ISOTOPIC CHEMICAL CHARACTERISTICS OF GROUNDWATER IN BANJARARUM AREA, WEST PROGO

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Abstrak

Survei airtanah di bidang kimia isotop dilakukan di daerah Banjararum Kabupaten West Progo, daerah yang relatif miskin air dan perlu dikaji kualitas airtanahnya. Pengamatan mataair Degan dan Dukuh dan sampling dua contoh airtanah dari mataair secara langsung di lapangan dilakukan untuk mengetahui karakteristik isotop airtanah di daerah tersebut. Metode penelitian adalah survei airtanah dan uji laboratorium isotop. Data yang dibutuhkan meliputi data fisik/kimia dan kandungan isotop airtanah. Analisis kandungan isotop airtanah khususnya isotop stabil ^{18}O *dan* ^{2}H *dilakukan guna mendukung pemahaman genetika airtanah dengan melihat variasi kandungan hidroisotopnya. Hasil penelitian menunjukkan bahwa di daerah penelitian diketahui adanya airtanah dengan karakter isotop stabil yang ringan maupun berat. Kandungan isotop yang ringan di daerah Degan menunjukkan bahwa presipitasi sangat berperan dalam mempengaruhi kualitas airtanah setempat. Sementara itu, mataair di daerah Dukuh menunjukkan genetik airtanah yang lebih kaya isotop, dan dapat diinterpretasikan adanya interaksi water-rocks yang lebih kuat, khususnya dari batuan karbonat Formasi Jonggrangan yang diinterpretasikan dilewati aliran airtanah setempat.*

Kata kunci: *kimia, airtanah, isotop stabil*

Abstract

Survey of groundwater in the field of isotope chemistry is done at the district of Banjararum, West Progo Regency, the hard water area and its groundwater quality need to be learned. The observations of Degan and Dukuh springs and sampling of two groundwater samples from those springs directly on the field were conducted to determine the characteristics of groundwater isotope in the area. The research method is groundwater survey and isotope laboratory testing. Required data include physical / chemical and groundwater isotope content data. Analysis of groundwater isotope contents especially for stable isotopes of ^{18}O *and* ^{2}H *was done to support the understanding of groundwater genetics by looking at the variation of its hydroisotopic content. The results show that there is known groundwater with stable and heavy isotope character in the research area. The light isotope content in the Degan area indicates that precipitation has strong influence to the quality of local groundwater. In the meantime, the Dukuh spring indicate richer isotope contents of groundwater, and can be interpreted by stronger water-rocks interactions, especially from Jonggrangan Formation carbonate rocks that are interpreted to be passed by local groundwater flows.*

Keywords*: chemical, groundwater, stable isotope*

1. Introduction

The study of groundwater chemistry especially about hydroisotopes was conducted in Banjararum area, which included in topographic map of Sendangagung Sheet, West Progo Regency [1], Yogyakarta Special Province (Figure 1). The study area is included in Purworejo Sheet topographic map, number 1408-232 according to Bakosurtanal, published in 2001.

Groundwater tested by isotopes comes from springs. The areas where the groundwater sampling is taken from the springs are Degan and Dukuh areas. The first spring is located in Degan II Hamlet, while the other spring is located in Dukuh Hamlet, Banjararum Village, Kalibawang Subdistrict, West Progo Regency. The study area is the eastern region of the West Progo Dome Physiographic zone [2].

One of the important things in assessing groundwater potential is its quality. Groundwater quality can be reviewed from the chemical aspects. The quality of groundwater in the region in general is influenced by the geological conditions, for example in terms of the type of rock [3]. This groundwater chemical aspect will support hydrogeological research of a region. Hydrogeological research has been developed in various regions throughout Indonesia to assist the community in terms of water supply.

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Water is a very vital and strategic need, therefore water must be maintained in adequate quantity and good quality.

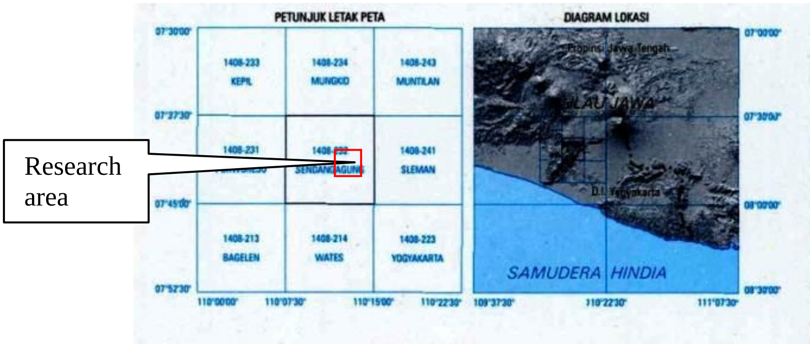

Figure 1. Research area in Topographic Map of Sendangagung [1].

The need for water for the community can be obtained from surface water and groundwater. Surface water can be obtained from rivers, lakes, marshes or seas. Nowadays, surface water is sometimes polluted so groundwater becomes a better alternative to meet the life needs of water. Therefore, the potential of groundwater in an area needs to be assessed so that we can provide water in sufficient quantity and good quality.

One of the things that can be studied from groundwater chemistry is the chemical content of groundwater isotope. The groundwater isotope content may vary in different regions. Furthermore, the contents of groundwater isotope can be used to interpret the groundwater geology of a region. Therefore, the determination of groundwater isotope content becomes very important in hydrogeological work, especially in the hydrochemical field.

By knowing the chemical content of groundwater isotope we can do hydrogeological analysis of a region. Some hydrogeological processes can also be known by looking at the dominant elements contained in groundwater. Groundwater evolution can also be seen by knowing the chemical content contained in groundwater.

The determination of the chemical character of groundwater isotopes is important in hydrogeological studies. The isotope content is part of groundwater chemical content. These isotopic chemistry characteristics can also be assessed as part of groundwater genetic understanding as well as studies of groundwater quality. Groundwater flow systems can also be understood through this hydroisotopes approach. By knowing the variation of the isotope content we can interpret the groundwater flow system in an area. This paper wants to know about groundwater origin or hydroisotopic process of groundwater in research area.

2. Methods

The tools needed in this research are field geology tools, laboratory equipment and stationery for studio work. Field geology tools include hammer, compass, camera, GPS, as well as stationery and sample bottles. Isotope laboratory work done at BATAN Jakarta using LWIA (Liquid Water Isotope Analyzer) type DLT-100 made by LGR USA. Meanwhile, studio work is done on campus using a set of computer and stationery.

Research materials needed in the field are the geological map scale 1 : 100.000 and topographic map scale of 1: 25.000. In addition, groundwater samples were taken in the field for testing in the isotope lab at a later stage. Samples of water taken as many as two samples, derived from two springs, namely Degan and Dukuh springs. The research stages used in this study include literature review, field hydrogeology survey as well as laboratory testing and data analysis.

3. Geological of Research Area

The Banjararum region is included in the eastern part of West Progo Dome's zone geologically [4]. In this area some various rocks can be found such as the Nanggulan Formation, Old Andesite and Jonggrangan as well as some of the Quarter sediments of volcanic deposits of Merapi and colluvial rock from debris of Tertiary Old Andesite Formation (Fig 2).

The Nanggulan Formation is the oldest group of rocks exposed in eastern West Progo high land, around Kalisonggo and Kalipuru. The lithology is composed by sandstones with lignite inserts, intercalation of sandstone, limonite limestone, intercalation of marl - limestones and tuffaceous sandstone containing fossils of foraminifera and molluscs [4].

The Old Andesite Formation is exposed in the center, north, west and southwest of West Progo high. It is deposited in a volcanic environment composed of volcanic breccia, lava, lapilli, tuff lapilli and volcanic sandstone. The dominant composite lithology consists of andesite breccia with a tuff matrix, fragments comprising andesite pyroxene to andesite hornblende. It also revealed the intrusion of igneous rocks [4].

Jonggrangan Formation is composed by tuffaceous marl, calcareous sandstone with lignite layer that upwards turn into bedded limestone and reef limestone. The thickness of this formation is approximately 150 m, the position is unconformable above the Old Andesite Formation and changed facies with Sentolo Formation [4].

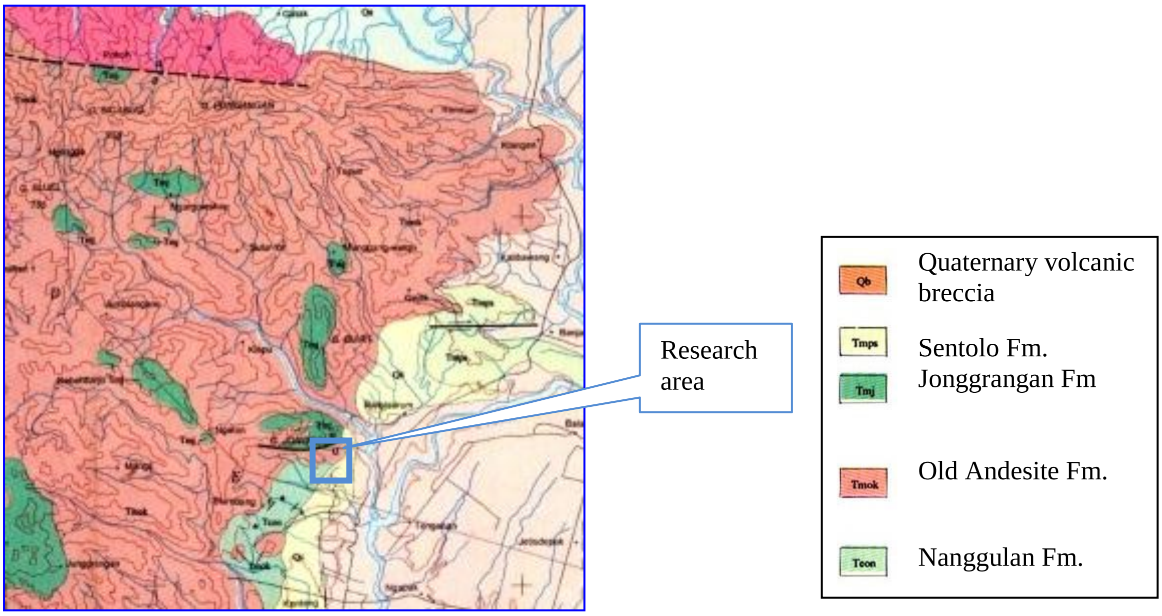

Figure 2. Geological map of research area [4].

4. Isotope Theory

This study used isotope ^{18}O and ^{2}H or D (deuterium) to be analyzed. Isotopes are elements that have the same atomic number but different mass numbers. These isotopes are often used in the study of chemical processes. Isotopes ^{18}O and D are stable, non-radioactive isotopes and primarily serve as indicators of groundwater sources [5].

Groundwater with an isotope composition on the meteoric water line comes from the atmosphere and is not influenced by other isotopic processes. Deviation of the meteoric water line indicates the existence of an isotopic fractionation process, which may occur due to exchange with mineral rocks [6]; IAEA, 1983 in [7]. Thus, the deviation can be studied to determine the processes occurring during groundwater evolution in an area.

Chemical and isotopic characteristics are associated with genetic of groundwater. Furthermore, isotopic evolution of deep groundwater in the basin can be studied to understand the genetic flow of groundwater [8].

4. Result and Analysis

4.1. Field Data

Groundwater observed in the field is generally of good quality, showing colorless, tasteless and odorless, and clear. There are only a few places that have slightly brownish and turbid water. However, the colored and cloudy groundwater is generally tasteless and odorless.

Groundwater samples used for isotope analysis were taken in two springs, ie Degan and Dukuh springs. The springs are big enough of their discharge rate. The spring at Degan have fluctuating discharge depending on the season, also strongly influenced by the existing Kalibawang ditch in the north of Degan Hamlet. Degan spring is utilized by STTNAS for daily campus purposes by creating a water torn container as shown in Figure 3 below.

The water emerging from Degan's spring is clear, colorless, tasteless and odorless. Groundwater is very well used for drinking water or daily living purposes.

Figure 3. Degan spring at Degan II, Banjararum Village.

Degan spring appears on topographical cutting morphology or a relatively steep river bank. Water emerging from this spring flows by making a small rapids about 1 m terrace. To the south of the Degan spring there is the Degan River which has a lower water level than this spring. Therefore, the river in the area is effluent type where groundwater acts as a supplier of river water.

Degan's spring appears on the young Merapi breccias aquifer. These rocks are black, clastic textures, gravel-boulder grain size fragments, medium sand sized matrix, open pack, massive structure, supported by composition of andesite fragment, while the matrix is sandstone (Fig. 4). In this weathered conditions, rocks are brownish, non-compact, porous and permeable so they are excellent as groundwater aquifers.

Figure 4. Aquifer of andesite breccia yields Degan spring.

The Dukuh spring is approximately 1.5 km to the north from Degan's spring. This spring is kept by the inhabitants by making concrete construction around it, in the area around (2x1) m^2 (Figure 5). This water is used by the people for everyday purposes.

Figure 5. Dukuh spring which be constructed by concrete.

Water that appears in the Dukuh spring is a rather turbid, transparent color to a little whitish. When compared with water in Degan spring then the water in the Dukuh spring looks less clear although not smelly.

The Dukuh spring appears on the tuff aquifer of the Old Andesite Formation (OAF). There are two adjacent springs in this area, approximately 10 m apart. The appearance of this spring is supported by a topographic cut by looking at its position below the cliff path (Figure 6) as well as on the riverbank below a steep cliff (Figure 7). In addition, these springs are also controlled by the different permeability of rock contacts, ie between tuffs with autoclastic lava / breccias whose outcrops can be observed on the edges and bottom of the stream near the springs.

Figure 6. Tuff of Old Andesite Formation aquifer that produces Dukuh spring. Groundwater samples for isotope testing are taken from this spring.

4.2. Laboratory Data

Groundwater isotope laboratory data can be seen in Table 2 below. Samples from two locations have been taken from Degan (S1) and Dukuh (S2) springs in the study area. Groundwater isotope data is used to determine the local groundwater flow system, especially in terms of groundwater genesis.

Figure 7. The other spring at Dukuh near the spring where the isotope sampling have been taken place.

Table 2. Isotope composition of groundwater in research area.

No.	Sample	Location	δO-18		δD	
			‰	+/-	‰	+/-
1	S1	Degan	6.07	0.62	45.1	4.5
2	S2	Dukuh	3.67	0.16	34.3	0.7

4.3. Aquifer

The rocks that consist the study area are rocks that belong to the Jonggrangan Formation, the Old Andesite Formation or the Quaternary sediment. Such rocks include sandstones, carbonate sandstones, andesite breccia, and andesite intrusion. The Quaternary sediments and rocky soil also covered much of the study area. The limestone aquifer is in the north of the Dukuh spring, which is at the upper slope to the peak of Mt. Jonggol.

The rocks in the research area that generally become as aquifers are Quaternary deposits, carbonate sandstones, and andesite breccia. These aquifer rocks generally have moderate porosity and medium - high permeability. Sandy or gravelly soil sometimes also acts as an aquifer, especially in lowland areas or valleys.

The rocks that compose the Old Andesite Formation include andesite, tuff and lava breccia. Andesite and tuff breccia can act as an aquifer, although its potency is less good, unless supported by secondary porosity. The rocks are generally compact and hard, so porosity and permeability are not good. One example of the tuf's outcrop can be seen in Figure 8 below.

Beside tuff layers, there are andesitic breccias of Old Andesite Formation can be found around the Dukuh spring. The andesite breccia usually has hard, compact characteristic. This rock can be aquifer through secondary porosity, usually supported by some cracks of joints or faults. The potential of this rock will increase when the rock start to be weathered. The intensity of weathering may determine the capacity of porosity as well as permeability of rocks.

Andesite breccia which is found at surrounding of Dukuh spring is a strong lithified Tertiary rocks. The rocks usually have massive or very thick bedded structure. On the other hand, andesite breccia at Degan Village usually found as young, Quaternary sedimentary rocks. Those rocks usually belong to colluvium sediments.

Breccia aquifer of Colluvium Sediments (Qc), has black color, clastic texture, gravel size fragment, poor sorted, open pack, massive structure. The rock is composed of andesite fragment with tuffaceous sandstone matrix (Fig. 9).

Soil of rocks and alluvial sediments may also become aquifer of shallow groundwater in research area. The shallow groundwater table of wells in Degan Village usually take groundwater the unconfined aquifer from the alluvial or colluvial sediments.

Figure 8. Tuff of the Old Andesite Formation exposed in Dukuh, has been weathered so that it is blackish brown, relatively soft and porous.

Figure 9. Andesite breccia of colluvium sediments found at Degan II Village.

4.4. Hydroisotope of Groundwater

The study area is included in the non groundwater basin [9]. However, in some places we can still find areas that have plenty of groundwater, both located in springs and dug wells. Degan spring represents groundwater derived from colluvium aquifers, whereas Dukuh spring represents groundwater from the Old Andesite Formation.

The result show that Degan spring contain light isotope ^{18}O and D, which is -6.07 ± 0.62 ‰ for ^{18}O and 45.1 ± 4.5 ‰ for D. The light isotopes content in groundwater of Degan spring show the strong effect of local precipitation. In addition, this light isotope also characterizes a relatively close distance drainage or flow time that has not been too long.

Meanwhile, the content of ^{18}O isotope in Dukuh spring is -3,67 ± 0,16 ‰ and D equal to -34,3 ± 0,7 ‰. The content of groundwater isotope in these spring shows a heavy value. It can be interpreted that the groundwater emerging in this spring has undergone a long circulation with considerable distance.

Another thing that makes isotopic contents in this area heavy may be due to long interaction between groundwater and rocks, especially interaction with Jonggrangan limestone which is located at higher elevation at north of Dukuh. The presence of a heavy content in groundwater isotope from Dukuh spring also shows that the precipitation has little effect on groundwater in this spring. In summary, the isotopic hydrogeological conditions are presented in Figure 10 below.

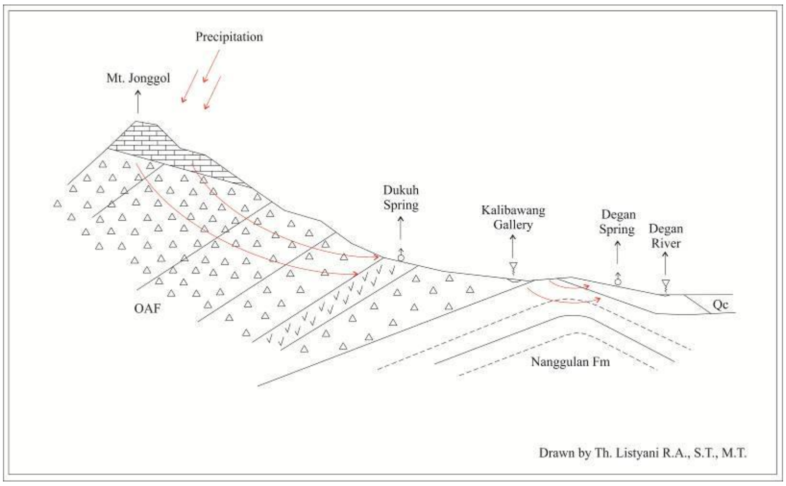

Figure 10. Isotopic hydrogeological setting of Banjararum area.

4. Conclusion

The hydrogeological condition of the research area is supported by rocks from the Old Andesite and Jonggrangan Formations, and the sediment of Young Merapi with an aquifer of andesite breccia and tuff. The aquifer composing the research area is dominated by volcanic rocks of andesite breccia and alluvial/colluvial sediments. These rocks act as aquifer through the porosity of the grains and cracks / fractures. The inter-grain porosity is obtained from the young Quaternary Merapi sediments.

The study of groundwater isotopic chemistry in Banjararum has been done by taking samples of groundwater from Degan and Dukuh springs. Groundwater in the study area has quite different ^{18}O and D isotope, where Degan springs show light isotope characters, whereas Dukuh springs have quite heavy isotopes.

Groundwater in the Degan area contains relatively light isotopes of ^{18}O, indicating strong precipitation as well as relatively close groundwater travel distances. Groundwater in the Dukuh area has heavy isotope content relatively, marking a further journey, with a strong water-rock interaction process, especially to Jonggrangan limestone in the northern heights of this spring.

Reference

[1] Bakosurtanal, 2001, *Indonesian Topographic Map of Sendangagung Sheet*, No. 1408-232, 1st Edition, Bakosurtanal, Cibinong.

[2] Van Bemmelen, R.W., 1949, *The Geology of Indonesia*, Vol. 1A, Martinus Nijhoff, The Hague, Netherland.

[3] Listyani. T., 2017, *Influence of Rock's Chemical Composition to Groundwater Quality in Jakarta Basin*, 3rd Annual Rural Development Conference, Tomorrow People Organization, Bangkok.

[4] Rahardjo, W., Sukandarrumidi dan Rosidi, H. M. D., 1995, *Geological Map of Yogyakarta Quadrangle*, Scale 1 : 100.000, 2nd edition, P3G, Bandung.

[5] Freeze, R.A. and Cherry, J.A., 1979, *Groundwater*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

[6] Clayton, R.N., Friedman, I., Graf, D.L., Mayeda, T.K., Meents, W.F., and Shimp, N.F., 1996, The *Origin of Saline Formation Waters, Isotopic Composition*, J. Geophys. Res., 71(16), 3869 – 3882.

[7] Domenico, P.A. dan Schwartz, F.W., 1990, *Physical and Chemical Hydrogeology*, John Wiley & Son, New York.

[8] Listyani, 2016, *Groundwater Flow and Its Isotopic Evolution in Deep Aquifer of Jakarta Groundwater Basin*, Journal of Geological Sciences (JGS) Vol. 3, No. 1, E-periodical 2335-6782, GSTF, Singapore.
[9] Geological Agency, 2011, *Indonesian Groundwater Basin Map*, Energy and Mineral Resources Department, Bandung, ISSN 987-602-9105-09-4.