The estimation of potential heatloss based on thermal geochemical data in the Mount Pancar, Bogor, West Java Province

R Deandra and F Hendrasto

1Department of Geological Engineering, Faculty of Earth and Energy Technology, Universitas Trisakti, D Building 2nd Fl, Campus A Usakti, Jl. Kyai Tapa No. 1 Jakarta 11440, Indonesia

*corresponding author: raideand@gmail.com

Abstract. The research area is located in Mount Pancar, Karang Tengah and the surrounding area, Bogor District, West Java Province. The object of this research is the geochemical characteristics of the manifestation of hot water. The manifestations on the hot springs water that appear are chloride, sulphate and bicarbonate water. Water conditions in the study area is immature water, and comes from seawater. Reservoir temperature in this research area is estimated less than 125°C and classified into a low temperature system. Heatloss estimation shows that the study area has the potential of 224.38 kW.

Keywords: Geochemistry, hot water, manifestation, heatloss.

1. Introduction

To determine the potential for the geothermal field, there are some analysis that must be done. One of them is to determine the type of water, subsurface temperature, and also heatloss contained in the geothermal field. Under these conditions, the research include: literature, interpretation and analysis of water geochemical data, and analysis heatloss conducted in the area of Mount Pancar, Bogor, West Java Province as been showed in Figure 1.

Figure 1. Appearance of the research areas from satellite image (Google Earth, November 10, 2017, 15:07 pm).
2. Regional Geology

2.1. Study Area Physiography

The study area is situated in the Bogor zone physiography. This zone is located on the south of the Jakarta Coastal Plain and extends to northwest through the city of Bogor, Purwakarta and continue up to Bumiayu area, Central Java. Bogor Zone has a hilly morphology, generally elongate from west to east in the south of the Bogor city. Meanwhile, on the east of Purwakarta, this hill turned south. Some intrusions have formed other morphologies as well, for example, Mount Sanggabuana (Purwakarta) and Mount Kromong (Cirebon).

2.2. Study Area Stratigraphy

Stratigraphy research area consists of 7 rock formations. The oldest stratigraphy is in Tmk Formation (Klapanunggal Formation) in early Miocene age that has an interfingering relation with the Tmj Formation (Jatiluhur Formation). Then, there is a formation of andesite with oligoclas-andesin, augit, hipertien, and hornblende, forming fractures, then Qvk Formation which is breccia and lava of Mount Kencana and Mount Limo. The next formation is Qvpo Formation of older sediments, volcanic mudflow and lava, basal andesite with oligoclas-andesin, labradorite, olivine, piroksen and hornblende. The next formation is the Qav Formation which is alluvium, and the youngest formation is qa Formation and that is alluvium.

3. Basic Theory

3.1. Geothermal Systems

Geothermal system is the convection of water in the upper crust in a limited space of geothermal flow from the heat source to the heat absorption at the surface (Hochstein and Browne, 2000). In determining the geothermal system, there are several things to be determined. The type of geothermal system in an area that is based on the reservoir equilibrium conditions, type of fluid, temperature reservoir, the host rock, and the heat source (Nicholson, 1993).

3.2. Water Geochemistry

Chemical properties of surface water geothermal manifestations such as hot water have a various chemical content. Chemical content is useful for interpreting the geothermal exploration activities. Water geochemistry used to determine the equilibrium concentration of ions, the type of geothermal water, geothermal water source, geothermometer, geoindicator, and isotopes.

3.2.1. Geothermal Water Type

In determining the type of geothermal water, the chemical data that is needed is the relative content of Cl, HCO3 and SO4. In determining the type of geothermal water use the triangular diagram Cl-SO4-HCO3 (Giggenbach (1991) in Powell and Cumming (2010)).

Here are the types of geothermal water by a triangular diagram Cl-SO4-HCO3 (Figure 2):

a. Chloride Water (Cl)

Area with this water type is characterized by areas with hot springs that flow in large scale with Cl-concentration coming from the reservoir. The hot springs with a high chloride element, a few elements of bicarbonate and sulphate indicate the outflow area in geothermal reservoirs (Powell, 2010). Chloride is an dominant anion element in this type of water, with a general concentration around 1,000 mg/kg up to 10,000 mg/kg. Chloride types of water has a pH that varies, starting from slightly acidic to slightly alkaline, which is almost neutral.

b. Bicarbonate Water (HCO3)

Hot water bicarbonate is the result of condensation of CO2 into the subsurface water or oxygen-poor groundwater. This indicates the water type boundary zone (peripheral waters) in the geothermal field.
The main ion in this type of water is $\text{HCO}_3^-$ and has a pH close to neutral as a result of the reaction of water with the local rock.

c. Sulfate Water (SO4)

This water type is the results from the shallow oxidation of water condensed by geothermal energy gas near the surface. This water type is found close to the upflow zone on a topographic height above the groundwater level. This type of hot water has a high ion $\text{SO}_4^{2-}$, $\text{Cl}^-$ and very low $\text{HCO}_3^-$ (sometimes 0), and a pH of 2-4 (acid). In this type of water, sulfate is the major anion and condensation formed by the oxidation of hydrogen sulfide.

![Figure 2. Triangle Cl-SO4-HCO3 (Giggenbach, 1991, in Cumming and Powell, 2010).](image)

3.2.2. Origin Water Geothermal

In determining the origin of geothermal water, use triangular diagram Cl-Li-B (Giggenbach., 1991 in Cumming and Powell, 2010) as been showed in Figure 3. The use of the elements Cl, Li, and B is to determine the origin of geothermal water based on the properties of both elements are dissolved and does not easily react when in solution (Simmons, 1998).

![Figure 3. Diagram Cl-Li-B.](image)

3.2.2.1. Equilibrium Fluid

Giggenbach (1988), in Powell and Cumming 2010 developed an indicator diagram triliner Na-K-Mg which combines geothermometer equation Na-K with K-Mg in the diagram (Figure 4). Plotting data on a diagram of Na-K-Mg requires a scaling factor because there is a huge difference in the value of a concentration of the three components.
Figure 4. Diagram triangle Na-K-Mg (Giggenbach, 1988 in Powell and Cumming, 2010).

3.2.3. Heatloss Calculation

The calculation of heat loss for the manifestation in the form of hot springs:

\begin{equation}
Q = m (H_{fT} - h_{fT0}) \approx mc (T - T_0)
\end{equation}

Where:
- \( M \) = mass flowrate (kg/s) = \( V \cdot p_f \rho_f \) fluid density (kg m\(^3\))
- \( V \) = vol. flow rate (m\(^3\)/s)
- \( H_{fT}, H_{fT0} \) = fluid enthalpy (kJ kg) - using steam table
- \( T \) = temp. of discharge fluids
- \( T_0 \) = mean annual temperature (from climatological station nearby using a mean lapse rate of -7\(^\circ\)C/100m)
- \( c \) = specific heat capacity (kJ/kg\(^0\)K)
- \( c \) for water has average value = 4.2 kJ/Kg\(^0\)K

Calculation of heat loss for the manifestation in the form of hot pool (Dawson, 1964):

\[ H_{L_{evaporasi}} = H_F \times A \text{ (kWatt)} \]

Where:
- \( H_L \) = heat loss (kWatt)
- \( H_F \) = heat flow / heat flow (kW/m\(^2\)) \( A \) = area appearance (m\(^2\))

4. Result and Discussion

4.1. Data

Data that is used in the study is the temperature of the hot springs, discharge manifestations, extensive manifestation, outside air temperature and water geochemical data located in the area of Mount Pancar, Bogor, West Java Province.

4.2. Analysis of Geochemical Mount Pancar Area

Chemical analysis of data using primary data in the form of chemical elements and compounds from water samples taken from three geothermal manifestations around the Mount Pancar area. Samples taken from hot spring manifestations, they are Kawah Merah (KM), Kawah Hitam (KH), and Kawah Putih (KP).
4.2.1. Regional Water Chemical Analysis Mount Pancar

Water analysis is based on the content of elements and compounds from chemical sample data hot springs manifestation in the study area (Table 1).

4.2.2. Geothermal Regional Water Type Mount Pancar

Analysis of the type of geothermal water area of Mount Pancar using a triangular diagram Cl-SO4-HCO3 (Giggenbach., 1991 in Powell and Cumming., 2010). From the results of the triangular plot diagram, type of geothermal water area of Mount Pancar consists of three types of water (Table 2) (Figure 5), including:

Table 1. Data manifestation from water chemistry samples (analysis in the Lab. of Water Quality FTSL ITB, 2017).

| No. | Code | Suhu | pH   | Li⁺ | Na⁺ | K⁺ | Ca²⁺ | Mg²⁺ | SiO₂ | B  | Cl⁻ | SO₄⁻ | HCO₃⁻ | Total |
|-----|------|------|------|-----|-----|----|------|------|------|----|-----|-------|-------|-------|
| 1   | KM   | 65.5 | 7.57 | 1.1 | 0.1 | 0.7 | 371  | 17.2 | 66.8 | 1.87| 1167| 560   | 70.4  | 1787.4 |
| 2   | KH   | 57.4 | 7.7  | 0   | 0.1 | 0.65| 162  | 42   | 55.6 | 0.32| 74.1| 545   | 69    | 688.1 |
| 3   | KP   | 43.5 | 7.69 | 0.08| 0.08| 0.48| 48   | 4.62 | 45.6 | 0.27| 21  | 105   | 69    | 15108 |

Table 2. The calculation of the percentage data for a diagram Cl-SO₄-HCO₃.

| No. | Code | Cl⁻ (ppm) | SO₄⁻ (ppm) | HCO₃⁻ (ppm) | Total | % Cl | % SO₄ | % HCO₃ |
|-----|------|-----------|------------|-------------|-------|------|-------|-------|
| 1   | KM   | 1167      | 560        | 70.4        | 1787.4| 64.927 | 31.156 | 3.917 |
| 2   | KH   | 74.1      | 545        | 69          | 688.1 | 10.769 | 79.204 | 10.028 |
| 3   | KP   | 21        | 105        | 151.8       | 277.8 | 7.593  | 37.797 | 54.644 |

From Table 2 above it can be concluded that the manifestation KM Cl content of 65%, 31% SO₄ and HCO₃ by 4%. In manifestation KH Cl content of 11%, SO₄ at 79%, and HCO₃ at 10%. At KP manifestation Cl content of 8%, 38% SO₄ and HCO₃ of 55%.

1. Chloride Water
   This water type is shown in hot water samples KM. Having a dominant Cl concentration (1,167 ppm) with concentrations of SO₄ and HCO₃ relatively small. It has a neutral pH 7.57.

2. Sulfate Water
   This water type is shown on the manifestation of hot springs KH. SO₄ abundant element in the manifestation comes from the oxidation of hydrogen sulfide (H₂S) on groundwater that is formed near the surface that is rich in oxygen (O₂) (Nicholson, 1993).
Figure 5. Diagram triangle Cl-SO4-HCO3 in research areas (Giggenbach., 1991 in Powell and Cumming., 2010).

The hot springs KH has a neutral pH (pH = 7.7). KH hot springs has SO4 concentration tends to be high (545 ppm) compared to the Cl concentration (74.1 ppm) and HCO3 (69 ppm).

3. Bicarbonate Water
   HCO3 with relatively large element (151.8 ppm) in this manifestation is derived from the condensation of CO2 in groundwater or surface water that has less oxygen. Having a near-neutral pH (pH = 7.69).

4.2.3. Origin Water Geothermal
   Geothermal manifestations KM, KH, and KP is located in the same reservoir zone indicating that the manifestation of all types of hot water coming from the same reservoir at geothermal systems area of Mount Pancar (Figure 6).

Figure 6. Diagram triangle Cl-Li-B (Giggenbach in Powell and Cumming, 2010).

4.2.4. Equilibrium Fluid Mount Pancar Area
   Based on a triangular diagram of Na-K-Mg(Giggenbach., 1991 in Powel and Cumming (2010) as shown in Figure 7, it can be seen that the hot springs KM, KH, KP classified into immature waters. Conditions such as these indicate that all the hot springs in the study area is groundwater that has been heated by steam.
4.3. Heat Loss Estimation Results
From the data taken in the area of research it is known that the large surface heat energy loss was calculated as follows (Table 3)

|   | KM  | KH  | KP  |
|---|-----|-----|-----|
| 1 | 132.22 kW | 68.89 kW | 23.27 kW |

**Table 3.** Estimation of heat loss from geothermal manifestations in the area of Mount Pancar

**Kawah Merah (KM)**
- Coordinate: Latitude 6.588855811581, Longitude 106.9243409503
- pH = 7.57
- Plenty of air bubbles
- Sulfuric odor
- Elevation 430 m

area 18.85 m², discharge = 0.315 l/s
water temperature = 65.5°C
outside temperature = 28.6°C

\[ Q = m \cdot c \cdot (T - T_0) \]
\[ = 0.315 \times 10^{-3} \text{m}^3/\text{s} \times 990 \text{kg/m}^3 \times 4.2 \text{kJ/kgK} \times (65.5 - 28.6)\degree \text{C} \]
\[ = 48.33 \text{kW} \]

\[ Q = m \cdot (h_{ft} - h_{ft0}) \]
\[ = 0.315 \times 10^{-3} \text{m}^3/\text{s} \times 990 \text{kg/m}^3 \times (274.1 - 119.92) \text{kJ/kg} \]
\[ = 48.11 \text{kW} \]

\[ H_{\text{evaporation}} = H_f \times A \text{ (kW)} \]
\[ = (5.2125 - 0.7565) \text{(kJ/m}^2\text{s}) \times 18.85 \text{m}^2 \]
\[ = 84 \text{ kW} \]

\[ H_{\text{map}} = (48.33 + 48.11) \times 2 \text{ kW} \]
\[ = 96.46 \text{ kW} \]

\[ H_{\text{tot}} = 48.22 + 84 \]
\[ = 132.22 \text{ kW} \]

**Kawah Hitam (KH)**
- Coordinate: Latitude 6.5874500200152, Longitude 106.92402600311
- pH = 7.7
- Plenty of air bubbles
- Less sulfuric odor
- Elevation 422 m

Area 19.48 m², discharge = 0.13 l/s
water temperature = 57.4°C
outside temperature = 31.8°C

\[ Q = m \cdot c \cdot (T - T_0) \]
\[ = 0.13 \times 10^{-3} \text{m}^3/\text{s} \times 990 \text{kg/m}^3 \times 4.2 \text{kJ/kgK} \times (57.4 - 31.8)\degree \text{C} \]
\[ = 14 \text{ kW} \]

\[ Q = m \cdot (h_{ft} - h_{ft0}) \]
\[ = 0.13 \times 10^{-3} \text{m}^3/\text{s} \times 990 \text{kg/m}^3 \times (240.28 - 132.46) \text{kJ/kg} \]
\[ = 13.9 \text{ kW} \]

\[ H_{\text{L}} = H_f \times A \text{ (kWatt)} \]
\[ = (0.39-0.57) \text{(kJ/m}^2\text{s}) \times 19.48 \text{m}^2 \]
5. Conclusion

Based on the results of this analysis, the results obtained the following conclusions:
1. The type of hot springs water in Kawah Merah is chloride water, in Kawah Hitam is sulfuric water and in Kawah Putih is bicarbonate water.
2. The research area has a geothermal potential of about 224.38 kWth.

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