that the total amount of water needed for daily use is 71.23 liters per day. The highest amount is for washing purposes for example for washing clothes or other items. The amount needed to fulfill this need reaches 28.96 liters per person per day. Washing needs are taken from the water that comes out of this spring. The need to drink is the need for the least amount, which is 2.30 liters per person per day. The fulfillment of the need to drink at the moment is mostly taking from other water sources such as several community wells with a limited amount. Bathing activities carried out twice a day by residents, namely morning and evening. Meeting this need is needed 30.88 liters per person per day. Some bathing activities are carried out directly in the Gremeng cave spring. Cooking needs start from washing cooking ingredients to making food. This need requires 9.09 liters of water per person per day. The total amount of water needed does not include the need for drinking water and bathing livestock. This is because not all of the population in the research area raises livestock. Only a small number of residents in the location have livestock. Therefore, the need to drink and bathe cattle is ignored in this study.

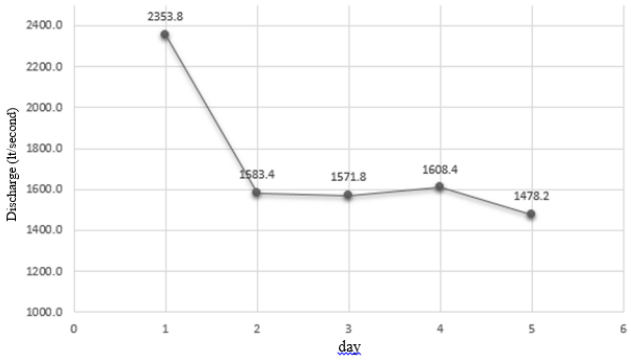
The availability of water from the Gremeng cave karst spring is calculated in the rainy season and the dry season. This calculation is intended to determine the highest and lowest discharge from the spring. The following is a chart of Gremeng cave spring water discharge in the dry and rainy seasons.



Source: calculation result, 2018

Fig. 2. The chart of Gremeng cave spring discharge in dry season

Figure 2 shows the karst spring discharge from Gremeng Cave in the dry season. Based on the graph the spring discharge ranges from 4.8 l / sec to 5.7 l / sec with an average of 5.2 l / sec. During the measurement there is a decrease in discharge with a small range.



Source: calculation result, 2018

Fig. 3. The chart of Gremeng cave spring discharge in rainy season

Figure 3 shows the Gremeng cave spring discharge during the rainy season along the measurement period. There are significant differences in character during the dry season and the rainy season. The Gremeng cave spring appears to be relatively stable with a small discharge in the dry season. This spring's flow in that season is only in the range of 4 to 6 liters / second. In this condition the flow of water from the Gremeng cave karst spring looks very slow. Substitution of water in locations where residents do bathing or washing activities does not occur quickly so water tends to look rather turbid.

Fluctuations in discharge are very real in the rainy season. The Gremeng cave spring debit has risen far above 1400 liters / second. Increased discharge occurs in response to rainfall that occurs in the catchment area. This condition was shown on the first day of measurement which coincided with rain in the study location. Floods occur shortly after rain and form a large volume of river flow. A rapid increase in spring discharge as a reaction to rain falling in the catchment area indicates the condition of this spring which is sensitive.

The condition of the water quality that comes out of the Gremeng cave spring has fluctuations in line with the seasons. The results of measurement of water quality parameters are shown in the following table.

TABLE II. WATER QUALITY PARAMETER VALUE FOR DRY SEASON

Turbid (NTU)	*TDS (mg/L)*	*Temp (^oC)*	*DO (mg/L)*	*pH*	*$CaCO_3$ (mg/L)*	*Nitrat (mg/L)*
0,6	159	26,1	2,1	8,53	202,99	0,72
1,0	158	28,8	1,2	8,52	145,45	0,61
1,0	158	25,7	1,6	8,57	192,96	0,63
0,6	157	26,9	0,9	8,56	180,90	0,61
0,6	158	25,1	1,1	8,66	217,08	0,67
1,8	157	26,8	1,3	8,55	156,78	0,69

Source : calculation result, 2018

The table above is the value of water quality parameters during the dry season. All parameters do not have large value fluctuations. The range of values of each parameter has the largest and smallest values with a small difference. Different conditions are indicated by the parameter values on

measurements during the rainy season. The parameter values of Gremeng cave spring water quality in the rainy season are shown in the following table.

TABLE III. WATER QUALITY PARAMETER VALUE FOR RAINY SEASON

Turbit *(NTU)*	***TDS*** *(mg/L)*	***Temp*** *(^oC)*	***DO*** *(mg/L)*	***pH***	***$CaCO_3$*** *(mg/L)*	***Nitrat*** *(mg/L)*
5,4	127	27,0	0,7	8,51	163,18	1,24
142,0	55	24,7	0,6	9,11	87,56	0,80
81,0	73	26,3	0,7	8,31	72,64	0,89
39,5	106	27,8	0,6	8,32	32,64	1,70
17,6	117	26,5	0,7	8,47	139,30	1,33
13,9	97	26,6	0,6	8,37	143,28	1,16
16,2	119	28,0	0,4	8,41	127,36	0,87
8,5	96	27,7	0,4	8,52	163,18	1,13
5,8	114	27,5	0,4	8,53	145,27	1,06
2740	067	26,8	0,2	8,53	56,00	0,48

Source: calculation result, 2018

In general, fluctuations in water quality parameters in the dry season appear to be more stable than in the rainy season. Turbidity has very distinct characteristic differences between the dry season and the rainy season. Turbidity of water in the rainy season fluctuates very large with a range between 5.4 to 142 NTU. Very high turbidity occurs just after it rains.

The TDS parameters appear to be very stable in the dry season measurements. Dry season TDS values range from 157 mg / L to 159 mg / L. Fluctuations did not occur significantly in this season's measurements. Whereas in the rainy season the TDS parameter values range between 55 mg / L to 127 mg / L. Fluctuations were evident in the measurement of this rainy season.

DO parameter values indicate different characteristics between the dry season and the rainy season. The range of DO in the dry season ranges from 0.4 mg / L to 2.1 mg / L, while in the rainy season it ranges between 0.2 mg / L to 0.7 mg / L. This data shows DO values in the rainy season have a lower mean compared to the dry season.

The temperature parameters are not too significant to show the difference between the rainy season and the dry season. The temperature of karst springs in Gremeng cave ranges from 25.1ºC to 28.8 ºC in the dry season and 24.7 ºC to 28.0 ºC in the rainy season.

The pH parameter values in the dry season fluctuates from 8.52 to 8.66. While in the rainy season it fluctuates between 8.31 and 9.11. Fluctuations in the pH of the dry season appear smaller than during the rainy season. The pH value in the dry season is more stable than it in the rainy season. The data shows the influence of rainwater on the pH value in the water that comes out of the Gremeng cave spring.

The value of CaCO3 dissolved in water appears to be more varied in the measurement of the rainy season, but has a lower mean than it in the dry season.

The mean value of nitrate in the rainy season sample was higher than the measurement of the dry season. The mean value of nitrate parameters in the dry season is 0.65 mg / L, while in the rainy season it is 1.06 mg / L. This condition shows the occurrence of more intensive nitrate distribution in the rainy season.

B. Discussion

The karst springs catchment area of Gremeng cave is located on a karst landscape that has been inhabited by residents. The residents utilize water from Gremeng cave for both bathing and washing purposes. While the needs for drinking and cooking are met from other sources which according to the population are more feasible. This form of water use has similarities with the pattern of utilization by residents in various springs or other karst ponds in the Gunungsewu region [7][8][11]. Residents use the water from this spring directly on the spring flow. This activity is generally carried out during the dry season. This method of water utilization by residents has the potential to reduce the quality of water as happened in the karst mountain of Gunungsewu. Reference [13] explains that the decline in the quality of karst lake water in the Gunungsewu karst region is caused by the pattern of utilization directly on the body of water. Pollutants such as detergents as a result of bathing and washing activities accumulate in the body of tears. The flow of karst springs in Gremeng cave during the slow dry season resulted in the concentration of pollutants in the mouth of the cave not immediately decreasing. Visually there is detergent deposition on the edges which is used as a container for washing by residents.

Water for residents around the Gremeng cave spring is used for drinking, cooking, bathing and washing purposes. The total water needs of the population at the study site were 71.23 liters per person per day. This amount is slightly above the value set in the Minister of Public Works Regulation No. 14 of 2010 concerning Minimum Service Standards in the field of Public Works and Spatial Planning. Based on the regulation, the amount of clean water needed per person per day is 60 liters [14][15]. This limit is the minimum limit, so that the total amount of drinking water needs of the population around Gremeng cave is in line with the limit set in the regulation. The total needs of each requirement are water needs for bathing (30.88 l / person / day), washing (28.96 l / person / day), cooking (9.09 l / person / day) and drinking (2.30 l / person / day). The need to drink and bathe cattle was not counted in this study.

The availability of water from the Gremeng cave spring can be known from the discharge measurement. Based on observations and measurements it is known that the Gremeng cave karst spring is a perennial spring. Water discharge fluctuates between the dry season and the rainy season. In the rainy season springs have a very large discharge, while in the dry season it is small. Based on the calculation results, the potential of Gremeng cave springs in the dry season reaches 449,280 liters per day. This amount can be used to meet the water needs of a population of 6,308 people. The measurement time in this study is the smallest discharge condition. Thus the karst springs of Gremeng cave can be utilized to meet the water needs of more than 6,308 residents in the dry season and will be far more in the rainy season. The magnitude of the potential of the Gremeng cave karst spring is in line with the nature of karst springs as mentioned by [3][4][5][6][16]. The fluctuation pattern of Gremeng cave spring discharge is similar to underground river systems in

the Gunungsewu karst region. Reference [14] describes the effect of rain on base flow discharge in the Bribin underground river system. Another similarity is related to the sensitivity of the Gremeng cave spring to high rainfall. The high sensitivity of Gremeng cave spring is shown by the high discharge and turbidity concentration in the spring immediately after rain. In accordance with the concept of cross time, the shorter time of pollutant distribution from pollutant sources to the spring means the spring is more sensitive or vulnerable [17]. This condition resembles several springs observed [11] in the karst region of Gunungsewu.

The quality of karst springs in Gremeng cave is known from the results of measurements of water quality parameters. These measurements show the sensitivity of the spring and the water quality conditions of the spring itself. The water quality of the Gremeng cave spring seems to fluctuate. Rain affects the concentration of water quality parameters. Feasibility of water quality from different springs during the dry season and rainy season. Based on [18] all water quality parameter values in the dry season are below the threshold quality standard of clean water. However, during the rainy season, most of the water quality parameter values are above the clean water quality standard. Considering that the water usage of the Gremeng cave spring at this time is mostly in the dry season, the limitations of the water quality conditions do not cause yet to cause problems for meeting the water needs of the surrounding population.

IV. CONCLUSION AND RECOMENDATION

A. Conclusion

Based on the results and discussion in this study, several conclusions were drawn:

- The total water needs of residents around the Gunungsewu karst spring is 71.23 liters per day used for bathing (30.88 liters per day), drinking (2.30 liters per day), cooking (9.09 liters per day) and washing (28.96 liters per day).
- Gremeng cave spring water discharge in the dry season an average of 5.2 liters per second and in the rainy season an average of 1739.12 liters per second. Based on these results the karst springs of Gremeng cave can be utilized to meet the water needs of more than 6,308 people and will be even greater during the rainy season.
- All parameters of the quality of karst springs in Gremeng cave during the dry season are below the threshold of clean water, while in the rainy season most are above the threshold of clean water.
- The Gremeng cave karst spring is a perennial spring but has a high sensitivity to rain in the catchment area.

B. Recomendation

Based on these conclusions the researchers put forward several suggestions for preserving and increasing the use of water in the karst springs of Gremeng cave. Some of these suggestions are as follows:

- It is necessary to develop a program of activities aimed at increasing awareness of the sustainability of water resources so that residents do not engage in activities that can reduce the quality of the environment.
- Physical facilities need to be built to evenly distribute the Gremeng cave springs to the entire population.
- Need water treatment facilities that can be used to improve water quality conditions, especially during the rainy season.
- An environmental management effort is needed in the Gremeng cave spring catchment area to minimize the potential for pollution in the Gremeng cave spring water.

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