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Sphericity Test in Hydrochemical Data, Case Study in the Southern Slope Merapi in Yogyakarta, Indonesia

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Abstract. Multivariate statistical using ANOVA analysis on the catchment area, concentrations allow for interactions between groundwater and lithology. The analysis applies to time series data to develop the hydrochemical evolution of groundwater during the rainy and dry seasons. The hydrochemical data used is the interval data for the chemical properties of groundwater in the exact observer location. Samples were taken at the same place by sampling at different time intervals, and the selection takes at 30-day intervals in the dry season and 180-day intervals in the dry season. The method chosen is the Mauchly test, the Greenhouse-Geisser test, and the Pairwise Comparison test. The three methods are analyzed to determine how the groundwater chemical concentrations changed at 30 days and 180 days. The analysis process shows a change in the concentration value caused by time and lithology factors. The catchment area chemically in the dry season with a high SO42- and HCO3 and low K and Cl, indicating a high connectivity level. In the rainy season, with a high ratio of HCO3 and low Cl, Rain that occurs during the rainy season is an essential mechanism for replenishing and maintaining groundwater quality. The approach used in this study allows for a practical interpretation of processes and can apply to various evaluations of hydrochemical data sets.

Keywords: Anova, hydrochemical evolution, Mauchly test, the Greenhouse-Geisser test, the Pairwise Comparison test.

INTRODUCTION

The length of time that groundwater is retained and trapped in the aquifer layer causes the dissolution of minerals in the lithological variations that make up the aquifer, increasing groundwater's chemical composition. The longer the groundwater is in contact with the lithology that composes the aquifer, and the farther the groundwater undergoes hydraulic movement, the more changes in the concentration of dissolved minerals in the groundwater, which is called the evolution of the properties groundwater [1].

The hydrogeochemical characteristics of a groundwater basin area determine from several factors. These factors are variations in the lithology of the aquifers, the dissolution of rock minerals with groundwater, the extended contact time between groundwater and rocks, and the speed of movement of groundwater flowing in the aquifer [1, 2]. Hydrogeochemical characteristics effect by the addition or reduction of specific ions, changes in pressure, and temperature. In the end, the groundwater will reach equilibrium conditions at the saturation value of the ions or compounds formed [3]. Based on this concept, during its journey, groundwater will develop towards a balance like seawater. Groundwater in coastal areas will experience changes as indicated by the relatively stable chemical concentration of groundwater.

The hydrochemical properties of groundwater are highly dependent on the rock minerals that make up the aquifer. They will dynamically affect the relationship between the groundwater conditions, particular aquifer strata, and the history of landform formation through lengthy processes and dynamics [4, 5]. Groundwater's implications can see groundwater flow moving through geological structures by passing through different lithology variations and aquifer layers. The significance process causes the hydrochemical concentration of groundwater to change [6].

This study aims to determine groundwater's hydrochemical distribution and describe the evolution of groundwater types using ANOVA statistical analysis. ANOVA statistical calculation aims to obtain repeated measurements of the value of a subject, and of course, this method is very susceptible to changes in values with rounding. Sphericity is one of the ANOVA methods used to determine how the variance values between all related group combinations are considered the same. A change in value by rounding is when the difference in the value of the variance between all connected group combinations is not equal. Sphericity that is suitable for determining the extent to which changes in the value of the geochemical concentration of groundwater is to use the Mauchly Test, Greenhouse-Geisser Test, and Pairwise Comparison Test methods.

The results of the hydrochemical data analysis expect to be used to divide groundwater properties. Based on time and space and be used to determine differences in properties from time to time which are specific cases with differences and limited litho-hydrochemical data, as well as the results of data analysis and interpretation. that can contribute to groundwater management.

MATERIALS AND METHODS

The material was analyzed using the value of the hydrochemical concentration of groundwater samples taken from different times. The difference in sampling time occurs at intervals of 1 month and six months at the exact five locations. The selection takes on the southern slope of Mount Merapi in the unconfined aquifer layer, located in the Sleman Regency, Yogyakarta Province, Indonesia. The concentration values for physical properties are DHL, TDS, and temperature, while the hydrochemical concentration values are anions (Cl^-, HCO_3^-, SO_4^{2-}) and cations (K^+, Na^+, Ca^{2+}, Mg^{2+}). The value of the hydrochemical concentration was analyzed by multivariate ANOVA statistics, in the form of analysis The Mauchly Sphere Test, Greenhouse-Geisser Test, Greenhouse-Geisser Test, and Pairwise Comparison Test.

The ANOVA statistical analysis formal way of testing commonly used sphericity assumptions. The ANOVA statistical analysis may be due to its automatic printing in SPSS for iterative ANOVA actions and the lack of available tests. The Mauchly Integrity Test tests the null hypothesis that the variances of the differences are the same. Thus, if the Mauchly sphericity test is statistically significant ($p < 0.05$), we can reject the null hypothesis and accept the alternative idea that the variances of the differences are unequal (that is, roundness violates) [7].

If the data does not violate the sphericity assumption, there is no need to change your degrees of freedom. Not breaking this assumption means that the F-statistic you calculated is valid and can be used to determine statistical significance. However, if the sphericity assumption violates, the F-statistic is positively biased, making it invalid and increasing the risk of error; a correction must apply to the degrees of freedom (df). A valid critical F value should obtain. The modifications made to combat the violation of the sphericity assumption on the estimated lower bound, the Greenhouse-Geisser correction and the Huynh-Feldt correction. This correction depends on the sphericity estimate.

In the process of estimating Sphericity (ε), the extent to which roundness is present, or not, is represented by a statistic called epsilon (ε). Epsilon 1 (i.e., = 1) indicates that the sphericity condition met precisely. The more epsilon decreases below 1 (i.e., < 1), the greater the roundness violation—the degrees of freedom used in calculating the F-statistics in the repeated measurement ANOVA.

A comparison of hydrochemical data was carried out based on the time of sampling at the exact location in the northern, central, and southern parts of the slopes of Mount Merapi. For every five samples, sample measurements taking at different time intervals, namely on January 18, February 5, and August 27, 2018.

RESULTS AND DISCUSSION

Hydrochemical data variables compare to test how big the significant difference was in different measurement results. The test uses the repeated measures method to try the magnitude of the change in hydrochemical values within one month from January 18, shown in table 1 and figure 1, to February 5, shown in table 2 and figure 2, and six months from February 5 to August 27 shown in table 3 and figure 3. The measurement variables divide into three hydrochemical variables three times. If there is a change from the initial time, one month and six months, it assumes that it occurs due to lithological factors that affect hydrochemical values.

TABLE 1. Groundwater samples taken on January 18, 2018, show the physical and chemical properties of groundwater.

Data taken	No.	hydro physics				hydrochemistry (meq/L)						
		pH	ºC	DHL ($^{\mu S}/_{cm}$)	TDS ($^{mg}/_{L}$)	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
18 Jan	372	7.3	25	264	132	0.205	1.217	1.640	0.324	0.690	1.500	1.271
	373	6.8	26	270	135	0.308	1.348	1.240	1.053	0.254	2.100	2.313
	375	7.0	28	392	196	0.692	1.739	1.960	1.174	0.775	2.200	1.271
	374	7.2	28	227	114	0.282	1.043	1.040	0.688	0.223	1.800	0.583
	371	7.2	25	262	131	0.179	1.130	1.280	0.688	0.394	1.600	1.604

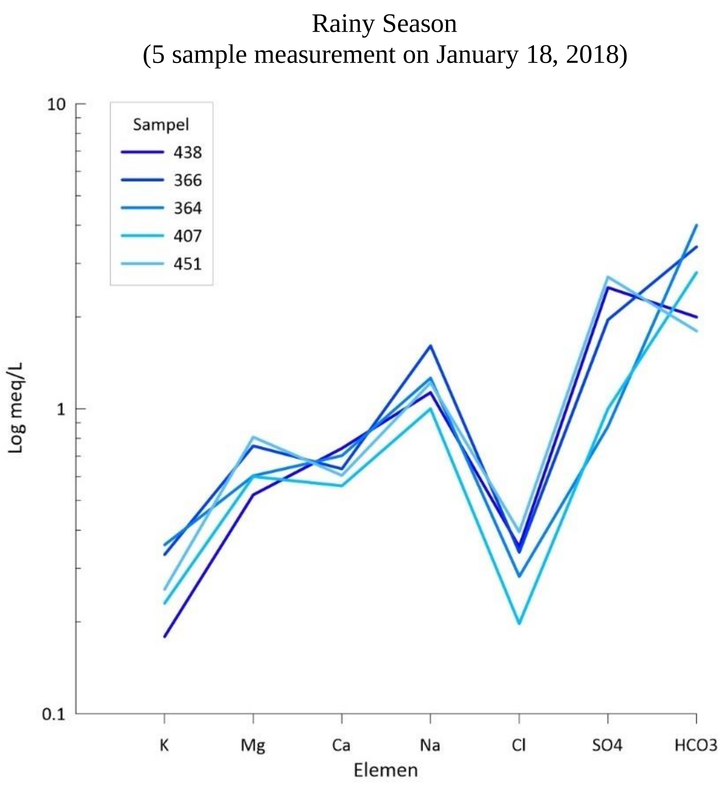

FIGURE 1. The results of the Schoeller diagram plot for the rainy season sample (January 18, 2018) show the higher concentrations of SO_4^{2-} and HCO_3^-, while the concentration of K^+ and Cl^- are the lowest.

TABLE 2. Groundwater samples taken on February 05, 2018, show the physical and chemical properties of groundwater.

Data taken	No.	hydro physics				hydrochemistry (meq/L)						
		pH	°C	DHL ($^{\mu S}/_{cm}$)	TDS ($^{mg}/_{L}$)	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
05 Feb	451	7.3	24	264	132	0.256	1.218	0.605	0.808	0.395	1.799	2.707
	407	6.9	27	226	112	0.230	1.000	0.559	0.600	0.197	2.799	0.999
	364	6.6	27	284	142	0.358	1.261	0.702	0.603	0.282	3.999	0.874
	366	7.0	28	251	121	0.332	1.609	0.635	0.756	0.338	3.399	1.957
	438	7.6	25	264	132	0.179	1.131	0.742	0.522	0.353	1.999	2.498

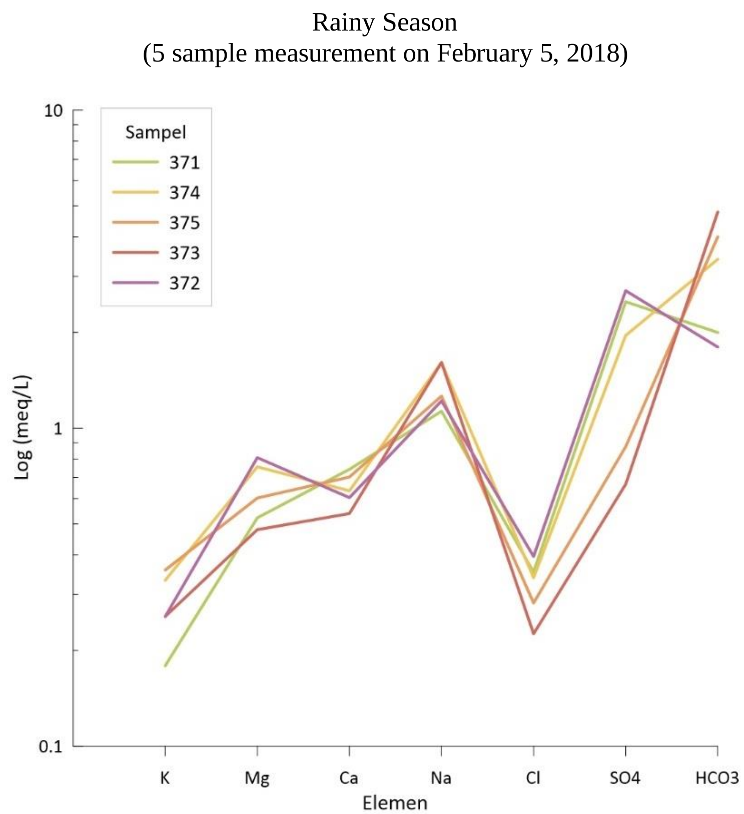

FIGURE 2. The results of the Schoeller plot diagram for the rainy season sample (February 5, 2018) show the higher concentrations of SO_4^{2-} and HCO_3^-, while the concentration of K^+ and Cl^- are the lowest.

TABLE 3. Groundwater samples taken on August 27, 2018, show the physical and chemical properties of groundwater.

Data taken	No.	hydro physics				hydrochemistry (meq/L)						
		pH	ºC	DHL ($^{\mu S}/_{cm}$)	TDS ($^{mg}/_{L}$)	K^+	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
27 Agt	871	6.8	26	202	115	0.179	1.522	0.599	0.959	0.113	5.998	0.541
	872	6.5	28	224	112	0.256	1.609	0.539	0.480	0.226	4.786	0.666
	875	6.9	27	270	135	0.358	2.436	0.719	0.879	0.268	7.998	0.458
	870	6.8	25	224	112	0.128	1.000	0.499	0.440	0.113	3.999	0.375
	874	7.2	26	184	92	0.153	1.218	0.579	0.720	0.127	4.799	0.625

Dry Season
(5 sample measurement on August 27, 2018)

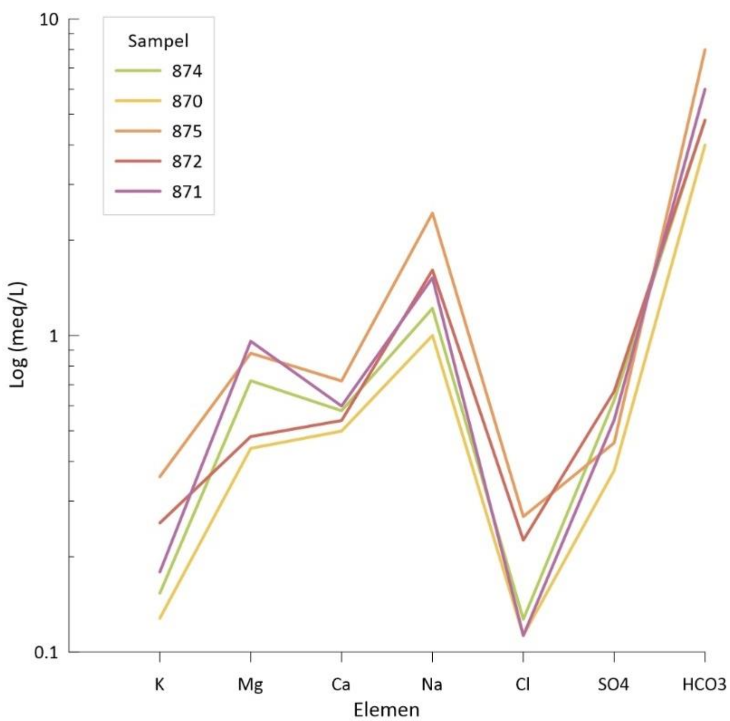

FIGURE 3. The results of the Schoeller diagram plot for the dry season sample (August 27, 2018) show that the concentration of HCO_3^- is very high, while the concentration of Cl^- is deficient.

Hydrochemical Mauchly Test

The Mauchly sphericity test determines that the variance of the differences between all combinations of the tested levels are the same. The test criteria base on probability numbers (Sig.: significance). If the probability number is above 0.05, Ho is accepted, and if the probability number is below 0.05, Ho rejects.

Mauchly's test in Ho for the variance of the differences among all combinations of tested levels is the same, and Hi, the variance of differences among all varieties of tested levels is unequal. In the significance column, the number 0.000 find is far below 0.05, so Ho is rejected, and Hi is accepted, which means that the variance between all combinations of levels tested is not the same. The results of the Mauchly sphericity test are to determine the difference between all variance combinations shown in table 4.

TABLE 4. The results of the Mauchly sphericity test are to determine the difference between all variance combinations.

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon [b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
time	0.486	23.790	2	0.000	0.661	0.677	0.500

b. Can be used to adjust the degrees of freedom for significance tests. Corrected tests calculate in the Test of Within Subjects Effects table.

Hydrochemical Greenhouse-Geisser Test

Hypothesis testing on the Greenhouse-Geisser measurement aims to determine whether or not there is a difference in the average decrease in hydrochemical elements in the three groups of measuring time intervals. The Greenhouse-Geisser figures show no significant reduction in the value of hydrochemical features over time, so it can conclude that lithology does not have a considerable influence factor to change the elements in the research area.

The hypothesis test on the Greenhouse-Geisser measurement is Ho for there is no difference in the average decrease in hydrochemical elements in the three measurement time interval groups, and Hi for there is a difference in the average reduction in hydrochemical elements in the three measurement time interval groups.

Based on the Greenhouse-Geisser number in the significance column, the number is 0.410, far above 0.05. This number means that Ho is accepted, or there is no significant decrease in the value of hydrochemical elements from time to time, so it can conclude that lithology does not have a considerable influence factor to change the hydrochemical aspects in the research area. Test of Within Subjects Effects for differences in the reduction of hydrochemical elements shown in table 5.

TABLE 5. Test of Within Subjects Effects for differences in the reduction of hydrochemical elements.

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	1.263	2	0.631	0.797	0.455
	Greenhouse-Geisser	1.263	1.321	0.956	0.797	0.410
	Huynh-Feldt	1.263	1.354	0.933	0.797	0.412
	Lower-bound	1.263	1.000	1.263	0.797	0.378
Error (time)	Sphericity Assumed	53.889	68	0.792		
	Greenhouse-Geisser	53.889	44.924	1.200		
	Huynh-Feldt	53.889	46.034	1.171		
	Lower-bound	53.889	34.000	1.585		

Changes in the interval value on the hydrochemical element can be shown in paired calculations (comparison of pairs) to determine the change in value in the gap of hydrochemical values. The analysis of pairwise comparisons indicates that there is no difference between time one and time two. The difference in the average element value change of 0.026 meq/L at time 1 (initial data) and 2 (data after one month) is insignificant. The difference in hydrochemical values that occur does not indicate the influence of lithological factors. All figures at times one (1) and three (3) show no significant difference when groundwater values deposit on lithology from a month (number 2) and six months (number 3).

Pairwise Comparison Test

At (i) time is one (1) and (j) time is two (2), or it is known that the difference in the average change in hydrochemical element values between time 1 (initial data January 18) to time 2 (data February 5) is 0.026 meq/L with an error standard 0.125 meq/L. A significant 1.0 above 0.005 indicates no difference between time one (1) and two (2). The difference in the average element value change is 0.026 meq/L that occurs at time 1 (initial hydrochemical data), and time 2 (data after one month) was not significant. The difference in hydrochemical values that occur does not indicate the influence of lithological factors. All figures at time one (1) and at time three (3) show a significance value of 0.984, indicating no significant difference when groundwater values deposit on lithology from a month (number 2) and six months (number 3). Pairwise comparisons to determine changes in the hydrochemical value interval shows in table 6.

TABLE 6. Pairwise comparisons (comparison in pairs) to determine changes in the value of the hydrochemical value interval.

(i) time	(j) time	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	0.026	0.125	1.000	-0.290	0.341
	3	-0.219	0.220	0.984	-0.774	0.336
2	1	-0.026	0.125	1.000	-0.341	0.290
	3	-0.244	0.268	1.000	-0.918	0.429
3	1	0.219	0.220	0.984	-0.336	0.774
	2	0.244	0.268	1.000	-0.429	0.918

a. Adjustment for multiple comparisons: Bonferroni.

The average value estimation plot in the margin on the influence of lithological factors shows that the sharpness of the increase in the line indicates the significant increase in the element's value. A sharp increase occurred from time to time 2 to time 3, and this shows that the lithology is ineffective in influencing groundwater within a month. Still, it begins to be effective after six months, and the plot of the average marginal estimation shows in figure 4.

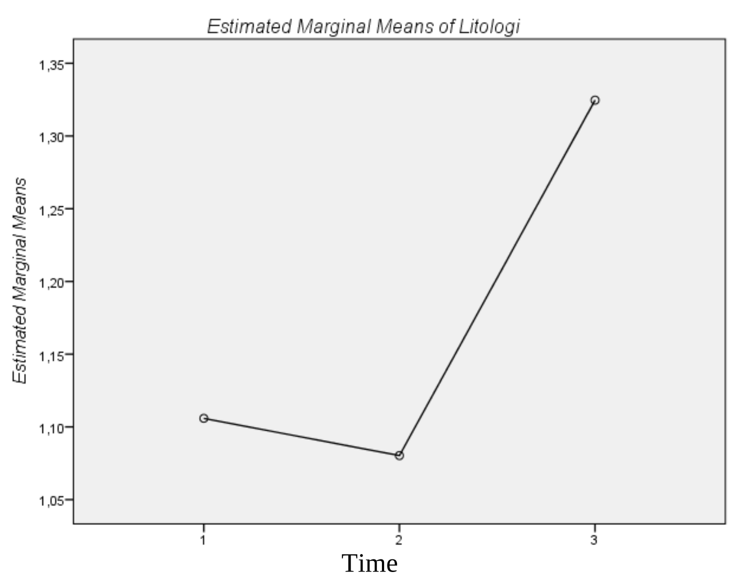

FIGURE 4. The plot of the average marginal estimation of lithological factors in influencing changes in the value of elements.

CONCLUSIONS

The physical and chemical concentrations of groundwater are very suitable to be used as parameters for quantitative changes in groundwater quality conditions. ANOVA statistics carry out using the Mauchly test, Greenhouse-Geisser Test, and Pairwise Comparison Test methods. The results of the ANOVA analysis show that the chemical concentration of groundwater changes over time. The longer the time, the more changes occur. The period of change in the concentration value for 30 days is very significant compared to a distance of 180 days. These changes cause by dissolving the minerals contained in the rock in the aquifer layer.

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