Hydrogeochemical model of Ciseeng geothermal field, Bogor, West Java

M A Ponka, D N Sahdarani, D T Kurniadi, D A Yoga, F M H Sihombing and Supriyanto
Geoscience Study Program, Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Indonesia, Depok 16424, Indonesia

Corresponding author’s email: dyahnindita@ui.ac.id

Abstract Ciseeng geothermal field is located Northwest of West Java 40 km from Jakarta. Three surface manifestations are in Tirta Sayaga, Panjang Mountain, and Peyek Mountain. This study aims to build a hydrogeochemical model based on water analysis. The secondary regional geological data are retrieved to complete geological information of Ciseeng. The research method is divided into several stages: introduction includes the literature study, data collection includes the measurement of temperature and pH in several surface manifestations, rock sampling and structural geology analysis in Ciseeng. The type of manifestation that can be found in Ciseeng is a warm pool with chloride fluid type. Extensive travertine deposits were found in all three locations. The fluid temperature of three surface manifestations is about 30-38 °C with pH 6. According to the measurement of Na-K-Ca geothermometer, the reservoir temperature in Ciseeng geothermal field is 180 °C. The three manifestations of Ciseeng geothermal field are classified as mature water based on a ternary plot diagram. The isotopic analysis shows shifting in O18 indicating hydrothermal process due to magmatic activities in the subsurface. It is predicted that Ciseeng geothermal field is part of Salak/Pangrango Mountain geothermal system. The presence of surface manifestation confirms that geological structure trending from North to South, play a significant role to circulate the heated fluid in the subsurface and subsequently to the surface. The result is a geothermal conceptual model of Ciseeng field that shows the fluid origin and movement in the subsurface.

Keywords: Ciseeng, hydrogeochemical, geochemistry, geothermal

1. Introduction
Geochemical analysis is early indicators to evaluate the potential of geothermal resources [1, 2]. Geothermal fluid analysis can demonstrate the variation in both chemical and isotopic compositions that infer their evolution [3]. Moreover, isotopic analysis of geothermal fluids can serve as their genesis and recharging area.

One of the existence indicators of a geothermal system is by the appearance of surface manifestation. Travertine deposits and thermal springs are common features for most geothermal areas [4]. Subsurface hydrogeochemical condition can be interpreted through the characterization of surface manifestations, deposits and alterations, and also from the characteristics of the thermal fluid [5]. Geochemical data in Ciseeng is very limited and outdated. This research aims to update geothermal fluid characteristic of
Ciseeng geothermal field and to create a preliminary hydrogeochemical model of Ciseeng geothermal field based on the origin and fluid chemical characteristics.

2. Geological Overview

Ciseeng geothermal field is in Parung, West Java (60 km south from City of Depok) as shown in figure 1. Three distinguishable travertine deposit mounts are spread throughout the area, Tirta Sanita Bathing Place, Panjang Mountain dan Peyek Mountain, respectively.

Figure 2 explains that there are five types of lithology in Ciseeng geothermal field:
- Quaternary Alluvium (Qa) is a surface deposit that is located in Jakarta plain as a swamp or stream deposit.
- Undak Purba Deposit (Qofc) is the product of precipitation from marine sedimentary rock and weathered volcanic rock.
- Volcanic Breccia Rock (Tpb) is the volcaniclastic sedimentary deposit with ancient lava deposit mechanism.
- Tuff Sandstone (Tnt) is deposited unconformity as disconcordance with sedimentary Miocene rock.
- Limestone (Tml) could be correlated with Lower Miocene limestone in Klapanunggal, unconformity under tuff sandstone unit.

3. Methodology

We limit the area for this research within a 0.7 x 0.7 km² area as shown in figure 3. Several rock samples and geological data were collected from the field. Field sampling includes rock and thermal water samples. Three warm spring water samples were collected from three different manifestations, includes of Tirta Sayaga 1, Tirta Sayaga 2, and Gunung Peyek. Three warm spring water samples were collected from three different manifestations, includes of Tirta Sayaga 1, Tirta Sayaga 2, and Gunung Peyek (figure 4).

Thermal fluid sampling follows the procedure in where untreated and treated samples (with addition of HNO₃) were retrieved [8]. Water analysis was carried out in Pusat Sumber Daya Geologi, Bandung. The laboratory results were then calculated and plotted using Powell calculation to determine the fluid characteristics, number of reservoirs, the origin of the fluid and geothermometer to predict reservoir temperature.

To help with data interpretation, we use secondary data based on the availability of satellite images and geological map of Parung, West Java. Stratigraphic, arbitrary structure and cross section from such geological map was used as a base for the preliminary hydrogeochemical model. Subsequently, we overlay the geochemical data with geological maps to create a hydrogeochemical model.

![Figure 1. Location of Ciseeng geothermal field [6]](image-url)
Figure 2. Geological Maps of Ciseeng geothermal field [7]

Figure 3. Topographic map Ciseeng geothermal field

Figure 4. Thermal water description in Ciseeng geothermal field.
4. Results and discussion

4.1. Geothermal fluid characteristics

Based on figure 5, all manifestation shows mature water characteristics with high concentration of Cl. The high Cl content also suggests that the water in Ciseeng is very saline (also considering Total Dissolved Solid and conductivity analysis of the water). Present day water analysis shows that the water is partially equilibrated, with the tendency of groundwater dilution based on the concentration of Mg in the fluid (high Mg concentration).

As illustrated in figure 6, Cl/Br ratio similarity indicate that the fluids derive from one reservoir and all manifestation has shifted to the right (positive shift). It means there is a surface evaporation occurring in the surface.

Table 1 shows the geoindicators and geothermometer each sample in Ciseeng geothermal field. The Na/K <15 can be associated with upflow structures or permeable zone which is shown in table 1. Ciseeng water data shows Na/K <15 meaning that the manifestation is located in a permeable zone. The highest Na/K ratio among all data may indicate the main upflow zone of the system in this case, CSN-2.

Normal Ca concentration (Ca < 50 mg/L). Ciseeng water data shows very high concentration of Ca. It is predicted that the loss of CO₂ during fluid-rock interaction triggers the formation of travertine deposits. Ca concentration also increase with the salinity of water. Mg concentrations are very low (0.01–0.1 mg/L). Ciseeng water data exhibit very high Mg concentration indicating possible dilution by groundwater. HCO₃ content reflects the CO₂ content in the deep fluid is influenced by permeability and lateral flow [8].

High HCO₃ content shows the direction of lateral flow. CSN-3 shows the highest HCO₃ concentration, showing that the fluid flows to the north of the research area. High Total Dissolved Solids (TDS) concentration shows that Ciseeng water is very saline. Increasing Boron concentration and increasing HCO₃ from CSN-1 to CSN-3 indicate shear faults [9], with possible direction along CSN-1 to CSN-3 (trending North-South). Quartz geothermometer is deemed to be the most suitable considering the temperature of the surface manifestation, water type, and other species concentrations. Subsurface temperature ranges from 91–93 ºC. Present and past data show vast differences, meaning that Ciseeng geothermal field has evolved in the past 25 years.

![Figure 5. Ternary diagram of Ciseeng thermal water.](image-url)
Table 1. Geoindicators and Geothermometer Thermal Water in Ciseeng

| Sample name | TDS (mg/L) | Ca (mg/L) | Mg (mg/L) | HCO₃ (mg/L) | Cl/B | Geoindicators Na/K (low) | Geoindicators Na/Mg (high) | Geothermometers (°C) |
|-------------|------------|-----------|-----------|-------------|------|-------------------------|--------------------------|------------------------|
| CSN-1       | 38,034     | 2,028     | 515       | 903         | 219  | 31.34                   | 14.82                    | 93                     |
| CSN-2       | 34,400     | 2,069     | 510       | 952         | 206  | 30.56                   | 15.74                    | 93                     |
| CSN-3       | 34,900     | 1,928     | 464       | 1,776       | 208  | 34.26                   | 13.84                    | 92                     |
| CSN-4       | N/A        | 1,764     | 207       | 1,357       | 227  | 75.56                   | 17.99                    | 110                    |
| CSN-5       | N/A        | 14        | 2.27      | 261         | 127  | 85.08                   | 19.95                    | 128                    |

4.2. Hydrogeochemical model

A simplified hydrogeochemical model is shown in figure 7. High salinity thermal fluid is caused by the circulation of thermal fluid within the limestone lithology in the subsurface rock and fluid in the subsurface triggers the formation of travertine terrace around Ciseeng, causing CO₂ loss in the
Figure 8. Detailed Hydrogeochemical Model in Ciseeng geothermal field

The fluid of Ciseeng geothermal field is very saline water and saturated with HCO₃ due to CO₂ loss and leading to the formation of CaCO₃ deposit (travertine terrace and mounds). The thermal waters are presumably originated from a common reservoir with meteoric water as recharge water. A preliminary hydrogeochemical model of Ciseeng geothermal field was completed. Enough improvement and further geological and geochemical samplings are required to complete a more comprehensive hydrogeochemical model of Ciseeng.

Acknowledgments
This work was financially supported by Universitas Indonesia under research grant PITTA B with grant contract number NKB-0671/UN2.R3.1/HKP.05.00/2019.

References
[1] Bozdag A 2016 J. Afr. Earth Sci. 121 72-83
[2] Zulwidyatama W 2014 Geological Engineering E-Journal 6 618-30
[3] Goff F and Janik C J 2000 Encyclopedia of Volcanoes- Geothermal System (United States: Academic Press)
[4] Brogi A et al. 2016 Tectonophysics 680 211-32
[5] Hochstein M F and Browne P 1999 Surface manifestation of geothermal system with volcanic heat sources Encyclopedia of Volcanoes (United States: Academic Press)
[6] Map of Ciseeng Geothermal Field, Kabupaten West Java Indonesia available at https://www.google.com/maps/search/ciseeng+geothermal/@-6.428624,106.6973268,17z
[7] Sudiharto K and Akbar H 1994 *Geologi Daerah Airpanas Ciseeng, Kecamatan Parung, Daerah TK II Kabupaten Bogor, Jawa Barat* (Bandung: Pusat Sumber Daya Geologi)

[8] Nicholson K 1993 *Geothermal Fluids* (United Kingdom: Springer Verlag Berlin Heidelberg)

[9] Moeck I S 2014 *Renew. Sust. Energ. Rev.* **37** 867-82

[10] Wohletz K and Heiken G 1992 *Volcanology and Geothermal Energy* (Berkeley: University of California Press)