SIM-Groundwater in Bener area, its quality and contribution for agriculture

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Groundwater in Bener area, its quality and contribution for agriculture

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Abstract. The existence of surface water is not always sufficient for the needs of the community, also for agricultural needs. Therefore, groundwater can be an alternative water supply in the irrigation system, so it is necessary to assess its quality. Groundwater quality is the result of the interaction of material (soil/rock), the type of flow/transport and the change processes. The results of these components produce different groundwater quality in each region. To assess the groundwater quality in Bener and its surrounding areas, this research was carried out by direct survey in the field and testing the physical/chemical properties of groundwater in the laboratory. Groundwater sampling was carried out at 6 dug wells and 2 springs. The analysis shows that all samples are bicarbonate groundwater types, with variations of Na^{+}, Ca^{2+} and Mg^{2+} dominant cations. Groundwater quality shows a pH value of 6.2 - 6.7, TDS of 45 - 306 ppm, hardness of 39.73 - 200.43 ppm, SAR (Sodium Adsorption Ratio) of 12.12 - 76.64, Na% of 19.81 - 62.11, and RSC (Residual Sodium Carbonate) of 0.04 - 1.35. According to its quality, groundwater can be used to support irrigation for agriculture in the area.

Keywords: groundwater, quality, irrigation, agriculture

1. Introduction

Several places in Yogyakarta and its surroundings area have each groundwater quality problems. This area is included in the non-groundwater basin of West Progo Hills, especially in the Kepil sheet topographic map [1]. This area is a water scarce area, but we can still obtain groundwater and become an alternative water resource besides surface water.

The need of water for the community can be obtained from surface water and groundwater. Surface water can be obtained from rivers, lakes, swamps or the sea. Nowadays, surface water is sometimes polluted so that groundwater is a better alternative become the needs of life for water [2]. In particular, the potential for groundwater in an area also needs to be studied so that we can provide water in sufficient quantities and of good quality, among others for irrigation to support agricultural needs. Several previous researchers were concerned about water quality which discussed the water quality index [3,4]. Meanwhile, the others specifically discussed water quality for irrigation or agriculture [5-8].

The potential of groundwater in an area can be assessed using the hydrochemical method [9-11]. Hydrochemical methods help in understanding the hydrogeology of an area. By knowing the chemical types of groundwater, we can carry out various analysis, interpretations and correlations of the chemical components of groundwater. This research is intended as a field geological survey which aims to determine the physical/chemical characteristics of groundwater in the study area, and to see its suitability as a useful water resource for local irrigation. Researchers also want to see the geological characteristics of the aquifer system as well as rock control of groundwater quality in the study area, so that understanding of groundwater quality that has the potential to support agriculture can be well understood.

2. Materials and Methods

2.1. Regional conditions of research area

This groundwater study was carried out in the Bener area and its surroundings, including in the Purworejo Regency area (Figure 1). Physiographically, the research area is included in the West Progo Dome Zone. This area is part of the physiography of the South Serayu Zone [12]. The West Progo Hills complex in the north is bounded by the lowlands of Kedu (Magelang) which are the deposits of Mt. Merapi and Mt. Sumbing. The eastern part of this zone is bordered by the Progo River valley with the Yogyakarta plains extending southward to the South Coast; the southern part is bordered by the alluvial plain and the western part is bordered by the vast alluvial plain of Bagelen. The West Progo Hills are in the form of turning to the northwest and are connected to the South Serayu Mountains.

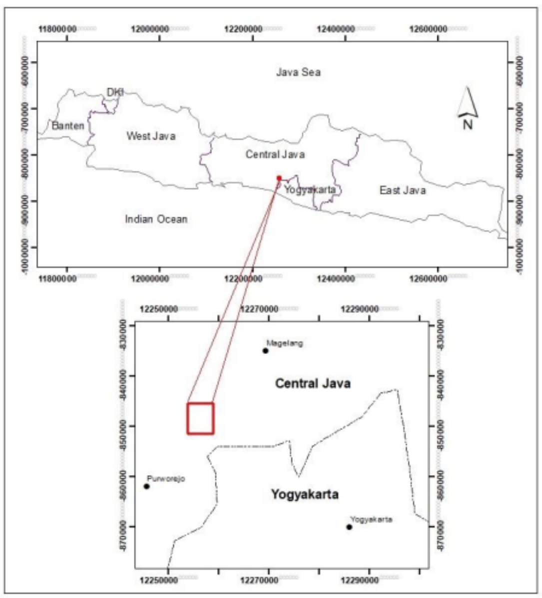

Figure 1. The research area is located in Bener and its surroundings, Purworejo Regency.

The results of previous researchers [12-14] concluded that the regional stratigraphy of the West Progo Hills from the oldest to the young is composed of the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations and alluvial deposits. The rocks exposed in the study area are generally include in the Old Andesite Formation and alluvial deposits. The other experts have discussed water issues in the West Progo area and its surroundings, including those related to landscapes [15].

Physiographically, the research area is included in the northern Menoreh Hill. The steep slope of these hills causes rainwater that is received by the ground surface to quickly collect in river channels and flow downstream. In this condition, the rainwater does not have enough time to infiltrate the soil.

In addition, the research area is dominated by materials in the form of andesite breccias, tuffs, lapilli tuffs, agglomerates, and impermeable andesite with intercalation of lava flow. As a result, the material is not able to store and then water flows so that the groundwater and surface water reserves in this area are in poor quantity. However, some springs and wells can still be found and can be used for everyday purposes. The existence of groundwater is supported by aquifers which have many rock cracks. The surface water is supported by several small tributaries which are the initial order of the development of the Bogowonto River.

2.2. Methods

Groundwater quality is very dependent on the hydrogeological system in which groundwater flows. The ion content of groundwater is influenced by aquifer-forming rocks, the depositional environment of aquifer-forming rocks, the length of the groundwater's pathway, the processes experienced by groundwater while flowing from the infiltration site, the depth of the aquifer, and the presence of contamination by salt water [16]. Groundwater quality is determined by various physical and chemical properties of groundwater. Several physical and chemical parameters of groundwater can be known in the field and laboratory tests. Several chemical parameters of groundwater can be studied to determine the chemical type of groundwater, including its physical and chemical properties. The chemical properties that are often used in the analysis of groundwater quality include hardness, total dissolved solids (TDS), electrical conductance (EC), acidity (pH) and ion content. Besides these parameters, the water quality for irrigation purposes also assessed from some addition parameters, such as Na%, SAR (Sodium Adsorption Ratio) and RSC (Residual Sodium Carbonate).

The geological field survey begins with finding the location of springs and dug wells, then conducting geological observations around them. Description of rock, geomorphology, and geological structures is carried out to understand the potential of groundwater aquifers. In addition, a hydrogeological description is also carried out on the quality of groundwater in the field, including color, taste, smell, and measurements of temperature, pH, TDS and EC. The equipment used includes standard geological equipment (hammer, compass, GPS) and hydrogeological equipment (pH-meter, TDS-meter, EC-meter). A field hydrogeological survey was carried out and simultaneously groundwater samples were taken. Eight samples have been taken, from six from dug wells and two from springs, to be further tested for their physical/chemical properties in the laboratory.

2.3. Data Analysis

Laboratory test results are used to determine the water quality index (WQI) of groundwater. WQI is calculated to see the capacity of groundwater in its designation as irrigation water, with reference to the PP RI 82/2001 standard [17]. This regulation classifies water quality into 4 classes, where irrigation water can be included in classes 2 - 4 according to the required quality criteria. The formula used refers to the WQI value (Brown *et al*, 1972 in [3]) as follows.

$$\mathrm{WQI} = \sum \mathrm{SI} \quad (1)$$

$$\mathrm{SI} = \mathrm{W_i} \times \mathrm{q_i} \quad (2)$$

$$\mathrm{W_i} = \frac{\mathrm{wi}}{\sum \mathrm{wi}} \quad (3)$$

$$\mathrm{q_i} = \frac{\mathrm{ci}}{\mathrm{si}} \times 100 \quad (4)$$

where c_i is concentration of groundwater parameter; si is the standard value of groundwater parameter; w_i weight and W_i is relative weight. The w_i value is determined by refer to previous expert [3].

The results of the physical / chemical test of water from the laboratory were then analyzed to obtain several parameters, including hardness (Sawyer & McCarty, 1967 in [2]), Na% [4], SAR [18] and RSC [6]. The formula used to calculate these parameters is as follows.

$$\mathrm{Hardness} = 2.5\,\mathrm{Ca} + 4.1\,\mathrm{Mg} \quad (5)$$

$$SAR = \frac{Na}{\sqrt{\frac{(Ca+Mg)}{2}}} \quad (6)$$

$$Na\,\% = \frac{(Na^{+} + K^{+}) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad (7)$$

$$RSC = (CO_3^{-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad (8)$$

3. Results and Discussion

3.1. Data Field

Groundwater conditions in the study area are supported by aquifers in the form of sandstones, andesite breccias, and agglomerates (Figure 2) through the intergranular porosity. Igneous rocks such as andesite are also found and can be aquifers through joints. Groundwater can be obtained from dug wells and spring (Figure 3).

Springs are found in two locations, such as Cacaban Lor and Medono Villages, Bener District. The spring in Cacaban Lor has a relatively small discharge, while in Medono, it has a moderate discharge. These springs appear in volcanic aquifer rocks of the Old Andesite Formation which are supported by fracture porosity. Apart from being supported by agglomerate aquifers, the springs in the Medono area are also supported by loose Quaternary deposits.

Figure 2. Sandstone outcrops (left) found in Pekacangan and agglomerates found in Cacaban Kidul (right), are rocks that can function as groundwater aquifers in Bener area.

3.2. Laboratory Result

Physical/chemical laboratory test results have also been obtained to determine physical properties (temperature, color, smell, taste and turbidity) as well as chemical properties (pH, TDS, and content of major and minor ions). As for the purposes of the irrigation water assessment, only a few parameters need to be examined, including pH, TDS, Zn^{2+} and sulfate. Therefore, these four parameters are calculated to determine the water quality index. In addition, Ca^{2+} and Mg^{2+} contents were also shown to calculate the hardness of groundwater (Sawyer & McCarty, 1967 in [16]; Table 1).

3.3. Discussion

Based on PP RI No. 82/2001 regulation [17], water that can be classified as irrigation water falls into classes 2 - 4. Therefore, the study of irrigation water in this study accommodates the groundwater quality index for these three classes (Table 2).

3.3.1. WQI. The value of the groundwater water quality index in the study area was assessed for the use of class 2 - 3 water standard according to the regulation [17] (Table 2). The summary in the table shows that groundwater has a type of good water for class 2 - 3 and excellent water for class 4 [19].

Thus, groundwater is safe to use as irrigation water, at least based on pH, TDS, Zn^{2+} and nitrate content parameters.

Figure 3. One example of the appearance of a dug well in Medono (left) and a spring in Pekacangan (right), where groundwater can be tapped for daily needs.

Table 1. Some parameters of groundwater for analyzing its quality.

Parameter	W1	W2	W3	W4	W5	W6	S7	S8	Mean	Std. Dev.
pH	6.2	6.3	6.7	6.5	6.5	6.4	6.4	6.6	6.45	0.16
TDS (mg/L)	45	306	205	117	124	75	76	161	138.63	84.80
EC (μS/cm)	70.2	477.36	319.8	182.52	193.44	117	118.56	251.16	216.26	216.26
Zn^{2+} (mg/L)	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.0083	0.083	0
NO_3^- (mg/L)	2.01	1.4	0.31	1.59	3.11	0.84	0.04	0.99	1.29	0.98
Ca^{2+} (mg/L)	10.35	18.31	23.88	26.27	31.84	11.14	18.31	40.6	22.59	22.59
Mg^{2+} (mg/L)	3.38	37.72	28.05	11.6	10.15	6.29	5.8	13.54	14.57	14.57
Hr	39.733	200.427	174.705	113.235	121.215	53.639	69.555	157.014	116.19	116.19

Notes: W = well, S = spring, 1-8 = number of location

Table 2. Statistics of some parameters for determined groundwater quality.

Parameter	Min	Max	Mean	Std. Dev.	Weight	Relative Weight	Class 2			Class 3			Class 4		
					(*wi*)[1]	(W*i*)	si[4]	qi	SI	si[4]	qi	SI	si[4]	qi	SI
pH	6.2	6.7	6.45	0.16	4	0.24	6 - 9	86	20.24	6 - 9	86	20	5 - 9	92	22
TDS	45	306	138.63	84.80	5	0.29	1000	13.86	4.08	1000	13.86	4	2000	6.93	2
Zn^{2+} (mg/L)	0.083	0.083	0.083	0	3	0.18	0.05	166	29.29	0.05	166	29	2	4.15	1
NO_3^- (mg/L)	0.04	3.11	1.2863	0.98	5	0.29	10	12.86	3.78	20	6.43	2	20	6.43	2
Σ					17	1			57.39			55			26
WQI[2]									57.39			55			26
Type of water[3]									Good water			Good water			Excellent water

Notes: [1]Kawo & Karuppannan (2018)
[2]Brown *et al* (1972, in Kawo & Karuppannan, 2018)
[3]Sahu and Sikdar (2008)
[4]PP RI (1982)

3.3.2. SAR. The groundwater sodium adsorption ratio studied ranged from 0.56 to 1.57, indicating that all groundwater samples were excellent water, because the SAR value was < 10 [20]. This means that groundwater is safe to use as a source of irrigation (Table 3; Figure 4). Irrigation water classes are in S1C1 and S1C2 classes, marking low sodium (alkaline) hazard and low - medium salinity hazard.

Samples with medium salinity hazard status came from dug wells in Cacaban Lor Village (W2, W3) with TDS values of 205 and 306 mg/L.

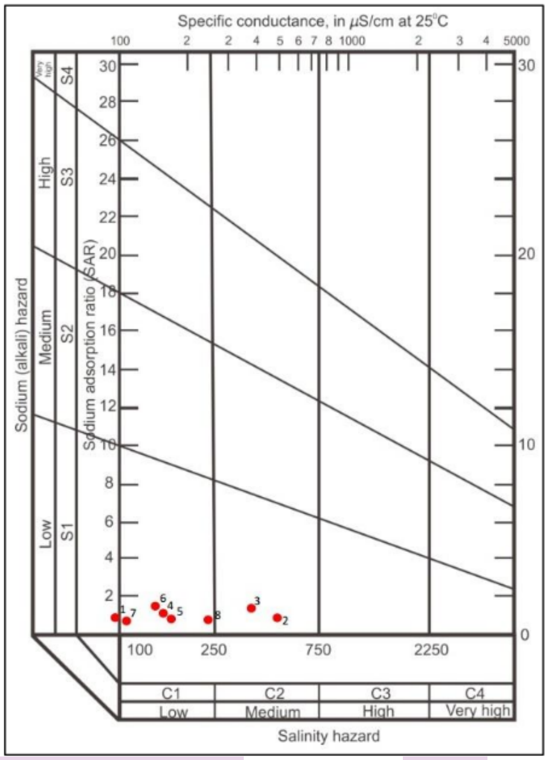

Figure 4. Irrigation water quality assessment of groundwater based on USSL diagram [3, 20].

Table 3. Classification of groundwater samples for irrigation uses in the study area.

Parameters (meq/L)	Value range				Classification		Explanation
	Min	Max	Mean	St. Dev.	Value	Quality	
[1]SAR	0.557564	1.570999	0.776796	0.346632	< 10	Excellent	- Low SAR water class - Less or no alkaline (Na) hazard
[2]Na%	19.81111	62.1149	31.49209	13.55972	< 20 20 - 40 60 - 80	Excellent Good Doubtful	
[3]RSC	-0.24614	1.350346	0.253661	0.507212	< 1.25 1.25–2.5	Good Doubtful	Safe to use

Notes: [1]Richards (1954)
[2]Wilcox (1955)
[3]Raghunath (1987)

3.3.3. Na%. The Na% value shows the variation in the groundwater samples. Based on these samples, the groundwater in the study area has excellent to doubtful water class (Table 3). The dug well in Jati (W2) shows excellent condition, and W6 well in Pekacangan is in doubtful status, while the other six sample locations are in the good class. However, based on Figure 5, all groundwater samples show good – excellent quality, because they have low EC.

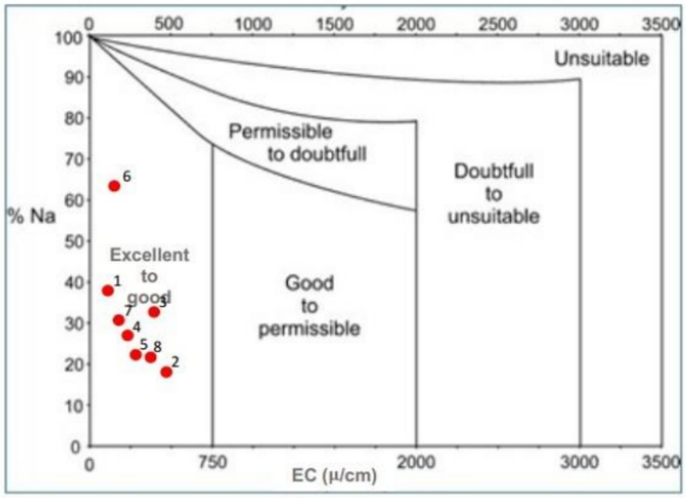

Figure 5. Wilcox diagram for assessing irrigation water quality of groundwater [21].

3.3.4. RSC. The residual value of groundwater sodium carbonate generally indicates good water class, except in W2 well (Table 3). This means, groundwater in the research area is safe enough to be used as irrigation water to support agriculture. The water quality based on Na% refers to Wilcox [21] whereas RSC refers to Raghunath classification [22].

4. Conclusion

A hydrogeological survey in the Bener area, Purworejo has been conducted to assess the quality of groundwater in order to support agriculture in the area. For irrigation use, groundwater can be used as water for 2 - 4 classes. Based on the WQI value, groundwater has good quality as raw water for class 2-3, and has excellent status for meeting the needs of class 4 raw water. The SAR, Na% and RSC values also provide almost the same conclusion, namely that the groundwater in study area can be used as irrigation water because of its good - excellent quality. Groundwater anomaly with doubtful status is not a problem, because it is still supported by a relatively low TDS, which is a maximum of 306 mg/L or a maximum EC of 477 μS/cm.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9