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Utilisation of the Excess Thermal Energy in the Geothermal Power Plants through the Reduction of Re-Injection Temperature

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INTRODUCTION

The amount of extractable energy from geothermal increases with the temperature difference, making thermal efficiency a key focus in geothermal operations.

The GeoSmart Project, funded by the EU Horizon 2020 program, aimed to enhance thermal efficiency at the Kızıldere-2 Geothermal Power Plant in Denizli, Türkiye, by lowering the re-injection temperature.

Geothermal fluids carry minerals from the underground rocks, and at Kızıldere-2, silica scaling is a major concern. As the re-injection temperature drops, silica solubility decreases, intensifying scaling risks. This study discusses the strategies implemented to manage scaling and optimize plant performance.

METHODS

To prevent silica scaling during low-temperature re-injection, a **two-stage retention system** consisting of a scaling reactor and a retention tank operating in sequence was designed.

In the scaling reactor, geothermal brine (~50 °C) is adjusted to an alkaline pH (~8.5) to promote controlled silica precipitation on designated surfaces. To reduce the reinjection brine temperature from 105°C to around 50°C, an additional heat exchanger was demonstrated. The fluid then passes to the retention tank, where pH is slightly reduced (~5.0) to stabilize the remaining silica

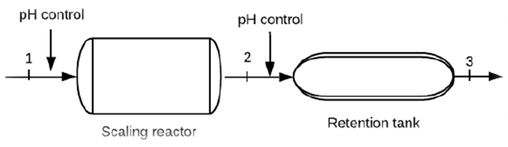


Figure 1. Two stage retention tank

Both units were modeled and optimized for flow dynamics and residence time. The efficiency of silica removal was determined by using the retention system efficiency formula:

where

$$\eta_{RS} = \frac{SiO_{2\,in} - SiO_{2\,out}}{SiO_{2\,in} - SiO_{2\,eq}(50°C)}$$

SiO_{2in}→ inlet silica concentration,
SiO_{2out}→ outlet silica concentration,
SiO_{2eq}→ equilibrium silica solubility at 50 °C

Given the initial silica concentration of 451 ppm and the equilibrium value of 183 ppm at 50 °C, the system achieved an efficiency close to 70% silica reduction.

Corrosion-resistant coatings were applied to internal surfaces to extend equipment lifetime and improve operational stability.

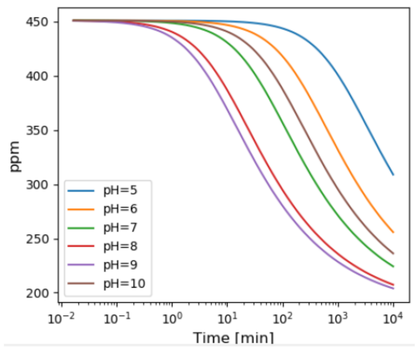


Figure 2. Concentration of SiO_2(ppm) in Kizildere fluid at 50 °C

RESULTS

As a result of the 2-month test period, the reinjection temperature was reduced to 50.9 degrees with the help of heat exchanger (HX-001 in Figure 4). Samples were taken throughout 2 month period for analysis.

SiO2 analysis performed by Kızıldere field laboratory with Hach DR 3900 device. In addition, anion and cation analyses were performed by IC -Dionex 5000 device. pH and EC (conductivity) are measurements by WTW devices. Analysis indicated that 3% SiO2 is removed from brine sample.

The scaling taken from the retention tank were analyzed by XRF-Niton XL5 device. 4% SiO2 is measured.

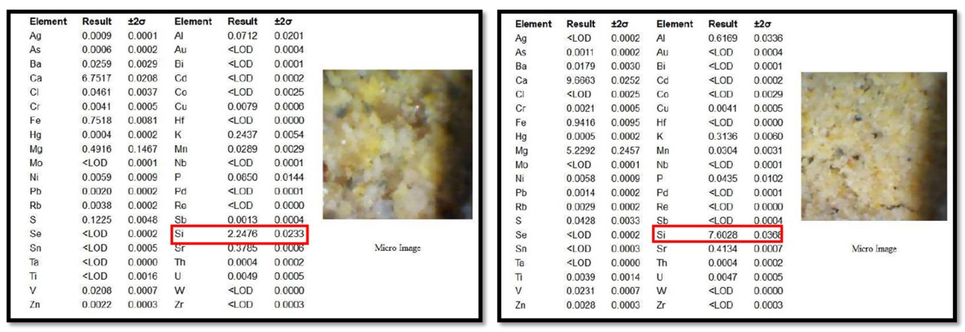


Figure 3. XRF Analysis Results

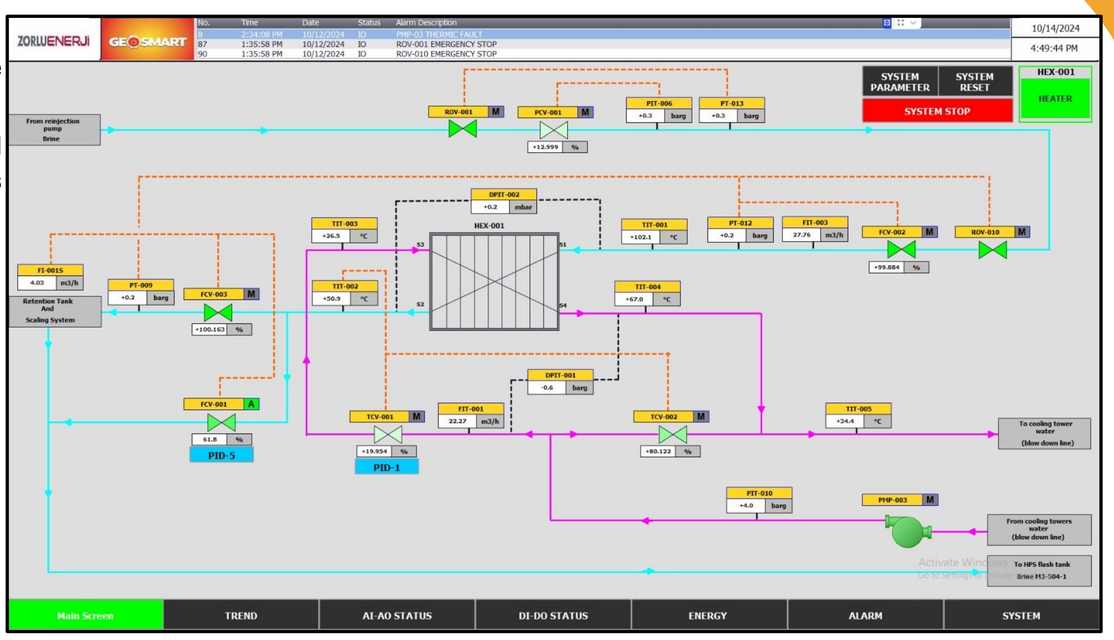


Figure 4. SCADA Screen showing GeoSmart System

Table 1. Brine sample composition from input, medium and output of the system

Sample	Date	pH	EC (µS/cm)	SiO_2 (mg/l)	F^- (mg/l)	Cl^- (mg/l)	NO_2^- (mg/l)	Br^- (mg/l)	NO_3^- (mg/l)	SO_2^{-2} (mg/l)	PO_4^{-3} (mg/l)	Li^+ (mg/l)	Na^+ (mg/l)	NH_4^+ (mg/l)	K^+ (mg/l)	Mg^{+2} (mg/l)	Ca^{+2} (mg/l)
INPUT	25.10.2024	9.524	6030	566	29.0293	141.4277	n.d.	0.7311	0.1894	1091.565	1.3274	3.5015	1496.49	0.7529	200.0669	0.2142	15.5056
MEDIUM	25.10.2024	9.525	6010	552	29.0588	141.8355	n.d.	0.732	0.1817	1093.908	2.0421	3.5188	1499.414	0.7349	200.6429	0.2161	15.778
OUTPUT	25.10.2024	9.526	6020	544	29.8814	141.9311	n.d.	0.7111	0.1863	1102.27	1.553	3.5195	1501.61	0.6573	200.8246	0.2059	15.7919



Figure 5. (a) GeoSmart Retention System, (b) Scaling Reactor module with its drawer open, (c) SiO_2 formation observed in Scaling Reactor

DISCUSSION

Silica analyses showed that approximately 3% of SiO_2 was removed from the brine, while scaling deposits collected from the retention tank contained around 4% SiO_2, confirming that the majority of silica precipitation occurred within the designed retention system.

In normal operation, a high amount of inhibitor is used to prevent silica in the line. Therefore, sediment formation has been less than planned. During the test period, 4% sediment formation occurred due to inhibitor degradation. In areas with high silicon concentrations, sediment formation can be increased by reducing the amount of inhibitor.

In the project, magnesium and calcium precipitates also formed at a re-injection temperature of 50.9 degrees due to the saturation of magnesium and calcium.

These results indicate that the two-stage retention system is effective in managing silica deposition. The combined approach of temperature reduction and chemical control allows safe operation at nearly half the initial reinjection temperature.

CONCLUSION

The production efficiency of geothermal power plants stems from the enthalpy difference. In other words, the more heat is extracted from the reservoir, the more efficient the plant is considered to be. For this reason, the reinjection temperature after the heat is used within the plant should be as low as possible. At the Kızıldere-2 Geothermal Power Plant, one of the main factors preventing the reduction of reinjection temperature is silica formation.

Moreover, the use of corrosion-resistant coatings on internal surfaces contributes to operational stability, suggesting that the system can sustain long-term performance in field conditions. Results also provide insight on excessive inhibitor consumption, which results in higher OPEX and requires further investigation.

Key takeaway: The retention system provides a scalable and replicable solution for silica management in low-temperature geothermal reinjection scenarios.

The retention system developed with the GeoSmart project, which consciously precipitates silica formation within controlled environment, has yielded positive results.

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