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RESEARCH ARTICLE

Spatial and Seasonal Variation of Doline Water Hydrochemistry in West Gunungsewu Karst Area, Yogyakarta Special Region, Indonesia

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Abstract

The doline water hydrochemical study was conducted in the Gunungsewu karst area, Yogyakarta Special Region. The hydrogeological survey followed by doline water sampling was carried out in the Panggang and Wonosari-Baron Hydrogeological Subsystems. Ten selected doline water samples were taken, each in the dry and rainy season, for further physical/chemical testing in the laboratory. Research analysis includes hydrochemical analysis of several parameters such as pH, TDS, EC, major and minor ions content and assisted by difference and variability tests statistical analysis. The hydrochemical variations of doline water in the study area generally did not show any spatial variations, except for the EC parameter. Temporal/seasonal hydrochemical variations are apparent, as evidenced by differences in many variations of TDS, EC, major ions (Ca^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}), and minor ions (sulfate and nitrate). In the dry season, the hydrochemical facies generally develop as Ca, Na-bicarbonate facies, while in the rainy season, doline water typically has Ca-bicarbonate facies. The hydrochemical of doline water may be influenced by groundwater.

Keywords: Doline, Karst, Water, Hydrochemistry, Variety

1. Introduction

One of the studies on water potential can be carried out from a quality perspective. The chemical quality of water is carried out by assessing the chemical content of the water (hydrochemical). This study is essential to support the potential of water/groundwater resources in the research area because this study supports the study of hydrogeological and environmental processes in the research area. Groundwater potential can be determined by conducting exploration as a way to increase the amount of water from water sources (Haerudin et al, 2024). The field hydrogeological exploration usually conducted to find out groundwater quality especially in pH, EC, TDS (Listyani et al, 2023).

The water potential in the study area can be assessed using the hydrochemical method. Groundwater hydrochemistry can also be used to determine the origin of the water (Pinning et al, 2023). This method will help to understand the hydrogeology of a site. By knowing the chemical types of groundwater that exist, we can carry out various analyzes, interpretations, and correlations of the chemical components of water.

Hydrochemical studies will help understand the hydrogeological model of a doline. The geology of an area controls various hydrochemical processes. Therefore, good research on hydrochemistry is needed. By knowing the groundwater hydrochemistry, we can find out the several hydrochemical processes in a doline and its relationship with the surrounding groundwater. Thus, the hydrogeological model can be approached by looking at the diversity of water chemistry types. Water hydrochemistry is also helpful in assessing the potential quality of groundwater, which is, of course, very beneficial for people living in the study area.

Groundwater hydrochemistry can vary from region to region (Listyani and Ning Peni, 2020), as well as for surface water hydrochemistry. Doline water hydrochemistry can be evaluated based on seasons and spatially. It is necessary to know the variations caused by the influence of place and time to see water quality dynamics in an area.

This hydrochemical study was carried out in the Gunungsewu karst region, Gunungkidul Regency, Yogyakarta Special Region (Fig. 1). This area is included in the Wonosari groundwater basin (Badan Geologi, 2011) and is formed by the karst hydrogeological system. The large number of cracks and dissolution holes of the limestone in this karst area supports the potential for good groundwater aquifers (Listyani, 2022). The water potential in karst areas is good, where water sources can be found on the surface and even develop as underground rivers (Goldscheider, 2019), therefore water quality studies are really needed to support understanding of karst water potential.

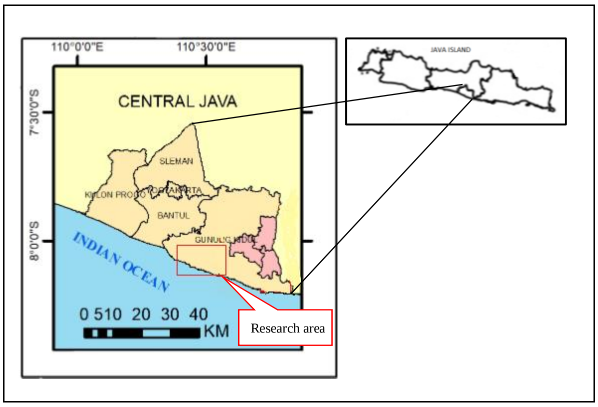


Fig. 1. The research area is located in the south of Java Island, Indonesia.

2. Materials and Methods

2.1 Geological and Hydrogeological Setting

Gunungsewu is a good example of tropical karst (Kusumayudha *et al*, 2015), The peculiarity of this tropical karst is characterized by the appearance of rolling hills, closed basins, and existing caves. The distribution patterns of caves in the Gunungsewu karst area have been studied to understand the potential for groundwater in the area (Pambudi *et al*, 2018). Geological lineaments influence the distribution pattern of vertical and horizontal cave entrances.

Closed depression is the most common karst landscape. This landscape functions to channel rain and run off vertically downwards as recharge water. These depressions range in diameter from several meters to tens of kilometers, with depths ranging from a few centimeters to hundreds of meters. The minor formation of this depression is commonly referred to as the doline (Dry *et al*, 2021).

Doline (or sinkhole as it is more commonly referred to in North America) is a closed natural depression found in the karst landscapes. Doline is the most common landscape in the karst region. This landform is described as a closed depression of small to medium size (diameter and depth), ranging from meters to tens of meters (Ford and Williams, 2013).

Groundwater hydrochemical variations have been widely studied (Setiawan et al, 2020; Listyani et al, 2021). Changes in the degree of karstification can occur temporally in the Gunungsewu area (Adji *et al*, 2017), marked by changes in the type of groundwater flow. The changes in doline water have not been further studied. Therefore, this study intends to reveal the phenomena that occur in the hydrochemical variations of doline water.

2.2 Field Sampling and Measurement of Doline Water Hydrochemistry

The geological field survey begins with finding the location of the doline. This fieldwork is, in principle, a hydrogeological survey complemented by water sampling. This field survey has been carried out by measuring the temperature (T), pH, total dissolved solids (TDS), and electrical conductivity (EC) of doline water, as well as a description of doline morphology. Doline water samples are taken at least in two periods, namely in the dry and rainy seasons. The selected doline was taken from two subsystems, namely the Panggang and Wonosari-Baron Hydrogeological Sub-systems.

Some physical/chemical parameters such as temperature, pH, total dissolved solid (TDS), electrical conductivity (EC),were examined in the field with a portable Hanna testing kit. Then, the water is collected in two liter polyethylene bottle for further laboratory test.

2.3 Laboratory Analysis

Analysis of major ions was carried out in the Water Physics Chemistry Laboratory of BBTKLPP Yogyakarta. The Ca^{2+}, Na^{+}, Mg^{2+}, and K^{+} ions were determined with ion chromatography system. The SO_4^{2-} and NO_3^{-} ions were analyzed using spectrophotometer. Whereas, Cl^{-} and HCO_3^{-} ions were measured by titration. The testing methode done by some standard, especially SNI (2004-2009) and APHA 2012.

All data obtained were then processed to obtain the hydrochemical characteristics of the water in the study area. This laboratory testing may support the understanding of the hydrogeology of the study area.

Principally, bivariate correlation of hydrochemical parameters is carried out using tables or figures. This illustration will show the relationship of one chemical parameter to another. The hydrochemical graph was also created to see the correlation between the EC and the major ion.

2.4 Statistical Analysis

The statistical test was carried out as a data verification method. Statistical tests that will be carried out in this study include normality test, difference test, and regression/correlation. The variables tested statistically were the chemical characteristics of water, including pH, TDS, EC, and ion content. The correlation test between ions can also be easily seen based on the Pearson correlation coefficient matrix.

Variability index (Iv) is the ratio of maximum discharge (Qmax) to minimum value (Qmin), whereas variability (V) can be calculated by the percentage of maximum-minimum difference value to average (Malik, 2015). Meanwhile, variation coefficient (CV) can be calculated by mathematical formula by dividing SD (standard deviation) by the average value (Avg) (Springer *et al*, 2008).

$$Iv = \frac{\text{Max value}}{\text{Min value}} \quad (1)$$

$$CV = \frac{SD}{Avg} \quad (2)$$

$$V = \frac{\text{Max}-\text{min value}}{Avg} \quad (3)$$

3. Result

3.1 Field Appearance

Doline is the morphology of exokarst, which is a valley basin between conical hills. In general, the morphology is formed by limestone dissolving, which is triggered by a geological structure in the form of a rigid or quite intensive fault. The weak zone caused by the geological structure is a vehicle that is easily dissolved so that relatively prominent hills appear and the morphology of the valley. The landscapes formed by the karst hills and valleys generally have slightly rough reliefs. These conical hills are usually not very high (about 20-30 m) with gentle slopes (<40^{o}). The morphology of conical hills and doline found in the field showed in Fig. 2.

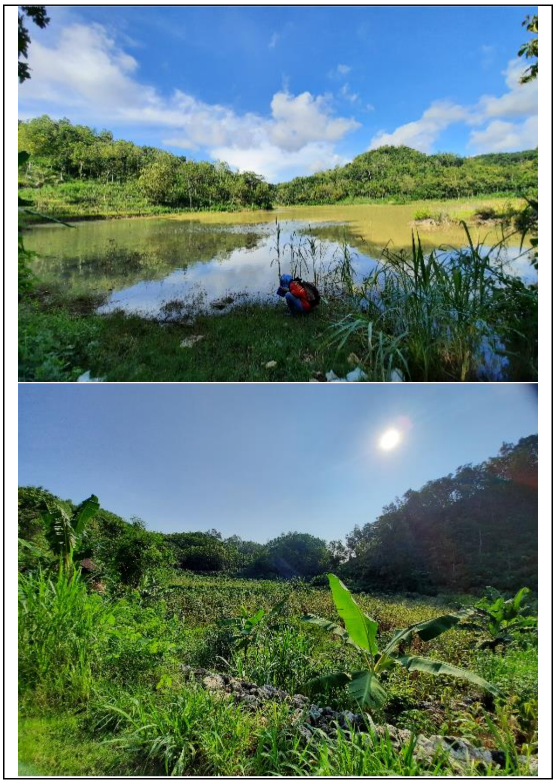


Fig. 2. Examples of epikarst morphological features found in the study area are conical hills and doline in Miriledok (upper) and Depok (bottom).

3.2 Variation of the Physical and Chemical Doline Water Properties

3.2.1 Spatial Hydrochemical Variation

Doline is part of the Gunungsewu karst system with a channel flow type in carbonate rock cavities (Kusumayudha, 2002). This karst system can be divided into three subsystems: Panggang, Wonosari-Baron, and Sadeng Hydrogeological Subsystems. The physical/chemical properties of doline water in the study area were studied spatially to distinguish the hydrochemical characteristics of doline water from Panggang and Wonosari-Baron Hydrogeological Subsystems.

Different tests using the T-test for normally distributed data or the Mann Whitney test for abnormal data have been carried out on several hydrochemical parameters in Pangganged and Wonosari-Baron Hydrogeological Subsystems. The results show no difference in almost all the parameters studied, except for EC (Table 1).

Table 1. The hydrochemical data of doline water at Panggang and Wonosari-Baron Hydrogeological Subsystems.

No	Para-meter	Normality Test Asymp. Sig.	Heterogeneity Test Sig	Difference Test Sig	Difference Test Mann-Whitney
1	pH	0.024	0.014		0.341
2	TDS	0.236	0.022	0.279	
3	EC	0.232	0.144	0.013	
4	Turbidity	0.021	0.064		0.564
5	Warna	0.390	0.233	0.074	
6	Ca^{+}	0.291	0.185	0.057	
7	Na^{+}	0.192	0.510	0.740	
8	K^{+}	0.113	0.028	0.510	
9	Mg^{2+}	0.070	0.064	0.908	
10	Cl^{-}	0.112	0.970	0.240	
11	HCO_3^{-}	0.230	0.273	0.918	
12	SO_4^{2-}	0.133	0.382	0.391	
13	SiO_2	0.933	0.014	0.639	
14	PO_4^{2-}	0.038	0.022		0.837
15	NO_3^{-}	0.267	0.144	0.531	
Explanation		Normal distribution except pH, turbidity, PO4	Homo-geneous, except TDS, EC, Cl-	No significant difference between doline's water hydrochemistry except for EC	

Based on Table 1, it seems that the hydrochemical characteristics of doline water in Panggang and Wonosari-Baron Hydrogeological Subsystems are generally not different. It means that the two subsystems do not affect doline water's physical/chemical elements, even though the two subsystems differ in their hydrodynamic characteristics. The variation of lithofacies (marl, bioclastic limestone, reef limestone), geological structure (faults and fractures), and slightly different bedrock configurations did not affect the hydrochemical characteristics of doline water.

3.2.2 Seasonal Hydrochemical Variation

The study of temporal hydrochemical variation was also assisted by statistical analysis. The results of statistical analysis of several parameters used in this study are presented in Table 2.

Based on different tests on several hydrochemical parameters, it is known that, in general, the data is usually distributed, except for T, pH, turbidity, PO_4^{2-}, and is heterogeneous except for color and SO_4^{2-} (Table 3). Significant differences occurred in many hydrochemical parameters except pH, turbidity, color, SO_4^{2-} and silica. It shows that the season strongly affects the changes in the hydrochemical characteristics of doline water. Doline water temperature is not discussed further because this parameter is very dependent on the weather and ambient air. The surrounding air is also greatly influenced by land use (Alif *et al*, 2020).

Table 2. Statistical descriptions of some hydrochemical parameters from doline water.

No.	Para-meter	Dry season min	Dry season max	Dry season mean	Rainy season min	Rainy season max	Rainy season mean
1	T	26.3	33.2	30.85	27.6	34.0	30.8
2	pH	7.40	10.1	9.03	8.00	9.40	8.80
3	TDS	82.0	299.0	164.5	45.0	76.0	54.0
4	EC	136.0	418.0	260.9	70.0	174.0	119.2
5	Turbidity	1.30	243.5	81.14	13.5	41.7	25.5
6	Color	8.00	148.0	62.70	7.00	200.0	55.5
7	Ca^{2+}	0.56	3.43	1.86	0.56	1.03	0.82
8	Na^{+}	0.20	2.38	1.17	0.08	0.59	0.26
9	K^{+}	0.17	1.17	0.39	0.09	0.22	0.15
10	Mg^{2+}	0.12	0.75	0.32	0.04	0.36	0.18
11	Cl^{-}	0.17	1.18	0.50	0.02	0.18	0.04
12	HCO_3^{-}	1.50	5.74	3.23	0.78	1.60	1.15
13	SO_4^{2-}	0.04	0.33	0.15	0.12	0.42	0.23
14	SiO_2	4.24	14.94	11.42	2.76	7.62	5.54
15	PO_4^{2-}	0.19	6.01	1.80	0.08	0.87	0.30
16	NO_3^{-}	0.09	2.72	1.24	0.01	1.70	0.44

*) ion content in meq / l.

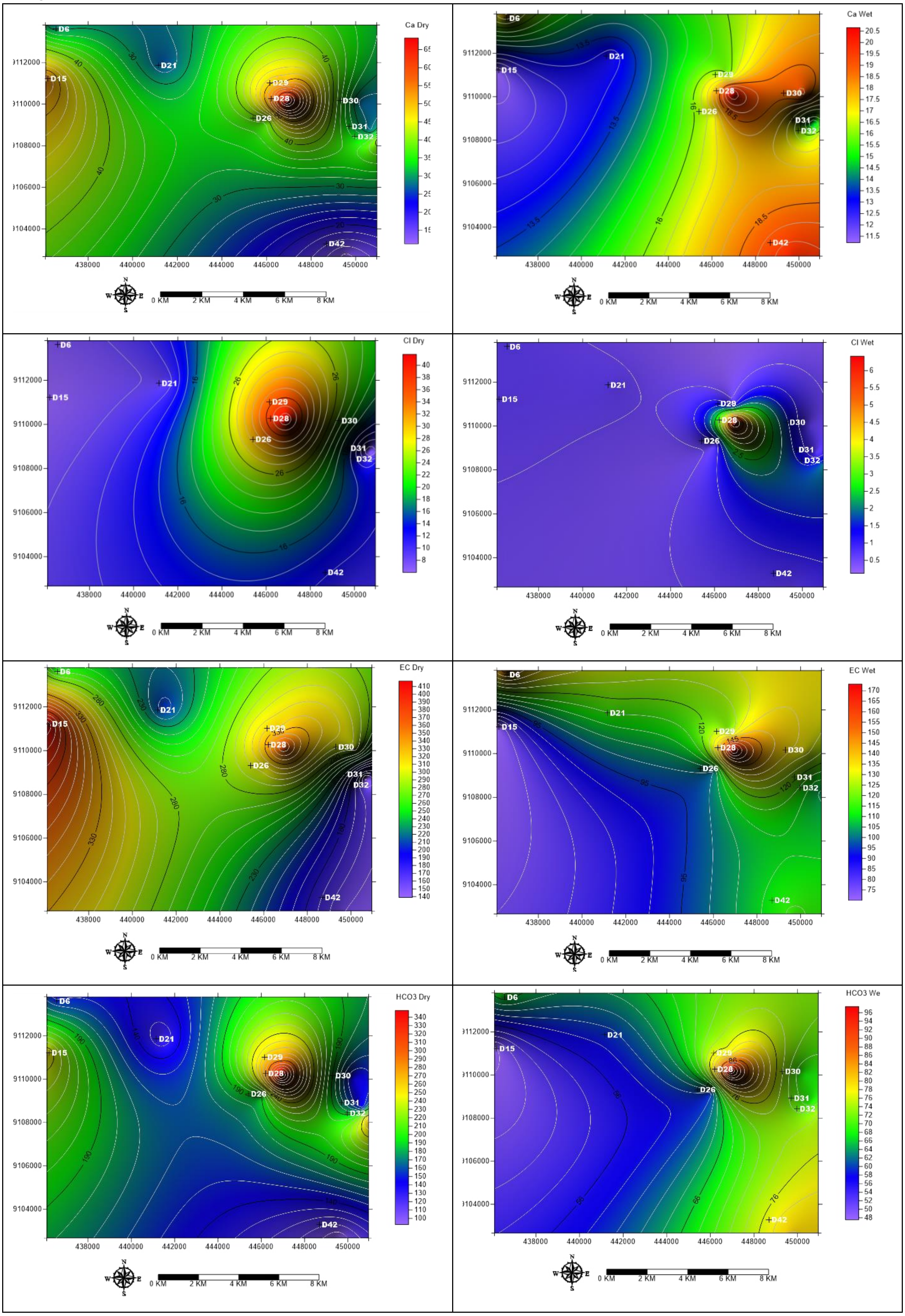
Table 3. The statistical test results of doline hydrochemical data by temporal.

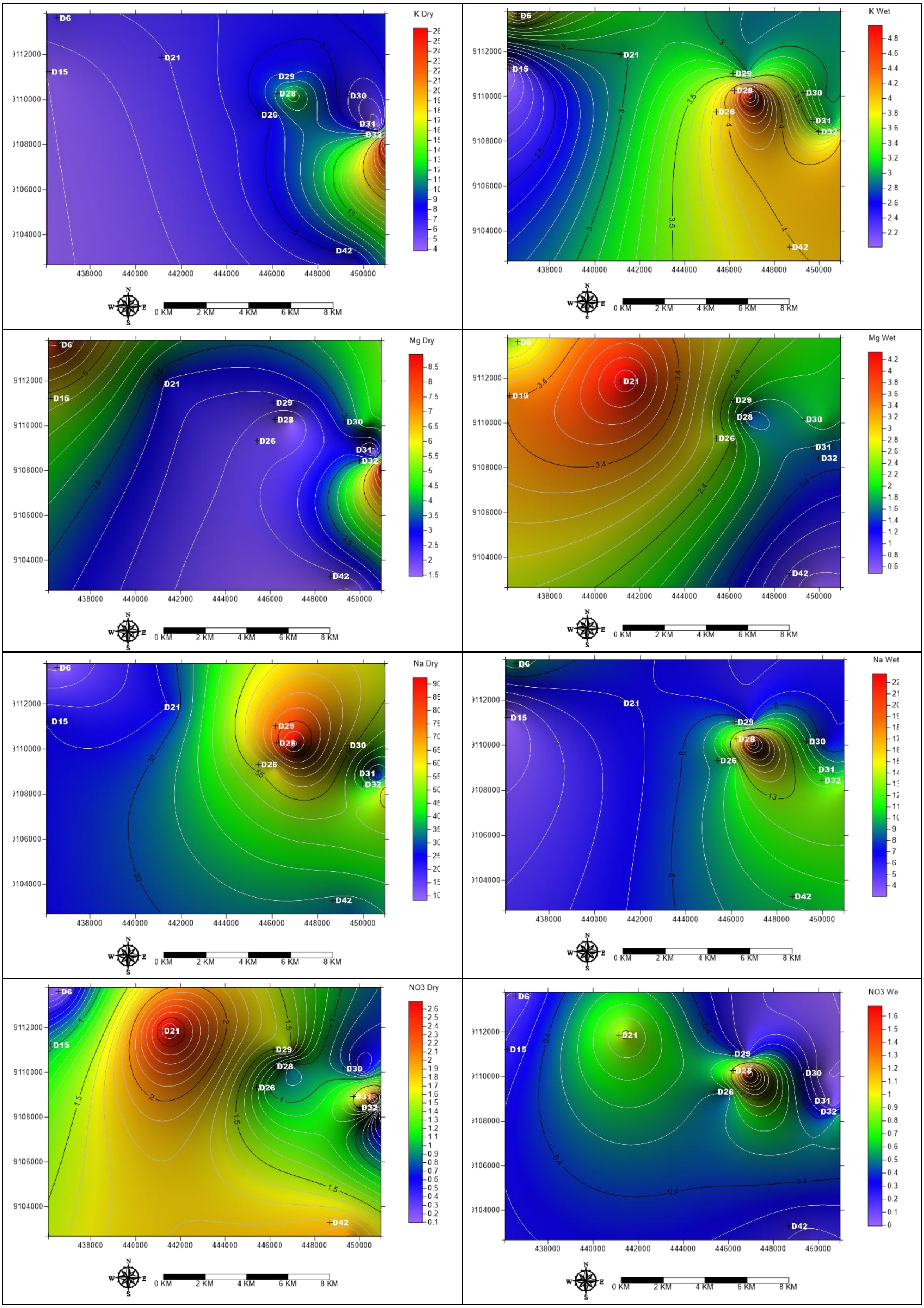
No	Para-meter	Normality Test Asymp. Sig.	Heterogeneity Test Sig	Difference Test Sig	Difference Test Mann-Whitney
1	pH	0.024	0.000		0.796
2	TDS	0.236	0.001	0.002	
3	EC	0.232	0.887	0.001	
4	Turbidity	0.021	0.006		0.684
5	Warna	0.390	0.000	0.761	
6	Ca^{+}	0.291	0.033	0.017	
7	Na^{+}	0.192	0.002	0.003	
8	K^{+}	0.113	0.000	0.032	
9	Mg^{2+}	0.070	0.001	0.025	
10	Cl^{-}	0.112	0.974	0.008	
11	HCO_3^{-}	0.230	0.005	0.003	
12	SO_4^{2-}	0.133	0.002	0.051	
13	SiO_2	0.933	0.000	0.061	
14	PO_4^{2-}	0.038	0.001		0.015
15	NO_3^{-}	0.267	0.887	0.016	
Explanation		Normal distribution except pH, turbidity, PO4	Normal distribution except pH, turbidity, PO4	Heterogeneous, except color and SO42-	

3.3 The pH distribution, Electrical Conductivity (EC), Ion Content

Of the ten selected doline whose water has been analyzed in the laboratory, several parameters are mapped to see their distribution in space and time, especially by visiting their seasonal variations. The distribution patterns of several hydrochemical parameters are presented in several maps in Fig. 3. This figure shows the variation in pH, TDS, EC values, and the content of chemical elements including Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}.

The distribution of several hydrochemical parameters, as illustrated in Fig. 3 shows that seasonal changes strongly influence the hydrochemical characteristics. The hydrochemical parameters that experience an increase in concentration during the rainy season are Ca^{2+}, Mg^{2+}, and HCO_3^-.

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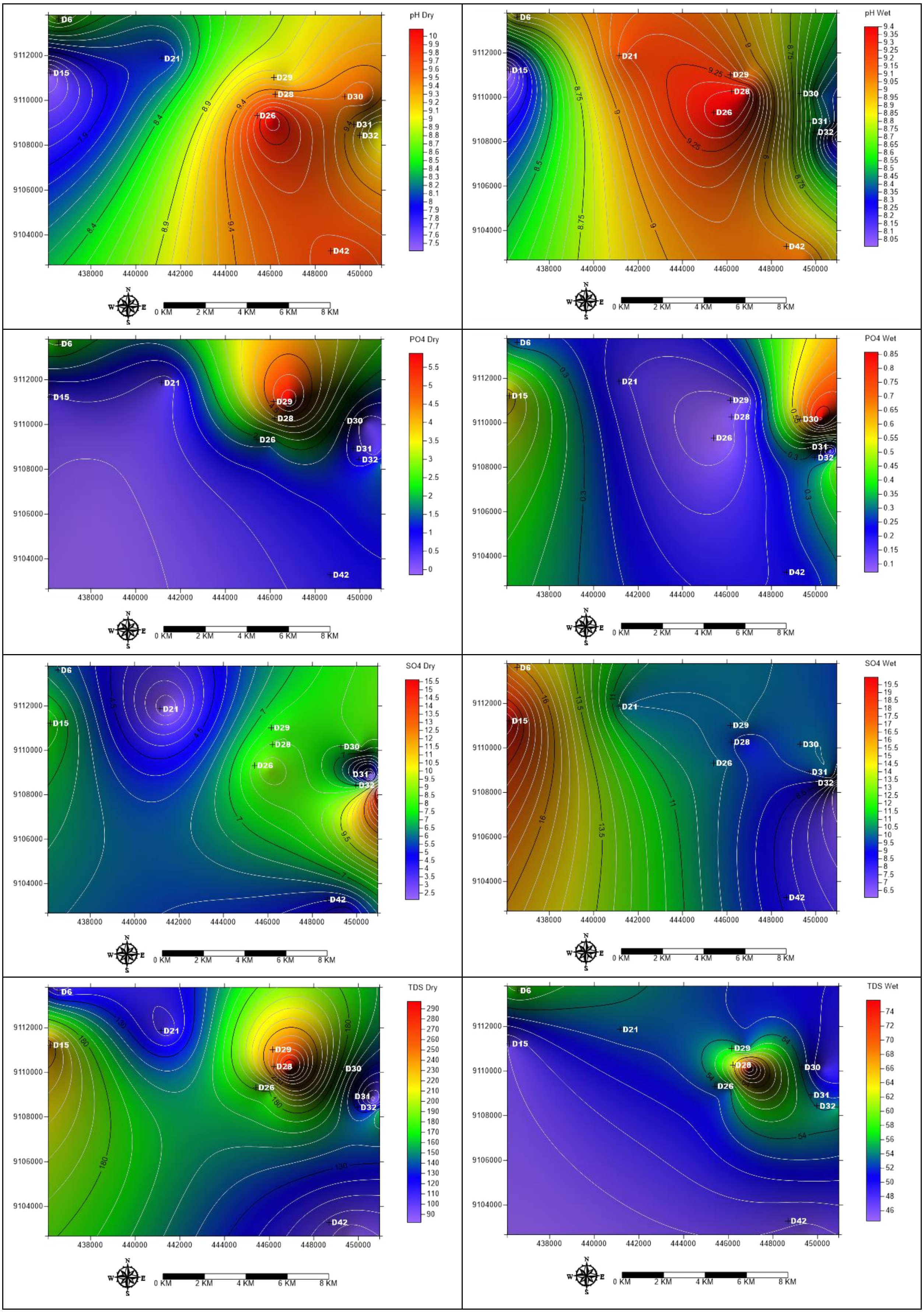

Fig. 3. Distribution of some of the studied doline water hydrochemical parameters

Dissolved Ca^{2+} elements usually come from the dissolution of calcite and dolomite minerals in limestone. Mg^{2+} ions can be supplied by the dissolution of minerals such as dolomite or impurity minerals such as hornblende and biotite. The increase of bicarbonate ions is greatly influenced by rainfall from CO_2 in the atmosphere or soil other than a dissolution of carbonate rocks.

3.4 Bivariate Correlation of Hydrochemical Parameters

The relationship between the hydrochemical parameters shows the hydrochemical process and its correlation. This relationship can be briefly examined using the Pearson & Spearman correlation coefficient matrix and the bivariate graph between ions.

3.4.1 Pearson & Spearman Correlation Coefficient Matrix

The relationship between the ions can be seen from the Pearson correlation value in Table 4. Pearson correlation values that are close to 1 indicate a solid and linear relationship, among other things shown by the relationship between EC to Ca^{2+}, Na^{+}, HCO_3^-, Cl^-; the relationship between Ca^{2+} and Na^{+}, HCO_3^-, Cl^-, PO_4^{2-}; the relationship of Mg^{2+} with K^{+}; the relationship between Na^{+} and K^{+}, HCO_3^-, Cl^-, PO_4^{2-}; the relationship of K^{+} to HCO_3^-; the relationship of HCO_3^- to Cl^- and PO_4^{2-}; as well as the relationship between Cl^- and PO_4^{2-}. The relationship of EC with some ions contained in the water is naturally powerful because EC is a property that is determined by the amount of salt in the water.

Table 4. Pearson & Spearman correlation of several hydrochemical parameters.

	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	SiO_2	HCO_3^-	Cl^-	SO_4^{2-}	NO_3^-	PO_4^{2-}
pH	1,000											
EC	0.239	1,000										
Ca^{2+}	0.209	0.882**	1,000									
Mg^{2+}	-0,203	0.371	0.064	1,000								
Na^{+}	0.066	0.699**	0.662**	0.188	1,000							
K^{+}	-0.279	0.258	0.093	0.604**	0.656**	1,000						
SiO_2	-0,319	0.520*	0.507*	0.232	0.553*	0.365	1,000					
HCO_3^-	0.040	0.750**	0.707**	0.433	0.825**	0.638**	0.547*	1,000				
Cl^-	0.244	0.727**	0.731**	0.079	0.947**	0.476 *	0.364	0.799**	1,000			
SO_4^{2-}	-0,120	-0.264	-0,313	0.058	-0,121	0.181	-0.044	-0.010	-0.119	1,000		
NO_3^-	-0.381	0.184	0.281	-0.159	0.272	0.022	0.304	0.096	0.197	-0.658**	1,000	
PO_4^{2-}	0.115	0.529*	0.633**	0.002	0.829**	0.435	0.465*	0.726**	0.848**	-0.009	0.222	1,000

Explanation:
The sign ** means that sig <0.01 means that the Pearson correlation value is very strong.
Sign * means 0.01 <sig <0.05 means that the Pearson correlation value is strong

3.4.2 Correlation of EC to Major Ions

Karimi *et al* (2005) stated the strength of water-rock interactions in the karst aquifer system by looking at the relationship between EC and major ions dissolved in water in the karst region. The EC value indicates the amount of TDS in water. The major ions commonly used for the hydrochemical analysis of the karst area include Ca^{2+}, Mg^{2+}, and HCO_3^-. The relationships between EC and the major ions studied are presented in Table 5 and Fig. 4.

Table 5. The correlation of EC and major ion contents of doline water.

EC vs ion	Dry Season			Rain Season		
	r^2	r	Category*	r^2	r	Category*
HCO_3^-	0.36	0.60	strong	0.62	0.79	strong
Ca_2^+	0.56	0.75	strong	0.53	0.73	strong
Mg^{2+}	-0.04	0.002	very low	0.30	-0.09	low

* after (Sugiyono, 1997)

This phenomenon due to the interactions of gas (CO_2) - water (H_2O) - rocks ($CaCO_3$) in the karst system. The strong correlation between EC and HCO_3^- in the dry season (r = 0.60) and the wet season (r = 0.79) indicates that EC was mainly due to the dissolution of $CaCO_3$. A stronger correlation is shown during the rainy season, meaning that rain has a role in increasing bicarbonate ions in doline water.

A strong and positive correlation was also shown by the relationship between EC and Ca in both seasons with similar correlation coefficients. It also indicates the existence of a rock dissolution process due to the interaction of H_2O and $CaCO_3$ (limestone). This interaction also runs quite intensively even though there is a dilution during the rainy season.

The very low - low correlation of the EC and HCO_3^- relationships in both seasons indicates that Mg^{2+} ion affects the EC value of doline water. It also means that the dissolution of Mg^{2+} in the rock is not intensive.

3.4.3 Hydrochemical Facies

The hydrochemical facies represent the type of doline water chemistry studied (Table 6). Furthermore, the hydrogeological system of this karst area can also be known based on the hydrochemical characteristics of the doline water (Listyani & Ridayati, 2021). They help the analysis or interpretation of the hydrochemical processes that occur in the doline water. Several diagrams are used to understand the water facies.

In the dry season, the hydrochemical facies are dominated by Ca and Na-bicarbonate facies, while in the rainy season, doline water generally has Ca-bicarbonate facies. The dominance of Ca facies during the rainy season indicates that rock dissolution continues during the rainy season, although the enrichment of this element is not clear.

4. Discussion

Based on several analyzes before, it is known that the location of doline (spatial) occurrence does not clearly show its effect on the hydrochemical variation of doline water. However, the changing of seasons will determine the quality of this water. Seasonal variations are evident in many hydrochemical parameters. Quantitatively, this condition can be observed based on statistical analysis as illustrated in the following Table 7. The coefficient of variation for several chemical parameters can be used as a reference for identifying groundwater flow in the karst area.

Table 6. Hydrochemical facies of doline water.

No	Para-meter (%)	D6	D15	D21	D26	D28	D29	D30	D31	D32	D42
		Dendeng welut	Sumur-wuni	Towet	Jambe-anom	Winong	Boro-mo	Nam-beran	Mong-gol	Klepu	Omang
	Dry Season										
	Cation	2,53	4,00	2,45	3,93	6,49	5,21	3,23	2,31	5,49	1,77
1	Ca^{2+}	54,90	67,76	53,58	48,68	52,80	48,37	41,99	59,56	37,42	31,36
2	Na^{+}	8,08	15,97	26,08	38,42	36,65	40,28	38,83	27,72	27,48	44,73
3	K^{+}	10,31	4,35	10,64	8,86	8,71	7,52	8,09	7,54	21,39	17,18
4	Mg^{2+}	26,71	11,92	9,70	4,04	1,84	3,82	11,09	5,17	13,71	6,73
	Anion	2,72	4,43	2,28	4,19	7,09	5,71	2,96	2,51	5,06	1,88
5	Cl^{-}	7,26	3,82	10,51	21,55	16,70	18,28	16,68	6,74	6,96	15,76
6	HCO_3^{-}	88,16	92,43	87,66	73,98	80,95	78,80	77,69	91,60	86,46	79,81
7	SO_4^{2-}	4,59	3,76	1,83	4,47	2,35	2,92	5,63	1,66	6,58	4,43
	Facies	Ca, Mg	Ca	Ca, Na	Ca, Na	Ca, Na bicarbonate	Ca, Na	Ca, Na	Ca, Na	Ca, Na	Ca, Na
	Rainy Season										
	Cation										
1	Ca^{2+}	58,24	55,76	48,84	57,02	52,76	62,91	67,05	58,58	57,14	67,91
2	Na^{+}	16,96	7,65	13,69	17,48	30,04	14,18	12,60	20,95	22,77	17,49
3	K^{+}	11,54	8,68	9,98	11,89	11,11	10,33	9,18	10,69	11,92	11,90
4	Mg^{2+}	13,26	27,91	27,49	13,61	6,09	12,57	11,17	9,77	8,17	2,70
	Anion										
5	Cl^{-}	1,15	1,40	1,41	1,41	9,28	1,14	1,26	1,26	4,04	1,13
6	HCO_3^{-}	76,18	64,24	81,22	81,22	81,23	84,90	83,26	83,26	87,02	87,74
7	SO_4^{2-}	22,67	34,36	17,37	17,37	9,49	13,97	15,48	15,48	8,94	11,13
	Facies	Ca	Ca, Mg	Ca, Mg	Ca	Ca, Na bicarbonate	Ca	Ca	Ca	Ca	Ca

Table 7. Statistical descriptions of some of the doline water's dry season hydrochemical parameters.

No.	Parameter	Dry Season				Rainy Season			
		SD	Iv	CV (%)	V	SD	Iv	CV (%)	V
1	T	1.93	1.26	6.24	0.22	2.10	1.23	6.81	0.21
2	pH	0.82	1.36	9.09	0.30	0.53	1.18	6.01	0.16
3	TDS	78.32	3.65	47.61	1.32	8.81	1.69	16.31	0.57
4	EC	97.97	3.07	37.55	1.08	28.15	2.49	23.61	0.87
5	Turbidity	80.04	187.31	98.65	2.98	10.48	3.09	41.07	1.11
6	Color	45.39	18.50	72.39	2.23	58.08	28.57	104.65	3.48
7	Ca^{2+}	0.84	6.16	45.18	1.54	0.15	1.85	18.53	0.58
8	Na^{+}	0.71	11.63	60.47	1.86	0.14	7.67	53.12	2.00
9	K^{+}	0.30	6.75	76.08	2.56	0.04	2.50	24.28	0.86
10	Mg^{2+}	0.24	6.31	73.88	1.97	0.09	9,10	51.87	1.83
11	Cl^{-}	0.39	7.00	77.21	2.01	0.05	10.83	140.53	4.44
12	HCO_3^{-}	1.37	3.83	42.46	1.31	0.22	2.06	19.56	0.72
13	SO_4^{2-}	0.08	8.00	57.29	1.97	0.08	3.33	37.32	1.28
14	SiO_2	3.08	3.52	26.99	0.94	1.66	2.77	29.95	0.88
15	PO_4^{2-}	1.95	30.96	108.06	3.23	0.26	11.47	87.40	2.64
16	NO_3^{-}	0.92	30.22	74.62	2.12	0.53	170.00	121.59	3.89

Table 8. Comparison of several CV parameters for hydrochemical parameters of the spring from many previous researchers in (Setiawan *et al*, 2020)

Spring Type	Coefficient of Variation (CV)						
	T	Q	EC	pH	Ca^{2+}	Mg^{2+}	HCO_3^{-}
Rock Spring conduit type	26.9	175	23	1.7	25.5	27.6	28.6
Iskert Spring conduit type	10.3	94.2	-	1.6	11.7	30	14.2
Conduit type	26.9	-	10 - 20	-	-	-	-
Thomson Springdiffusive type	1.4	26.3	6.2	0.6	6.4	2	2.7
Blue Spring diffusive type	0.6	-	5	-	-	-	-
Pellumbas diffusive type	4.2	-	7.2	-	12.6	23.5	-
Diffusive type	1.4	-	<10	-	-	-	-

Explanation: T = temperature; Q = discharge; EC = electric conductivity; pH = acidity value

As a comparison, the calculated CV values for various parameters in the field were then compared with the CV values that had been made by previous researchers (Table 8). In general, conduit flow is characterized by a relatively large CV value, while diffusion flow has a low CV value.

Based on Table 8, it appears that the conduit flow plays a greater role in the hydrochemistry of doline water. However, this is not necessarily appropriate, considering that the source of doline water is not necessarily dominated by groundwater supply. However, from this statistical analysis, it can be interpreted that the influence of conduit flow in groundwater also supports the presence of doline water. It means doline water can be related to the surrounding groundwater flow, although locally.

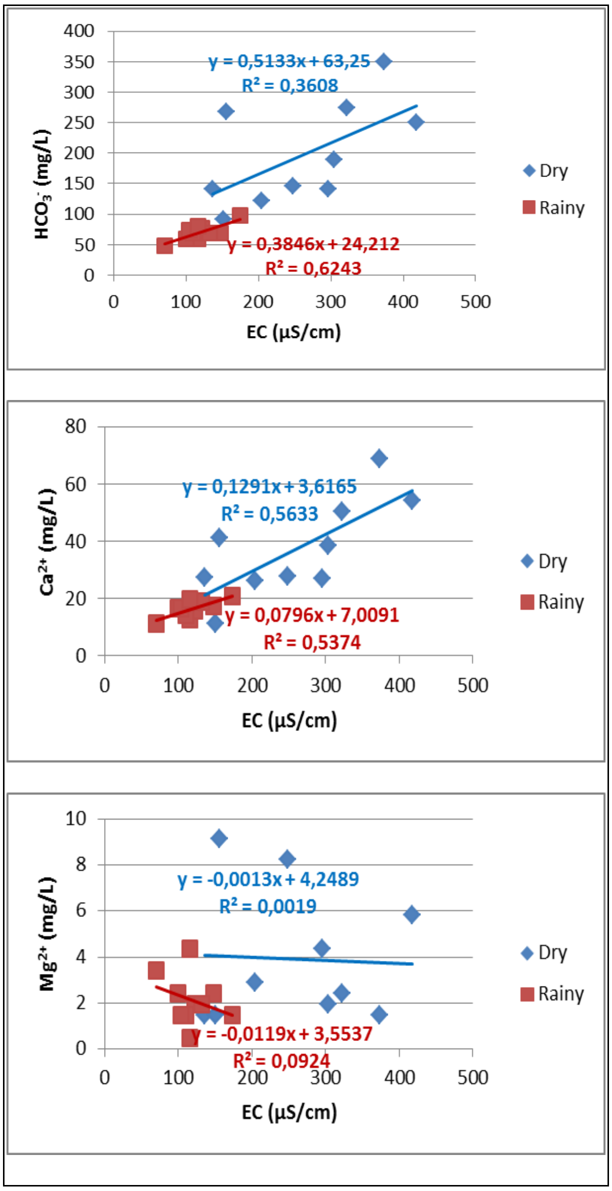

Fig. 4. Correlation of doline water's EC parameters to the major ion (HCO_3^-, Ca^{2+} and Mg^{2+}).

5. Conclusion

The hydrochemical variation of doline water in the Panggang and Wonosari - Baron Hydrogeological Subsystem (HSS) has been analyzed, particularly in the ten selected doline. Samples were taken in the dry and rainy seasons and then analyzed through various hydrochemical diagrams and statistical methods. Some of the resulting findings can be summarized as follows.

1. The hydrochemical characteristics of doline water in the study area did not show significant differences between water doline in the Panggang HSS and the Wonosari-Baron HSS. From statistical analysis, it is known that only the EC variable shows a difference.

2. The hydrochemical characteristics of doline water seasonally vary widely with differences in many hydrochemical parameters, including TDS, EC, major ions (Ca^{2+}, Na^+, K^+, HCO_3^-, Cl^-), and minor ions (sulfate and nitrate). The Ca, Na-bicarbonate facies develop in the dry season. In contrast, in the rainy season, the doline water facies generally show the Ca-bicarbonate type. The hydrochemistry of doline water may support by the conduit flow of groundwater.

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