Hydrochemical Study in Determining Characteristic Of Fluid And Geothermal Reservoir In Sanggabuana Mountain Area And Its Surrounding, Citeureup, Bogor, West Java

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Abstract. The research location is administratively included into the sub-district of Citeureup, Bogor, West Java. Geographically, it’s located at coordinates BT 106°54’36” -107°00’00” 6°35’46” -6°40’74” LS. This study aims to determine the temperature of the reservoir of subsurface, the determination of fluid type and the origin of hot water on the surface manifestation and the process of formation under the surface. The method used is descriptive method and chemical analysis including geothermometer and geoindicators based on geothermal fluid geothermal chemistry data. Water chemistry analysis based on geoindicators showed that type of hot water of study area was dominated by sulfate water with relatively high proportion of sulfate (SO₄) to concentration of Cl and HCO₃ as the outflow area identifier in condition of relative Na-K-Mg proportion and relative K-Na and Mg-Ca concentration diagram at the position is not equal (immature water) and the area is outflow geothermal system. Mg is very dominating with concentration. The high concentration of Mg in calculations and plotting results on immature water indicates that in the formation of surface water geothermal manifestation comes from reservoirs that have been mixed with meteoric water and reaction / interaction with the rocks it passes. Temperature of subsurface manifestations based on geothermometers Na-K-Ca in the study area of approximately 50.617 to 92.627°C which is belong to low temperature geothermal system.

1. Introduction
The world has a finite amount of natural resources; coal and hydrocarbon (oil and natural gas), they have fueled our demand of energy for at least the last 200 years. Hydrocarbon resources fuel the entire world lifestyle, yet the resources are rapidly depleting, along with the depletion of oil and gas reserves worldwide due to continuous exploitation, it is necessary to search for new alternative energy sources to cope with the reduced energy supply from oil and gas in the future. In this case, one of the energy sources that can be developed to overcome oil and gas crisis is geothermal energy. Indonesia as the country that has the most volcanoes and also located in the ring of fire area, makes Indonesia has large amount of geothermal energy reserves. Based on initial research Indonesia save about 40% of world geothermal energy reserves. Geothermal energy is the heat energy from the earth that is generated by the magmatization of tectonic plates, the resources of geothermal energy range from the shallow ground to steam, hot water, and hot rock. The amount of the potential reserve of a geothermal field can be illustrated by several reservoir parameters such as temperature, pressure and enthalpy that
representing the thermal energy contained in the reservoir fluid. Therefore, knowledge about the distribution of temperature, pressure and enthalpy of the reservoir system is very important.

The research location is administratively included into the sub-district of Citeureup, Bogor, West Java. Geographically, it’s located at coordinates BT 106°54’36”-107°00’00” 6°35’46”-6°40’74” LS with an area about 200 km². The highest peak in this area include Paniisan Mountain, Kendeng Mountain, Kancana Mountain and Halimun Mountain with elevation ranging from 500 mdpl.

2. Data and Method

The method that used in this paper is field method and chemical analysis. Field method comprising field investigation, targeting, sampling water, gas and soil. And chemical analysis which is geothermometer and geoinicators based on chemical data of water geothermal. Geothermometer is a method used to predict subsurface temperature [1],geoindicators can be used in the measurement of zonation in the form of flow at the temperature of the geothermal system, the chemical indicator which includes the ratio of Na/K, K/Mg, Cl/SO₄, and SO₄/HCO₃. Na/K geothermometers assumes that fluids have equilibrated with sodium-bearing feldspar and potassium-bearing feldspar which are common and abundant hydrothermal minerals. The benefit of this geothermometer is less affected by dilution and steam separation than other geothermometer.

K/Mg geothermometer was developed in the 1980’s, and it was applied by [2]. This geothermometer basis assumes that fluids have equilibrated with K-feldspar, K-mica, chlorite and chalcedony. This geothermometer is used in all phases and applied in spring and deep well samples.

Na-K-Cageothermometer was developed by [3] for application to waters with elevated Ca²⁺ contents that give an anomalously high calculated temperature for the Na/K geothermometer.

Cl-SO₄-HCO₃ ternary diagram is used to classify geothermal fluids on the basis of the major anion concentrations [2]. It helps to discern immature unstable waters and gives an initial indication of mixing relationship or geographic groupings Na-K-Mg ternary diagram is used to classify waters into fully equilibrated, partially equilibrated and immature waters. This diagram can be used to predict the equilibrium of the temperature and suitability of thermal waters for the application of solute geothermometer. It is based on the temperature dependence of the full equilibrium assemblage of potassium and sodium minerals that are expected to form after the isochemical recrystallization of average crustal rock under conditions of geothermal interest [2] [4,5].

3. Result and Discussion

3.1. Results of Fluid Chemistry Analysis

Fluids from the five hot springs are analyzed to find out the contained chemical elements in there can then be used for geothermometer calculations. The results of the chemical analysis of the five hot springs are shown in Table 1. (C1-C4 = Cimandala 1 - Cimandala 4, AD. C = AD.Ciangsana)

3.2. Determination of Water Type

The chemical data required in the determination of reservoir fluid type is the relative content of chloride (Cl), bicarbonate (HCO₃) and sulfate (SO₄). The data is processed by calculating the percentage of Cl, HCO₃ and SO₄ elements (Table 2). Then the data is plotted in Giggenbach triangle diagram (Fig 1).

| Lokasi     | Cl (%)   | SO₄ (%) | HCO₃ (%) |
|------------|----------|---------|----------|
| Cimandala 1| 69,26    | 26,46   | 4,28     |
| Cimandala 2| 10,40    | 77,88   | 11,73    |
| Cimandala 3| 6,69     | 79,63   | 13,69    |
| Cimandala 4| 6,27     | 80,16   | 13,57    |
Generally, the type of hot water consists of chloride (Cl), sulfate (SO$_4$), and bicarbonate (HCO$_3$) type, which determined based on the relative content of Cl, SO$_4$, and HCO$_3$ anions. From the result of chemical analysis of hot water which has been plotted in triangular diagram, the types of geothermal hot water at Sanggabuana mountain area and its surroundings is divided into three types of water, there is:

3.2.1. Water Chloride

This type of water is located in the hot springs at the Cimandala 1. This type of water has a high Cl content of 69.26%, SO$_4$ content of 26.46% and HCO$_3$ content of 4.28%. This type of water represents geothermal fluid that originating from the internal reservoir. This may be due to the presence of HCL gas condensation derived from the magmatic gas into the water at the manifestation. This type of water typically has a pH near-neutral, and in an upflow zone.

3.2.2. Water Sulfate

This type of water is located in the hot springs at the Cimandala 2, Cimandala 3, and Cimandala 4. This type of water has a high SO$_4$ content ranging from 77.8 - 80.16%, HCO$_3$ content ranging from 11.73 - 13.69% and Cl content ranging from 6.27 - 10.40%. This water is formed by the condensation of the geothermal gas into the ground water near the surface that contain high amount of oxygen. This type of water cannot be used to determine the subsurface temperature because its chemical content does not represent the reservoir condition and its essentially derived from groundwater heated by steamheated steam. Because of its process it is called the sulfate water type in the Outflow zone.

3.2.3. Dilute Chloride (Bicarbonate) Water
This type of water is located in the hot springs at the AD. Ciangsana. This type of water has a high \( \text{HCO}_3 \) content of 67.72%, SO4 content of 17.89% and Cl content of 14.39%. This water formed due to the attenuation of water chloride due to contact with ground water or bicarbonate water during lateral migration resulting the formation of \( \text{HCO}_3 \). This type of water can also be an indicator of the area around the boundary of upflow and outflow zone in high temperature geothermal system.

![Figure 2. ternary Diagram content of Na, K, Mg in Sanggabuana area hot water and its surroundings](image)

The triangular diagram of Na/1000-K/100-Mg\(^{1/2}\) shown by Giggenbach (1988) is a method that used to estimate the reservoir temperatures and to find water that achieves an equilibrium in lithology. From the data and calculation, the plotting of the Na/1000-K/100-Mg\(^{1/2}\) in triangle diagram (Figure 2) for each hot spring sample. Based on the calculation result of relative content of Na/1000–K/100–Mg\(^{1/2}\) which has been plotted in triangular diagram, From the data processing indicate that manifestation in Cimandala 1, Cimandala2, Cimandala 3, Cimandala 4, and AD. Ciangsana is on immature water zone which is the fluid is in equilibrium, this zone also indicates that manifestation temperature that comes to the surface tend to have low temperature and is influenced by the interaction between hydrothermal fluids with elements such as silica, also immature water condition also indicates that reservoir rocks located at high pressure and temperature condition where before comes to the surface also has undergone dilution by surface water (meteoric water).

High concentration of Mg in the calculation and plotting results on immature water, indicates that in the forming of ground geothermal manifestation is very affected by meteoric water. on its way to the surface, the geothermal fluid has is has some contact with meteoric and shallow groundwater. Attenuation or dilution of the geothermal fluid is due to contact with meteoric and shallow groundwater.

3.2.4. Calculation of Na-K-Ca Geothermometer

Furthermore from the chemical analysis can be known the reservoir temperature (T). The temperature (T) is known based on Na-K-Cageothermometer calculations Fournier and Truesdell (1973), The use of Na-K-Cageothermometer calculation because from the elemental analysis known that element Na-K-Cacation is much contained and dominate than other cation elements.

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T^\circ\text{C Na-K-Ca} = \frac{1647}{\log_{10} + 107.58 + 2.06 + 2.47} = 273
\]

The result from calculation of Na-K-Cageothermometer is known that reservoir temperature at Cimandala 1 is 92.6279°C, and AD. Ciangsana is 50.617°C, so it is included in the Low Temperature system [7,8]. The temperature (T) result of the Na-K-Cageothermometer calculation is not the exact temperature (T) of the geothermal reservoir at the study site, but is a near-same range temperature, possibly the actual reservoir temperature may be higher or lower than the temperature from the calculation. This is due to the flowing geothermal fluid that flows near the surface, many soluble elements settle on the surface, especially the Na-K-Ca element, so that the chemical content contained in the fluid of the sample differs with the fluid in the reservoir.
4. Conclusion
Cimandala 1 has a chloride water type as an upflow zone characteristic. Cimandala 2, Cimandala 3, and Cimandala 4 having sulfate water type as the outflow zone identifier, and AD. Ciangsana has a water type Dilute Chloride (bicarbonate) as the borderline between the zone of upflow and outflow.

The reservoir temperature based on the geothermometer calculation is 50.617°C - 92.6279°C. The area of Sanggabuana mountain area and its surroundings hot springs are a low temperature system.

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