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Geohydrology, geochemistry, geothermal potency of Rianiate Toba Lake North Sumatera

Juliper Nainggolan^{1,*}, Cristin Sitepu¹, Sanggam Pardede¹, Markus Diantoro²
Department of Physics, Nommensen HKBP University Jl. Sutomo No. 4a Medan,
Indonesia

Department of Physics, Faculty of Mathematics and Natural Sciences, State
University of Malang, Jl. Semarang 5 Malang 65145, Indonesia

*juliper_n@yahoo.com

Abstract. This research was performed to determine the potency of Rianiate's geothermal an alternative of energy source and determine the types of geothermal that was begun with the position's measurement by using GPS (Global Position System), and then the direct observation of chemical and physical properties such as pH, surface's temperature, color etc. The following steps were taking sample in four different springs indicated by spring 1, spring 2, spring 3, and spring 4. The chemical nature was measured by titrimetry method by using AAS, XRD, and gas Chromathology. The calculating of temperature of subsurface has done by using geothermometer and sequentially followed by geothermal potency's calculation. The position of four springs are located about N: 02° 31,852' and E: 098° 44.021' where were average height from sea's level is 958 m. The highest surface's temperature is 80 °C and the temperature under soil is about 130.5 °C described the average of geothermal. The calculation of content of chloride, sulfate, bicarbonations revealed that the water can be categorized as chloride type. The trilateral diagram Na/1000 – K/100 - $\sqrt{\text{Mg}}$ of hot water is in the regime of *immature water*. From the calculation of Indonesia's Standardized Geotherm, it was obtained that the estimated reservoir potency of Rianiate geotherm is 2,68 MWe.

1. Introduction

The increase of energy demand is strongly relates to the increase of civilization, industries and daily life. It is about 87% of world energy consumption is from fossil. Oil and coal is decreasing in potentially (Gençer and Agrawal, 2016). Another colossal potency of energy source may be coming from geothermal which should be a huge amount available in Indonesia. Geothermal is a source of energy, such as hot water, steam heat, and other gases. Scientists defined that the geothermal energy as the amount of heat that comes from the earth and is close enough to the surface of the earth that can be use economically. Indonesia has abundant geothermal potency, but less explored.

Estimation of geothermal energy potential is base on geological, geophysical and reservoir studies. Geological studies are more emphasize on volcanic systems, geological structures, rock age, type and type of rock changes in relation to geothermal systems. Geochemical studies are emphasizes on the type and level of water mature, the origin of hot water hydrological models and their fluid systems. Geophysical studies produce physical parameters of rocks and subsurface structures of geothermal systems. The reservoir engineering study yields a technical phase that defines the classification of reserves including the physical properties of rocks and fluids as well as the removal of fluids from the reservoir.



The previous of our unpublished work has performed in Dolok area, North Sumatera (2010). We have measured using a geothermometer, than followed by measuring chemical elemental analyses of hot spring. We found that the chemical elemental content of Dolok Marawa area contain of Na, K, Mg, Ca, and SiO₂. We also found that the reservoir temperature was about $\pm 187^{\circ}\text{C}$ (Cristina, 2010).

Basically a geothermal system basically was formed as result of heat transfer from a heat source to its surroundings which are occurred by conduction and by convection. The occurrence of geothermal energy sources in Indonesia and its characteristics are briefly described as follows (Hazuardi, 1992): There are three plates interacting in Indonesia, namely the Pacific plate, the Indian-Australian plate and the Eurasian plate. The collision between the Indian-Australian plate to the south and the Eurasian plate in the north produced subduction zones at a depth of 160 - 210 km below Java-Nusa Tenggara Island and at depth of about 100 km under the island of Sumatra (Herdianita, 2006). Based on the magnitude of the temperature, Ralph (1985) distinguishes the geothermal system into three, there are low ($<125^{\circ}\text{C}$), moderate ($125^{\circ}\text{C} - 225^{\circ}\text{C}$), and high ($>225^{\circ}\text{C}$) temperature heat systems.

It is difficult to get information related geophysics, geology, geochemistry, as well as geothermal condition of Toba lake area, although a preliminary investigation has been performed by a group of research by Ari et al. (2012). Unfortunately, there is insufficient information could be obtained from the previous report. So far, in our knowledge, there is not comprehensive report related to the geochemistry, geophysics, geohydrology, and geothermal conditions of Toba lake area, especially in Rianiate district. In order to obtain the important information to predict the potency of geothermal in Rianiate, we have performed an investigation four different springs, and related rocks and soils in the area of Toba lake. The investigation was comprehensively performed involving geochemistry, geophysics, as well as geothermal experiment.

2. Materials and Method

The research conducted in Rianiate Village, Pangururan sub-district which administratively under governance of Samosir Regency. Geographically, this area is located at position $98^{\circ}42' - 98^{\circ}47'$ East Longitude and $2^{\circ}32' - 2^{\circ}45'$ North latitude. This location has an area of 121.43 km², with the boundaries of the region is as follows. North side is Simanindo Sub-district, South side is District Palipi, West side is Sianjur Mulamula District, and East is Ronggur Nihuta District.

2.1 Geophysics Investigation

The principle of conducting a survey of resistance type is by injecting an electric current through electrode current and measuring its response (voltage) to a potential electrode in a particular configuration (Hochstein, 1982). Geoelectric survey was carried out as the following procedure: Determine the 3 paths of data retrieval and simultaneously determine the position of the survey area by using GPS. Measuring distance between electrodes (5 m) on specified path. Data collection using the Geoelectric (Resistivity meter) ARES-G4 v4.7, SN:0609135 (Automatic Resistivity System) schlumberger method on specified path. Processing data obtained from the Geoelectric data using Res2Dinv software to obtain 2D cross-sectional model along the track. The data obtained were presented indifferent colors. Each color indicates resistivity difference in each layer of the 2D cross-sectional model along the path.

2.2 Geohydrology Investigation

Geohydrological investigations in addition to measuring water debit, the number of springs, also investigate water absorption, groundwater runoff, electrical conductivity, and surface flows.

2.3 Geochemistry Investigation

The geochemical investigation focused on chemical content analysis. The existed chemical element may include pH, Hg and CO₂, SiO₂, Al, Fe, Ca, Mg, Cl, SO₄, HCO₃, As, F, Hg, CO, CH₄, H₂, O₂, N₂, NH₃, SO₂, CO₂, H₂S and HCl by titrimetric methods using AAS, Gas Chromatography, and other equipment. These results used to determine the water type of the area (chloride type, sulfate type or carbonate type). Chemical analysis has taken the rock's sample just under spring by means of X-Ray diffraction technique. The instrument used in this experiment was Philips PW 1710 diffractometer of UNIMED Physics Laboratory. The anode or target used is copper (Cu) with the typical wavelength of $\lambda = 1.56054 \text{ \AA}$. The measurement was performed under voltage used s 40 KV with a current intensity of 30 mA.

3. Results and Discussions

Firstly, we describe the hot springs in terms their specific geological location, physical as well as chemical properties. The four springs identified as spring 1, spring 2, spring 3, and spring 4. The spring1 is gushing water that has passed through the rock gap away from the source the real. The gushing water is at the coordinates of N: 02° 31,852' and E: 098° 44, 021' with the elevation from mean sea level (msl): 958 m, there are air temperatures of 26° C and hot water surface temperature of 43° C with pH of 6.2. Water in acidic conditions is seen from changing of blue litmus paper color to be a red and the red litmus paper unchanged when was immersed into the sample. The Spring 2 is at the coordinates of N: 02° 31.813 'and E: 098° 44,014' with the elevation from mean sea level (msl): 946 m, there are air temperatures of 26° C and hot water surface temperature of 77° C with pH of 6.3. Water in acidic conditions are seen from changing of blue litmus paper color to be a red and red litmus paper unchanged when was immersed into the sample. The spring 3 is at the coordinates of N: 02° 31, 785 'and E: 098° 44', 045' with the elevation from mean sea level (msl): 977 m, there are air temperatures of 26.5° C and hot water surface temperature of 79° C with pH of 6.5. Water in acidic conditions seen from changing of blue litmus paper color to be a red and red litmus paper unchanged when immersed into the sample. The spring 4 is at the coordinates of N: 02° 31, 759 'and E: 098° 44', 060" with the elevation from mean sea level (msl): 930 m, there are air temperatures of 27° C and hot water surface temperature of 80° C with pH of 6.4. Water in acidic conditions is seen from changing of blue litmus paper color to be a red and red litmus paper unchanged when was immersed into the sample.

3.1 Geochemistry of springs

Geochemical analysis is very helpful to obtain information about reservoir condition for determining characteristics of geothermal in the study area. Chemical analysis conducted at PT Sucofindo. In the geochemical process of hot spring of the research area, that is known that heat transfer is accompanied by chemical reactions from the magma as a heat source with the medium through which the reservoir and the rock cover up by heat to reach the surface. The indication of heat transfer and the chemical reaction, can be obtain from the content of the elemental/ chemical content (Ca, Mg, K, Na, Cl, NH₃, SO₄, Hg and HCO₃) which is relatively constant in the hot spring sample.

3.2 Type of hot springs

To determine types of hot water, we calculated the ion content in meq/L, the result was compared using trilinear classification diagram. In this case, we focus on the relative content of chloride, sulfate, and bicarbonate ions. The amount of ion content is expressed in units of meq/L (miliequivalent per liter), so it must be converted from ppm to meq/L. The conversion was calculated using $\text{Meq/L} = \text{ppm}/(\text{Rel. atomic mass compound}/\text{Valence})$. From laboratory test data, calculation of chloride ion, sulfate and bicarbonate ions to determine the hot spring type for springs 1, 2, 3 and 4 as in table 1.

Table 1. The chloride, sulfate, and bicarbonate ion content of various spring.

content (%)	Spring 1	Spring 2	Spring 3	Spring 4
HCO ₃	0.00	0.00	0.00	38.71(9)
SO ₄	4.36(0)	7.18(5)	10.02(2)	7.45(3)
Cl	95.63(9)	92.81(4)	89.97(7)	53.82(7)

Based on the percentage of ion content in hot water samples which have been analyzed chemical element content especially Bioarbonate anion content (HCO₃⁻), Chlorida (Cl⁻), and Sulfate (SO₄²⁻) that be determined trough Water type. The four of hot springs were included in the chloride type, especially the spring 1, 2, and 3 samples. This is characterized by the high content of chloride ions in hot water compared to the concentration of bicarbonate and sulfate. Also characterized by a relatively acidic pH (pH between 6.3 - 6.5) and surface temperatures between 43 °C to 79 °C. Further anlysis was converting the three chemical indicators of natrium, potassium and magnesium into a specific ratio of Na/1000, K/100 and $\sqrt{\text{Mg}}$. The results of calculation is depicted in table 2.

Table 2. Elemental ratio of Na/1000, K/100, and $\sqrt{\text{Mg}}$

Springs	Na/1000	K/100	$\sqrt{\text{Mg}}$
1	0.00084	0.001	0.52
2	0.0879	0.2189	0.89
3	0.02978	0.1711	0.94
4	0.0886	0.001	0.74

Based on table 2, the water type was determined by using triangle diagram, generally the water under inspection is in the immature waters area. Although the composition of the most dominant ionic ratio of Na/1000 – K/100 - $\sqrt{\text{Mg}}$ relatively difference, the global type are similar. It means that the hot water springs has contaminated by surface water.

3.3 Temperature under soil surface of springs

The calculation of under soil surface performed using Equation 1, Equation 2, and Equation 3 for geothermometer (SiO₂), geothermometer Na-K, and geothermometer Na-K–Ca, respectively. The SiO₂ in Equation 1, Na, K in Equation 2 and Na, K, Ca in Equation 3 is the respective content in mg/L. The results of temperature calculation using Equation 1, 2, and 3 can be concluded that the closed reliable value of reservoir temperature are 130.5°C. If the average temperature reduced gradient is 3°C per km, it could calculated that the surface temperature is about 69.75 °C and the reservoir temperature is 130.5 °C, the depth of the reservoir is 20.25 km from the surface.

Other important identity is the mineral containing in the underwater springs as well as the crystallinity. A small sample of the rock has just taken and inspected under X-RD machine

using Cu-K α wavelength. The main peaks are found to be at the position of $2\theta = 22.56^\circ$, 29.9° , 31.46° , 35.94° , 48.61° , and 59.96° are fit with the database AMCS0000098 of Markgraf dan Reeder (1985). Those peaks exactly fit with calcite CaCO_3 . The intensity and the full width at half maximum (FWHM) of the pattern may be described sample preparation or from the rock properties. It obtained that the rock is calcite, while the relative wide of FWHM is describing a relatively low crystallinity of the rocks. This result told us that the rocks may be not naturally built in relatively low pressure.

3.4 Geohydrology

By inspection of the surface temperature of the four samples, samples from spring 2, 3, and 4 are categorized a high temperature regime at about 79°C . This shows that these three hot springs are relatively close to the reservoir compared to the spring 1 sample. The water of spring 1 sample has undergone cooling in the distant stream through the rock gap. So that the surface temperature is very low compared to the other samples. The four samples can be said to have contaminated with surface water. This can be seen from the $\text{Na} / 1000\text{-K} / 100 - \sqrt{\text{Mg}}$ diagram.

The precipitation area is only about 20%. In this area, rainwater precipitates into the earth through the permeability of the rock (feed - zone) then flows into the lake Toba. The area under investigation is measured by the geothermal manifestation of about 2.2 km^2 . To determine the potential of geothermal water as an alternative energy source based on Indonesian Geothermal Potential Standardization (DGSM, 1999) is $Q = 0,11585 \times A \times (T_{\text{Res}} - T_{\text{cut-off}}) ^\circ\text{C}$. By putting the cut-off temperature as $120 ^\circ\text{C}$, the potency of expected geothermal of Rianiate is 2.68 Mwe.

3.5 Geophysics

Data retrieval in this research is done by using tools of geoelectric (resistivity meter), ARES G4 v4. 7 SN: 0609135 (Automatic Resistivity System), GPS (Global Position System) and compass on three tracks. Results Measurement and data processing on the three tracks are as follows: First trajectory (crater 2): apparent resistivity (ρ_a) varies considerably between 1.6 to $444 \Omega\text{m}$. Second trajectory (crater 1): apparent resistivity (ρ_a) varies considerably between 2.02 to $144.66 \Omega\text{m}$. The third trajectory (side along the highway): The apparent resistivity (ρ_a) varies greatly between 3.48 to $94.81 \Omega\text{m}$. These prove the underground structure is highly inhomogeneous.

4. Conclusions

Based on the results of data research processing was found that the apparent resistivity (ρ_s) vary from $1.62 \Omega\text{m}$ to $444 \Omega\text{m}$. It is revealed that the underground soils are not homogeneous. The three types of geothermometer of reservoir temperature calculation were SiO_2 geothermometer. The expected temperature was 130.5°C . Based on the trilinear diagram of chloride, sulfate, and bicarbonate ions content, the Rianiate's hot water can be categorized ionic chloride's type. Further analyses of element ratio of $\text{Na}/1000$, $\text{K}/100$, and $\sqrt{\text{Mg}}$ it could be concluded that the four hot springs are *immature water* area. It means that the water had contaminated by surface water. The rocks of Rianiate area is mostly calcite under XRD inspection. The low intensities of the XRD pattern indicating that the crystallinity of calcite is not high. We found also that the precipitation area just about 20%. The rains water precipitates into the earth through the feed zone of rock's permeability. The remaining water

flows to Toba lake through small river which are laying the three craters. We also found that the reservoir of geothermal potency of Rianiate is 2.68 Mwe.

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