PROCEEDINGS, 50th Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 10-12, 2025
SGP-TR-229

The Impact of Exploitation in the Surface Manifestations at Karaha Bodas Geothermal Field, Indonesia

Anjani Puspadianti, Aththur Maulana Effendi, R. M. Tofan Sastranegara

Anjani.p@pertamina.com

Keywords: Karaha Bodas, Manifestations, Fumaroles, Hot Springs

ABSTRACT

The Karaha Bodas Geothermal Field, operated by PT. Pertamina Geothermal Energy, is located in Tasikmalaya and Garut Region of West Java, Indonesia. The Geothermal power plant with a capacity of 30 MWe began commercial operations in April 2018. In 2023, geochemical monitoring of the surface manifestations identified four distinct complexes: Karaha, Cipanas-Pamoyanan, Talaga Bodas, and Pancur Tujuh. Each complex has a unique water chemistry: sulphate-type waters dominate in Karaha and Talaga Bodas, bicarbonate type waters in Cipanas-Pamoyanan, and chloride-rich water in Pancur Tujuh, where the high chloride levels are linked to magmatic fluids. Recent monitoring has shown rising temperatures and chloride levels in Pancur Tujuh, accompanied by a decrease in magnesium, indicating extensive reservoir boiling. This phenomenon is further supported by an increase in non-condensible gas (NCG) content in fumaroles of Talaga Bodas.

Additionally, extensive boiling has been observed in the production wells, attributed to the non-return of reinjected fluids. To address these challenges, an injection strategy is currently being tested in the Karaha Bodas filed to improve reservoir management

1. INTRODUCTION

The Karaha Bodas Geothermal Field, operated by PT. Pertamina Geothermal Energy, has an installed capacity of 30 MWe and began operation in April 2018. It is located in Tasikmalaya and Garut, West Java Province, Indonesia. The Karaha Bodas Geothermal Field has more extensive vapor-dominated regimes like those found at Darajat-Kamojang. Allis and Moore (2000) suggested that these zones might develop from higher temperature magmatic chimneys (Reyes et al., 1983) due to the combined effects of low permeabilities, high-heat flow and open-system boiling. According to the conceptual model, the Karaha Bodas Geothermal Field is divided into two separate compartments: the Karaha compartment and the Talaga Bodas compartment, separated by a structural barrier oriented ENE-WSW in the central part of the Karaha-Bodas area. These two compartments exhibit distinct geochemical fluid characteristics, both in surface manifestations and production wells.

Karaha Bodas is characterized by surface manifestations, including solfataras, fumaroles, hot springs, and warm springs. These manifestations are grouped into five complexes:

a. Karaha Complex (KRH, KRA, CNK)

b. Cipanas-Pamoyanan Complex (PYS, PYA, CPC, CPK)

c. Talaga Bodas Complex (TBD, TB1, TB2, PJA, PJG, KSA)

d. Pancur Tujuh Complex (CPS, CTL, CKH, CKJ, CBR, CRM, CNG)

e. Cipanas-Sumursari Complex (SS1, SS2)

The Karaha and Cipanas-Pamoyanan complexes represent the Karaha compartment, while the Talaga Bodas and Pancur Tujuh complexes represent the Talaga compartment.

The Karaha compartment contains three production wells, which are part of a two-phase steam-dominated reservoir with reservoir temperatures between 250–280°C, dryness levels ranging from 45–90%, and enthalpy values ranging from 1400–2700 kJ/kg. In the Talaga Bodas compartment, there are three other production wells, also in a two-phase steam-dominated reservoir, with reservoir temperatures ranging from 280–300°C, dryness levels between 80–99%, and enthalpy values ranging from 2600–2700 kJ/kg. Additionally, one injection well is currently active, with an injection rate of 60–100 tph.

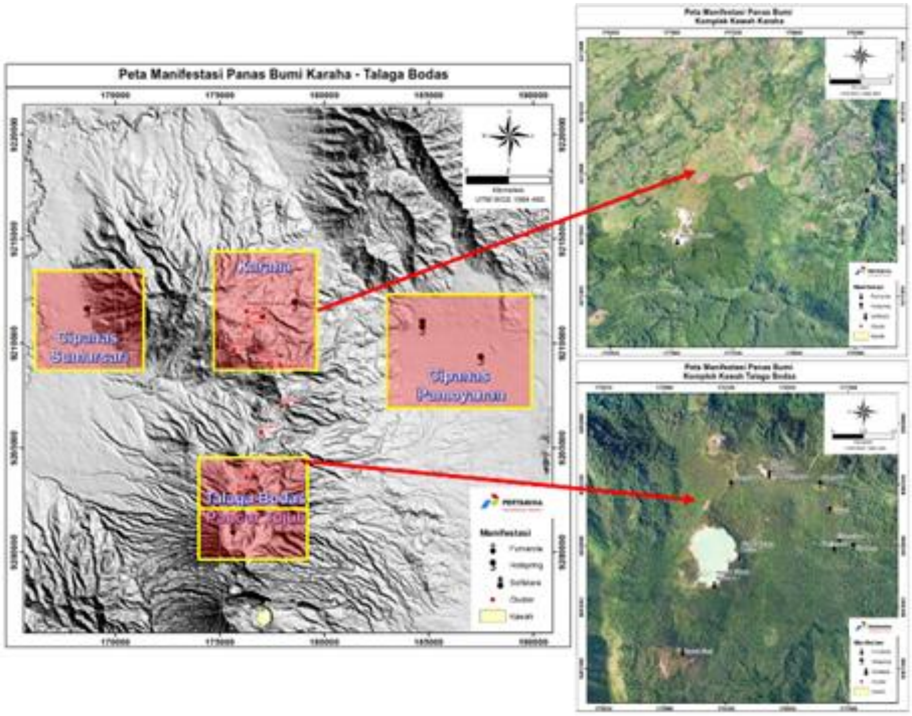

Figure 1: The distribution map of manifestations in the Karaha Bodas Field

2. GEOCHEMICAL CHARACTERISTICS OF MANIFESTATIONS

Fluids in the Pancur Tujuh Complex are of the chloride water type, likely derived from magmatic volatiles that condensed into shallow groundwater, and are characterized by a pH of 1–2. The Cipanas-Pamoyanan and Sumursari complexes contain bicarbonate water, formed due to the absorption of CO_2 gas into a perched shallow aquifer. In contrast, the Karaha and Talaga Bodas complexes contain sulfate water, originating as steam-heated water. The Karaha waters are formed due to the oxidation of H_2S exsolved from boiling fluids into shallow groundwater. All manifestation fluids in the Karaha Bodas area are immature waters with magnesium concentrations exceeding 10 ppm, as indicated by plotting data on the Mg apex. High magnesium levels typically suggest surface water influence.

The fumaroles at KSA, TB1, and PJG are influenced by magmatic volatiles. The indication of the magmatic input is characterised by excess CO2 and H2S in gas samples. The KRH manifestation originates from benign fluids heated by the reservoir heat source. This is confirmed by plotting results that deviate from the magmatic line. Anomalies observed in 2022 data, particularly in the trilinear N_2-CO_2-Ar diagram (Figure 3A), suggest significant deviations. Furthermore, a plot of H2-H2S-CH4 (Figure 3B) shows that Karaha and Talaga have different fluid characteristics and processes. The KRH fumarole has undergone hydrogen re-equilibration, while the TB1 and PJG fumaroles exhibit quenching processes.

In addition to differences in fluid characteristics between the Karaha and Talaga compartments, variations in reservoir temperature values are also observed based on the CAR-HAR gas geothermometer. The manifestations within the Karaha compartment (KRA) exhibit lower reservoir temperatures, approximately 200°C, whereas in the Talaga Bodas compartment (PJG, KSA, TB1), reservoir temperatures reach up to 300°C.

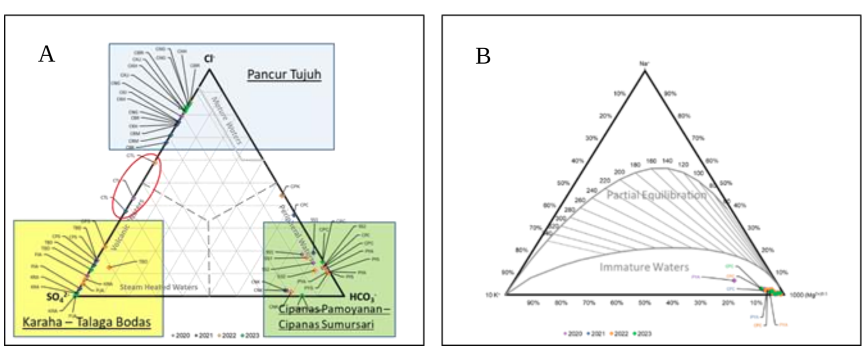

Figure 2: A) Trilinear diagram of Cl-SO_4-HCO_3, B) Trilinear diagram of Na-K-Mg

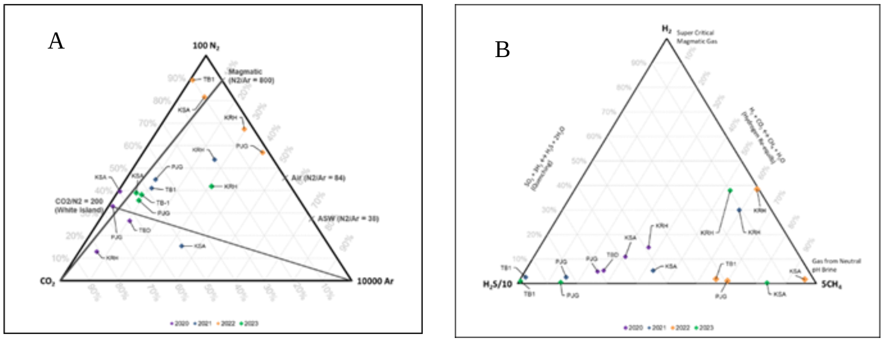

Figure 3: A) Trilinear diagram of N2-CO2-Ar, B) Trilinear diagram of H2-H2S-CH4

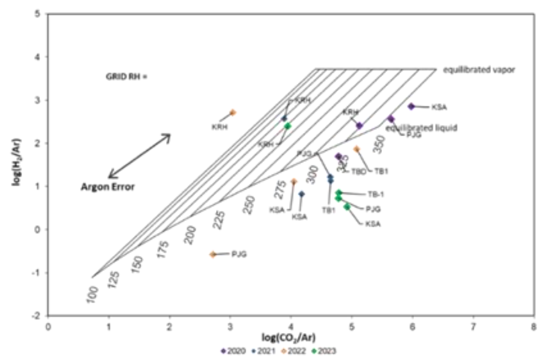

Figure 4: Gas geothermometer CAR-HAR

3. GEOCHEMICAL MONITORING OF MANIFESTATIONS

Geochemical monitoring of manifestations has been conducted since before the Karaha Bodas area became operational. This paper focuses on monitoring data from 2020 to 2023. The Karaha and Cipanas-Pamoyanan complexes exhibit stable temperatures from 2020 to 2023. However, surface temperature increases were observed in the Pancur Tujuh Complex during this period (Table 1).

Table 1: Comparison of surface temperatures in the Pancur Tujuh Manifestation Complex

Manifestations	2020 (°C)	2023 (°C)
CKH	49.9	53.5
CKJ	51.1	55
CBR	48.4	50.1
CNG	65.3	67.8

Chloride concentrations in the Pancur Tujuh Complex manifestations also increased significantly in 2023, ranging from 400–1100 ppm, accompanied by a rise in sulfate concentrations. Magnesium levels decreased across all manifestations in the Karaha Bodas area, with the largest drop (23–41 ppm) observed in the Pancur Tujuh Complex. The Na/K ratio, used to indicate water-rock interaction, increased significantly in Pancur Tujuh manifestations compared to 2022.

Non-condensable gas (NCG) concentrations also showed a notable increase, particularly at KSA, where levels reached 94 wt%. The CO_2 concentration rise aligns with this increase. NCG concentrations were recorded at 20.5 wt% in PJG, 14.9 wt% in TB1, and the lowest at KRH (5.03 wt%).

These parameters indicate that extensive boiling has occurred in the Talaga Bodas and Pancur Tujuh complexes.

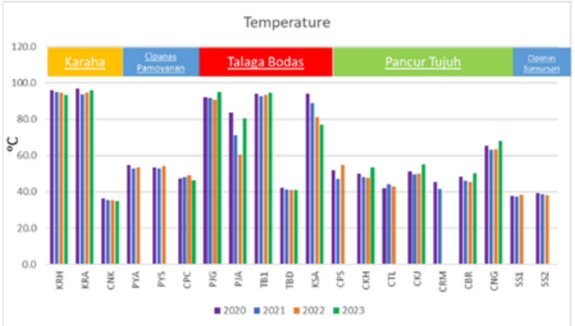

Figure 5: Graph of temperature versus time comparison

Figure 6: Graph of dissolved element comparison over time A) Chloride, B) Sulfate, C) Magnesium, D) Na/K Ratio

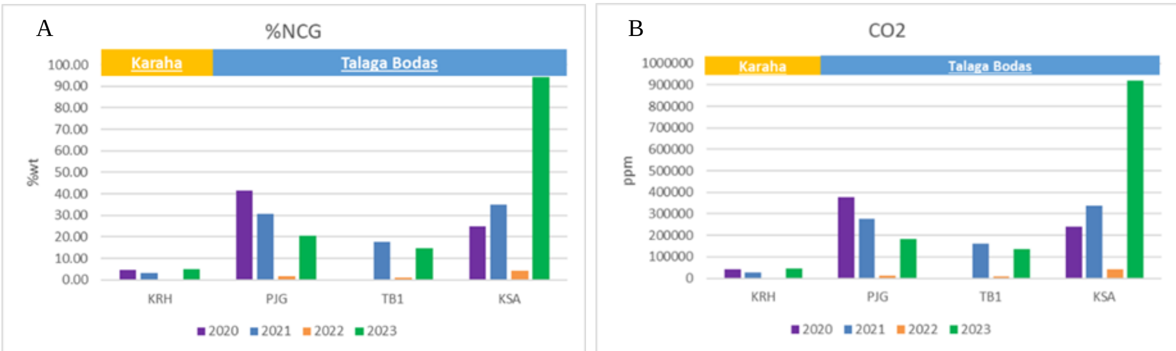

Figure 7: Graph of gas comparison over time A) NCG, B) CO2

4. GEOCHEMICAL MONITORING OF PRODUCTION WELLS

Geochemical production monitoring has been conducted since 2018 and continues to date in the production wells from both the Karaha and Talaga Bodas compartments, which contribute to a 30 MWe power generation capacity. This discussion on geochemical production monitoring will focus on the wells located in the Talaga Bodas compartment. Geochemical monitoring of production wells in the Talaga compartment (TLG-A, TLG-B, TLG-C) revealed an increase in enthalpy in TLG-A from 2169 kJ/kg to 2635 kJ/kg, while the other two wells remained relatively stable. Chloride and NCG concentrations also increased, indicating extensive boiling in the Talaga compartment. This extensive boiling is caused by the absence of reinjection fluid support for the production wells, especially in the Talaga compartment, as discussed in more detail in the publication by Cici et al (2023).

Table 2: Compilation of operational data parameters and geochemical production monitoring in the Talaga Bodas compartment

Well	WHP (barg)	FCV (%)	Brine Rate (t/h)	Steam Rate (t/h)	TMF (t/h)	Dryness (%)	H (kJ/kg)	Cl (ppm)	NCG (ppm)	Indication
TLG-A	↔	↔	↓	↑	↔	↑	↑	↑	↑	Extensive boiling
TLG-B	↔	↔	↔	↓	↓	↔	↔	↑	↔	
TLG-C	↔	↔	↔	↔	↔	↔	↔	↑	↑	

5. CONCLUSION

The increase in surface temperature and chloride concentrations, accompanied by a decrease in magnesium levels in the Pancur Tujuh Complex (representing the Talaga Bodas compartment), as well as rising NCG and CO_2 levels in the Talaga Bodas Complex, indicate extensive boiling in these areas. Similar phenomena were observed in the production wells of the Talaga compartment (TLG-A, TLG-B, and TLG-C). Since 2022, monitoring wells have been repurposed as injection wells to ensure the sustainability of steam supply in the Karaha Bodas Geothermal Field. However, the activation of these wells has been limited to the Karaha compartment, with no connectivity to the Talaga Bodas compartment. As a result, the extensive boiling process remains apparent in the production wells and has also affected the surface manifestations in the Talaga Bodas compartment.

6. DISCLAIMER

In this paper, the wells name is not the real name due to confidentiality.

REFERENCES

Cici, K.E., Puspadianti, A., Haq, F.D., Prasetyo, I.M, Prabowo, T, Untoro, R., Pasaribu, F.: Reinjection Management Evaluation in Karaha Bodas Field 2022. Proceedings New Zealand Geothermal Workshop. (2023).

Moore J.N. [et al.] Petrologic evidence for boiling to dryness in the Karaha - Telaga Bodas geothermal system, Indonesia [Conference] // 27th Workshop on Geothermal Reservoir Engineering. - [s.l.] : Stanford, 2002.

Moore J.N. [et al.] The mineralogical consequences and behavior of descending acid-sulfate waters: an example from the Karaha - Telaga Bodas geothermal system, Indonesia [Journal]. - [s.l.] : The Canadian Mineralogist, 2004. - Vol. 42. - pp. 1483-1499.

Nemcok M. [et al.] Controls on the Karaha-Telaga Bodas geothermal reservoir, Indonesia [Journal]. - [s.l.] : Geothermics, 2007. - Vol. 36. - pp. 9-46.

Nemcok M. [et al.] Controls on the Karaha-Telaga Bodas geothermal reservoir, Indonesia [Journal] // Geothermics. - 2007. - Vol. 36. - pp. 9-46.