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EVALUATION ON GEOTHERMAL INJECTION TREATMENT BY pH MODIFICATION

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ABSTRACT

The Hatchobaru power station has the largest rated capacity of geothermal power generation in Japan. It is well known that the first double-flash system was adopted here. In this area, the whole of geothermal brine, about 1,500 t/h, is reinjected through a retaining tank for silica scale prevention, which is one of the extra features of this power station. However, the present reinjection system is not always adequate for scale prevention. Therefore, adoption of pH modification is considered as an alternative scale prevention method.

In order to clarify the effects and impact of pH modification on the Hatchobaru field, brine transmission experiments were carried out using a flow-type autoclave. Silica scale deposition in the inlet of the passage was restrained, and the permeability decline was improved by adjusting brine pH to 5.5. Furthermore, it was proven that the acid brine was neutralized by interaction with rocks. According to these results, it is considered that reinjection of pH adjusted brine will prevent the reinjection capacity decline due to concentrated silica scale deposition, and will not give adverse environment impacts.

The effect of pH modification on the prevention of declining reinjection capacity was estimated by numerical simulation. It was estimated that lives of reinjection wells would be prolonged around three times of present situation by pH adjusted to 5.5 in the Hatchobaru field.

1. INTRODUCTION

Silica scale deposition causes not only plugging trouble in surface facilities such as brine transportation lines, but also reduction of the reinjection capacity. In the early stage of reinjection in the Hatchobaru power station, the reinjection capacity greatly decreased. On the adoption of a double-flash system for efficient generation, the brine temperature decreased below the flash point of water. Therefore, the retaining tank system was originally developed in the Hatchobaru power station as a countermeasure against scaling problems. However, when the chemical composition such as pH and silica concentration of the brine changed, polymerization of supersaturated silica didn't progress in the retaining tank, and silica scale deposition was accelerated on surface facilities.

A number of scale prevention methods have been proposed. It is well known that keeping brine pH acid prevents silica deposition (Nishiyama *et al*., 1985). Gallup (1996) reported that scale deposition rates in brine transportation line were reduced and brine injectivity was also sustained by pH modification. However, in the cases that brine contains high concentrations of silica or high salinity, pH modification is not always successful in preventing silica scale deposition (Garcia *et al*., 1996). The pH modification method should be investigated with variations in some of the brine conditions such as silica concentration, temperature, salinity and others. The pH modification of geothermal brine by acid addition has not been applied to geothermal power station in Japan, because of the potential of environmental impact. This study aimed to confirm the effects of pH modification method in the Hatchobaru field and predict environmental impact.

2. EFFECT ON RESTRAINT OF POLYMERIZATION OF SILICA BY pH MODIFICATION

Silica scale formation is basically regarded as polymerization of silica, and this reaction is controlled by several factors such as silica concentration, temperature, pH, salinity of brine and so on. To clarify the effect of pH on polymerization of silica, experiments were carried out using Hatchobaru geothermal brines (pH=7.4, M-SiO_2=722 mg/L) and (pH=6.6, M-SiO_2=648 mg/L). The brines were adjusted to a given pH with sulfuric acid and packed in polyethylene bottles, which were retained at about 95°C. Aliquots of the brines were sampled and analyzed periodically for monomeric silica (M-SiO_2) by the molybdate method.

It was confirmed that the polymerization of silica in Hatchobaru brines were restrained at pH=5-6, as shown in Fig. 1. The difference of pH dependence of these brines is caused by differences of above-mentioned factors such as silica concentration.

In the case of brine used following transmission experiments, polymerization of silica was restrained at pH=5.5, as shown in Fig. 2. This result indicates that the amount of silica deposition will decrease by adjusting brine pH to 5.5.

3. BRINE TRANSMISSION EXPERIMENTS

3.1 Experimental method

In order to investigate the effects of pH modification on scale deposition rate, permeability reduction related to amount of scale, and change of chemical composition of brine in the permeable layer, brine transmission experiments were carried out using a flow-type autoclave. It was composed of five columns (200 mm x 20 mmφ) connected in series and packed with rock fragments (0.8 or 2 mmφ) to simulate the reinjection zone. Hatchobaru geothermal brine, with a pH of 6.7 (untreated) or 5.5 (adjusted with sulfuric acid), passed through the equipment at a flow rate of 5.5 mL/min. at 100°C for 7 days (168 hours). The experimental parameters such as the temperature, pressure, flow rate and the chemical compositions of outlet brines like pH, T-SiO_2, Cl concentrations were observed periodically during the experimental period of 7 days. The chemical composition of the inlet brine was analyzed just before starting the experiments.

3.2 Effects of pH Modification

Fig. 3(a) shows scale deposition rates on each column packed with rock fragments (0.8 mmφ). In the experiment using untreated brine, the scale deposition in the simulated permeable layer concentrated in the first column (7.1 g/column) and the scale deposition rate decreased with flow pass. The total amount of silica deposition was 19.2 g.

On the other hand, in the case of brine with pH adjusted to 5.5, the scale deposition rates were almost same in all five columns. Although the total deposition rate due to pH modification is reduced to around 70 %, the deposition rate in the first column decreased to around 45 % of that measured using untreated brine. Considering that concentrated deposition causes serious permeability decline, pH modification is effective in preventing injectivity decline due to not only decrease the amount of scale deposition but also preventing a concentrated deposition near the inlet.

Fig. 3(b) shows the permeability change of each individual column packed with rock fragments. They declined after the experiment with pH untreated brine. The permeability changed in No.1 to No.5 column to 75 %, 86 %, 93 %, 99 % and 100 % of the original permeability. No changes in permeability were observed when the pH adjusted brine was used.

From these results, the effects of pH modification for prevention reinjection capacity decline are considered as follows:

- To reduce the amount of silica scale deposition
- To prevent concentrated deposition of silica scale in the vicinity of reinjection well
- To prevent permeability reduction due to silica scale deposition

3.3 Changes in Brine Chemical Composition

The changes with time of the chemical composition of brine passed through the columns packed with rock fragments (2 mmφ) are shown in Fig. 4(a) and (b). In the case of pH untreated (a), T-SiO_2 concentration of outlet brine decreased compared with inlet brine, and they were almost constant for the experimental period. It is considered that these differences of T-SiO_2 concentrations correspond to the silica deposition in the equipment.

On the other hands, in the case of pH adjusted to 5.5 (Fig. 4(b)), the T-SiO_2 concentration of outlet brine changed with time. At first, it was lower than T-SiO_2 concentration of inlet brine like pH untreated case, but it gradually increased, and became equal to that of the inlet brine. In this case, silica scale deposited only during the first stage of the experimental period.

Similar results were obtained in experiments using smaller rock fragments (0.8 mmφ), as shown in Fig. 4(c) and (d). T-SiO_2 concentrations of the outlet brine were constant in the experiment using pH untreated brine (Fig. 4(c)). In the case of brine pH adjusted to 5.5, T-SiO_2 concentrations increased with time (Fig. 4(d)), however they did not become equal that of the inlet brine.

These T-SiO_2 concentration changes seemed occur with pH changes of outlet brines (Fig. 4). When brine pHs were neutral as in the cases of pH untreated or first stage of pH adjusted, T-SiO_2 concentrations were lower than those of inlet brine. As the pH of outlet brine dropped, T-SiO_2 concentrations increased. This means that even though the pH of the brine is adjusted with acid, silica scale has the potential to deposit in the permeable layer while brine is neutralized by interaction with rock.

4. NEUTRALIZATION OF ACID BRINE

From the results of above-mentioned experiments, it was confirmed that the pH of the brine was neutralized, when the acid brine was flowed into the columns packed with rock fragments (Fig. 4(b) and (d)). In these cases, after some hours, the pH change by the neutralization was not recognized.

Batch type water-rock interaction experiments were carried out at 90°C an autoclave. Hatchobaru geothermal brine (2L) was adjusted to pH of 5.5 with sulfuric acid, and mixed with rock fragments (40g). pH of the brine was analyzed periodically. As showing in Fig. 5, the pH of brine began to change within short time, then it was neutralized. The neutralization capacity and reaction rate depends on the surface area of rock fragments (diameter of rocks).

5. SIMULATION OF INJECTIVITY DECREASE

In order to estimate the preventive effect of pH modification on the decrease of reinjection capacity, a numerical simulation was carried out. It became possible to predict injectivity reduction due to both pressure interference and permeability decrease caused by the silica scale deposition in porous reservoir, by connecting a reservoir simulator with a mathematical model developed by Itoi *et al*., (1987, 1989).

Decrement rates of reinjection capacity of the Hatchobaru wells were calculated from 30 to 70 % a year in the case of pH untreated brine. These estimated rates are similar to actual decrement rates of reinjection capacity in the Hatchobaru field. On the other hand, in the case of pH adjusted to 5.5, decrement rates were calculated from 10 to 30 % a year. It is estimated that lives of reinjection wells are prolonged around three times by pH modification in the Hatchobaru field.

6. CONCLUSIONS

The pH modification is well known as one of the most promising methods for preventing scale deposition, but this method has not been commercially applied so far to geothermal power stations in Japan. From our experimental results, the advantages of the pH modification method were studied, the scale preventive effect by pH modification is summarized below.

- The amount of silica scale deposition is decreased, not only in surface facilities, but also in the reinjection zone.
- The concentration of silica scale deposition in the vicinity of the well, the biggest problem of reinjection capacity decline, is prevented.
- The scale preventive effect in the permeable layer decreases with distance from the reinjection well because of neutralization.
- Injected acid brine is neutralized by interaction with rocks.
- Lives of reinjection wells are prolonged around three times by pH adjusted to 5.5 in the Hatchobaru field.

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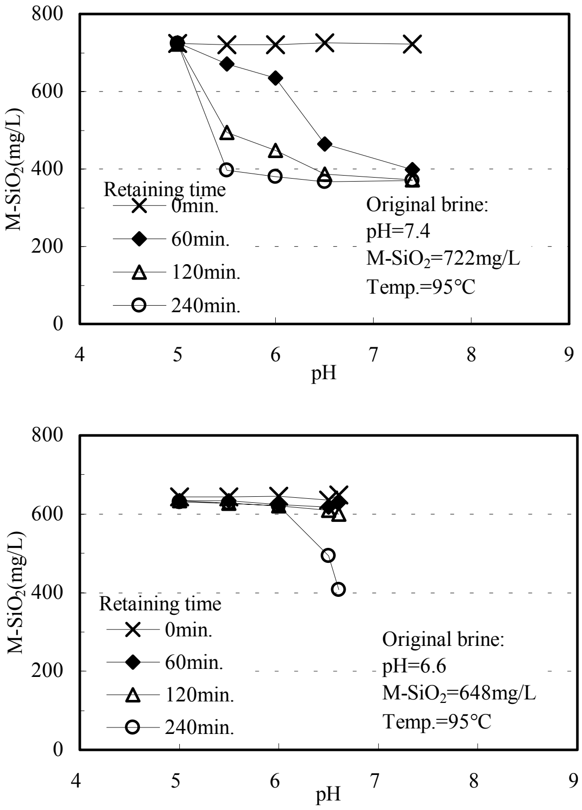

Fig. 1. M-SiO$_2$ concentration changes with time depend on pH.

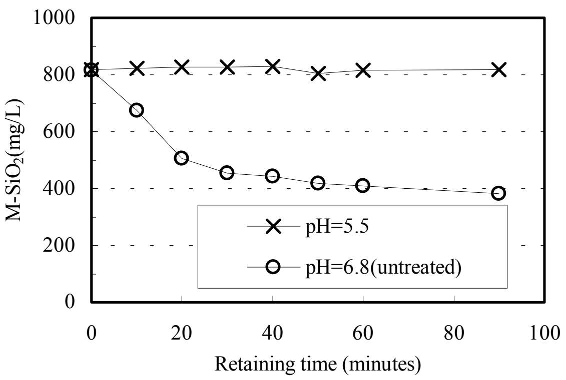

Fig. 2. M-SiO$_2$ concentration changes with time.

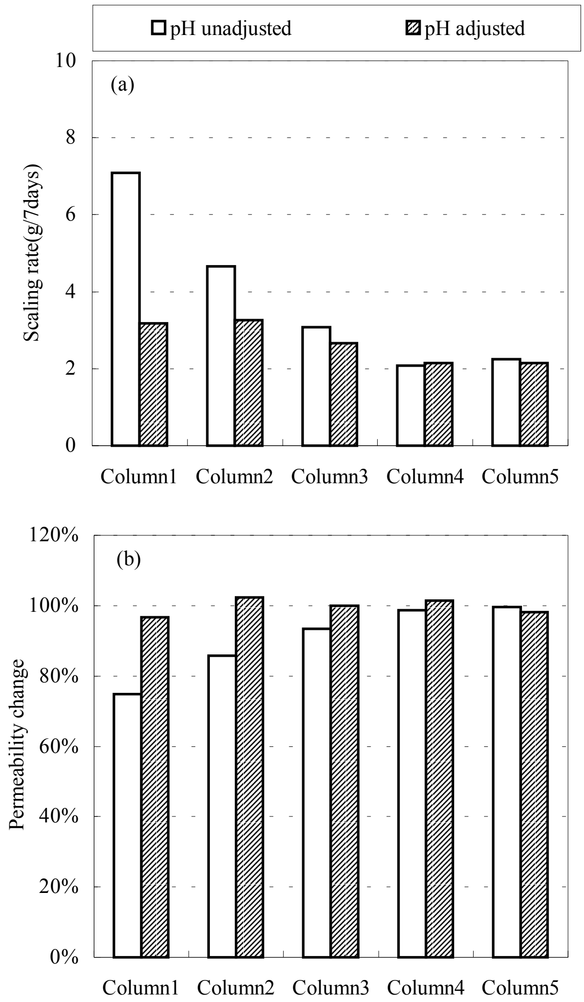

Fig. 3. Scaling rate (a) and permeability change (b) of each column packed with rock fragments.

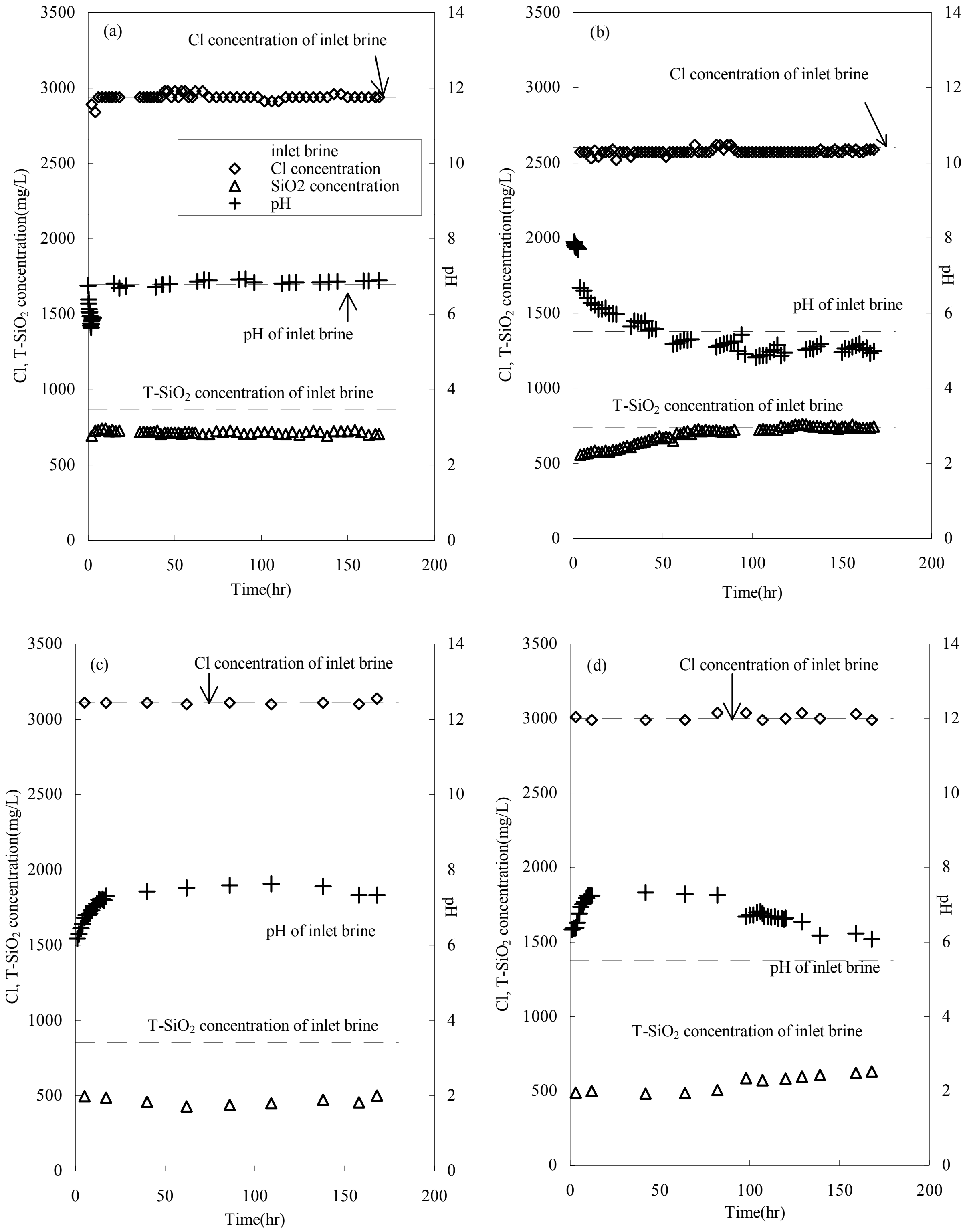

Fig. 4. Chemical composition changes of outlet brine with time.
(a): pH untreated brine passed through rock fragments (2mmφ)
(b): pH adjusted brine passed through rock fragments (2mmφ)
(c): pH untreated brine passed through rock fragments (0.8mmφ)
(d): pH adjusted brine passed through rock fragments (0.8mmφ)

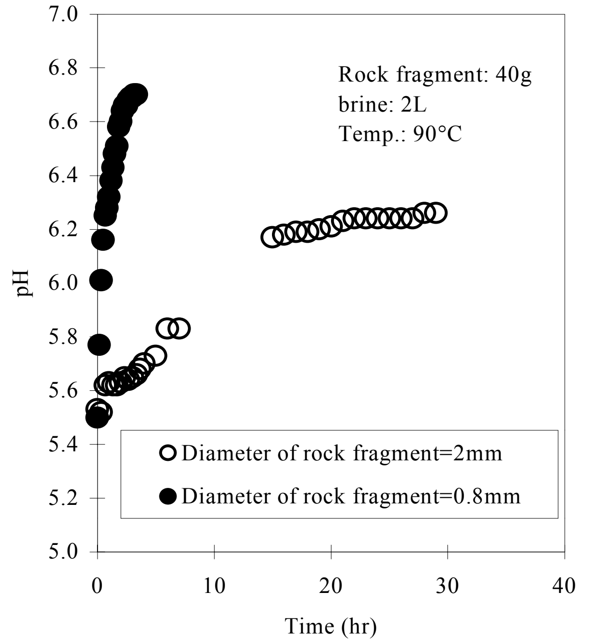

Fig. 5. pH changes with reaction time interacting with rock fragment.