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The Effect of Geological Conditions on Groundwater Quality Characteristics in Kalipancur Village, Bojong Subdistrict, Pekalongan Regency, Central Java

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Abstract. Kalipancur Village in Pekalongan Regency has two springs that continue to flow every year and are used for daily needs. Residents have wells with an abundant amount of water but prefer to use the spring. This research aims to conduct hydrogeological mapping to know the hydrogeological conditions, including flow patterns and groundwater quality. It also wants to determine the influence of geology on groundwater conditions. The research method used is a geological survey to obtain data on morphology, lithology, geological structure, and physical/chemical data of groundwater such as temperature, pH, Total Dissolved Solids (TDS), and Electrical Conductivity (EC). The tools used are geological field equipment (GPS, hammer, compass, loupe) and hydrogeological equipment, including pH meters, TDS meters, and EC meters. The results showed that the study area was composed of Damar and Alluvium Formation rocks. Lithology and structure (joints and faults) are thought to affect the emergence of springs. The flow pattern that develops is relatively spread from south to north. Groundwater quality shows temperature 26-29ºC, pH 4.5-7, TDS 60-167 ppm, and EC 122-344 µS/cm. Groundwater in alluvial plains generally has a higher TDS than groundwater in springs located on hillsides in the Damar Formation. The flow pattern that develops is relatively spread from south to north. Groundwater quality shows temperature 26-29ºC, pH 4.5-7, TDS 60-167 ppm, and EC 122-344 µS/cm. Groundwater in alluvial plains generally has a higher TDS than groundwater in springs located on hillsides in the Damar Formation. The flow pattern that develops is relatively spread from south to north. Groundwater quality shows temperature 26-29ºC, pH 4.5-7, TDS 60-167 ppm, and EC 122-344 µS/cm. Groundwater in alluvial plains generally has a higher TDS than groundwater in springs located on hillsides in the Damar Formation.

Keywords: groundwater, geology, quality, spring, Kalipancur.

INTRODUCTION

Water is one of the most critical natural resources and necessities of life and an essential element for all life on earth. Without water, various life processes for both animals, plants, and humans will not be able to take place (Hendrayana, 2004 in [1]. The utilization of water resources from year to year is increasing, directly proportional to the increase in population. On the other hand, the availability of groundwater should meet the feasibility of good quality for health. Water quality is essential in addition to quantity. Therefore, water quality is also essential to evaluate daily life [2].

The research area is located in Kalipancur Village, Bojong Subdistrict, Pekalongan Regency has two springs as water sources [3] which continue to flow every year. The spring is used by residents for their daily needs, especially for consumption. Residents have wells with abundant water, but they prefer to use springs to meet their daily needs.

The amount of dissolved elements in the groundwater is also determined by the geological and hydrogeological conditions of the local area [4,5]. The mineralogy composition affects groundwater quality. Besides that, the chemical composition of rocks also needs to be studied related to groundwater quality [6]. Some of these things encourage research in the Kalipancur area by looking for hydrogeological data. Preliminary hydrogeological studies in the research area are needed to understand the spring emergence factors and the feasibility of shallow groundwater quality.

This research is intended as a surface hydrogeological survey with qualitative and quantitative methods. The research objective is to determine the study area's hydrogeological conditions, flow patterns, and groundwater quality.

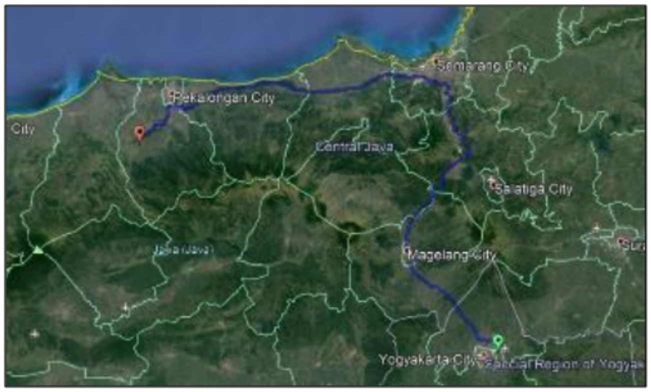


FIGURE 1. Research area in Pekalongan Regency [7].

The research area is administratively located in Kalipancur Village, Bojong Subdistrict, Pekalongan Regency, Central Java Province (Figure 1). Geographically, this area is located at coordinates 6°59'28.00" South Latitude and 109°33'38.00" East Longitude, and 6°59'48.00" South Latitude and 109°33'59.00" East Longitude with an area of ± 403 m². The distance from Yogyakarta to the research area is ± 230 km with a travel time of ± 5 hours, crossing the national road via the Yogyakarta – Magelang – Semarang – Kendal – Batang – Pekalongan route. The research area can be reached from Yogyakarta by using a motorized vehicle.

GEOLOGY OF THE RESEARCH AREA

Physiography

Physiographically, the research area is included in the North Serayu Zone and the North Alluvial Plain of Java [8]. The research area is located in the northern part of the Regional Geological Map of Banjarnegara-Pekalongan Sheet [9]. Physiographically, this area is included in the North Serayu Zone and the North Alluvial Plain of Java.

Stratigraphy

The study area comprises the Damar Formation rock, composed of tuffaceous claystone, sandstone, tuff, breccia, conglomerate, and lahar deposits [9]. Volcanic breccia and tuff are composed of andesite, whereas conglomerates are basal, locally compacted. Sandstone consists of feldspar and mafic mineral grains. These rocks are of the Early Pleistocene age with a non-marine depositional environment. The Damar Formation overlaps conformably above the Kalibiuk Formation.

Geological Structure

The tectonics of the study area in the Early Tertiary period is characterized by uplift and erosion. This erosion formed the sediment of the Rambatan Formation, which was followed by the deposition of the Halang Formation in deep marine and then the Damar Formation deposition in the transitional to the bathyal environment. Plio-Pleistocene tectonic activity reactivated Early Tertiary tectonic results. It formed unequal folds followed by upturning faults with a relatively east direction, normal faults, and shear faults trending northwest-southeast and northeast-southwest. The existing fractures become weak areas where Young Quaternary volcanic rocks emerge to the surface [9].

METHOD

This research was conducted using a surface geological survey method with a quantitative and qualitative approach. The quantitative method looks for hydrogeological data in the field in numbers from Total Dissolved Solid (TDS), Electrical Conductivity (EC), pH, and groundwater temperature. Qualitative methods are carried out by taking morphological, lithological, and geological structure data.

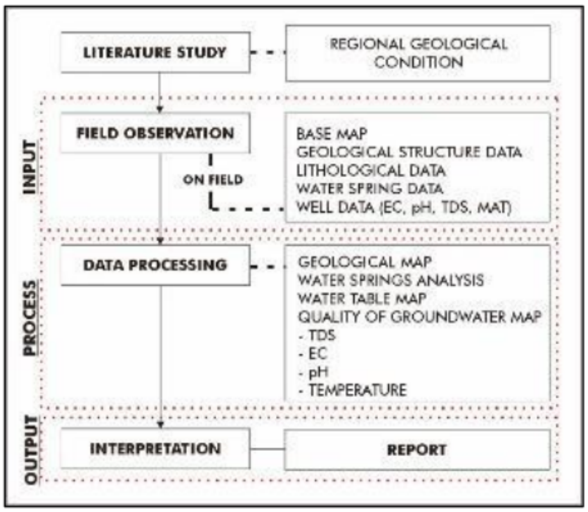


FIGURE 2. Flowchart of research implementation

This research was conducted in several stages. The first stage is a literature study to obtain geological information on the research area, such as lithology, geological structure, and regional information related to groundwater conditions. The second stage is making a base map/topography of the research area. The third stage is field observation, geological data collection, and water quality measurement in 16 dug wells and two springs. The next step is data processing using Arc GIS 10.5 software and Surfer 15 software. The last stage is data interpretation to achieve research objectives.

RESULTS AND DISCUSSION

The research area shows two geomorphological relief units. Rocks exposed in the study area include the Damar formation and Alluvial deposits. Some structural lineaments may be found as morphological or structural ones.

Geomorphology

The division of geomorphological units is based on two aspects, namely morphometry [10] and morphogenesis [11]. Based on the morphometric data obtained, the researchers divided the geomorphological units as follows.

FIGURE 3. (a) Fluvial Undulating - Rolling Unit (F8); (b) Structural Hilly Unit (S6)

1. Fluvial Undulating - Rolling Geomorphological Unit (F8)

This unit has a slope value of 13% and a height difference of 10 meters. This geomorphological unit is composed of lithology in the form of Quaternary deposits. The flow pattern develops in parallel. This geomorphological unit is used for rice fields and settlements.

2. Structural Hilly Geomorphological Unit (S6)

This unit has a slope value of 34% and a height difference of 80 meters. The flow pattern that develops in this unit is parallel. This geomorphological unit is composed of claystone, sandstone, conglomerate, breccia, and tuff. This geomorphological unit is used as plantation and residential land.

Stratigraphy

The stratigraphy of the research area was referred to the regional geological map of the Banjarnegara-Pekalongan Sheet [9]. The rocks in this area are included in the Damar Formation (QTd) and Alluvium (Qa). Based on the mapping results, the study area consists of (in order from old to young) Damar sandstone units, Damar breccia units, and alluvial deposits (Table 1).

Geological Structure

The geological structure found in the research area can be interpreted based on the study of DEMNAS maps, regional geological maps, topographic maps, and detailed mapping data. The lineament pattern that develops in the study area is dominantly trending southwest-northeast (Figure 4).

Based on the analysis of the straightness of the hills and valleys/rivers in the DEMNAS image, it is known that the lineaments in the study area are dominant in the southwest-northeast direction. The straightness pattern is obtained by drawing straight lines using Global Mapper 20 software.

In the research area, there are many joint structures formed as a result of tectonic forces. Shear fractures dominate joints in the study area. From the measurement of the joint data, it is known that the general direction of the joint is relatively west-east at location 1 (Figure 5a), and the joint is relatively southwest-northeast at location 2 (Figure 5b), close to the appearance of the spring.

TABLE 1. Stratigraphic Column of Study Area

AGE		FORMATION Condon *et al* (1996)	STRATIGRAPHY OF OBSERVATION AREA			
PERIOD	ERA		THICKNESS (Meter)	LITHOLOGIC COLUMN	SEDIMENTARY STRUCTURE	LITHOLOGIC UNIT
QUATERNARY	HOLOCENE	Aluvium	± 10			Alluvium
	…OCENE		± 40.75			Damar Breccia

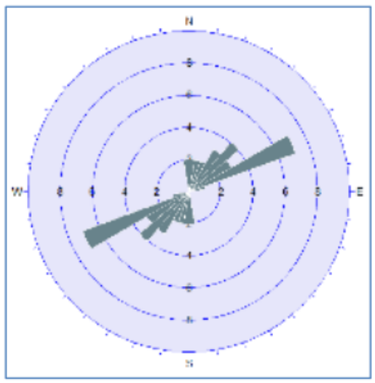


FIGURE 4. Rosette diagram of the lineament pattern in the study area shows the dominant direction southwest-northeast.

FIGURE 5. (a) Appearance of shear fractures at location 1. (b) Appearance of shear fractures at location 2 near the spring.

The research area interprets that there is a rising fault formed due to tectonic forces. This rising fault is estimated from the geomorphological formation of the cuesta. The indication of a horizontal fault is estimated from lineament analysis on DEMNAS images and topographic maps and is supported by the intensive joint in the study area. Lineament identification from the DEMNAS image shows a continuous pattern in the southwest-northeast with the direction of N197ºE. Lineament identification from the DEMNAS image shows a continuous pattern with a southeast-northwest direction with an N157ºE direction that extends in Kalipancur Village. Based on image interpretation and topographic maps, it is known that there is an offset that is relatively moving to the right.

Groundwater Flow Pattern

The existence of dug wells in the research area is used as supporting data in this study. Several data can be obtained from dug wells, including the study area's location elevation and groundwater level.

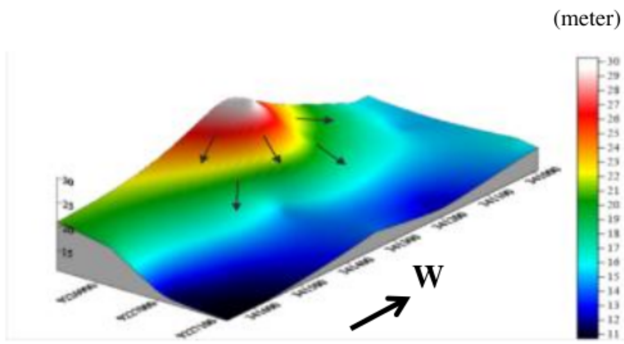


FIGURE 6. Three-dimensional modeling of the distribution of the groundwater table using Surfer 15 software.

The groundwater distribution map in the study area shows that groundwater generally flows from the south to the north. This groundwater flow pattern tends to be radial in various directions. Larger contour values are believed to be groundwater recharge areas.

Spring Appearance

There are two springs with discharges ranging from 20-50 L/sec [3]. One of the springs is located at coordinates UTM 341157 and 9226668 (Figure 8b). The spring found in the study area has a perennial flow characteristic flowing throughout the year. Even though the water is never dry in the dry season, there is only a difference in discharge.

The emergence of springs in the study area may be influenced by two factors: lithological and geological fault structures. Lithology that has potential as an aquifer is Damar andesite breccia supported by fracture porosity.

FIGURE 7. The appearance of springs in the study area.

Groundwater Quality

Groundwater quality data was obtained by taking random samples and representing the research area. The data were obtained from 16 dug wells (Table 2) and two spring samples (Table 3) in Kalipancur Desa Village.

TABLE 2. Hydrogeological measurement data in dug wells in the study area.

No.	Coordinate UTM		Elevation (m)	Water Table (m)	Depth (m)	TDS (ppm)	EC (μS/cm)	pH	Temperature (°C)
	X	Y							
1	341435	9227045	13.75	13/45	9.5	93	186	6	27
2	341475	9226959	17	16.64	3.39	86	172	5.5	29
3	341365	9226977	16.25	14.92	2.85	80	160	5.5	28
4	341539	9227033	13	12.25	9.45	75	150	5.4	28
5	341655	9226920	26	18.7	10.3	99	198	5.6	28
6	341641	9227008	12.5	11.55	5.65	88	176	4.5	28
7	314043	9226921	16	15.13	8	127	254	5.4	26
8	341090	9226879	18.75	17.9	4.55	120	240	6	27
9	340990	9227078	17	16.1	7.3	137	272	6	26
10	341022	9226830	16.5	15.8	6.6	140	280	5.5	27
11	341338	9226872	28.75	26.93	4.12	167	334	5.5	27
12	341287	9226870	32	30.5	6.2	60	122	5.5	26
13	341225	9226899	24	21.7	6.9	145	280	5.6	27
14	341338	9227114	15	14.3	3.7	170	340	6.3	29
15	341282	9227036	15	14.55	6.25	166	334	5.5	28
16	341196	9227082	13	12.45	8.2	166	332	7	28

TABLE 3. Groundwater quality of springs water in the study area.

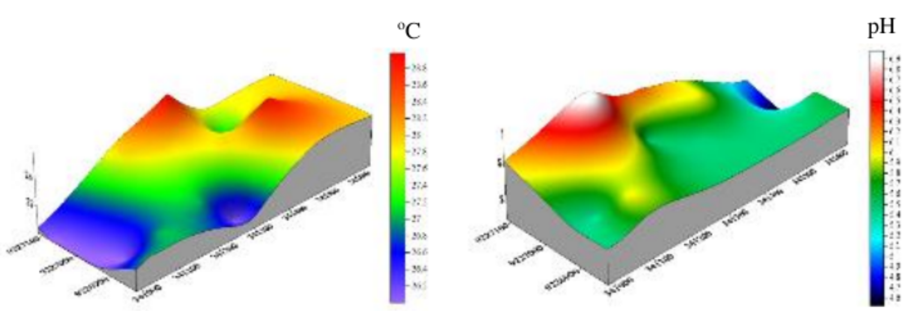
Data	Coordinate UTM		TDS (ppm)	EC (μS/cm)	pH	Temperature (°C)
	X	Y				
Spring - 1	341157	9226668	56	107	6.5	27
Spring - 2	341426	9226820	79	164	7	27

Groundwater quality includes temperature, pH, TDS, and EC. Groundwater temperature in the study area (Figure 8a) ranges from 26-29°C and is considered suitable for consumption. The pH value of groundwater in the study area (Figure 8b) ranges from 4.5-7. According to Health Ministry Regulation [12] No. 492 of 2010, the limit for the suitability of water for consumption is between 6.5-8.5. The TDS of groundwater is in the range of 60-167 ppm (Figure 8c), indicating that the water is fresh and safe for consumption because it does not exceed the maximum level of contaminants in drinking water of 500 mg/L. The EC groundwater value ranges from 122-340 μS/cm (Figure 8d), which means freshwater [13] and is a typical value in groundwater [14].

The overall data obtained is a graph that shows the relationship between groundwater quality parameters. The following is the relationship between the TDS value and the EC value, pH, and temperature with the depth of the well.

The data graph (Figure 9a) shows a trend that is the same or directly proportional to the EC value. The TDS assessment reads solid, organic, and inorganic, while the EC value indicates the content of ions in organic or inorganic materials. The TDS value itself can be influenced naturally or chemically. Meanwhile, shallow groundwater temperature is not related to groundwater table depth (Figure 9b).

This data acquisition was carried out under one particular condition, namely in a situation where there was not much additional water supply in the research area. Data collection is during the dry season in September, and it is possible to change the value if it is carried out in the rainy season. In the rainy season, rainwater with different TDS, EC, pH, and temperature values will be mixed with shallow groundwater. Rainwater infiltration will trigger dissolution and form a water balance.



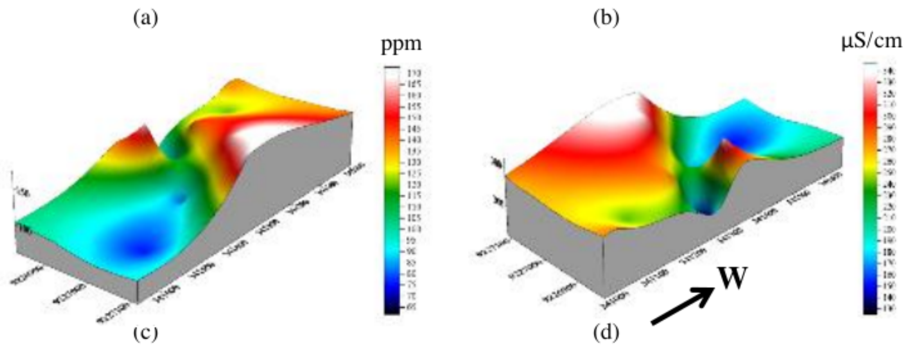


FIGURE 8. Three-dimensional distribution modeling (a) temperature; (b) pH; (c) TDS (Total Dissolved Solids); (d) EC groundwater using Surfer 15 software.

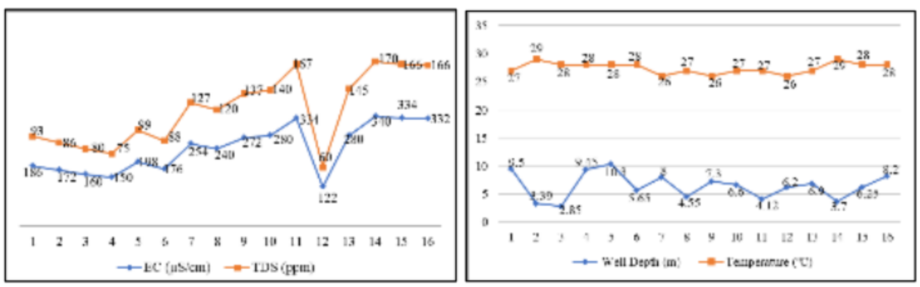


FIGURE 9. (a) The graph of the relationship between EC and shallow groundwater TDS; (b) Graph comparing temperature values with shallow groundwater depths in the study area.

Geological Control of Groundwater Quality

Groundwater quality in the study area shows differences in TDS and EC values at dug wells and spring locations. Both TDS and EC values are interrelated. They dug wells show TDS values of 100-170 ppm and EC 190-340 μS/cm). Meanwhile, spring has groundwater with a TDS value of 56-79 and EC 107-164 μS/cm. The TDS value is influenced by the material that makes up the rock and soil layers, while the EC value comes from the content of ions contained in organic and inorganic materials in the soil.

Hydrochemical conditions in water bodies, both surface water and groundwater are strongly influenced by the weathering of a rock [15,16]. Soil weathered in Damar breccia and alluvial deposits have the potential to affect groundwater quality due to the entry of major ions into groundwater flow systems.

The research location is composed of two formations, namely the Damar Formation and Alluvium. The location of the dug well is in Alluvium, which consists of alluvial deposits and is located at the foot of the hill, which allows groundwater to accumulate from higher areas, which results in higher TDS and EC values. Meanwhile, the spring is in the Damar Formation, located on the hillside, a catchment area so that the groundwater contained is minimally contaminated. Groundwater sources in springs may be more profound than groundwater in dug wells, so the TDS value in springs tends to be lower than groundwater TDS in dug wells.

CONCLUSION

Hydrogeological research based on direct observation in the field has been carried out during dry season conditions in the Kalipancur Village area. The results of the study resulted in the following conclusions.

1. The shallow groundwater surface in the study area shows groundwater flow from south to north. In the south, the groundwater level is higher than in the north, along with the ground surface elevation. The highlands in the south are believed to be groundwater recharge areas. This groundwater flow pattern is somewhat diffuse (radial).
2. Groundwater quality
   a) Based on standard regulation, the overall shallow groundwater temperature can be consumed because it has a temperature value of 26-29°C.
   b) The pH of groundwater in the study area is 4.5 – 7, which means it is acidic to neutral. Only one well is suitable for consumption, namely well 16, while all springs are suitable for consumption because they have a pH value of 6.5-7.
   c) The TDS value of groundwater in dug wells ranges from 60-167 ppm; the EC value ranges from 122-344 μS/cm. Meanwhile, groundwater in spring shows TDS in the range of 56-79 ppm and EC in 107-164 μS/cm. Based on the TDS value, groundwater in this area is suitable for consumption.
3. The research area found outcrops of sandstone, tuff, conglomerate, and breccia. There are two springs in the research area. The emergence of this spring is influenced by two factors, such as lithological and geological structures factors. Lithological factors influence groundwater quality in dug and spring wells.

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