KURVATEK Vol. 1, No. 2, November 2016, pp. 13 – 19
ISSN: 2477-7870


# HYDROCHEMISTRY OF GROUNDWATER IN GEYER, GROBOGAN PROVINCE, CENTRAL JAVA

**T. Listyani R.A.**
Geological Department, Sekolah Tinggi Teknologi Nasional Yogyakarta, Indonesia
listyani_theo@yahoo.co.id

***Abstract***

*The demand of clean water as well as good quality of drinking water in research area puss the author for knowing about groundwater quality in research area. The aim of the research is to understand the hydrochemistry of groundwater in study area, including hydrochemical processes and the influence of minerals or rocks to groundwater quality. The methods in the research are groundwater and rocks sampling, petrography and also groundwater's chemical analysis. Result of this study shows that groundwater quality in Geyer area is influenced by minerals and rocks in that place with dissolution and ions exchange would be important processes. Minerals which composed rocks are dominated by calcareous and clay minerals. These minerals supply chemical components such as Ca2+, Mg2+, Na+, Cl-, carbonate and bicarbonate to groundwater.*

***Keywords****: hydrochemistry, groundwater, hydrochemical process, major ion*

## 1. Introduction

The study area is located at Geyer Sub District, Grobogan District, Central Java, between latitude 7°12'30" – 7°17'30" S and longitude 4°4'35" – 4°6'15" E (where longitude is measured from Jakarta) (Fig. 1). Administratively, the research area located at Kedunglo, Kentrungan, Gundih and Kedungampo Village and includes in Salatiga Regional Geological Map, sheet no. 1408-6.

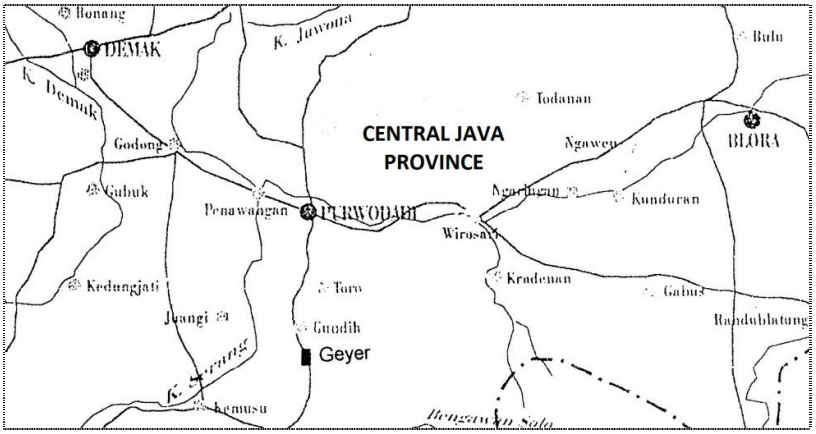


Figure 1. Location map of Geyer in Central Java topographic map

Availability of good quality groundwater is needed by people in daily life. Unfortunately, groundwater in Geyer area has worse quality to drink. For this reason, many people in the area usually drink packed mineral water. Therefore, the author wants to know about groundwater quality in this area, especially in its relation to geological rocks which are consisted at the study area.

The rock is one of the factors to determine the quality of groundwater. The chemical composition of groundwater is affected by the chemical composition of the minerals in the rock in which

*Received September 27, 2016; Revised December 07, 2016; Accepted February 12, 2017*

groundwater through. The chemical composition of groundwater can be used to make an interpretation of rocks / minerals that affect the chemical composition of groundwater. Not all chemical elements in rocks can be dissolved in groundwater. Some soluble material dissolves readily in groundwater, but there are other materials that are difficult to dissolve and does not affect to the chemical composition of groundwater.

Sedimentary rocks would affect the composition of the groundwater because of their soluble components [9]. The rocks that composed Geyer area mainly consist of sedimentary rocks, namely calcareous claystone. These rocks will support the amount of the composition of carbonate compounds in groundwater. It may be interested to see the rocks/minerals that play a role in determining the chemical composition of groundwater in Geyer.

This study aimed to identify the characteristics of groundwater in the study area, both of the physical and chemical properties. Whereas the purpose of research are to know the type of groundwater chemistry on the basis of physical and chemical properties of groundwater; to know the various hydrochemical processes that work on groundwater; and to build the interpretation of the minerals / rocks affecting the quality of groundwater.

There are seven physiographc units of Central Java - East Java [12], where the research area included in western part of Kendeng Zone. The West Kendeng Zone starts from Mt. Ungaran until Purwodadi area that shows very complex structure pattern, such as asymmetry folds and thrust faults to the north [11].

Stratigraphy of Kendeng Zone is dominated by clastic turbidite deposition that usually contains pyroclastic material with intercalation of marl or carbonate rocks. Sedimentary rocks in this zone are generally has been strongly folded and faulted. Kendeng Zone generally associated with volcanic lithology such as tuff, tuffaceous sandstones, volcanic breccias and lava which content of increasingly upward of volcanic elements such as the Kabuh, Pucangan and Notopuro Formations. Conversely, to the downward the lithology more contain carbonate minerals such as limestone and marl.

According to the regional stratigraphy [11], the rock formations that composed Geyer area are Kerek and Kalibeng Formations. Kerek formation composed by repetitive layers of silty marl with sandstones, calcareous tuffs and tuff sandstone at the bottom, while in the medial part consists of intercalation of claystone with pyroclastic deposits, and at the top of this formation is composed of clastic limestone. Whereas, the Kalibeng Formation composed by sequence of monotonous rocks consisting of marl and Globigerina marl which contains plankton and inserts tuff.

Groundwater quality is influenced by rock materials in its paths. The development of the ion in groundwater depends on the availability of minerals and their mineral solubility [3]. The chemical composition of groundwater can be used to look at the possibility of influencing rock.

Some inorganic and organic solids, organic liquids and gases found in groundwater [4]. Diversity of solutes in groundwater can occur. The content of dissolved inorganic classified as a major component with a concentration > 5 mg / l, and a minor component if the content of the them with concentrations <0.01 mg / l [3]. The analysis of the groundwater is generally performed to determine the major and minor components.

The composition of the groundwater varies in its flow process. The chemical content has also changed / evolved over the groundwater moves under surface. From geochemical standpoint, anion evolution sequence is determined by the availability and solubility mineral. The content of $HCO_3^-$ in groundwater zone generally comes from the ground and from the $CO_2$ dissolution of calcite / dolomite. Because calcite and dolomite present in large enough quantities in almost all the sedimentary basins and this mineral can quickly dissolved, $HCO_3^-$ almost always to be the dominant anions in recharge areas [5].

The quality of groundwater is affected by the aquifer material because of diagenetic changes that occurred during past groundwater aquifers, such as various hydrochemical processes [9]. These processes include the dissolution - hydrolysis - precipitation, adsorption, ion exchange, reduction - oxidation, mixing, membrane filtration and microbiological metabolism. The chemical composition of groundwater depends on the composition of the water in the recharge area and reactions that occur in the flow system.

## 2. Method

This study began with the geological field observation and include sampling of rocks and groundwater. Petrography analysis conducted to determine the mineral composition and possibilities of their chemical composition. Chemical analysis conducted on groundwater sample taken directly in the field and tested at water chemistry laboratory.

## 4. Result and Analysis

Data of groundwater sample has been taken at four villages in the Geyer Subdistrict, namely in Kedunglo, Gundih, Kedungampo and Kentrungan Villages (Figure 2). From the four samples taken, sample groundwater from Kedunglo seen most turbid. The four groundwater samples have been physically and chemically tested, and the results are presented in Table 1.


Figure 2. a. Sampling location in geological map of studied area [7]
b. Dug well at Kentrungan, one of sampling location

Table 1. Data of pH, TDS and Major Chemical Elements of Groundwater in Research Area

| No. | Location | Cation (mg/l) | | | Anion (mg/l) | | | pH | TDS |
|---|---|---|---|---|---|---|---|---|---|
| | | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $HCO_3^{-}$ | $SO_4^{2-}$ | $Cl^{-}$ | | |
| 1 | Kedunglo | 78.62 | 30.49 | 88.6 | 321.2 | 69.7 | 72.4 | 7.3 | 702 |
| 2 | Kentrungan | 40.70 | 16.50 | 41.00 | 189.1 | 35.9 | 24.4 | 7.1 | 377 |
| 3 | Gundih | 56.59 | 22.94 | 55.00 | 262.3 | 37.2 | 30.6 | 7.2 | 522 |
| 4 | Kedungampo | 52.87 | 21.44 | 50.00 | 250.1 | 36.7 | 28.7 | 7.0 | 497 |

Interpretation of the type of quality of groundwater showed that the groundwater under study belongs to class 2, 3 and 9 (Figure 3a) [10]. Class 2 indicates that the alcaline content excess its earth alcaline. Class 3 means that a weak acid content of groundwater exceed its strong acid. Whereas class 9 shows that the groundwater has balance of cation / anion pairs.

Plot of the groundwater data in Durov diagram shows that the groundwater enter the area 2 and 3 (Figure 3b). Groundwater from Kedungampo included in area 2, which means having characteristic of the dominant $HCO_3^-$, quite large quantity of $Ca^{2+}$ and $Mg^{2+}$, and is usually associated with certain minerals. $Ca^{2+}$ and $Na^+$ are part of an important ion exchange [8]. These three other samples included in area 3, which indicates the ion exchange, although the present of $CO_2$ in depth can produce $HCO_3^-$ and $Na^+$ which were dominant [8].

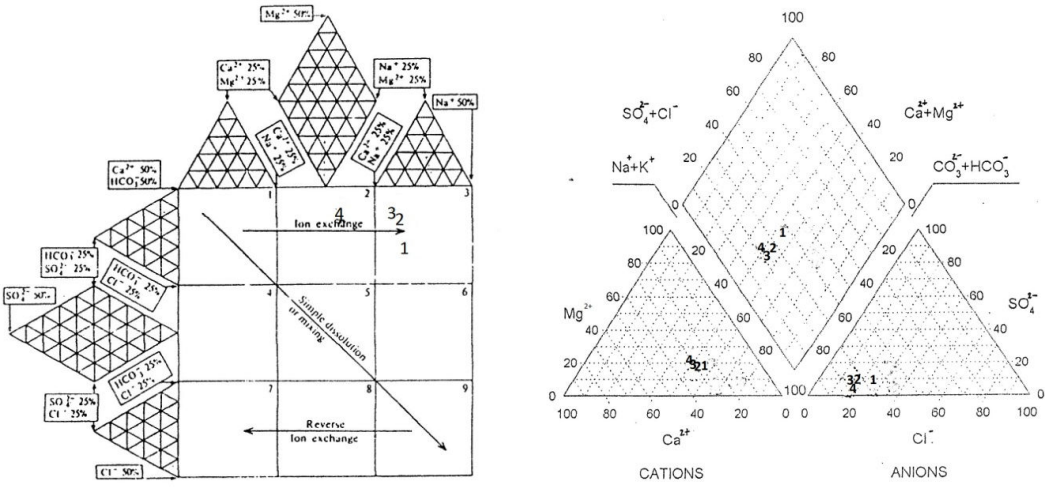


Figure 3. Plot the data of groundwater at Piper (a) and Durov (b) diagrams

From the Durov Diagram, it appears that the ion exchange process is an important one in the study area. This may happen because a lot of rocks in the area composed of clay minerals. Porous geological materials composed of a number of colloidal size particles such as clay minerals have the ability to exchange ions adsorbed on the surface of particles. Clay minerals generally show surface charge cause by ions substitution [5]. Trend of ion adsorption depends on the pH of solution. The weathering process is an example of the ion exchange process involving the leaching of alkaline or earth alkaline ions [6]. Variations in the number and kinds of ions will reflect the composition of ions in clayey sediments.

Ion exchange processes that occur in the groundwater in the study area generally occur without dissolution of calcite minerals (Figure 4). This hydrochemical process is particularly the case in clay minerals. This is supported by numbers of clayey rock outcrops in the field.

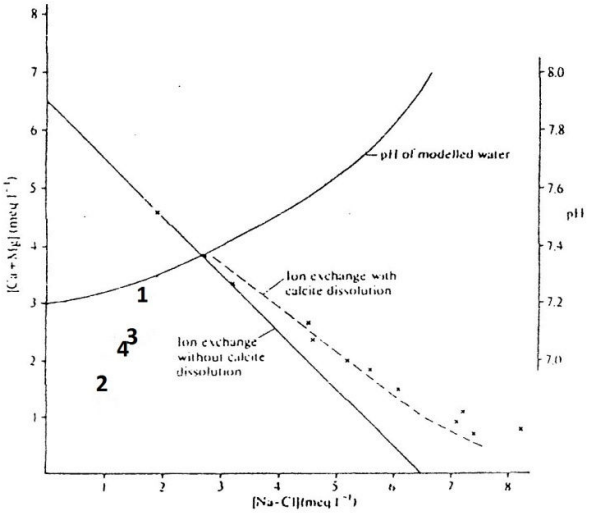


Figure 4. Chemical data of groundwater plotting in ion exchange model [9]

The rocks that compose of study area are included in calcareous sandstone, calcareous claystone and alluvial deposit units [7]. An outcrop sample is shown in Figure 5. Leaching in sedimentary rocks would affect the composition of the groundwater because of their soluble components. Therefore, groundwater characteristics will be influenced by sedimentary rock as follows [9].

1. Groundwater in sandstone/calcareous sandstone generally has TDS depends on the materials in sandstones. Low TDS may be caused by rainwater. Sandstones with soluble calcareous cement result groundwater containing more numbers of $Mg^{2+}$, $Ca^{2+}$, $Na^{+}$, $SO_4^{2-}$ and $Cl^{-}$.
2. Groundwater in the mudstone /calcareous claystone generally experience slow movement and long period of contact time with the rock because of small permeability in these rocks. Small pore size resulting in high contact surfaces of rocks - water, support the adsorption and ion exchange of $Cl^{-}$ and $SO_4^{2-}$ salt were previously trapped during the deposition and tough it out because of the low flow velocity. In general, the groundwater in these rocks have a big enough of TDS and silica content and high enough level of the cation exchange process.

Figure 5. Calcareous sandstone outcropped at Kentrungan Village (a) and intercalation of calcareous sandstone and calcareous claystone found at Kentrungan River (b)

The petrographic analysis showed that the constituent minerals of rocks are dominated by clay minerals and carbonates [7]. Mineral supply much chemical contents in the research area in the form of $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $Cl^{-}$, carbonates and bicarbonates (Table 2).

Table 2. Compilation of Petrography Data and Theoretical Chemical Association of Groundwater in Research Area

| No | Composition | Thin section number 1 2 3 4 Mineral (%) | | | | Chemical association of groundwater [4], [11] | Chemical data of gw Cation | Anion |
|---|---|---|---|---|---|---|---|---|
| 1 | Feldspar | 22 | - | - | - | Silica, Mg, Ca, Na, K | Ca, Mg, Na | Cl, carbonate, bicarbonate, sulfate |
| 2 | Quartz | 8 | 2 | 2 | 3 | Silica | | |
| 3 | Rock fragment | 30 | - | - | - | Silica, $Fe^{2+}$, $Fe^{3+}$, Mg, Ca, Na, K, $SO_4$, Cl | | |
| 4 | Fossil | 3 | 5 | 9 | 7 | Ca, carbonate, bicarbonate | | |
| 5 | Opaque mineral | 3 | 3 | 2 | 6 | Silica, $Fe^{2+}$, $Fe^{3+}$, Mg | | |
| 6 | Clay mineral | 7 | 80 | 72 | 70 | Silica, $Fe^{2+}$, $Fe^{3+}$, Mg, Ca, Na, K, $SO_4$ | | |
| 7 | Calcareous mud | 27 | 10 | 15 | 14 | Ca, carbonate, bicarbonate | | |

The table shows that the mineral / rock in the study area strong affect to the groundwater quality. Elements / compounds present in groundwater is affected by the level of solubility of the mineral. Minor element of iron can be understood as $Fe^{3+}$ usually undergo precipitation at pH above 3, while $Fe^{2+}$ begins to settle at pH 5.1 as hydroxide but these ions are not completely precipitate at neutral solution [9].

The weathering of silicate minerals can be explained as follows [1].

1. Changes resulting from silicate weathering in groundwater chemistry are less visible because dissolution of silicate minerals generally run very slowly.
2. The order of the disappearance of silicate minerals reflect differences in dissolution rate.
3. Effect of silicate weathering on groundwater chemistry mainly is the addition of cations and silica.
4. High silica content of the groundwater degradation mark active degradation of silicate minerals.

The absence of data on the quantity of silica in the groundwater under study lead author can not discuss the stability of silicate in the study area.

On the other hand, carbonate/bicarbonate ions which dissolved in groundwater can be explained as shown in Figure 6. The content of bicarbonate ions in groundwater are affected by the pH of the solution. $HCO_3^-$ ion more dominant than $CO_3^{2-}$ in groundwater at studied area because of pH range from 7 to 7.3.

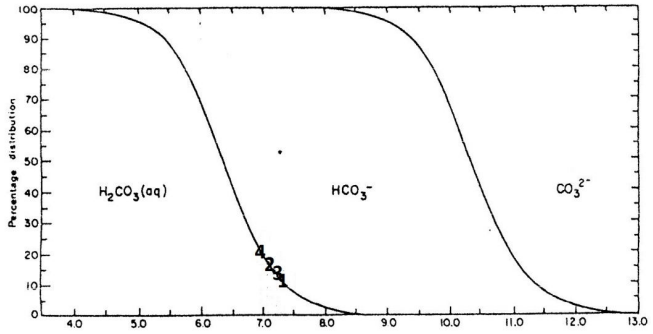


Figure 6. Plot of groundwater data in the dissolved carbonate percentage diagram as a function of pH at a standard temperature and pressure [9]

**5. Conclusion**

Study of groundwater hydrochemistry at Geyer area, Grobogan District showed that dominant rock constituent of calcareous sandstone and calcareous claystone supply various chemical elements dissolved in the groundwater and affect its quality. Groundwater in the study area has a type of water that

in equilibrium, where none pairs of cations and anions exceeds 50%, the alkali content in excess of earth alkaline, as well as a weak acid content exceeds the strong acid.

The quality of groundwater in the study area is affected by the dissolution of minerals / rocks in the area. Minerals which contribute to affect the quality of groundwater are feldspar, opaque minerals, clay minerals and carbonates minerals. The dominant hydrochemical process is ion exchange was typical of clay minerals in addition to the mineral dissolution process of soluble material.

**Daftar Pustaka**

[1] Appelo, C.A.J. and Postma, D., *Geochemistry, Groundwater and Pollution*, A.A. Balkema, Rotterdam, 1996.
[2] Bowen, R., *Groundwater*, 2nd. Ed., Applied Science Publisher, London, 1986.
[3] Davis, S.N. and De Wiest, R.J.M., *Hydrogeology*, 1st Ed., John Wiley & Sons Inc., New York, 1966.
[4] Domenico, P.A. & Schwartz, F.W., *Physical and Chemical Hydrogeology*, John Wiley & Sons, New York, 1990.
[5] Freeze, R.A. and Cherry, J.A., *Groundwater*, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1979.
[6] Grim, R.E., *Clay Mineralogy*, McGraw-Hill Book Co., New York, 1953.
[7] Lingga, P.L., *Geologi dan Teknik Pembersihan Air Daerah Jambangan dan Sekitarnya, Kecamatan Geyer, Kabupaten Grobogan, Propinsi Jawa Tengah*, Tugas Akhir, Sekolah Tinggi Teknologi Nasional Yogyakarta, unpublished, 2002.
[8] Lloyd, J.W. & Heathcote, J.A., *Natural Inorganic Hydrochemistry in Relation to Groundwater, An Introduction*, Clarendon Press, Oxford, 1985.
[9] Matthess, G., *The Properties of Groundwater*, John Wiley & Sons, Inc., New York, 1982.
[10] Piper, A.M., 1944, A Graphic Procedure in The Geochemical Interpretation of Water Analysis, in Back, W. & Freeze, R.A., 1983, *Chemical Hydrogeology*, Benchmark Papers in Geology, V. 73, Hutchinson Ross Publishing Company, New York.
[11] Pringgoprawiro, H., *Biostratigrafi dan Paleogeografi Cekungan Jawa Timur Utara: Suatu Pendekatan Baru*, Disertasi ITB, Bandung, unpublished, 1983.
[12] Van Bemmelen, R.W., *The Geology of Indonesia*, Vol. 1A, Martinus Nijhoff, The Hague, Netherland, 1949.