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## The Committees of The Second International Conference on Environmental Geography and Geography Education

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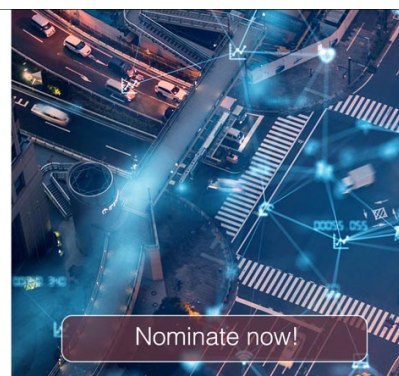


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## The quality and usability of spring water for irrigation (case study: Ngerong Spring, Rengel Karst, Tuban, East Java)

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## The quality and usability of spring water for irrigation (case study: Ngerong Spring, Rengel Karst, Tuban, East Java)

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**Abstract.** Karst springs have an essential role as sources of drinking water, agriculture, industry, and other domestic needs. This research was conducted on the Ngerong spring as the largest water source for irrigation needs in the Rengel Karst. This study aims to determine the quality and usability of spring water for irrigation by using available data on hydrochemistry. The automatic measurement of water level, conductivity, and temperature parameters was observed at karst spring during sixteen months monitoring period. Furthermore, the water samples were collected every two weeks and more intensive in flood events to analyze major ions. Irrigation quality parameters such as salinity, Sodium Absorption Ratio, Sodium Percentage (Na%), Permeability Index (PI), Kelly Ratio (KR), and Magnesium Hazards (MH) were analyzed for the suitability for irrigation. This study revealed that major ion types in the Ngerong Spring are Ca-HCO<sub>3</sub> (calcium bicarbonate). The value of irrigation quality parameters showed at excellent to good category, and grouped as C2S1 (medium-low) indicates that spring waters quality is considered well qualified for irrigation.

### 1. Introduction

Spring in the karst area plays an essential role as sources of drinking water, irrigation, industry, and other domestic needs. At the same time, it is particularly vulnerable to contamination because of its characteristics. Spring in karst aquifers has high discharge fluctuations, dominantly has large discharges, the rapid response to rainfall, and dissolved sediments, which will vary with the seasons [5, 15, 19, 23]. Furthermore, the quantity and quality of spring in the karst area always vary over time, tend to be unstable when compared to other rock formations [3, 20].

Spring is an integral part of irrigation in the karst area. The quality and quantity of springs for supplying irrigation needs in one karst area has different potential. Therefore there are zones or clusters mapped based on water chemistry and applying GIS (geostatistics) to determine variations in water quality within a karst region [6, 9]. Exemplified by Zhang [40] in South China, to produce 1 kg of rice in the karst area requires about  $\pm 5 \text{ m}^3$  of irrigation water. The need for irrigation water in the karst area is twice when compared with the non-karst area. This is because some of the water is lost to the underlying karst aquifer.

The main characteristics of water quality for irrigation, according to Wilcox, et al., [39] are (1) total salt concentration and (2) the proportion of sodium salts contained. This is a particular concern in karst spring because the bicarbonate content that dissolves calcium and magnesium under certain conditions will be able to increase the proportion of sodium in the soil and cation exchange process [2, 14, 39]. Furthermore, the bicarbonate content in water can influence the chemical quality by increasing sodium accumulation..

A common problem that often makes irrigation water quality decline is the presence of chloride, sodium, and toxic elements such as boron, nitrates, and iron [3]. The standard for determining water quality for irrigation, according to [10], was first published in 1931. The parameters used are based on



the conductivity parameters of Electrical Conductivity (EC), Boron, Sodium, and Chloride, each of which is divided into three classes. Besides, [12] classified it into five classes. The parameters of EC, Sodium, and Boron are also used by [38] to determine five classes of irrigation water quality.

The standard and vital parameters in analyzing the suitability of water for irrigation are the EC (for salts dissolved calculation) and the SAR index (for sodium hazards calculation). Other parameters are Percent Sodium, Residual Sodium Carbonate (RSC), Permeability Index (PI), Kely's Ratio (KR), Magnesium Ratio, Gibbs Ratio, Total Hardness (TH), Alkalinity, Salt Index (SI), and some toxic elements [3, 26, 35]. All of these parameters are based on an analysis of their chemical content, so, understanding of the chemical quality of water is needed to take a proper measurement [3].

The spring is the pulse of a karst aquifer, which characterizes the condition of the recharge area. Therefore, the most appropriate monitoring of water quality is conducted in spring [29]. Nowadays, automatic monitoring of data with recording intervals of 30 minutes, hourly, or daily has been carried out to determine the hydrographic characteristics and synthetic chemistry systematically. Although the parameters that can be recorded are only limited, such as water level, temperature, pH, electrical conductivity, and rainfall [21, 22, 24, 36]. Furthermore, the results of monitoring these parameters are combined with monitoring of water chemical samples such as major ions in daily or weekly periods.

The objectives of this study are to determine the quality and suitability of spring water for irrigation. Chemical parameters that were used in this study are EC and major ions. The EC was recorded automatically every 15 minutes, and it will show the condition of water salinity during normal discharge and flood events. Then, it is combined with other irrigation parameters such as Sodium hazard, SAR, MH, PI, and Kelly's Ratio based on major ions to identify the suitability of spring water for irrigation.

## 2. Hydrogeological Conditions

The Ngerong spring is on the foothills of the southern Karst Rengel, which borders the alluvial plains of Bengawan Solo. Rengel Karst is a part of the Rembang Anticlinorium Zone, which is formed from the folding and enlargement process since the Miocene and Plio-Pleistocene. Physiographically it is in the form of hills and alternating with alluvial plains [33]. The elevation of Rengel Karst ranges from 50 meters to 500 meters above the sea level with a regional fault structure of the Meratus type (northeast-southwest) and Java type (west-east) [28, 33]. [7] identified the limestone of Rengel Karst as Karren Limestone. This reeflimestone lithology was formed in the early to mid-Pliocene and began to be exposed since the late Pleistocene.

[28] concluded that the Paciran Formation is a shallow marine reef with hermatypic corals as a dominant skeleton that is built together with algae, mollusks (Gastropods, Pelecypods, Scaphopoda), Benton foraminifera, Bryozoa, Echinodermata, Porifera, and Ostraca. The distribution of carbonate facies of Paciran Formation found in the Rengel Karst consists of wackestone and boundstone. The carbonate components comprise fossils, pellets, ooids, intraclasts, micrites, sparites, and crystalline minerals. Rengel Karst and its surroundings are an anticlinal which is eroded with the direction of the east-west stance with an apparent slope of 15 ° [16, 17]. The results of topographic map interpretation and DEM data analysis show that the Rengel Karst is generally a hill with increasing elevation from south to north up to 335 meters. The Ngerong spring is a type of tropical climate spring. It is characterized by heavy rainfall at the rainy season and high temperatures throughout the year. Average annual temperatures range from 24-28 ° C and the mean annual rainfall range from 1347-1561 mm/year [25].

The Ngerong Spring is an underground river flowing out of the mouth of the cave with a tunnel length of around 1800 meters, and width ranges from 4 to 8 meters and a roof height of about 2-7 meters [31]. This cave is a fluviokarst cave formed at the border between limestone and impermeable rock at the bottom. The spring water flows out throughout the year (perennial). Based on water balance analysis, Mujib [25] concludes that the recharge area of Ngerong Spring is estimated to be 1922 Ha, and it is classified as an Allogenic recharge (Figure 1). It was further explained that the

average spring discharge was 911 l/sec; in the wet months (December-April), the average discharge was 1228 l/sec and could increase several times up to 7500 l/sec during flood conditions.

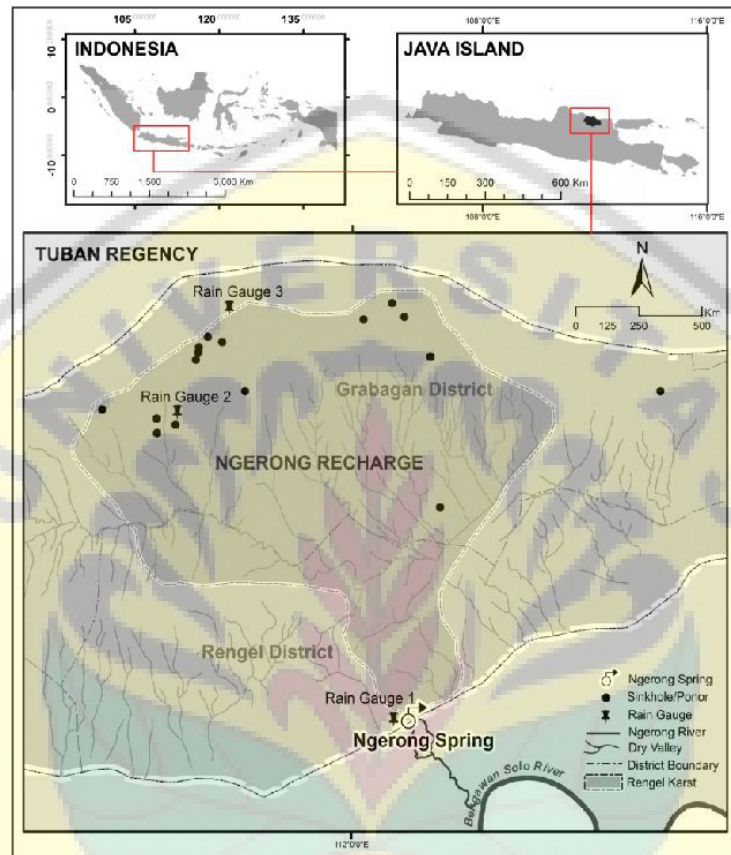


Figure 1. The study area of Ngerong Spring

### 3. Method

#### 3.1. Temporal monitoring of water level, temperature, and EC

Automatic data recording is carried out for 16 months (January 2014 to June 2015) to determine the condition of the spring discharge during low discharge and flood events. Water level and temperature data are recorded periodically at 15 minute recording time intervals using a water level logger (HOBO Water Level U20L-02) while recording electrical conductivity data use the Hobo Conductivity logger U24-00. On the other hand, discharge measurements are also carried out on several variations of low, medium, and high discharge conditions using the buoy and sudden injection methods, then calibrated with the results of the discharge measurements from Cipolleti Weir. Then, the stage-discharge rating curve method is applied to change the water level data into discharge data, which is taken from the measurement of the discharge during the study period.

#### 3.2. Analysis of Major Ion Concentration

Water samples were collected from the spring by titrating method to examine the general chemistry of major ion in the spring. Then they were analyzed in the laboratory at a two weekly for six months. During floods, more intensive sampling is carried out three times a day. Besides recording temperature

and EC data periodically every hour, measurements were also made using a portable device to calibrate data with an accuracy of  $\pm 0.1^\circ\text{C}$ , and  $\pm 1 \mu\text{S/cm}$ .  $\text{Ca}^{2+}$ ,  $\text{CaCO}_3$ , and  $\text{HCO}_3^-$  water were measured by titration method used Calcium for irrigation and Aquamark alkalinity test kits. Analysis in the laboratory adopted the APHA method for  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{CO}_3^-$ , and  $\text{NO}_3^-$ . The Mohr titration for  $\text{Cl}^-$  and titration with EDTA for  $\text{SO}_4^{2-}$ .

### 3.3. Composite Indices for irrigation water quality

Parametric indicators to identify the suitability of spring water for irrigation in this study are Electrical Conductivity (EC), Sodium Absorption Ratio (SAR), Percent Sodium (% NA), Magnesium Hazard (MH), Permeability Index (PI), and Kelly Ratio (KR). EC is often used to indicate the total dissolved salts in the water, also known as salinity, were expressed in  $\mu\text{S/cm}$ . The suitability water for irrigation based on EC values was classified as: (C1) Low salinity ranging from 0-250  $\mu\text{S/cm}$ , can be used for irrigation in most soils and most plant species; (C2) Medium salinity ranging from 250-750  $\mu\text{S/cm}$ , can be used for irrigation of plants that have moderate salt tolerance, there is no special treatment to control salinity; (C3) High salinity ranging from 750-2250  $\mu\text{S/cm}$ , can not be used on land with limited irrigation, even adequate, requires special treatment to control salinity and select plants that are tolerant of salt; and (C4) Very high salinity ( $>2250 \mu\text{S/cm}$ ), under normal conditions, it is not suitable for irrigation, but can be used occasionally in particular conditions, water drainage must be adequate and excessive in order to wash salt, the soil must be permeable and choose plants that are very tolerant of salt [4,9,32].

Sodium adsorption ratio (SAR) can indicate the level of sodium exchange in physical soil conditions and the harmful effects of sodium on crops [2, 34]. SAR represented by:

$$S = \frac{N^{+}}{\sqrt{\frac{C^{2+} + M^{2+}}{2}}} \quad [32]$$

The ionic concentrations on SAR are reported in meq/l. The suitability water for irrigation based on SAR was classified into four classes. (S1) low sodium ( $<10$ ); (S2) medium sodium (10-18); (S3) high sodium (18-26); and (S4) very high sodium ( $>26$ ) [9, 32].

The sodium percentage (% Na), the concentration of sodium can reduce the permeability of the soil. When the soil has a dominant anion of sodium and carbonate, the soil is alkaline. However, when the dominant anion is chloride and sulfate, it is saline [26, 35]. The sodium percentage is almost the same as SAR, but the percentage of sodium only correlates with calcium and magnesium [8]. %Na is expressed as:

$$\%N = \frac{N^{+} + K^{+}}{C^{2+} + M^{2+} + N^{+} + K^{+}} \times 100 \quad [34]$$

Ionic concentrations on %Na are expressed in meq/l. %Na to evaluate irrigation waters given five qualification zones, from excellent ( $>20$ ) to unsuitable ( $>80$ ).

Generally, in most waters that maintain a state of equilibrium are  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ , whereas, in carbonate rocks, the main minerals are  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$ , which are readily soluble and hard in the groundwater. Furthermore, crop yields can be influenced by irrigation water, which has more magnesium [26]. As in the research area, which is a calcium carbonate rock, most water contains more Ca and Mg. Mg hazards are expressed as:

$$M = \frac{M^{2+}}{C^{2+} + M^{2+}} \times 100 \quad [30]$$

Magnesium hazard values within the permissible limit  $<50 \text{ meq/L}$  is suitable for irrigation, and if values higher than  $50 \text{ meq/L}$  is unsuitable for irrigation [8].

Sodium, calcium, magnesium, and bicarbonate content in irrigation water for a long time will affect soil permeability. The suitability of water for irrigation based on permeability index was developed by Doneen [11] by assessing the following criteria:

$$P = \frac{N^{+} + \sqrt{H^{-}}}{(C^{2+} + M^{2+} + N^{+})} \times 100 \quad [11]$$



The ionic concentrations are expressed in meq/l. Based on the PI method, the classification of water irrigation is divided into two classes, suitable (<80) dan unsuitable (>80).

The other parameter used in this study is Kelly’s Ratio. Kelly [18] evolve parameter sodium measured against calcium and magnesium. Soil conditions that do not have permeability problems are indicated by Kelly Ratio values <1. KR is expressed as:

$$K = \frac{N^{+}}{C^{2+}+M^{2+}} \quad [18]$$

**4. Result and Discussion**

*4.1. Chemograph Parameters (Temperature and Electrical Conductivity)*

The Ngerong spring has a high variability of discharge between the low discharge and flood events. The fluctuation of discharge in the flood events is due to the allogenic recharge system, especially during the rainy season [25]. [1] confirms that the type of flow in the Ngerong spring is dominated by laminar flow, with a slight combination of sub-turbulent flow when flood discharge. Also, the karstification degree of Rengel Karst is lower than Gunungsewu Karst with a value of 4.8.

During the recording period, the average discharge of the Ngerong Spring is 911 l/s. Whereas, the average discharge in the flood event is 1359.3 l/s, and increase up to 7535.4 l/s (Table 1). Temperature and EC vary along discharge fluctuations. As strengthened by [36] that the chemistry of karst aquifers can change in a short time, sometimes in minutes, so that continuous data recording is needed for more detailed interpretation.

Table 1. Parameters for discharge, temperature, and EC of the Ngerong spring

Parameter	Discharge (L/s)	Temperature (°C)	Electrical Conductivity (µS/cm)
Q <sub>min</sub>	456.8	25.03	243.0
Q <sub>max</sub>	7535.4	28.56	613.4
Ø	1018.1	27.72	549.8
Q <sub>10</sub>	1359.3	27.86	589.1
Q <sub>50</sub>	911.0	27.86	570.4
Q <sub>90</sub>	592.5	27.37	503.0
σ	621.2	0.33	60.4
c.v (%)	61.0	1.20	11.0

where: Q<sub>min</sub>minimum discharge; Q<sub>max</sub>maximum discharge; ØAverage; Q<sub>10</sub>10<sup>th</sup>Percentile; Q<sub>50</sub>50<sup>th</sup>Percentile; Q<sub>90</sub>90<sup>th</sup>Percentile; σstandard deviation; c.vCoefficient of Variation[(σ/ Ø)x100].

In this study, an interesting thing is automatic EC data recording (15-minute intervals) that can characterize salinity levels at various discharge levels. The Ngerong spring discharge has a negative correlation with temperature and electrical conductivity. When the discharge increases, the temperature, and EC tend to decrease because of the large amount of rainwater that supplies most of the total flow. The temperature of the spring discharge is predominantly affected by the low temperature of rainwater. Newly infiltrated water generally has a low EC character, so when the water discharge increases, the value of EC decreases. This is also affected by the shortness of the transit time of groundwater, which affects the least mineral content dissolved in water. During the study, the minimum average of EC value is 395 µS/cm and can increase up 517.2 µS/cm at the time of peak flood discharge. The higher the flood discharge, the value of minimum EC will be lower, such as floods on 7 and 12 April 2014, which reached the minimum EC value of 268.8 µS/cm and 243 µS/cm. The EC value of Ngerong spring ranges from 300 to 613 µS/cm, which indicates that the spring has low rock minerals.

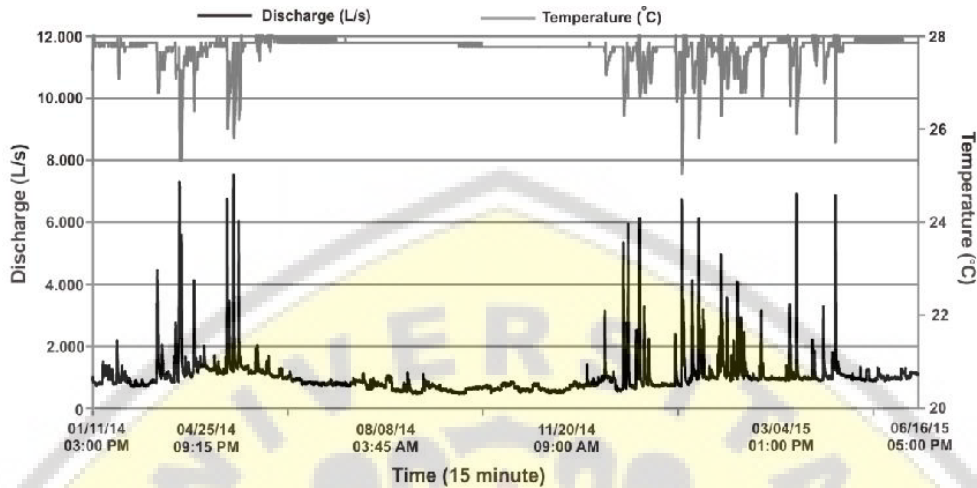


Figure 2. Chemograph of discharge and temperature of the Ngerong Spring

#### 4.2. The Major Ion Type

The concentrations of major cation and anions can be plotted in Piper trilinear diagram for understanding the major ion type [27]. Piper diagrams make it easy to plot the results of several analyzes on one diagram to group the same parameters so that a uniform water type can be identified. The chief cations are dominated by calcium (60-79%) and magnesium (15-20%) of the total cations, while the main anions are dominated by bicarbonate with a percentage of 75-88% of the total anions. The chemical type of spring water is of the type Ca-HCO<sub>3</sub> (calcium bicarbonate) depicted in the piper diagram (Figure 3). This water type characterizes the lithological properties of rocks in the Ngerong Spring recharge system in the form of pure limestone.

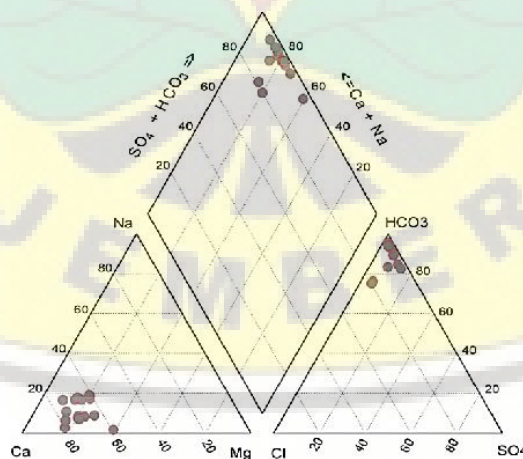


Figure 3. Piper diagram for representing the main water types of Ngerong Spring

#### 4.3. Irrigation water quality

The hydrochemical analysis of water samples based on several parameters for the suitability of irrigation purposes are represented in Table 3. Discharge conditions during low discharge and flood

events are displayed due to the chemical conditions of karst springs that change rapidly in the flood and recession events. The results of the analysis of 6 water quality parameters for irrigation under various discharge conditions are listed in Table 2.

Table 2. Hydrochemical analysis for suitable irrigation

Date	EC ( $\mu\text{S/cm}$ )	SAR	%NA	MH	PI	KR	Discharge Condition
09-Feb-14	547.05	0.58	3.28	17.77	12.27	0.03	Low
06-Mar-14	567.30	0.36	2.29	39.68	10.89	0.02	Low
08-Mar-14	246.8	3.90	19.12	18.48	26.57	0.22	Flood
08-Mar-14	386.30	4.11	19.95	25.03	28.15	0.23	Flood
08-Mar-14	422.50	3.81	18.55	25.35	26.87	0.21	Flood
09-Mar-14	293.10	4.21	21.07	24.25	27.93	0.24	Flood
23-Mar-14	584	1.85	11.06	29.83	18.50	0.10	Low
25-Mar-14	522.00	2.27	13.64	15.59	20.53	0.12	Low
07-Apr-14	603.60	1.47	7.50	23.00	16.54	0.08	Low
09-Apr-14	397	3.66	18.26	20.90	26.04	0.20	Flood
20-Apr-14	586.30	1.57	7.96	22.41	16.95	0.08	Low
4 May 14	557.80	3.67	17.72	17.63	25.70	0.20	Flood
18 May 14	584.90	1.76	11.55	22.17	18.30	0.09	Low
1 June 2014	524.68	1.32	7.30	16.89	15.94	0.07	Low
18 June 2014	539.27	1.76	8.84	25.13	17.79	0.09	Low
6 July 2014	559.42	3.63	17.42	11.37	26.10	0.20	Low

Source : Data Processing(2019)

4.3.1. Salinity (Electrical Conductivity)

Electrical Conductivity is used to measure the water salinity or salt content in irrigation water. Irrigation water that has a high salt concentration will affect the intake of salt absorbed by plant roots, and make the soil saline. EC of water samples ranges from 246.8 to 557.8 ( $\mu\text{S/cm}$ ) at flood events and 522-603.6 ( $\mu\text{S/cm}$ ) at normal discharge (Table 3). Based on the results of automatic EC recordings and water chemistry samples, the value of water salinity can reach up to  $<250 \mu\text{S/cm}$  (C1 level) at the time of peak flood discharge. This can occur due to the previous flooding, which precedes so that the EC value reaches the lowest point.

On the other hand, the EC value during flood and regular events is in the range of 293.1-603.6  $\mu\text{S/cm}$  or classified at the C2 level. So, the classification of suitability water for irrigation in Ngerong Spring based on EC is at Level C2 (250-750  $\mu\text{S/cm}$ ). The classification of Ngerong spring samples based on EC (salinity) is listed in Table 3.

Table 3. Classification of the suitability water for irrigation based on EC (salinity)

Level	Salinity (EC) ( $\mu\text{S/cm}$ )	Annotation	Flood event	Normal Discharge
C1	$<250$	Can be used for irrigation in most soils and most plant species	246.8 (1 sample)	
C2	250 – 750	Can be used for irrigation of plants that have moderate salt tolerance, there is no special treatment to control salinity	293.1 – 557.8 (5 samples)	522-603.6 (10 samples)
C3	750 – 2250	Cannot be used on land with limited irrigation, even adequate, requires special		

<b>C4</b>	>2250	<p>treatment to control salinity and select plants that are tolerant of salt.</p> <p>Under normal conditions, it is not suitable for irrigation, but can be used occasionally in particular conditions. Water drainage must be adequate and excessive in order to wash salt, and the soil must be permeable and choose plants that are very tolerant of salt</p>
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Source : (Data Processing, 2019,[8, 32] )

4.3.2. Sodium Adsorption Ratio (SAR)

SAR is an essential parameter for the determination of sodium concentration. SAR is an indicator for determine of sodium concentration in irrigation water. When there is a sodium exchange capacity in the soil, if the value of sodium in the water is lower than the sufficient value of sodium in the soil, the physical condition of the soil will be damaged. SAR classification of water samples ranges from 3.67-4.21 (meq/l) at flood event and 0.58-3.63 (meq/l) at normal discharge. The water samples of Ngerong Spring during the observation period were classified as excellent for irrigation or S1 level with an SAR value of less than 5. The classification of Ngerong spring samples based on SAR is listed in Table 4.

Table 4. Classification of the suitability water for irrigation based on SAR

Level	SAR	Annotation	Flood event	Normal Discharge
<b>S1</b>	<10	Irrigated water can be used for all types of soil	3.67 – 4.21 (6 samples)	0.58 – 3.63 (10 samples)
<b>S2</b>	10-18	Irrigation water can be used on coarse-textured soils or organic soils with good permeability, but on fine-textured soils with high cation exchange capacity and low washing conditions will be harmful to plants		
<b>S3</b>	18-26	Irrigation water has a sodium exchange capacity, which is harmful to the soil. Specific management that can be done is with good drainage, high washing, and the addition of organic matter.		
<b>S4</b>	>26	The water is not suitable for irrigation, and the solution is to add calcium or gypsum to the soil.		

Source : (Data Processing, 2019, [8, 32])

The SAR is plotted against EC, which is designated as a Wilcox diagram [32] (Figure 4). Most of all, water samples of Ngerong Spring are classified into C2-S1 (medium salinity water-low sodium water), and only 1 sample is classified into C1-S1 (low salinity water-low sodium water). Water in the Ngerong spring, whether in flood or normal conditions are suitable for irrigation.

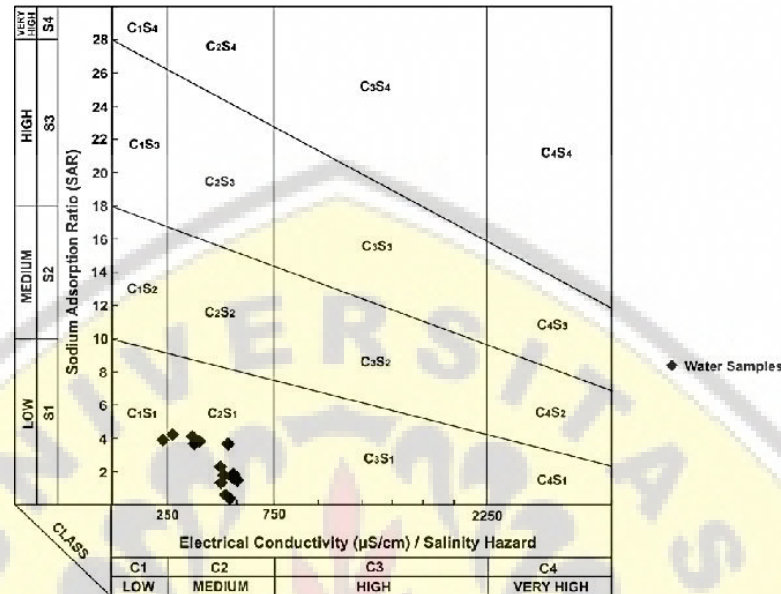


Figure 4. Diagram for the classification of irrigation water based on EC and SAR in Ngerong Spring after [32]

4.3.3. Sodium Percentage (%Na)

Sodium percentage is a parameter that can affect soil permeability [38]. The dominant anion contained in the soil with high sodium concentration will affect the nature of the soil; in alkali soils, the dominant anion is carbonate, whereas, in saline soils, the dominant anions are chloride and sulfate. Generally, soils with high sodium concentrations will not support plant growth [35]. Most of all, water samples of Ngerong Spring have ranges of the sodium percentage at 2.29-19.95 and classified into Excellent water classes. There is only 1 sample classified in Good class with a value of 21.07 (Table 5). The sodium percentage is plotted against the EC to determine the suitability of water for irrigation (Figure 5). Based on this classification, all water samples fall into the category “Excellent to Good.” The classification of Ngerong Spring samples based on Sodium Percentage is listed in Table 5.

Table 5. Classification of the suitability water for irrigation based on %Na

Water Class	%Na	Flood event	Normal Discharge
Excellent	<20	17.72 – 19.95 (5 samples)	2.29 – 17.42 (10 sample)
Good	20 - 40	21.07 (1 samples)	
Permissible	40 - 60		
Doubtful	60 - 80		
Unsuitable	>80		

Source : Data Processing(2019)

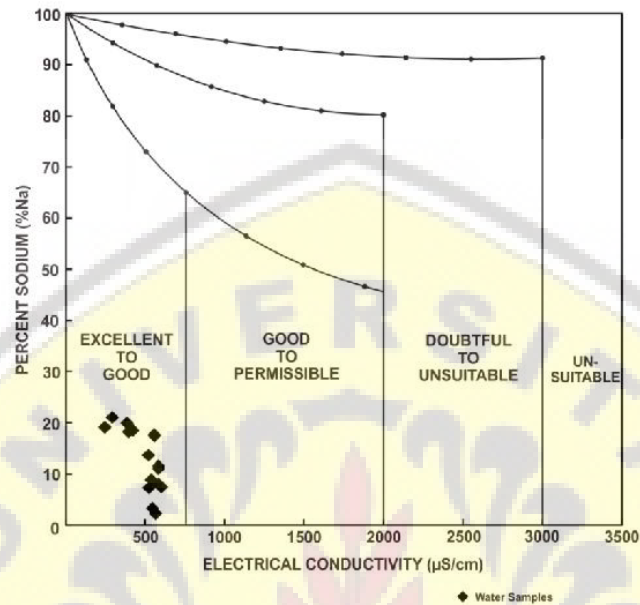


Figure 5. Diagram for the classification of irrigation water based on EC and %NA in Ngerong Spring (Wilcox Diagram)

4.4.4. Magnesium Hazard (MH)

The chemical type of water in the Ngerong Spring shown in Figure 4 (Piper diagram) shows that the Calcium (Ca) content is more dominant than magnesium (Mg), because of pure limestone. The Magnesium Hazard of water samples values vary from 11.37 to 39.68; this sample value is still within the allowable limit value of <50 meq/l and is suitable for irrigation. The classification of Ngerong spring samples based on Magnesium Hazard is listed in Table 6.

Table 6. Classification of the suitability water for irrigation based on MH,PI, and KR.

Parameters	Water Class	Range	Flood event	Normal Discharge
Magnesium Hazard (MH)	Suitable	<50	17.63 – 25.35 (6 samples)	11.37 – 39.68 (10 samples)
	Unsuitable	>50		
Permeability Index (PI)	Suitable	<80	25.70 – 28.15 (6 samples)	10.89 – 26.10 (10 samples)
	Unsuitable	>80		
Kelly’s Ratio (KR)	Suitable	<1	0.20 – 0.24 (6 samples)	0.02 – 0.20 (10 samples)
	Unsuitable	>1		

Source : Data Processing (2019)

4.4.5. Permeability Index (PI)

The PI will affect soil permeability caused by the presence of calcium, magnesium, sodium, and bicarbonate over a long period. In this study, all samples were suitable for irrigation (<80) category either during normal or flood conditions. The classification of Ngerong spring samples based on the PI is listed in Table 6.

#### 4.4.6. Kelly Ratio (KR)

Kelly Ratio calculates the sodium parameters measured against calcium and magnesium to classify water suitable for irrigation. Based on Kelly's Ratio, a value of more than one indicates the level of sodium in excess water and is not suitable for irrigation. In contrast, water with Kelly's Ratio of less than one indicates the value of sodium is still within reasonable limits and is suitable for irrigation. Kelly's Ratio in this study ranges 0.20-0.24 in the flood events and 0.02- 0.20 in the normal discharge. Kelly's ratio value in normal discharge is lower than in flood discharge. The classification of Ngerong Spring samples based on Kelly's Ratio is listed in Table 6.

Springwater fluctuation during the rainy season affects the chemical quality of spring. The higher the flood discharge, the lower the EC value. It is affected by the low concentration of Ca, Mg, and HCO<sub>3</sub>. Based on the salinity category, EC value in flood and normal discharge is still classified into medium salinity (C2), which is suitable for irrigation. On the other hand, during the flood discharge, the SAR, Sodium percentage (% Na), and Kelly Ratio parameters showed that the concentration of sodium increased. Increased sodium content will reduce soil permeability due to blockage in soil particles. Based on the three parameters mentioned before, sodium concentration in the Ngerong spring is still in the S1 (low sodium) category, excellent class, and suitable for irrigation.

## 5. Conclusion

The hydrochemical condition of water in the karst area always varies over time along the seasons. The water chemistry fluctuation will affect the water suitability for irrigation. The chemical type of water in Ngerong spring is Ca-HCO<sub>3</sub>. Water samples show that cations are dominated by calcium, and anions are dominated by bicarbonate. In this study, the major ion and automatic monitoring of Electrical Conductivity methods are applied to analyze the chemical water of Ngerong Spring. Based on the salinity analysis, the water of Ngerong Spring is classified in C2S1 (medium salinity with low sodium). The same result is showed by the percent sodium method. It shows that water is classified as Excellent to Good Class, and also strengthened by the parameters of Magnesium Hazards, Permeability Index, dan Kelly's Ratio shows that water in the Ngerong spring all year round is suitable for irrigation.

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