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**STUDY OF WATER-ROCK INTERACTION TO CHARACTERIZE KARST
AQUIFER IN NGELENG SPRING**

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Abstract

Barren condition in karst area surface make the existence of the springs very important and valuable. Ngeleng Spring is one of the several large springs in Giritirto village with intensive usage. Concerning to those conditions this research aims to ; separating diffuse flow from total discharge; and comparing the bicarbonate and calcium characteristic that emerge between the spring and seepage as indicator of water-rock interaction.

Several data collected for this research e.g. spring discharge, rainfall, calcium, bicarbonate, temperature, pH, both from the spring or seepage. Rainfall and water level data collected using automatic water level logger and automatic rainfall logger. Meanwhile, calcium, bicarbonate, temperature, and pH data taken systematically for 24 hours with 2 hours interval. Samples taken in different season in order to compare the result from each season. Analysis that used in this research are descriptive, graphical, comparative, and correlation-regression analysis.

The results shows that diffuse flow dominating total discharge with Diffuse Flow Proportion reach 81.06 %. Value of the other parameters such as pH, Ca^{2+} , HCO_3^- , and temperature from the spring recorded in higher concentration than value from seepage. This result shows that water-rock interaction processes occurs and indicate that Ngeleng Spring has dominated by diffuse aquifer.

Keywords : Karst spring; Diffuse Flow Proportion; water-rock interaction

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Background

Gunung Sewu karst area located in three provincial areas of Java Island that widespread up to 741,01 km². Gunungkidul Regency, Yogyakarta Special Province, dominating the hilly limestone area than Wonogiri and Pacitan Regency. Development of karst features caused water shortages because surface streams sunk to underground system. Gunungsewu karst area has a distinctive conical and sinusoidal hills or kegelkarst that reach more or less 50 m high. Intensive karstification processes lead the formation of conical hills called Wonosari Formation **(Tmwl)** that formed in early Miocene that consist of massive coral reef limestone and bedded limestone. (Waltham et al, 1983).

Karstification play a big role in the development of karst landform. Haryono and Adji (2004) explain that the karstification process is influenced by two factors: controlling factors and driving factors. One of the controlling factors that influence the process of karstification is the solubility of the rock. Karstification in limestone is strongly influenced by the purity or the amount of CaCO₃. The amount of CO₂ (gas) that dissolved in the water will be influence the rate of dissolution that occurs in carbonate rocks. Further karstification processes in carbonate rocks formulated as follows:

Karstification in carbonate rocks has associated with Karst Dynamic System (KDS). Daoxian (2002) explained that the process of karstification is one phase of the global carbon cycle. Karst process is dynamic because the response of the flow is always changing according to season and flow properties. Karst Dynamic System occurs in 3 phases, solid, liquid, and gas. Solid phase karst dominated by various types of carbonate rocks. Liquid phase includes various chemical elements dissolved in water such as Ca + (and Mg +), HCO₃⁻, CO₃²⁻, H⁺ and dissolved CO₂ as the main element. CO₂ is also very dominant in the gas phase.

Several chemical compounds that construct a liquid phase of Karst Dynamic System is alkalinity. Effendi (2003) mentioned that the alkalinity is the quantity of anions in the water related to its ability to neutralize the hydrogen cation. More simply put, the alkalinity in the water is the ability neutralize acid (Acid Neutralizing Capacity). Alkalinity composed by a variety of ion contains in the water, but the most important constituent is bicarbonate (HCO₃⁻), carbonate (CO₃²⁻) and hydroxide (OH⁻). Actually several ions such as borate, phosphate, silicate have a role, but due to the weak contribution of those organic acids to the ANC so the presence of those ions are ignored (Chandler and Bisogni, 1999).

The formation of karst landform through the dissolution process is closely associated with the carbon cycle. One of the chemical character of karst springs that could be observed is alkalinity. Alkalinity reflects the ability of water to neutralize acid

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(Acid Neutralizing Capacity). Carbon content in the water are represent by the alkalinity of the water itself. The objectives of this research are:

- Determine the correlation between the flow type and the content of calcium and bicarbonate in Ngeleng karst spring;
- Determine temporal variations of Acid Neutralizing Capacity (ANC) in the HCO_3^- form in Ngeleng Spring.
- Comparing ANC characters that emerges from spring and seepage as water-rock interaction indication.

Ngeleng karst spring located in Purwosari Sub-district, Gunungkidul Regency, Yogyakarta Special Province (see fig. 1). Several data collected in this research such as discharge, rainfall, Ca^{2+} , HCO_3^- , temperature, and pH (spring and seepage). Rainfall and water level data were collected using automatic tipping bucket and automatic water level recording. Meanwhile data Ca^{2+} , HCO_3^- , temperature, and pH are systematically taken for 24 hours with time interval every 2 hours. Samples were taken in different season in order to make comparison. Hydrograph data is processed to determine flow characteristics and calculate the constant recession. Flow recession constant value is obtained from the formula 2 below :

$$Q_t = Q_0 \cdot e^{-\alpha \cdot t} \quad (2)$$

Whereas for (α) Alpha or flow recession coefficient, obtained with the formula 3 below :

$$\alpha = \frac{(\ln Q_0 - \ln Q_t)}{T_t - T_0} \quad (3)$$

For baseflow separation method using a model developed by Eckhardt (2005), called automated base flow separation by digital filtering method.

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Figure 1. Map Location of Research Area

Results and Discussion

Discharge data that obtained compared to water level to determine their correlation in a stage-discharge rating curve. Discharge measurement was collected from October 2012 until June 2013, Discharge data variation can be seen in Table 1 below :

Table 1. Discharge data measurement of Ngeleng spring

Date	Water Level (m)	Discharge (lit/sec)
October 13 th , 2012	0.045	5.20
October 21 st , 2012	0.071	6.90
October 28 th , 2012	0.090	9.50
November 10 th , 2012	0.028	3.60
November 21 st , 2012	0.045	4.28
February 23 rd , 2013	0.063	6.20
March 3 rd , 2013	0.048	5.40
March 09 th , 2013	0.089	9.20
June 17 th , 2013	0.054	5.80

Regression curve were made based on the correlation between water level and discharge data, which resulting a correlation equation 4 below :

$$y = 94.591x + 0.6292 \quad (4)$$

y= discharge(lit/sec), x = water level (meter)

The result from the regression equation shows that the value of the coefficient determination is 0.9655 (see fig.2). This value indicates that the two variables have a positive and significant correlation.

Figure 2. Ngeleng Spring stage-discharge rating curve

Furthermore, rating curve regression formula is used to calculate discharge in accordance to recorded water level. According to hydrograph data, 10 flood events recorded with rainfall data peak occurred in January. Spring properties dominated by diffuse flow so that the spring still have a huge storage baseflow in the dry season. Despite the discharge rate decrease during dry season, the amount of water that emerges from the spring still can fulfill water demand. Based on hydrograph, the data shows that spring character is laminar. That character indicates that the diffuse component is more dominant in giving total recharge to the spring. However, aquifer character also must be proved in more detail data because hydrograph does not show the dominance component that contributes to total flow. Karst aquifer is an aquifer with unique properties and has a different character with surface stream in releasing runoff component.

Schulz (1976) introduced a recession model to calculate the constant flow recession. The model called the tank model that can calculate the value of the conduit recession constant (K_c), interflow recession constant / fissure (K_i), and baseflow constant (K_b). Analysis was performed on several flood events that qualify for calculating constant recession. Floods are selected based on the length of time of the flood peak until return to normal condition (T_b = time to baseflow). Flood events with too short T_b values that were not used in the calculation because mathematically invalid for calculating constant recession (Schulz, 1976).

Interflow that recorded within flood period has a various supply, shown in interflow constant range around 0,4475 – 0,9782 with average value 0,7481. Meanwhile, baseflow rate dominating total flow supply within flood period, proved with baseflow recession constant around 0,9497 – 0,9971 with average value 0,9818. Flow component that derived from conduit channel only found in several flood events with enormous discharge. Average conduit flow constant is

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0,5526, indicates that baseflow dominating total flow. It could be proved and reinforced with time to peak (Tp) and time to baseflow (Tb) value that can be seen in Table 2. Time to peak is the length of time needed to reach flood peak from normal discharge. Time to peak value of Ngeleng Spring ranged between 0,5-8 hours with time average 3,6 hours. While the time required from the peak discharge to base flow ranged between 0.5-8 hours with an average time of 9.3 hours. Based on these values, time difference between Tp and Tb are not too long. This indicate that the total flow during floods is dominated by base flow. The result from baseflow separation using BFI index or tank model reinforce that baseflow dominating total discharge (see fig.3). Diffuse flow dominates the total discharge with diffuse flow proportion reaches 81.06%.

Table 2. Recession constant, Tp and Tb in Ngeleng Spring Selected Hydrograph

Date	Peak Discharge	Kb	Ki	Kc	Tp	Tb	% baseflow
10/18/12	21.16	0.979	0.7354	-	1	4.5	38.05
11/10/12	24.75	0.9921	0.9782	-	0.5	46	20.04
11/22/12	22.48	0.9694	0.7465	-	5.5	5	49.44
11/23/12	22.48	0.9828	0.4475	-	6	4	53.91
12/10/12	44.14	0.9936	0.7605	0.788	0.5	7	11.83
12/21/12	23.14	0.9913	0.7935	0.7935	4	4	23.75
12/28/12	24.66	0.9832	0.7937	0.026	3.5	8	28.37
12/31/12	48.49	0.9497	0.7346	0.6029	4	7	26.74
1/7/13	18.03	0.9971	0.7429	-	4	7	41.19
2/3/13	24.56	0.9798	-	-	7	0.5	37.93
Average		0.9818	0.7481	0.5526	3.6	9.3	33.12

Figure 3. Baseflow separation graphic

Appelo and Postma (1994) noted that there are 3 phases related to water-rock interaction processes. Those processes are water in undersaturated condition, equilibrium, and water in supersaturated condition. In undersaturated condition water easily dissolve the carbonate rock. Dissolution stalled in equilibrium phase and precipitation or sedimentation occurs in when the water has saturated. In an open system with more carbon dioxide content in the water, dissolution process will be more intensive. The more intensive dissolution process will increase Ca^{2+} and HCO_3^- content in the water. Figure 4 shows Calcium and Bicarbonate content from that collected in different season.

Figure 4. (a) calcium and (b) bicarbonate content in spring discharge

Both correlation between discharge and calcium or discharge and bicarbonate content indicate very low correlation among them. This is implication from diffuse flow proportion that dominating total recharge. The domination of diffuse flow drive the water to saturated condition, but could turned aggressive when the rain occurs more than 100 mm for several hours. When the flood peak occurred in the diffuse flow, the partial pressure of carbon dioxide will be increase, so there are more intensive dissolution (Adji, 2009). Spring character that dominated by diffuse flow affect to the surface water from recharge area velocity in order to reach spring and turned into discharge. Diffuse flow character is different with conduit flow that has quick respon to the rain. Based on the comparison between seepage and springs measured parameters could be seen that the dominance of diffuse flow in the springs caused the water-rock interaction processes occurs. Release of diffuse flow that has been saturated with carbonate rock cause the value of calcium, pH and bicarbonate in the spring are higher than seepage (see Tab.3). This results indicate water-rock interaction because some parameters measured in the spring is higher. This results convince that Ngeleng Spring dominated by diffuse aquifer system than conduit.

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Table 3. Measured parameters from the spring and seepage

Parameters	Spring	Seepage
pH	6.92	6.82
	7.1	6.63
HCO ₃ ⁻ (mg/l)	359.98	311.17
	384.39	329.47
Ca ²⁺ (mg/l)	124	118
	130	106
Temperature (°C)	26	25
	25	25

Conclusions

Statistically, there is no strong correlation between discharge and content of calcium and bicarbonate. Diffuse flow dominates the total discharge with diffuse flow proportion reaches 81.06%. Release of diffuse flow that has been saturated with carbonate rock cause the value of calcium, pH and bicarbonate in the spring are higher than seepage and convince that Ngeleng Spring dominated by diffuse aquifer system than conduit.

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