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Groundwater Quality Assessment for Suitable Drinking and Agricultural Irrigation Using Physico-Chemical Water Analysis in the Rancaekek-Jatinangor District, West Java, Indonesia

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Abstract. Groundwater plays a vital role as important source of drinking water and irrigation. Usage of surface water such as rivers, lakes and others have not already meet the standards of safe drinking water and irrigation due to the amount of domestic waste produced by the people who dump it into water surface. Therefore, studies were performed to assess the levels of some physical and chemical water quality in thirty-one dug wells and two springs in the region Rancaekek - Jatinangor. The following 9 parameters have been considered viz. pH, EC (Electrical Conductivity), TDS (Total Dissolved Solids), calcium, magnesium, sodium, potassium, bicarbonate, sulfate and chloride. These parameters are used to determine the quality of groundwater by comparing the quality of drinking water standards published by WHO and ISI (Indian standard specification for drinking water). The results of the analysis concluded that the water quality in the study area is a good category. It was shown from the results of physico-chemical analysis (EC, TDS, pH) and chemical composition of water (Ca, Mg, Na, K, Cl, SO_4) which tend to approach 100% feasible for drinking and agricultural irrigation. This condition occurs because the study area is located in a volcanic area that is far from the beach, so it is not affected by the intrusion of sea water which increase levels of Na and Cl, the natural water filtration process by volcanic rock, resistant to chemical weathering and a balanced acidity. On the upstream before reaching settlements and industry, this situation can be maintained by increasing groundwater and waste management from households and industry. Engineering to treat wastewater before discharge to the river is required.

Keywords: Groundwater quality, drinking water, agriculture irrigation, physico-chemical parameters, hydro-geochemical facies.

1. Introduction

Groundwater is an important natural resource both in terms of yield and water quality. Groundwater is water stored under ground surface in the tiny pore spaces between rock, sand, soil, and gravel. Nowadays, groundwater is used by 80% population of Indonesia for clean water resources both in the urban and rural area. In general, groundwater has better quality compared to surface water, but the portability is not guaranteed. Increased need of water for industry, agriculture and animal husbandry possess a risk of water quality and quantity degradation. Furthermore, natural environment of groundwater occurences will influence its quality.

In assessing groundwater quality, the GSI (Geological Survey of Ireland) distinguishes between the terms contamination and pollution. Groundwater contamination occured when substances enter groundwater as a result of human activity whereas pollution is reserved for situations where contaminant concentrations are suffeciently high to be objectionable. It is above maximum admissable concentration [1]. Groundwater

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quality can be determined more efficiently by analyzing selected groundwater physical and chemical parameters such as EC (Electrical conductivity), TDS (Total Dissolved Solids) and pH [2].

Groundwater used for drinking and agriculture purposes have different characteristic. Indonesia Government Regulation Number 82 of 2001, classify standard of water quality into (I) water safe for consumption, (II) water usable for water based recreation, irrigation, fisheries and livestock, (III) water usable for irrigation, fisheries and livestock, (IV) water usable for irrigation other usage that require water quality of the same requirement.

Rancaekek is one of the biggest industrial area in Bandung, capital of West Java Province. Textile is one of Rancaekek's main industrial product. Industrial activities carried out in this region tend to have a negative impact to the environment and humans. Textile waste pollution caused the groundwater quality to be unsuitable for consumption and irrigation. If the polluted water is used as source of irrigation, it will directly or indirectly affect quality of agriculture production. Hence, the present study was carried out to assess groundwater quality and its suitability for drinking and agricultural irrigation using physico-chemical water analysis.

2. Study Area

The study was conducted in district Rancaekek-Jatinangor, West Java, Indonesia. This area covered 4329,50 ha, with population density 160.435 person/km^2. The present study area lies between 107°45'19"-107°49'34'' longitudes and 6º56'20'' - 7°00'45" latitudes. Rancaekek-Jatinangor has tropical climates with the temperature between 22,6 º- 23,9 ºC and humidity between 70 – 83%. Frequency of rainfall in November – April is above 200 mm and Mei – October is below 200 mm. Evapotranspiration lies between 102-192 mm/year. Geomorphology of the area regions include 60% a unit sedimentary plains, 15% volcanic ramp plains and 25% volcanic steep mountain. Scatter of rocks in the study area is a generally old quarter covers 25% a unit of rock vulcanic breccia (Qbv), 15% a unit tuff (Qtf), 20% a unit andesit (Qa) and 40% a unit tuff clay.

3. Methodology

Thirty three groundwater samples from springs and wells was collected during Oktober (2012) in region Rancaekek-Jatinangor. Sampling was conducted by getting groundwater in wells and filled up the samples systematically for analys. pH, Electrical Conductivity (EC), and Total Dissolved Solid (TDS) were measured by using Hanna Multi-Parameter Probe and chemical composition of major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4, Cl^{-}) were analyzed in The Quality of Water Laboratory – (Institut Teknologi Bandung), using Standard Methods for The Examination of Water and Wastewater 21th Edition 2005 (SMEWW) and Indonesian National Standard 1991 (SNI). The suitability of groundwater for domestic purpose and agricultural were assessed by comparing the parameter value with WHO, 2004 and ISI, 1993. GIS analysis were performed using Mapinfo 10. In order to interpolate the spatial data with procedure IDW calculates a value by averaging the weighted sum of all the points.

4. Result and Discussion

In this study, the parameters are classified is a major chemical element that is (Ca, Mg, Na, K, HCO_3, SO_4, Cl) and physico-chemical parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS) (Table 1 and 2). From these data can be analyzed descriptively about the feasibility and usefulness of water for consumption and the suitability of water for agricultural irrigation. Physico-chemical parameters and chemical composition of major ions analysis were performed to compare the composition of water samples in the field with the standards which has been specified by the World Health Organization [3] and the Indian Standard [4]. This analysis will determine percentage of water suitable for consumption and irrigation. Descriptive analysis of each parameter will be discussed below.

4.1. pH

pH is measure of intensity of acidity or alkalinity of water. All chemical and biological reactions are directly dependent upon the pH of water system. The pH of water provides vital information in many types of geochemical equilibrium or solubility calculations [5]. The limit of pH value for drinking water is specified as 6.5–8.5 [3], [4]. The pH value of most of the groundwater samples in the study area varies from 6.33 – 7.58. Most of pH condition in the study sites proved that the water is safe for consumption, except from three samples with pH ranges below the suitable standard i.e. the sample W.13, W.16 and W.38. The third sample tends to be acidic. This is possibly due to domestic waste from humans or household activity waste generated by industrial and geological conditions such as rocks that affect groundwater conditions. Moreover, pH of the nutrient solution will determine the solubility of nutrients, and the availability of nutrients for plants, in this case for irrigation. The optimum pH condition for irrigation (i.e. Water fourth class according to Indonesia Government Regulation Number 82 of 2001) ranges between 6-9. The results showed that the groundwater from different locations were moderately alkaline (pH 7.26 and 7.58) and slightly acidic (pH 6.33-6.96) within the permissible limit (pH 5-9) of agriculture. Thus, it is usable for agriculture irrigation.

Table 1: Physico characteristics of groundwater in the study area

Code	pH	TDS (mg/l)	EC (Imhos/cm)	Type	Code	pH	TDS (mg/l)	EC (Imhos/cm)	Type
W.13	6.46	266	215	Dug wells	SMR 8	6.8	561	901	Dug wells
W.14	7.58	434	620	Dug wells	SMR 9	7.34	407	433	Dug wells
W.15	6.57	423	604	Dug wells	SMR 10	7.1	422	726	Dug wells
W.16	6.41	808	596	Dug wells	SMR 11	6.87	452	765	Dug wells
W.38	6.33	198	349	Dug wells	SMR 12	7.2	409	734	Dug wells
W.39	6.66	188	311	Dug wells	SMR 13	6.55	320	418	Dug wells
W.40	6.54	242	388	Spring	SMR 14	6.63	301	433	Dug wells
W.41	6.69	441	423	Dug wells	A 1	7.4	116	175	Dug wells
W.42	6.96	407	324	Dug wells	A 2	6.9	249	372	Dug wells
W.43	7.26	192	362	Spring	A 3	6.6	94	141	Dug wells
SMR 1	7.2	389	498	Dug wells	A 4	6.4	207	111	Dug wells
SMR 2	6.74	679	1108	Dug wells	A 5	6.6	207	81	Dug wells
SMR 3	6.77	708	1135	Dug wells	A 6	6.7	321	488	Dug wells
SMR 4	6.73	703	1024	Dug wells	A 7	6.7	308	463	Dug wells
SMR 5	7.13	408	493	Dug wells	A 8	6.9	338	507	Dug wells
SMR 6	7.2	411	501	Dug wells	A 9	7	288	432	Dug wells
SMR 7	7.16	421	513	Dug wells					

Table 2: Chemical characteristics of groundwater in the study area

Code	**Laboratory Result (mg/liter)**						
	Ca^{2+}	**Mg^{2+}**	**K^{+}**	**Na^{+}**	**HCO_3^{-}**	**Cl^{-}**	**SO_4**
W.13	33.53	12.07	2.38	31.1	205	10.31	2.78
W.14	32.78	13	8.52	82.82	278	10.01	16.76
W.15	25.33	11.86	4.96	81.14	217	42.04	2.63
W.16	44	35	5.22	98.4	323	73	49.8
W.38	23.84	6.69	2.87	19	105	31.53	6.47
W.39	26.08	9.84	1.58	14.18	151	7.5	1.9
W.40	32.04	12.52	1.71	20.07	205	10.71	3.09
W.41	58.86	19.66	3.32	30.4	251	68.07	19.24
W.42	40.23	11.6	13.46	52	195	53.6	21.53
W.43	29.8	13.43	2.19	12.3	171	4.5	1.34

4.2. Electrical Conductivity (EC)

Electrical conductivity is a measure of water capacity to convey electric current. The most desirable limit of EC in drinking water is prescribed as 1.500 lmhos/cm [3]. In the study area. The EC of the groundwater is varying from 81-1135 lmhos/cm with an average value of 504.3636 lmhos/cm. High EC values at some sampling locations is likely caused by the high salt composition contained in groundwater. The EC can be categorized into three types (Table 3.), namely (I) type with a low salt content (value of EC <1.500 lmhos/cm); (II) type with medium salt level (value of EC 1.500 and 3.000 lmhos/cm); (III) type with high salt content (value of EC > 3.000 lmhos/cm). Water sample from study area is 100% classified as the first category with a low salt content. This may be due to the study area are within the volcanic region and too far away from the shore line, therefore the levels of NaCl accumulation in groundwater tends to be low, and the distance transport of groundwater tend to be short.

Table 3: Classification of groundwater based on EC

EC	Salts Type	(%)
<1500	Tipe I as salts are low	100
1500-3000	Tipe II as salts are medium	0
>3000	Tipe III as salts are high	0

4.3. Total Dissolved Solids (TDS)

According to WHO specification TDS up to 500 mg/l is the highest desirable and up to 1.500 mg/l is maximum permissible. In the study area, the TDS has value varies between 94 – 808 mg/l. According to table 4 indicates that groundwater samples in the study area is in a good level for consumption which is about 84.85%. The maximum permitted levels of analysis sample approximately 15.15% and 100% TDS value that allowed for irrigation. Based on Indonesia Government Regulation Number 82 of 2001, the maximum TDS value is 2000 mg/l. Low TDS values can be caused by natural filtering performed by the rock through groundwater, commonly volcanic rocks is a good agent to conduct groundwater filtration.

Table 4: Classification of groundwater based on TDS [6].

TDS(mg/l)	Water Type	(% of sample)
<500	Desirable for drinking	84.85
500-1000	Permissible for drinking	15.15
<3000	Useful for irrigation	100
>3000	Unfit for drinking and irrigation	0

4.4. Calcium and Magnesium (Ca and Mg)

Calcium and magnesium are the most abundant elements in the natural surface and groundwater. It exist mainly as bicarbonates and a lesser degree in the form of sulfate and chloride. Ca^{2+} concentrations are varying from 23.84 to 58.86 mg/l. The desirable limit of calcium concentration for drinking water is specified as 75 mg/l (ISI, 1993). The sample tend to show a good level to be taken up to 100% of samples. The higher Ca^{2+} content can cause abdominal ailments and is undesirable for domestic usage as it cause encrustation and scaling. Low calcium content can be caused due to the volcanic region of the study area is generally rare that calcium accumulation that usually arise from living organisms, such as shells and animal bones. Magnesium content is varying from 6.69–35 mg/l. The maximum permissible limit of Mg^{2+} concentration of drinking water is specified as 100 mg/l [4] and 150 mg/l [3].

4.5. Sodium and Potassium (Na and K)

Sodium is generally found in lower concentration than Ca^{2+} and Mg^{2+} in freshwater. The concentration of Na^{+} is varied from 12.3 – 98.4 mg/l, The maximum permissible limit of sodium is 200 mg/l [3], [4]. Accordingly, 100% of the samples had levels of sodium are allowed to drink. The intake of high level of Na^{+} cause increased blood pressure, arteriosclerosis, oedema and hyperosmolarity. Groundwater with high Na content is not suitable for agricultural usage as it tends to deteriorate soil quality. Potassium levels lower than Ca, Mg and Na. The concentration of K^{+} is observed between 1.58 – 13.46 mg/l. The maximum permissible limit of potassium in the drinking water is 12 mg/l [3]. Almost all of samples tend to be safe to drink when seen from potassium levels, but there is one sample which W.42 samples that have high levels is 13.46 mg/l. In comparison with Na^{+}, the low concentration of K+ is due to the high resistance of potash feldspars to chemical weathering in the study area.

4.6. Sulfate (SO_4)

Sulphate is one of the major anion contained in the groundwater. The value of sulfate is observed from 1.34 – 49.8 mg/l. The concentration standard that allowed for drinking water is 150 mg/l [4]. Based on this, the entire sample has a good sulphate and the concentration to be used as drinking water.

4.7. Chloride (Cl)

The origin of chloride in groundwater may be from diverse sources such as weathering, leaching of sedimentary rocks and soils, intrusion of saltwater, windblown salt inprecipitation, domestic and industrial waste discharges, municipal effluents, etc [7]. In the study area, the concentration of chloride is between 4.5–73 mg/l. The desirable limit of chloride for drinking water is specified as 250 mg/l [4]. It shows that the sample of water surround the study area has a low concenteration of chloride which caused volcanic area within the study area and away from distractions sea water intrusion, and has a high level of resistance to weathering making it possible to drink.

Table 5: Groundwater samples of the study area exceeding the permissible limits for drinking purpose [3], [4].

Parameter Water Quality	WHO		Indian		Data samples
	Most	Max	Highest	Max	
pH	6.5	8.5	6.5 – 8.5	6.5 – 9.5	6.33 – 7.58
EC	1400	-	-	-	81 - 1135
TDS	500	1500	500	2000	94 - 808
TH	100	500	300	600	-
Ca^{2+}	75	200	75	200	23.84-58.86
Mg^{2+}	50	150	30	100	6.69-35
Na^{+}	-	200	-	200	12.3-98.4
K^{+}	-	12	-	-	1.58-13.46
CO_3^{2-}	-	-	-	-	-
HCO_3^{-}	-	-	-	-	105-323
SO_4^{2-}	200	400	200	400	1.34-49.8
Cl^{-}	200	600	250	1000	4.5-73

4.8. Sodium Percent (Na%)

Sodium percentage (Na%) is important parameters for determining the suitability of groundwater for agricultural usage. The sodium in irrigation water is usually denoted as percent of sodium. In all natural water Na% is a common parameter to assess its suitability for irrigation purposes [8]. The sodium percent (Na%) values was obtained by using the following equation:

$$Na\% = Na^{+} \times 100 / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+})$$

where all ionic concentrations are expressed in meq/l. The results as presented in Table 6 shows that the groundwater samples fall in the field of good to permissible and just one of the groundwater samples fall in the field of excellent for irrigation and no samples fall in the unsuitable category.

4.9. Magnesium Hazard

The most water calcium and magnesium maintains a state of equilibrium. A ratio namely index of magnesium hazard has been developed [9]. Accordingly, high magnesium hazard value (>50 %) has an adverse affect on the crop yield as the soil becomes more alkaline.

$$\text{Magnesium ratio} = Mg^{2+} + 100 / (Ca^{2+} + Mg^{2+})$$

In the study area the magnesium hazard values falls in the range of 23.5 to 48.4 % (Table 5). In the study area, all the samples collected showed Magnesium hazard ratio <50 % (suitable for irrigation) (Table 6) and no one samples are an unsuitable category. The evaluation illustrates that all the samples can give profitable effect on the agricultural yield.

Table 6: Computed values of Na% and Magnesium Hazard in the study area

Sample no.	Na (%)	Type	Magnesium Hazard	Type
W.13	33,16953	Good	38,583985	Suitable
W.14	55,24540	Permissible	38,038577	Suitable
W.15	59,72696	Permissible	45,622857	Suitable
W.16	50,05848	Permissible	27,034589	Suitable
W.38	31,43939	Good	58,021264	Suitable
W.39	22,46377	Good	48,419048	Suitable
W.40	24,57627	Good	39,052814	Suitable
W.41	22,14765	Good	23,549825	Suitable
W.42	40,72072	Permissible	34,848305	Suitable
W.43	16,98113	Excellent	39,710039	Suitable

4.10. Hydro-Geochemical Facies

Grouping facies of groundwater in the study area based on the results of the piper diagram analysis [10] using data from chemicals laboratory already in the conversion. Hydrogeochemical facies in the study area can be classified into 3 (three) facies, namely; Ca, $MgHCO_3$ facies (calcium, magnesium bicarbonate) The facies analysis covers the sample (W.38), (W.39), (W.40), (W.41), (W.42) and(W.43) contained in the rock units Qbv, Qtf and Qlt; Mg, $NaHCO_3$ facies (magnesium, sodium bicarbonate) The facies analysis covers the sample (W.14) and (W.15) contained in the rock units Qlt and Qbv; Na, $MgHCO_3$ facies (sodium, magnesium bicarbonate) the facies analysis covers the sample (W.16) lithologies present in Qlt.

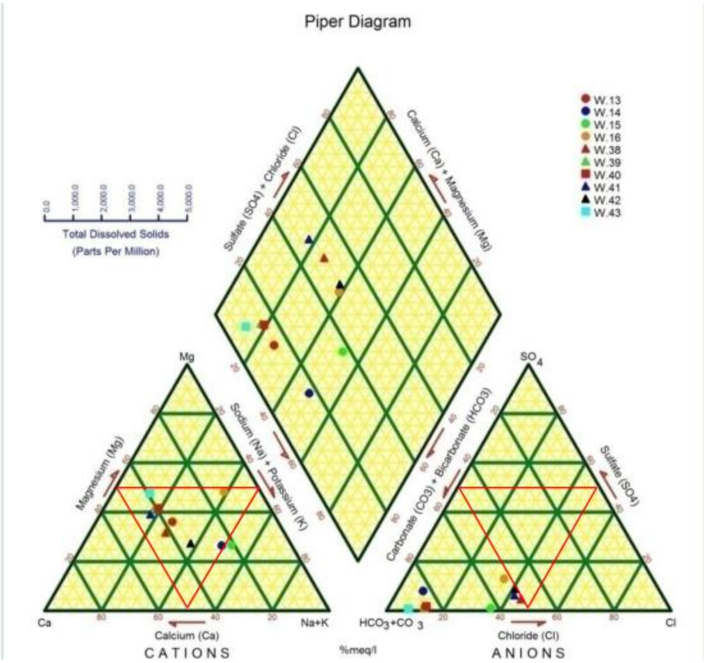

Fig. 1: Piper diagram for hydrogeochemical facies of study area

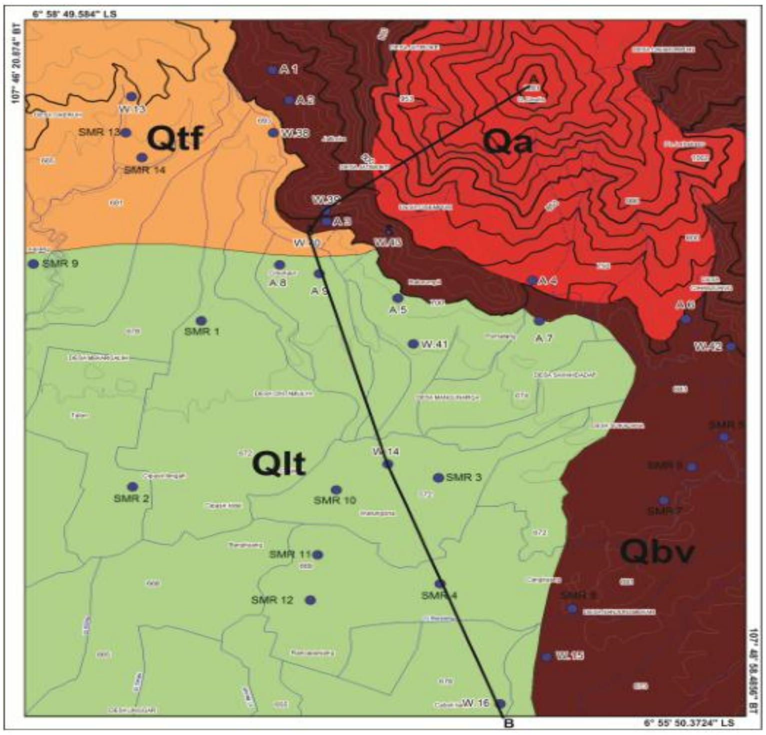

Fig. 2 : Hydrogeochemical facies map

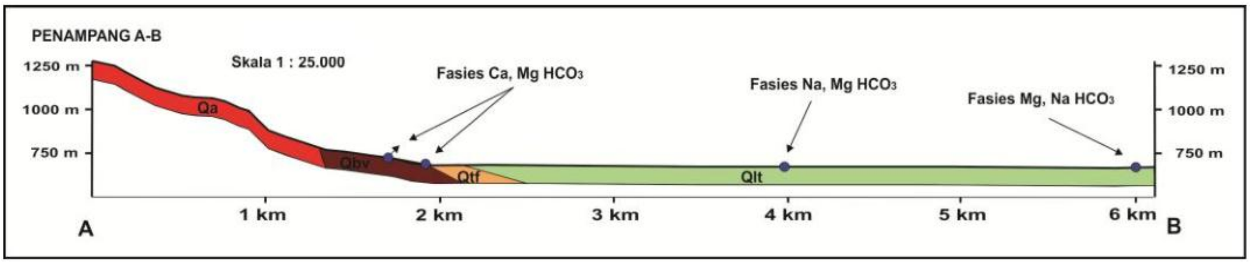

Fig. 3 : Cross section

5. Conclusion

The study indicates that the dug wells and springs samples in the district Rancaekek area are generally soft. Most of the physico-chemical parameters of the samples were within acceptable limits for human consumption and irrigation purposes. However, pH in some samples were below suitable standard for drinking. This is possibly due to domestic waste from humans or household activity waste generated by industrial and geological conditions such as rocks that affect groundwater conditions. Moreover, the concentrations of TDS in a good level for consumption which is about 84.85%. The maximum permitted levels of analysis sample approximately 15.15% and 100% TDS value that allowed for irrigation. These constituents should be monitored over a period of time because of possible threats to health at higher concentrations.

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