

# Temperature Estimation of Blawan Geothermal Reservoir Using Geothermometer Method

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## ABSTRACT

A study on the temperature estimation of the geothermal reservoir from indications contained in Blawan has fully been carried out by the researchers. Geothermometer equations are used for temperature calculations involving the concentrations of Na, K, Ca, and SiO<sub>2</sub> in hot water samples that have been analyzed by using the AAS (Atomic Absorption Spectrophotometer) method. Based on the test using Na, K, Ca and SiO<sub>2</sub> geothermometers, the appropriate geothermometer for the Blawan area is the Na-K-Ca geothermometer with an average reservoir temperature of 653.8 °C with a potential of 100 MW. This result indicates that there is a high-temperature geothermal reservoir in Blawan.

**Keywords:** Blawan, Geothermal, Geothermometer, Reservoir, Temperature.

## 1. INTRODUCTION

Geothermal is heat energy that is naturally formed below the ground surface. It is one of the alternative energies which is expected to be able to produce electrical power as a source of fossil energy (petroleum and coal). Indonesia has 40% of the total geothermal energy potential existing globally, which is divided into two routes, namely volcanic and non-volcanic.

Blawan-Ijen is one of the geothermal prospects in East Java, which has a potential of 270 MW. There are two geothermal locations in Blawan-Ijen; those are Mount Ijen which is marked by the presence of fumaroles, and Blawan, which is characterized by the presence of geothermal manifestations. This research was conducted in the Blawan area, Sempol District, and Bondowoso Regency, where it has several geothermal manifestations, namely the appearance of hot water on the ground. It is caused by Blawan's fault, which appears in the north Ijen caldera [1].

Reservoir temperature research is fundamental initial research to explore the origin of fluids and reservoir temperature estimation to determine the potential sources of geothermal from surface manifestations [2]. One of the methods used to determine reservoir temperature estimation is a geothermometer, it is considered the best method to apply because it can provide more accurate temperature calculation results with error value estimation in less than 5% [3].

The reservoir temperature measurement can be estimated by determining the metal contents of Na, K, Ca, and Si in hot water [4]. As an additional factor, pH and surface temperature of hot water will be used to expose their correlations with the temperature of geothermal reservoir estimation. Geothermal systems associated with volcanic activity are generally high-temperature geothermal systems. The reservoir temperature in this system can reach 200°C [5]. As an additional factor, the pH and surface temperature of hot springs will be used to determine their relationship to the estimated geothermal reservoir temperature. This study predicted reservoir temperature by utilizing the geothermometer method of Na-K, SiO<sub>2</sub>, and Na-K-Ca.

## 2. METHOD

This study utilized several water samples in the hot water manifestation of Blawan with 12 different locations of hot water because the location is the biggest source. At each location, the temperature of hot water is measure by a thermocouple, and pH is measure by a pH meter (Table 1). Then, the researchers took a water sample, put it in a glass bottle, and is brought it to the laboratory to be analyzed using the Atomic Absorption Spectrophotometer (AAS) method of Na, K, and SiO<sub>2</sub> content for each water sample (Figure 1). From the results of the analysis by using the Atomic Absorption Spectrophotometer (AAS) method, Na-K, SiO<sub>2</sub>, and

Na-K-Ca calculations were performed to predict reservoir temperature by using the equation [6]:

$$T = \frac{1217}{\log_{10} \frac{\{Na\}}{\{K\}} + 1.483} - 273.15 \quad (1)$$

$$T = \frac{1647}{\log_{10} \frac{\{Na\}}{\{K\}} + \beta \left[ \log_{10} \frac{\sqrt{\{Ca\}}}{\{Na\}} + 2.06 \right] + 2.47} - 273.15 \quad (2)$$

$$T = \frac{1309}{5.19 - \log_{10}\{Si\}} - 273.15 \quad (3)$$

for:

Na : sodium concentration

K : potassium concentration

Ca : calcium concentration

Si : concentration of silicon

$\beta = 4/3$ , if  $T < 100 \text{ }^\circ\text{C}$

$\beta = 1/3$ , if  $T > 100 \text{ }^\circ\text{C}$

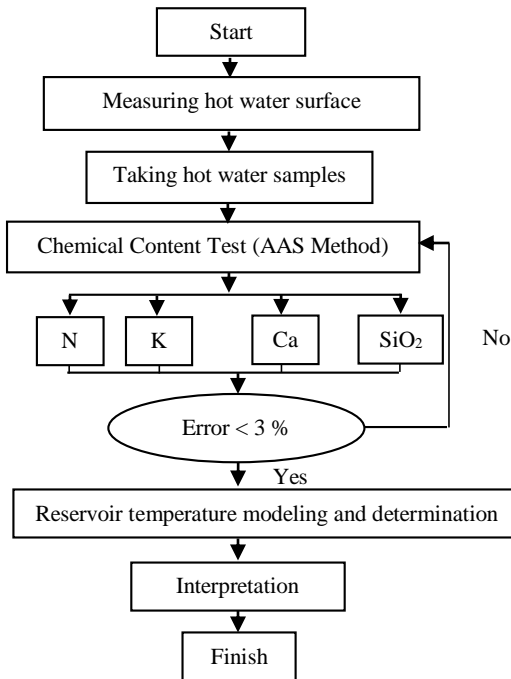


Figure 1. Flowchart Method

### 3. RESULT

In table 1, the measurement result of pH is between (7.0-7.9) with an average score of 7.5 (pH=7). It indicated that the hot water in Blawan has a neutral pH. As a result, the hot water in this location is deserved to use for the research of modeling and estimating geothermal reservoir [7]. The results of laboratory tests are using the Atomic Absorption Spectrophotometer (AAS) method, the content of Na, K, Ca and SiO<sub>2</sub> in each water sample shown in Table 2.

Table 1 pH and temperature measurement results

No	Location Name	pH	Temperature (°C)
1	Blw – 1	7.7	43.7
2	Blw – 2	7.5	34.5
3	Blw – 3	7.5	37.2
4	Blw – 4	7.3	39.0
5	Blw – 5	7.3	48.0
6	Blw – 6	7.5	48.8
7	Blw – 7	7.8	42.5
8	Blw – 8	7.7	45.0
9	Blw – 9	7.0	48.3
10	Blw – 10	7.4	46.0
11	Blw – 11	7.7	40.5
12	Blw – 12	7.3	42

Table 2 The analysis by using the Atomic Absorption Spectrophotometer (AAS) method

No	Location name	Concentration (PPM)			
		Na	K	Ca	SiO <sub>2</sub>
1	Blw – 1	0.7467	1.8848	0.3386	4.2057
2	Blw – 2	0.6509	1.6618	0.2619	5.1387
3	Blw – 3	0.6889	1.4875	0.4732	4.2059
4	Blw – 4	0.7427	1.7113	0.4872	4.2394
5	Blw – 5	1.0521	2.4728	0.2405	4.2326
6	Blw – 6	0.7300	2.1346	0.1901	4.2033
7	Blw – 7	0.6756	1.8603	0.3685	5.1731
8	Blw – 8	0.7173	2.1602	0.3024	5.1322
9	Blw – 9	0.7628	2.2891	0.2608	4.0776
10	Blw – 10	0.6359	2.0114	0.3272	4.1451
11	Blw – 11	0.5784	1.8875	1.0184	4.0557
12	Blw – 12	0.5877	1.9724	0.7331	4.1543

#### a. Na-K Method

The Na-K method was used to detect geothermal temperature estimation in fluid geothermal using Na and K contents [8]. Using equation 1 and PPM concentration (Table 2) from Na and K contents showed that geothermal temperature estimation is the same as the data in table 3. The lowest reservoir temperature is 1383.8°C, and the highest reservoir temperature is 2341.3°C, while the average temperature is 1847.07°C. Na-K geothermometer method is not appropriate to predict geothermal reservoir temperature in Blawan. Because the calculation temperature exceeds 1000°C, where the temperature exceeds 1000°C, it will melt the rock above it [9]. Rock formation arrangement positively influences the geothermal reservoir so that the reservoir temperature results of Na-K (table 3) are impossible to use.

#### b. SiO<sub>2</sub>

After the analysis results of the Na-K geothermometer method is not precisely used in predicting, the analysis using the silica geothermometer (SiO<sub>2</sub>) method was then carried out. From the concentration PPM score (table 2)

and the use of calculation in equation 2, it reveals that the highest geothermal temperature estimation is 19.1°C, which is located in 2 points, namely BLW 2 and BLW 8, and the lowest temperature is 12.5°C (table 4). Meanwhile, the average temperature is 14.74°C.

From those results, it cannot be used either to predict reservoir temperature because it is under surface hot water temperature (34.5°C - 48.8°C). Where the deeper it gets, the higher the temperature obtained. According to Zheng and Zhang [10], temperature increase indicates more or less 3°C/100 m.

**Table 3** The results of Na-K method calculations

No	Location name	Concentration (PPM)		Geothermal temperature estimation (°C)
		Na	K	
1	Blw - 1	0.7467	1.8848	1630.7
2	Blw - 2	0.6509	1.6618	1651.6
3	Blw - 3	0.6889	1.4875	1383.8
4	Blw - 4	0.7427	1.7113	1478.3
5	Blw - 5	1.0521	2.4728	1509.4
6	Blw - 6	0.7300	2.1346	1941.5
7	Blw - 7	0.6756	1.8603	1803.0
8	Blw - 8	0.7173	2.1602	2016.4
9	Blw - 9	0.7628	2.2891	2007.1
10	Blw - 10	0.6359	2.0114	2153.0
11	Blw - 11	0.5784	1.8875	2248.7
12	Blw - 12	0.5877	1.9724	2341.3

**Table 4** The results of SiO<sub>2</sub> method calculations

No	Location name	Concentration (PPM)	Geothermal temperature estimation (°C)
		SiO <sub>2</sub>	
1	Blw - 1	0.7467	4.2057
2	Blw - 2	0.6509	5.1387
3	Blw - 3	0.6889	4.2059
4	Blw - 4	0.7427	4.2394
5	Blw - 5	1.0521	4.2326
6	Blw - 6	0.7300	4.2033
7	Blw - 7	0.6756	5.1731
8	Blw - 8	0.7173	2.1322
9	Blw - 9	0.7628	4.0776
10	Blw - 10	0.6359	2.1451
11	Blw - 11	0.5784	2.0557
12	Blw - 12	0.5877	2.1543

### c. Na-K-Ca

The equilibrium between feldspar Na & K, calcite, or mineral containing Ca and hot water is described on geothermometer Na-K-Ca. It applies hot water having high Ca content [11]. From the laboratory analysis of Na-K-Ca and equation 2, it is obtained that the geothermal temperature estimation Blawan is in table 5. The lowest temperature estimation is 591.2°C in Blw-3 and the highest temperature is 696°C in Blw-6. Meanwhile, the average is 653.8°C.

From those three methods, the appropriate method to predict geothermal temperature estimation in Blawan is the Na-K-Ca geothermometer method. Because the Na-K geothermometer method has too high-temperature estimation while the SiO<sub>2</sub> geothermometer method is too low. Based on the estimated reservoir temperature obtained (653.8°C), it can be predicted that the potential of Blawan's geothermal energy is 100 MW (Geological Agency, 2009).

**Table 5** The results of Na-K-Ca calculations

No	Location name	Concentration (PPM)			Geothermal temperature estimation (°C)
		Na	K	Ca	
1	Blw - 1	0.7467	1.8848	0.3386	640.9
2	Blw - 2	0.6509	1.6618	0.2619	642.8
3	Blw - 3	0.6889	1.4875	0.4732	591.2
4	Blw - 4	0.7427	1.7113	0.4872	608.3
5	Blw - 5	1.0521	2.4728	0.2405	663.5
6	Blw - 6	0.7300	2.1346	0.1901	696.0
7	Blw - 7	0.6756	1.8603	0.3685	649.7
8	Blw - 8	0.7173	2.1602	0.3024	682.9
9	Blw - 9	0.7628	2.2891	0.2608	693.0
10	Blw - 10	0.6359	2.0114	0.3272	681.9
11	Blw - 11	0.5784	1.8875	1.0184	638.4
12	Blw - 12	0.5877	1.9724	0.7331	658.1

## 4. CONCLUSION

Based on the results of calculations that have been done, it is possible to use the Na-K-Ca geothermometer with an average temperature of 653.8°C. In the Na-K geothermometer, the temperature is too high (average 1847.1°C) so that it can melt the rock above it with a potential of 100 MW. Meanwhile, in the SiO<sub>2</sub> geothermometer, the temperature is below the surface water temperature (average 14.7°C).

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