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Kinetics of Silica Precipitation in Geothermal Brine with the Addition of Nano Silica Seeds

Abstract

The utilization of geothermal energy in Indonesia has not been carried out optimally due to several obstacles. One of the obstacles that are often encountered is silica scaling. The silica contained in the brine is generally deposited in canals or settling tanks that are extensive before the brine is reinjected into the earth's bowels. To reduce investment in geothermal development, the process of silica precipitation in the canals/settling tanks needs to be accelerated. Accelerating the precipitation process can be done by adding seeds to the geothermal brine. In this study, brine was taken from geothermal wells at the Dieng geothermal power plant Jawa Tengah, Indonesia. Nano silica seeds were added to the brine at the adjusted pH, temperature, and stirring speed, and then the silica concentration was measured using an Inductively Coupled Plasma (ICP). Based on the experiments that have been carried out, it was found that the concentration of silica in the liquid phase can be reduced by adding nano-silica seeds. The higher the temperature, the higher the silica concentration. The higher the pH, the lower the silica concentration. The optimal precipitation process is at 60°C, pH 5, stirring speed of 800 rpm, and 0.3 g of seeds.

Introduction

The total geothermal potential in Indonesia is estimated at 28,910 MW. However, most of this potential has not been used. Currently, Indonesia only uses less than 5% of these resources [1]. The utilization of geothermal energy in Indonesia has not been maximized due to several obstacles, one of which is silica scaling.

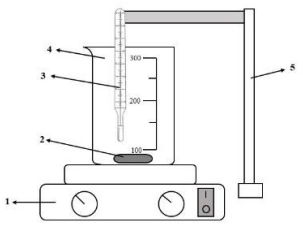
Fig 1. Silica scaling [2]

Fig 2. Brine storage pond [3]

The silica contained in the brine is generally deposited in canals or settling tanks that are extensive before the brine is reinjected into the earth's bowels. In order to reduce investment in geothermal development, the process of silica precipitation in the canals/settling tanks needs to be accelerated. The precipitation process can be accelerated by adding precipitation seeds to the geothermal brine to reduce the nucleation time. Conditions of pH, temperature, and turbulence are the variables studied. Through this research, it is hoped that the optimum operating conditions and dosage of adding nano silica seeds can be obtained to reduce the concentration of silica in the brine relatively more quickly.

Methods and Materials

Geothermal brine obtained from geothermal wells at the Dieng Geothermal Power Plant (PLTP), Jawa Tengah, Indonesia. Wacker Chemie AG supplies nano silica as seeds, 1000 ppm standard silica ($SiCl_4$) solution, nitric acid (HNO_3, pro analysis), sodium hydroxide (NaOH, pellets for analysis) is supplied by Merck, deionized water with the brand Water One is supplied by PT. Jayamas Medica Industries.



Caption:
1. Hot Plate Magnetic stirrer
2. Stirrer bar
3. Thermometer
4. Beaker glass
5. Stative and clamp

Fig 3. Research tool suite

200 mL of geothermal brine was taken and put into a 300 mL beaker glass. A beaker glass containing brine which has been mixed with nitric acid is placed on a magnetic stirrer hot plate, and the brine is adjusted to a temperature of 30, 60, and 80°C. After the reaction temperature was reached, sodium hydroxide solution was added to adjust the pH to 5, 6, and 7. The stirring speed was varied to 300, 600, and 800 rpm at pH 6 and a temperature of 60°C. After the reaction conditions were reached, 0.3 grams of nano silica was added to the solution.

Results

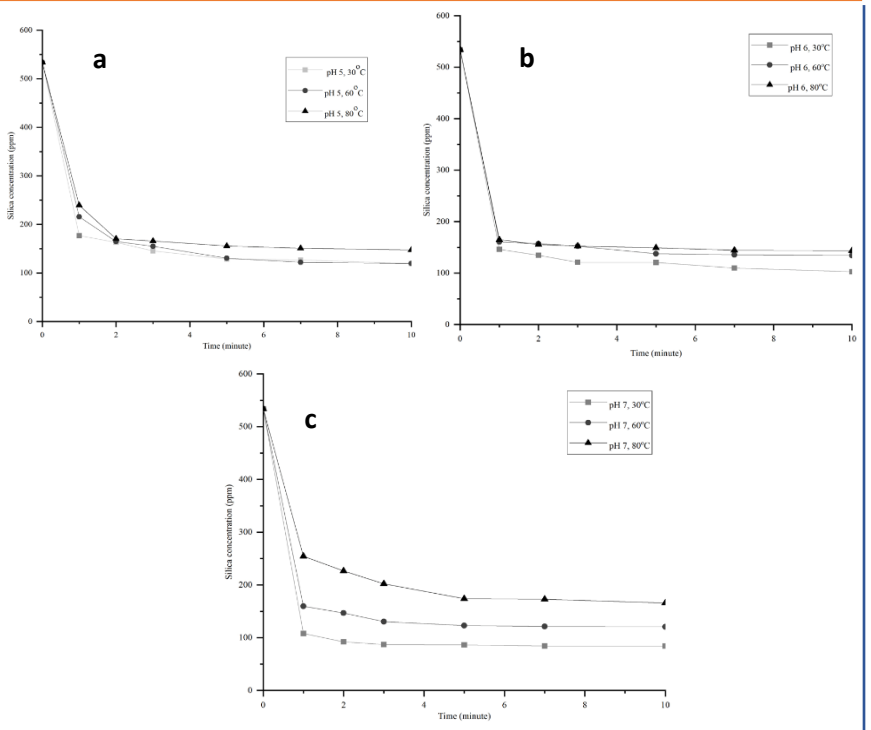


Fig 4. Silica concentration at various pH and temperature; **a**. pH 5 at different temperatures, **b**. pH 6 at different temperatures, and **c**. pH 7 at different temperatures.

Discussion

The most significant decrease in the final concentration of silica was at pH 7 at 30°C, which was 87 ppm. Decreasing this concentration will increase the size of the seeds, meaning that mass transfer occurs from liquid to solid. The results of our experiments show that the addition of seeds can eliminate the induction and nucleation phases so as to speed up the precipitation time. From the results of surface area analysis, the initial surface area of nano silica seeds was 181.346 m^2/g. After precipitation, a surface area of 123.401 m^2/g was obtained. The size of the nano-silica particles, with an initial size of 232.5 nm, after precipitation was 257.1 nm. From the results of the analysis of the initial seeds and after precipitation, there was an increase, meaning that there was growth in nano silica seeds.

The Silica Saturation Index (SSI) value is also calculated to determine the optimum conditions.

Table. 1 SSI values at various pH and temperature

pH	Silica Saturation Index (SSI)		
	30°C	60°C	80°C
5	1,38	1,02	0,85
6	1,14	0,76	0,58
7	0,84	0,75	0,90

The best SSI value was achieved at pH 5 at 60°C, namely 1.02. The higher the temperature and pH, the lower the SSI value.

Conclusions

The addition of nano-silica seeds to geothermal brine can speed up the precipitation process. Precipitation process that occurs through mass transfer from liquid to solid. The time needed to reach equilibrium is 5-10 minutes. The higher the temperature, the higher the silica concentration. The higher the pH, the lower the silica concentration. The speed of stirring accelerates the decrease in silica concentration but does not shift the equilibrium. In this study, the optimal dosage and conditions for precipitation were obtained, namely 0.3 gr seeds, pH 5, temperature 60°C, and stirring speed of 800 rpm.

Contact

Riskal Fadli
Department of Chemical Engineering, Faculty of Engineering, Universitas Gadjah Mada, Jl.Grafika 2 Bulaksumur, Yogyakarta 55281, Indonesia.
Website: chemeng.ugm.ac.id
Email: Riskalfadli@mail.ugm.ac.id
Phone: 082280024656

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