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EVALUATION OF GEOTHERMAL RESERVOIR CONDITIONS BASED ON WELL PADS GEOCHEMICAL DATA IN LX GEOTHERMAL FIELD

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Abstract

The research was conducted at the Geothermal Company Energy Lx Area. The research area includes three well pads of geothermal power plants, namely X1, X2, and X3, which are stratigraphically composed of quaternary volcanic rocks. Based on the geochemical data of the well pad, it shows that the chloride type fluid is in equilibrium/partial equilibrium with the reservoir temperature in the range of 230 – 300°C from the silica and Na-K geothermometer analysis. The geothermal system in the research area is a hydrothermal magmatic system with two-phase fluid dominated by water. Evaluation of reservoir conditions from monitoring the X3 well pad shows a decrease in temperature for the last 3 years from 320°C in 2018 to 290°C in 2020. Graphical analysis of several chemical elements including Ca, Cl, SiO2, Boron and HCO3 shows a trend with the same pattern on several elements/compounds so it can interpret that there are no mixing process occurs in the reservoir, especially mixing with drill pipe wall cement or groundwater. Utilization of two-phase geothermal fluid in the Lx Geothermal Field produces electricity with a capacity reaches more than 100 MW and is still being developed in several areas that are currently in the geothermal geochemical exploration stage.

***Keywords**: Evaluation, Geothermal, Reservoir*

Abstrak

Penelitian dilakukan di Lapangan Panasbumi Area Lx. Daerah penelitian mencakup tiga lokasi sumur produksi uap pembangkit listrik yaitu X1, X2 dan X3, yang secara stratigrafi disusun oleh batuan gunungapi kuarter. Berdasarkan data geokimia sumur produksi menunjukkan fluida tipe klorida yang setimbang/partial equilibrium dengan temperatur reservoar berada pada kisaran 230 – 300°C dari analisis geothermometer silika dan Na-K. Sistem panasbumi daerah penelitian merupakan sistem magmatik hidrotermal dengan fluida dua fasa dominasi air. Evaluasi kondisi reservoar dari monitoring sumur produksi X3 menunjukkan terjadi penurunan temperatur selama 3 tahun terakhir dari 320°C pada tahun 2018 menjadi 290°C pada tahun 2020. Analisis grafik beberapa unsur kimia diantaranya Ca, Cl, SiO2, Boron dan HCO3 menunjukkan trend dengan pola yang sama pada beberapa unsur/senyawa sehingga tidak terjadi proses mixing dalam reservoar, terutama pencampuran dengan semen dinding drill pipe ataupun air tanah. Pemanfaatan fluida panasbumi dua fasa pada lapangan panasbumi Lx menghasilkan tenaga listrik dengan kapasitas mencapai lebih dari 100 MW dan masih terus dilakukan pengembangan pada beberapa daerah yang saat ini dalam tahap eksplorasi geokimia panasbumi.

***Kata kunci:** Evaluasi, Panasbumi, Reservoar*

1. Introduction

Volcanoes have potential resources that can be utilized and are available in abundance. Another potential is for mineral materials and geothermal. Indonesia has geothermal energy potential reaching 28,617 Megawatts spread over 299 locations. This important energy source must be utilized for the benefit of the nation. Therefore, the way of management and exploitation must be truly measurable and accountable.

Geothermal potential in Indonesia reaches 40% of the world's total geothermal potential, making Indonesia the country with the largest geothermal potential in the world. Sulawesi Island has the potential to reach 3,044 Megawatts [1]. One of the areas in Sulawesi that has geothermal prospects and has built a Geothermal Power Plant is the Lx Area. This research was conducted in the working area of a state company where the research location, coordinates, and all data used were disguised, to keep the vital company data confidential. The purpose of this research is to evaluate the condition of the geothermal reservoir to optimize the geothermal production process in the research area.

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2. Methodology

This research was conducted in the Lx Area Geothermal Field. The data used is secondary data from a related company, which comes from 3 wells, namely wells X1, X2, and X3. The data is analyzed by the researcher with the following flow.

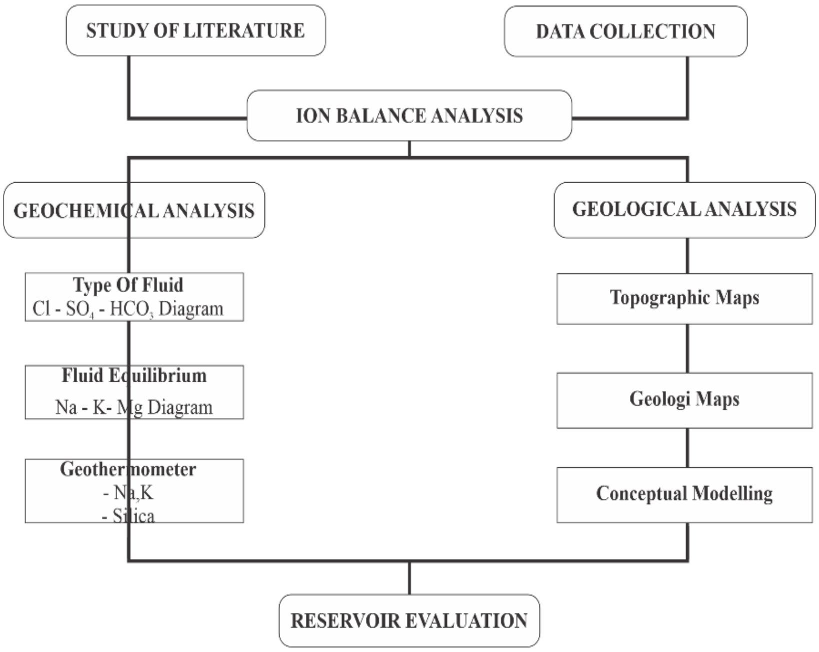


Figure 1. Research Method Flowchart

3. Result and Analysis

The research locations are in several villages and sub-districts spread over two regencies/cities, namely in "T" City and "M" Regency, with manifestations in the form of acid sulfate water lake in the middle of the research area.

Geothermal well pads in the research area include (Figure 2) :

a. Well pad X1 with a depth of 1890 meters.
b. Well pad X2 with a depth of 2170 meters.
c. Well pad X3 with a depth of 2830 meters, well pad data can be seen in Attachment 1.

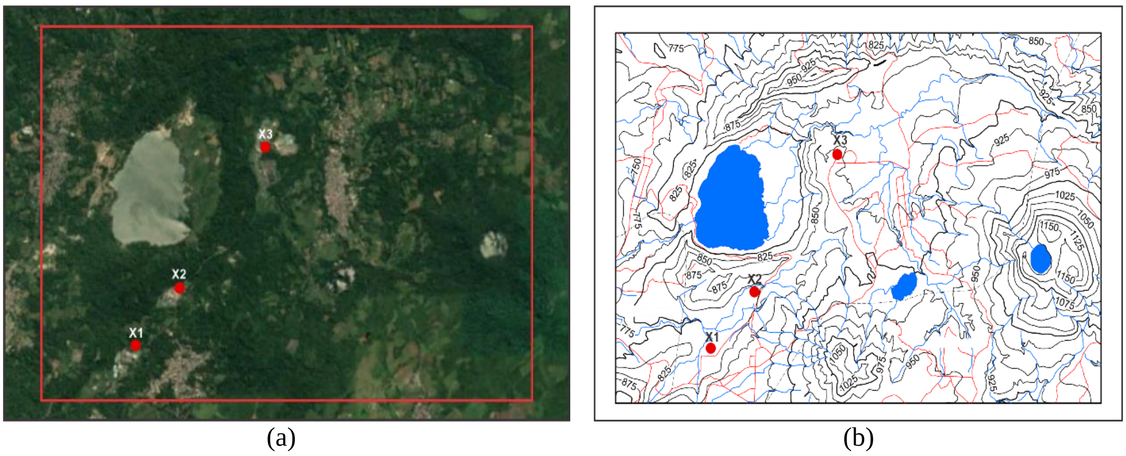


Figure 2. Map of the research area (red box) based on google earth map and sample location are indicated by a red dot (a) and (b) shows the Topographic Map of the study area

3.1. Geochemical Analysis

a). *Ion Balance Analysis*

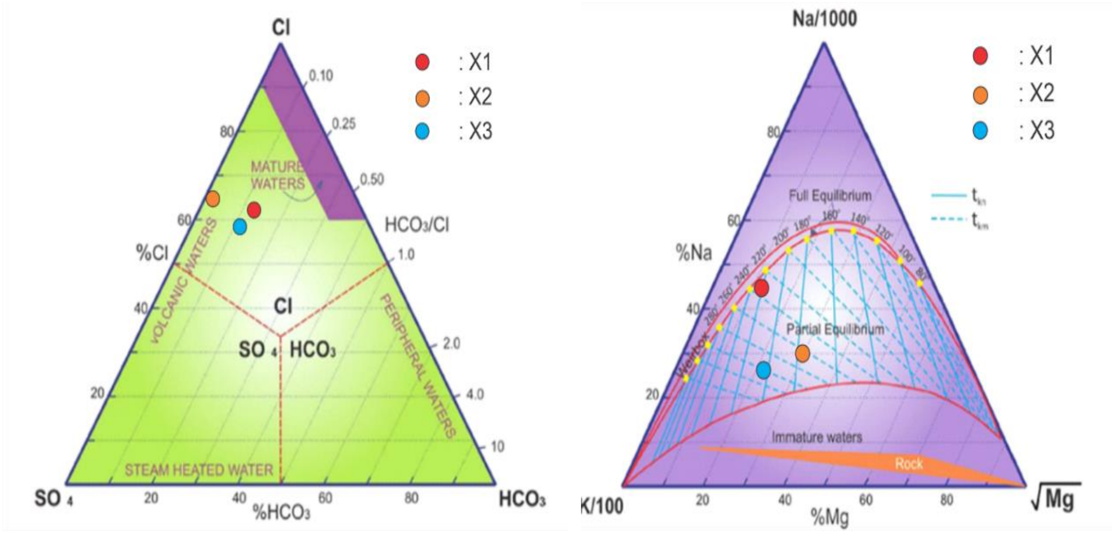
Data evaluation on the feasibility of chemical analysis can be known by checking the ion balance. Analysis The results of the ion balance of the two samples show a value of less than 5 (Table 3), so it can be said that the research data is feasible to be tested and used for the next stage of geochemical analysis.

Table 1. Ion Balance Analysis Results

PARAMETERS	WELL PADS		
	X1	X2	X3
∑ Kation	14.97	44.60	6.38
∑ Anion	18.15	46.56	7.14
Ion Balance Value	0.19	0.04	0.11
Requirements	< 5 %	< 5 %	< 5 %
RESULT	Qualify	Qualify	Qualify

b). Fluid Type Analysis

The main anions contained in the geothermal fluid can determine the type of the fluid, using the concentration of Cl, HCO_3, and SO_4 Ternary Diagram [2] (Figure 3). Based on the plotting results on the diagram, it founds that X1, X2, and X3 well are classified as chloride water fluid types. Chloride water indicates that the fluid is from the deep reservoir.



(a) (b)

Figure 3. Result of (a) Cl – SO_4 – HCO_3 and (b) Na – K – Mg Ternary Diagram Plot

c). Fluid Equilibrium Analysis

Fluid Equilibrium Analysis was carried out to look for fluid maturity in a reservoir system based on the content of Na, K, and Mg elements, by looking for values of [Na]/1000, [K]/100, and $[Mg]^{1/2}$ [3]. This ternary diagram also can be used as a justification for the mixing process and an indicator for the fluid flow zone (Figure 3). The result of ternary diagram plot of the Na - K - Mg diagram shows that including the partial equilibration zone, with a temperature of X1 approaching 240°C, X2 260°C, and X3 300°C. Based on these results, it can be interpreted that geothermal fluid in equilibrium which has not been processed mixing with other fluids.

d). Geothermometer Analysis

Based on the calculation of the Na-K Geothermometer [3] and the Silica Geothermometer [4], the estimated reservoir temperature results from the well pads of the Lx geothermal field (Table 2 and Table 3) are obtained. The estimated subsurface reservoir temperature from the X1 well pad is about 230-239°C, and the X2 well pad is about 259-288°C, while the X3 well pad has the highest temperature. The estimated temperature of X3 well pad is about 280-290°C. The research area has a high-temperature reservoir system because the result of temperature shows the value above 225°C [5].

Table 2. Silica Geothermometer Calculation Results

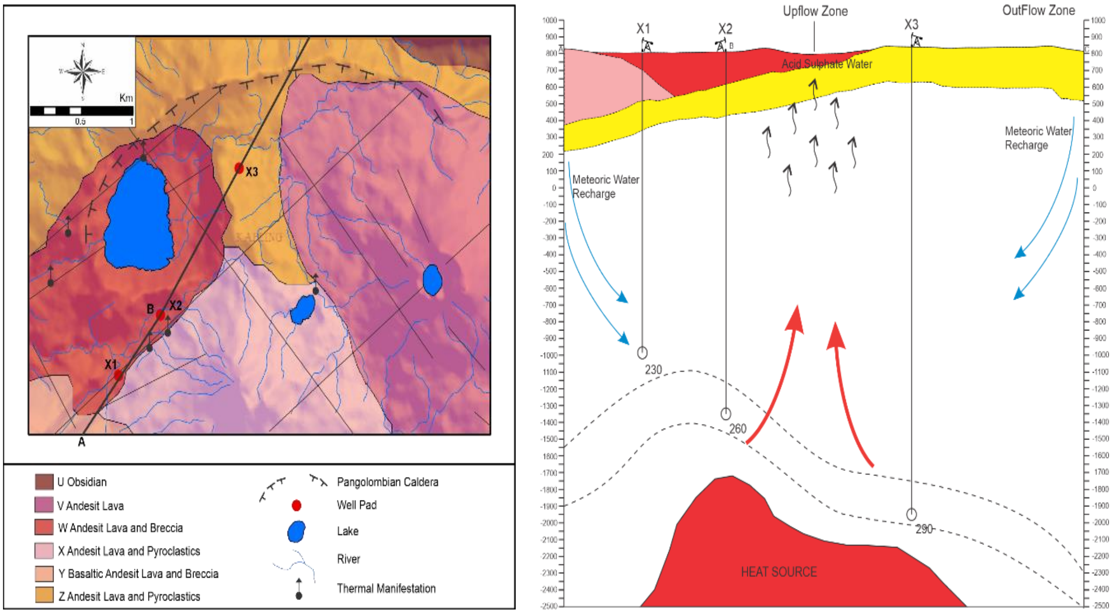
No.	Well Pad			X	Y	TEMP (°C)
		C	Log C	5.19 - Log C	1309 / X	Y - 273.15
1	X1	435.00	2.64	2.55	513.03	239.88
2	X2	724.00	2.86	2.33	561.74	288.59
3	X3	671.00	2.83	2.36	553.89	280.74

Table 3. Na-K Geothermometer Calculation Results

No.	Well Pad				X	Y	Z	TEMP (°C)
		Na	K	NA / K	LOG NA / K	1750 + X	1390 / Y	Z- 273.15
1	X1	318	31	10.26	1.01	2.76	503.43	230.28
2	X2	931	128	7.27	0.86	2.61	532.21	259.06
3	X3	125	24	5.21	0.72	2.47	563.51	290.36

3.2. Geothermal System

The geothermal system in the research area is the magmatic-hydrothermal geothermal system with two-phase fluid water domination. The fluid is then exploited from well pads with a depth of approximately 2-3 kilometers from the ground where the well is drilled. The upflow zone is the manifestation of geothermal water in the form of lake acid sulfate water (Figure 6 and Figure 7). According to previous researchers, other manifestations can be interpreted, that is warm springs near the easternmost lake of the study area with a temperature of 43°C, neutral and alkaline pH which can be identified as outflow zones [6].



(a) (b)

Figure 4. Geological Map of Research Area (a) and Conceptual Model of Lx Geothermal Field (b)

3.3. Reservoir Condition Evaluation

Evaluation related to reservoir conditions was carried out at well X3. This X3 well pad data from 2019 to 2020 (can be seen in Attachment 2). Tren Analysis of the calcium and chloride content in the X3 well pad shows a decreased concentration of Ca and Cl ions with a similar pattern without anomalies (Figure 5). This shows that in the reservoir there is no mixing process with other fluids, both cement fluid, and groundwater.

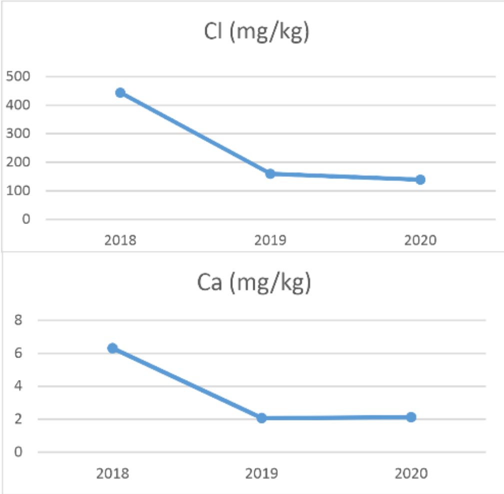


Figure 5. Geochemical Monitoring Curve of Calcium, and Chloride ion

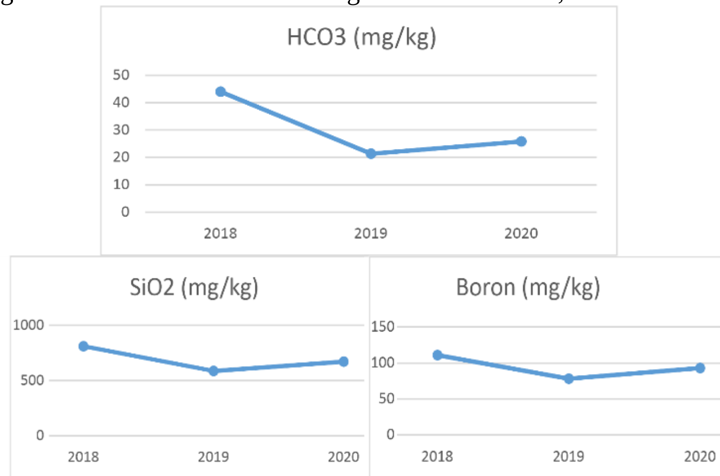


Figure 6. Geochemical Monitoring Curve of Silica (SiO_2), Boron, and Bicarbonate (HCO_3)

Observation of the chemical content of the X3 well pad was also from the concentration of SiO2, Boron, and Bicarbonate (HCO_3). The results of the trend analysis show the same pattern where the decline occurred in 2019 and experienced a slight increase in the concentration value at the end of 2020 (Figure 6). This is based on the volume of magmatic and meteoric fluids below the surface that have increased on its respectively volume. Magmatic fluids are rich in Silica and Boron while meteoric fluids are rich in bicarbonate ions.

Evaluation of reservoir conditions from temperature data has also been carried out for the last 3 years. The results show that based on the overall trend, the temperature of the Lx geothermal field reservoir has decreased (see Figure 7). It can be interpreted that several things must be evaluated on the injection well in the geothermal field area Lx because it is suspected that the volume and flow velocity of the fluid that is reinjected into the reservoir has increased so that it affects the decrease in reservoir temperature.

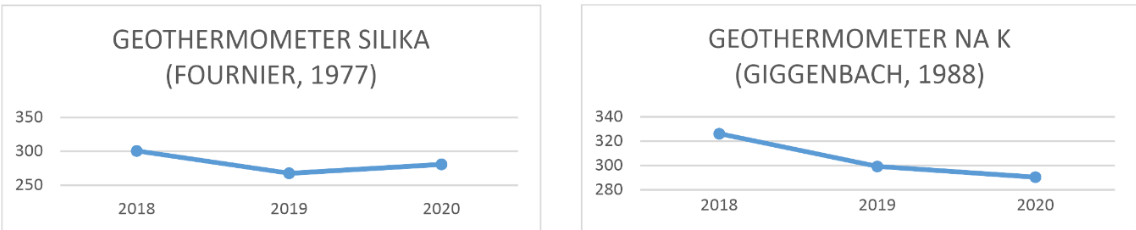


Figure 7. Reservoir Temperature Monitoring Curve

4. Conclusion

Based on the analysis and interpretation of geological and geochemical data, it can be concluded that:

1. The type of fluid contained in the geothermal reservoir in the study area is chloride water which is in the Partial Equilibrium zone.
2. The Lx Geothermal area has a high-temperature reservoir system in the range of 230 – 300°C.
3. The geothermal system in the research area is the magmatic-hydrothermal geothermal system with two-phase fluid water domination.
4. Based on the geochemical data analysis of well pads, there is a decreasing trend with the same pattern on some elements/compounds so that no other processes occur in the reservoir.
5. The temperature decreases every year from 2018 to 2020, evaluation needs to be done in volume and flow velocity of the reinjection well which controls the fluid reinjected into the reservoir. increase meteoric water affects the decrease in reservoir temperature.

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APPENDIX

1. Well pad Geochemical Data

PARAMETERS	WELL PAD		
	X1	X2	X3
Separator Pressure (barg)	8.45	10.7	13.8
Separator Temperature (°C)	176.9	186.4	196.7
TDS (Calculated)	1360	3620	1170
Lab pH (units)	8.72	3.31	6.53
Field pH (units)	7.94	3.37	4.96
Analyte (mg/kg)			
Natrium	318	931	125
Kalium	31	128	24.5
Calcium	2.63	4.43	2.12
Magnesium	<0.01	0.946	<0.01
Lithium	0.671	2.96	0.648
Strontium	0.022	0.034	0.011
Barium	<0.005	0.027	<0.005
Iron	0.03	0.86	0.029
Aluminum	1.09	0.674	1.08
Antimony	0.06	0.312	0.023
Manganese	<0.005	1.43	0.009
Chloride	365	1130	139
Fluoride	2.45	1.95	2.91
Sulfate	146	630	75.9
Total Alkalinity (as HCO3-)	82.9	<2	25.8
Carbonate Alkalinity (as CO3=)	40.6	<2	<2
Bicarbonate Alkalinity (as HCO3-)	0.39	<2	25.8
Total Inorganic Carbon (as CO2)	25.6	<20	<20
Ammonia	1.23	4.42	0.546
Hydrogen Sulfide	5.46	5.14	84.1
Boron	14	53.4	93
Arsenic	1.56	7.18	8.25
Silica	435	724	671

2. X3 Well Pad Geochemical Data

PARAMETER	2018	2019	2020
Separator Pressure (barg)			13.8
Separator Temperature (°C)			196.7
TDS (Calculated)	927	1090	1170
Lab pH (units)	7.2	5.44	6.53
Field pH (units)		5.84	4.96
Analyte (mg/kg)			
Natrium	319	126	125
Kalium	86	26.4	24.5
Calcium	6.3	2.07	2.12
Magnesium	<0.1	<0,01	<0.01
Lithium	2.1	0.68	0.648
Strontium		<0,01	0.011
Barium		<0,005	<0.005
Iron (Fe)	<0,01	0.053	0.029
Aluminum	0.74	1.14	1.08
Antimony		0.032	0.023
Manganese		0.008	0.009
Chloride	444	160	139
Fluoride	3.2	2.58	2.91
Sulfate (SO4)	88		75.9
Total Alkalinity (as HCO3-)			25.8
Carbonate Alkalinity (as CO3=)			<2
Bicarbonate Alkalinity (as HCO3-)	44	21.3	25.8
Total Inorganic Carbon (as CO2)	65	96	<20
Ammonia		0.394	0.546
Hydrogen Sulfide	14	29.9	84.1
Boron	111	78	93
Arsenic	0.04	7.52	8.25
Silica	810	586	671