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Carbonates and Silica Scaling Model Applied to Hot Water Pipes for Sanitary Use at Hotel Río Perlas, Costa Rica

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ABSTRACT

Río Perlas Spa & Resort is located at the Central Region of Costa Rica, on the Navarro fault system. This hotel exploits the two known hot water springs in the vicinity, they are both sulphated and immature springs, and there is an opportunity to use them to heat sanitary waters. For this reason, a project is being proposed, which aims to drill a well to extract brine at a rate of 79 l/min, with temperatures between 80 °C and 90°C. By using PHREEQC Version 3, it was determined that calcite, dolomite and silica are the minerals most likely to precipitate. Several scenarios were simulated with variable temperatures (from 30 °C to 90 °C) and pH (from 7.5 up to the maximum determined in the field tests). As a model assumption, 1 atm pressure was set for every simulated scenario. Results show that chemical composition of brine #1 is likely to produce silica precipitate (53.4 mg/kg H_2O) and carbonates precipitate (10.7 mg/kg H_2O). By contrast, brine #2 could precipitate 18.3 mg/kg H_2O of silica and 38.2 mg/kg H_2O of carbonates. By reducing brine's pH, carbonate formation could be suppressed, but this is not the case for silica. Brine #2 is less likely to produce silica precipitate, for this reason it is selected to feed the planned heating system.

1. INTRODUCTION

Río Perlas Spa & Resort is located at the Central Region of Costa Rica (see figure 1), in the Navarro River valley, which is controlled by the Navarro fault system. This system is a high angle strike-slip fault, left-lateral displacement and transtensional (Montero, Linkimer and Rojas, 2016). Hot water comes from this system, but the water source is the Talamanca mountain range (volcanic arc). Nowadays, the hotel uses this water just for bathing, but there is a plan to use it as sanitary hot water for showers, restaurant kitchen and laundry.

2. GEOCHEMISTRY

This hotel benefits from two hot springs, the first is located by the pool (brine #1) and the second is located 200 m south, bordering Río Perlas creek (brine #2). The first one shows a measured temperature of 65 °C and a pH of 9.03, the second one is about 47 °C with an 8.71 pH. Composition of each brine is shown in table 1.

Table 1: Chemical composition of thermal hot springs.

Sample	pH	T (ºC)	SiO_2 (mg/kg)	Na+ (mg/kg)	K+ (mg/kg)	Ca++ (mg/kg)	Mg++ (mg/kg)	HCO_3 (mg/kg)	SO_4= (mg/kg)	Cl- (mg/kg)	F- (mg/kg)
Brine #1	9.03	65.00	72.69	161.97	6.87	11.10	6.30	33.23	258.55	45.89	1.72
Brine #2	8.71	47.00	70.59	187.96	7.55	19.80	6.30	46.75	246.55	59.99	1.83

Figure 2 was obtained by analyzing geochemical composition. Figure 2a shows that both brines are sulphated (Giggenbach, 1988), while figure 2b shows they are immature and reservoir temperature is approximately 160 °C (Giggenbach, 1988).

To deploy the project, it is planned to drill a well, from which brine would be extracted at a rate of 79 l/min, with temperatures between 80 °C and 90°C, in order to satisfy hotel needs. As previously mentioned springs are immature, probably because combination of brines with surface water, for this reason extracted brine is expected to have a higher concentration of salts.

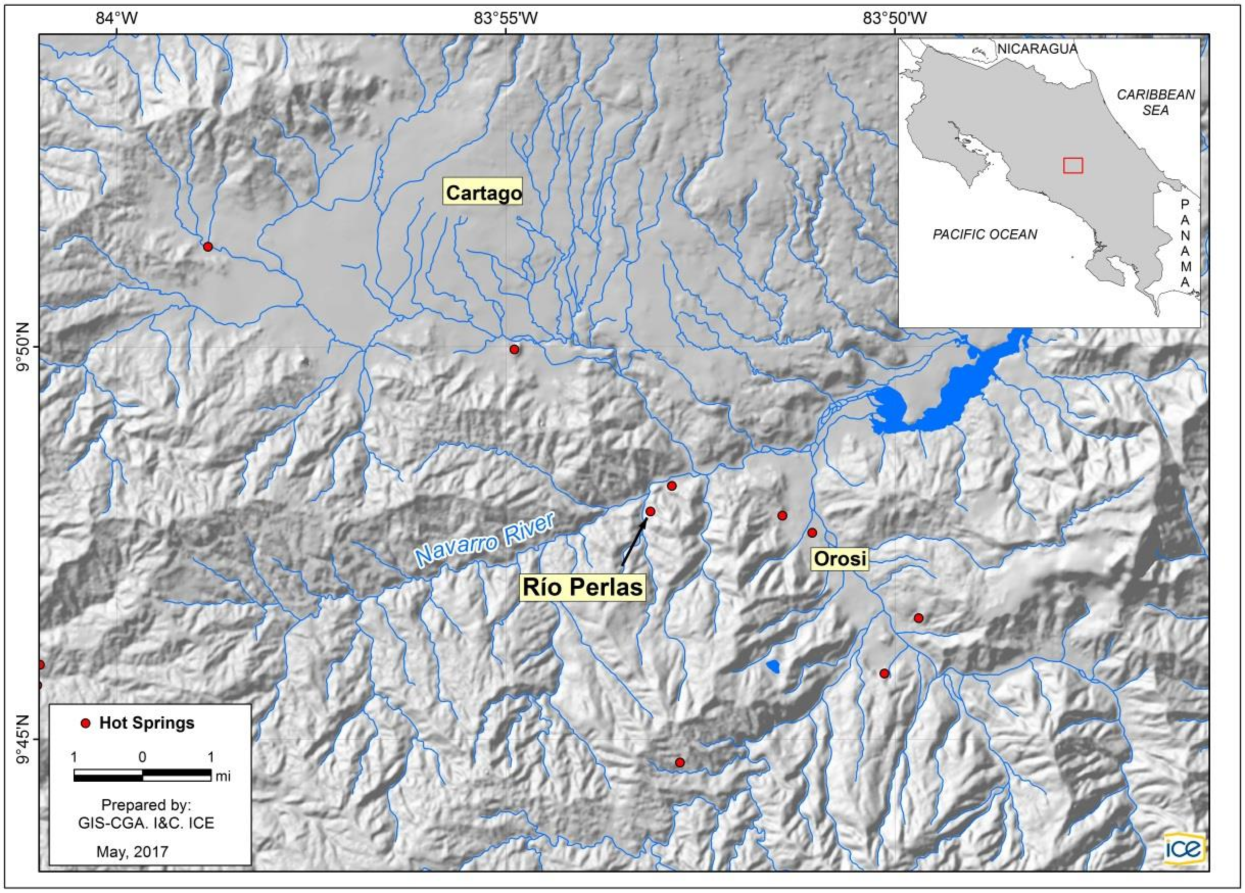

Figure 1: Map showing the study location site (Lat. 9º 48' 13.18"; Lon. 83º 53' 34.04").

3. MODEL RESULTS AND DISCUSSION

One of the early stages to be solved during preliminary studies is predicting the existence, type and quantity of scaling in the pipes and the heat exchanger where brine flows. In order to obtain this information several scenarios were simulated while varying temperature and pH of brines, but keeping pressure as a constant.

By using PHREEQC Version 3 (Parkhurst and Appelo, 2013), it was determined that calcite, dolomite and silica are the minerals most likely to precipitate. Several scenarios were simulated with variable temperatures (from 30 °C to 90 °C) and pH (from 7.5 up to the maximum determined in the field tests, 9.03 for brine #1 and 8.71 for brine #2). As a model assumption, 1 atm of pressure was set for every simulated scenario (see figure 3).

Simulation results show that initial chemical composition of brine #1 is most likely to precipitate silica (53.4 mg · kg^{-1} H_2O) and a lower quantity of carbonates (10.7 mg · kg^{-1} H_2O), while brine #2 scales less silica (18.7 mg · kg^{-1} H_2O), while figure 2b shows they are immature and reservoir temperature is approximately 160 °C (Giggenbach, 1988).

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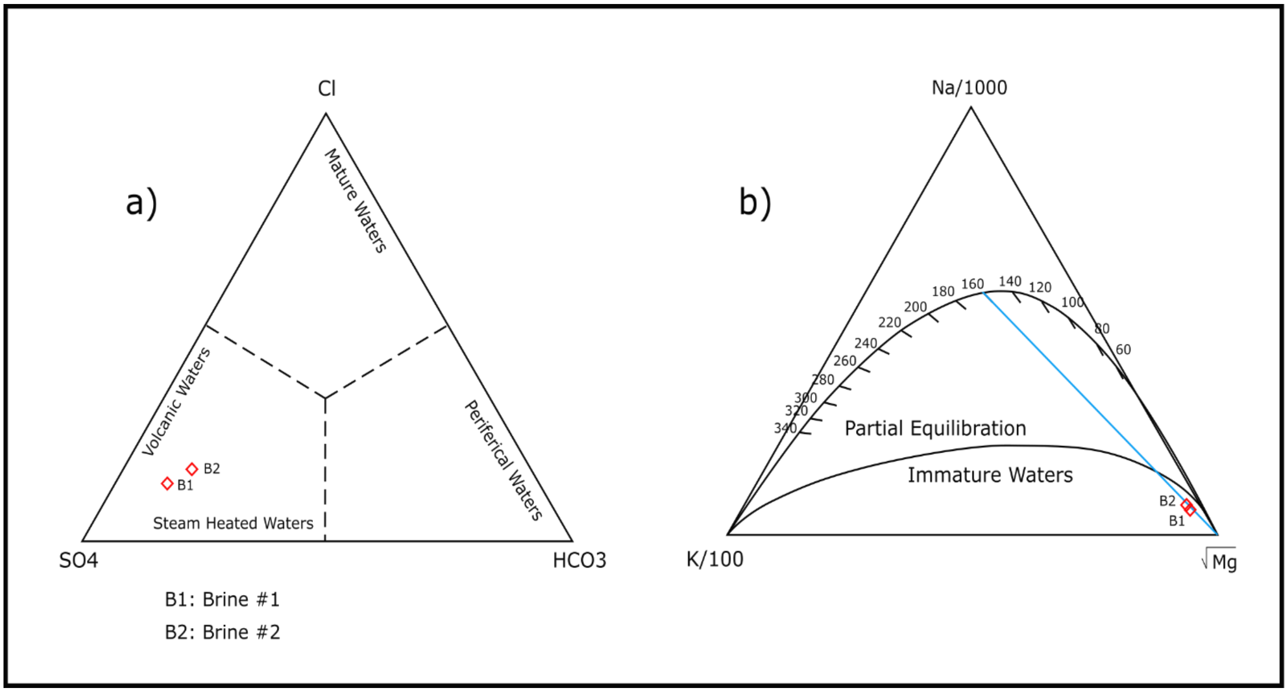

Figure 2: Water classification: a) ternary diagram Cl, SO_4 and HCO_3; b) geothermometer Na-K-Mg. Adapted from Giggenbach (1988).

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If brine's pH is reduced by adding an acid (HCl, for example), carbonate formation could be suppressed (when brine #1 pH reaches 8.0, and brine #2 pH reaches 7.6, see figure 3), but this is not the case for silica, which precipitates at a higher rate when pH is reduced (when using brine #1). By contrast, silica scaling in brine #2 is less prone to change with pH modification, but more susceptible to rise when temperature drops.

Quartz precipitate at temperatures lower than 100 °C is directly related to input pH and temperature conditions. At a lower temperature and a lower pH, higher quartz precipitate is expected (Rimstid, 1997 p.496). However, these silica species are expected to form silica gel, which is the first precipitate at low temperatures in a silica-rich solution (Hem, 1985 p. 72) and not necessarily quartz crystal scaling (Muljani et al., 2014).

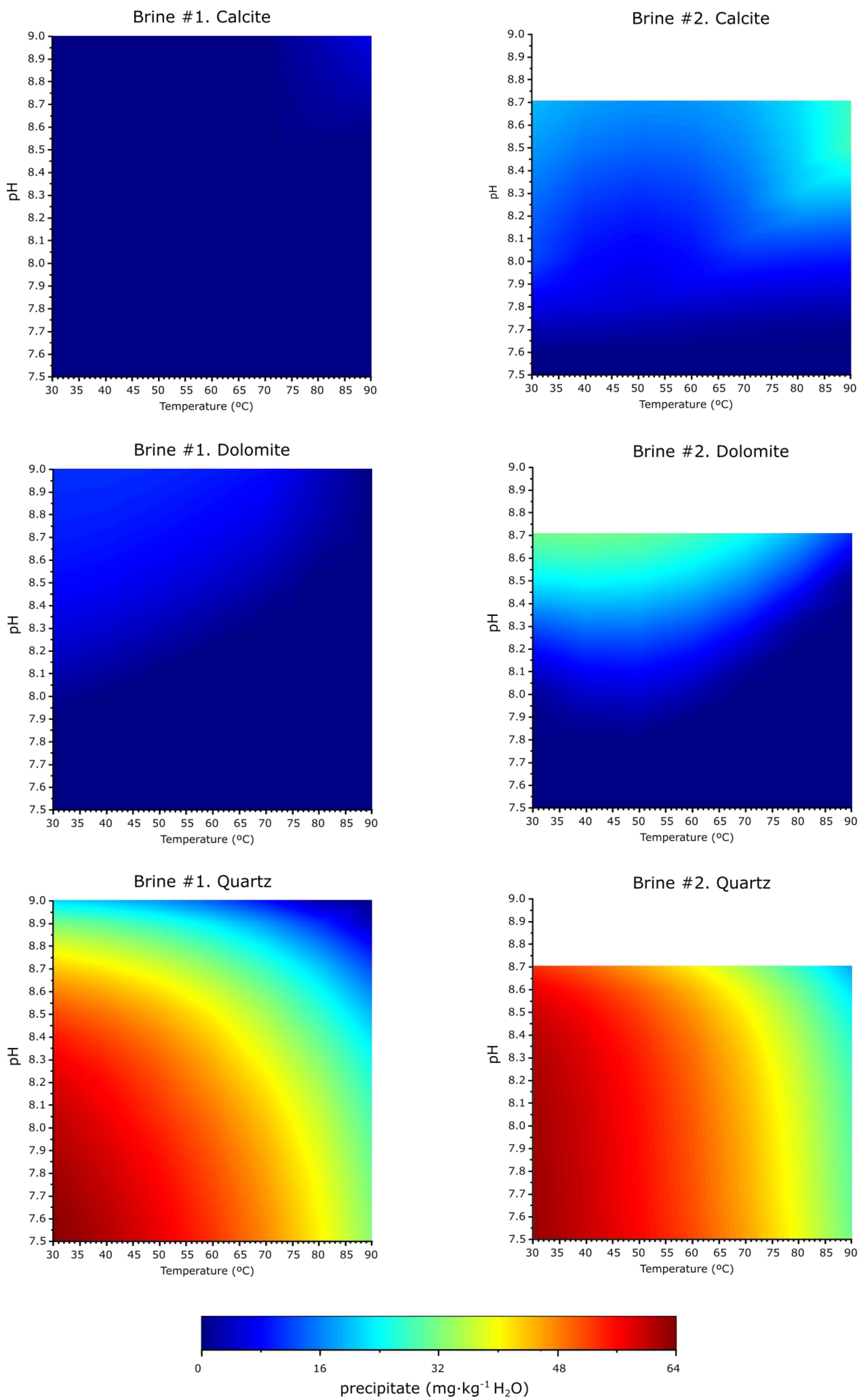

Figure 3: Silica, calcite and dolomite precipitates model, from brine simulation under different temperatures and initial pH conditions (different input values for the system).

5. CONCLUSIONS

Both brines, at the study site, are expected to produce scaling when exploiting hot water in pipes. Scaling is expected as calcite, dolomite (both carbonates) and silica. Precipitate can be suppressed by reducing pH level in both brines (through an acid, HCl for example). Nevertheless, when pH is reduced, silica formations are not avoided. As determined through the model it is recommended not to reduce pH level under 7.6 to avoid increasing silica formations.

After treatment (reducing pH, for example) water will go through a swimming pool, for that reason chemicals showing potential danger to human health are not recommended, and pipes scraping (including heat exchanger) is advised instead.

As shown, brine #2 is less likely to show precipitates, for this reason, this brine would be the best option to use when deploying the project.

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