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Effect of pH and Surfactant Concentration Sodium Lignosulfonate (SLS) towards Reduction of Silica Mass from Geothermal Brine

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Abstract

Geothermal energy source is one of the wealth of mineral resources that are being widely used. Geothermal Power Plant is a solution to the needs of New Renewable Energy to overcome energy needs and dependence on renewable energy. However, there were important problems that occurred in the geothermal field, namely the formation of silica scaling in the production pipe causing the brine injection process to be disrupted, the injection process aims to maintain the volume of the geothermal reservoir and maintain the quantity of production steam in the long run. Therefore, controlling silica in the brine injection path in geothermal fields is very much needed. This paper discussed the decrease in silica mass influenced by pH and the addition of Sodium Lignosulfonate (SLS) surfactants that studying the changes in pH (7, 8 and 9), and surfactant concentrations (0.05, 0.15 and 0.30% (w/v)). The results showed that the dissolved silica in the geothermal solution was reduced and could be controlled by the addition of SLS surfactants. The greater the surfactant concentration and pH, the more the mass of silica will be taken. The best conditions are at pH 9 and SLS surfactant concentration 0.30%w/v.

Keywords: geothermal; silica scaling; sodium lignosulfonate; surfactant.

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Introduction

Indonesia is blessed with enormous and diverse potential energy resources. Not only fossil energy but renewable energy potential is also spread throughout Indonesia including geothermal energy. Geothermal as an environmentally friendly and renewable natural resource is one alternative energy source that can be developed to generate electricity and support the growth of electricity development in Indonesia.

One of the power plants that utilize the geothermal potential in Indonesia is PT Geo Dipa Energy Dieng Unit. This Dieng geothermal field production fluid has a high silica content of 440 ppm (Setiawan et al., 2015). The high silica content causes scaling problems both in geothermal steam production wells and in the brine injection pathway, as a result, the injection pipes become clogged and the process of distributing brine to the injection wells is disrupted (Haklidir & Haklidir, 2017; Cano et al., 2022). It can be seen in Figure 1.

The injection process aims to maintain the volume of the geothermal reservoir (Mori et al., 2019) and maintain the quantity of steam production in the long run (Sandoval et al., 2018).

Figure 1. Silica scaling on geothermal pipes (Pusat Kajian Sumberdaya Bumi Non-Konvensional, FT UGM)

Thus, it is necessary to reduce the mass of silica to reduce scaling in the injection pipe. One of them is by controlling brine pH (Ikeda & Ueda, 2017) and adding Sodium Lignosulfonate (SLS) surfactants. The addition of surfactants will help to reduce surface tension so that silica can be easily controlled. While the research conducted by Setiawan et al. (2015), only added Calcium hydroxide ($Ca(OH)_2$) compounds without surfactant. This study aims to determine the effect of pH and SLS surfactant concentration on decreasing the mass of silica in the brine. So, there is no need to do continuous pipe cleaning which results in a decrease in the production of geothermal steam.

Materials and Methods

The material used in this study is ammonium hepta-molybdate ($(NH_4)_6Mo_7O_{24}\bullet{}_4H_2O$) (Servis et al., 2021). This solution is used as a reagent in the analysis of silica monomer concentrations in brines using UV/Vis spectrophotometry with the yellow molybdate method. Sulfuric acid (H_2SO_4) 96% was used as a reagent in the analysis of silica monomer concentrations in brines using UV/Vis spectrophotometry (Ito et al., 2017. $Ca(OH)_2$ is used as a reagent and adjusts the reaction pH.

SLS surfactants are used to reduce surface tension and prevent coagulation in geothermal solutions so that the silica content is easy to control. This surfactant is not obtained through this method but comes from waste empty fruit bunches of oil palm. Utilization This waste is used as a surfactant SLS.

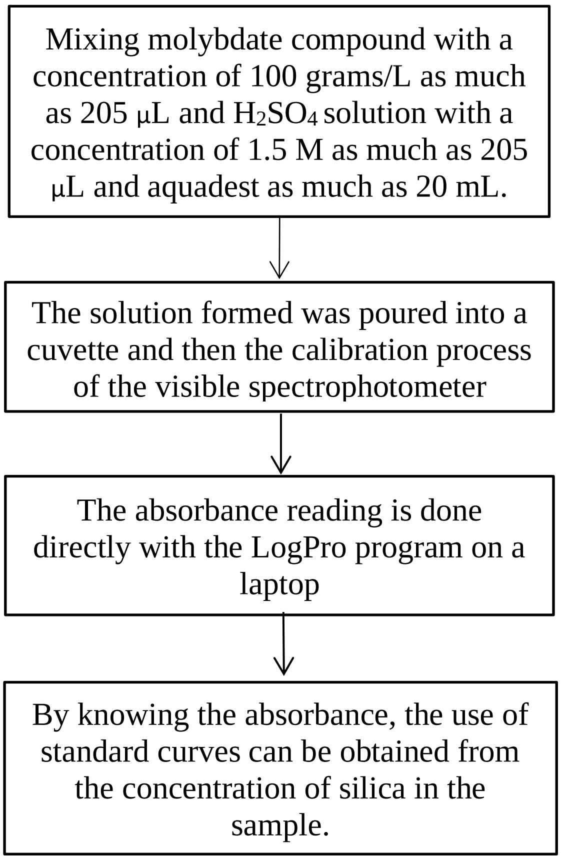
Silica content in the geothermal solution was analyzed using UV-Visible spectrophotometer (Dubey & Bende, 2018). This step is used to determine the level of silica dissolved in the solution taken at certain pH conditions.

UV visible spectrophotometer using absorption of wave radiation ranging from UV light to visible light. Based on this principle, UV-visible spectrophotometers can be used to determine the content of inorganic or organic substances in solution. For the relationship between concentration and absorbance at the wavelength (λ), it is necessary to make a standard solution at various concentrations whose absorbance measurement results are expressed by a calibration curve of the relationship between absorbance (Ab) and concentration (C) (Larson et al., 2018).

The spectrophotometry calibration process needs to be done before measuring the absorbance of the solution. According to Tahir (2008), the calibration process has an important role in providing analysis results with maintained precision and accuracy. The instrument calibration process is carried out using a blank solution. The UV visible spectrophotometer process can be seen in Figure 2.

The surfactant used is a natural surfactant that is widely used in the industry. Lignosulfonate is a water-soluble surfactant so it is widely used as an admixture material, which is to assists the stirring process in the cement mill and makes the building construction more robust because lignosulfonate is also a good binding agent (Fitriani, 2016).

One of the potential natural ingredients for making SLS surfactants is an empty fruit bunch (EFB). This material has the potential to be used as a raw material to produce lignosulfonate surfactants because EFB has a high lignin content (Putri et al., 2019). The molecular structure of SLS can be seen in Figure 3.



Mixing molybdate compound with a concentration of 100 grams/L as much as 205 μL and H_2SO_4 solution with a concentration of 1.5 M as much as 205 μL and aquadest as much as 20 mL.

The solution formed was poured into a cuvette and then the calibration process of the visible spectrophotometer

The absorbance reading is done directly with the LogPro program on a laptop

By knowing the absorbance, the use of standard curves can be obtained from the concentration of silica in the sample.

Figure 2. The UV visible spectrophotometer process.

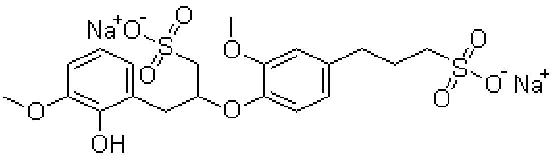


Figure 3. Molecular structure of SLS surfactants (Chemblink, MSDS, 2022).

The SLS surfactant molecular structure in Figure 3 shows that SLS is a reaction between sodium bisulfite ($NaHCO_3$) and the lignin molecule, it can be seen from its hydrocarbon chain as a hydrophobic group and SO_3 ion as its hydrophilic group. Reactions that occur in the lignin sulfonation process include irreversible and endothermic reactions (Tang et al., 2015). The reaction occurs in a homogeneous phase (Sudarmoyo et al., 2020). Temperature and pH are the most influential factors in the reaction of SLS formation. The higher the acidity, the hydrolysis rate will increase, and the higher the temperature, the reaction rate will be even greater.

The tool used is the hot plate magnetic stirrer, devices are designed in batches equipped with temperature settings and playback scales; the thermometer is mounted on a thermometer to determine the temperature conditions that are set by the temperature control knob. Although there is a temperature control button, researchers still install a thermometer inside the liquid to determine whether the temperature control switch is operating properly and following a predetermined reaction temperature.

In the initial stage, the brine condition is adjusted to the reaction temperature, which is 30^{o}C, so this temperature condition is the optimum condition which shows the lowest silica concentration in the solution (Ulya et al., 2017). After the reaction temperature is reached, the SLS surfactant is added to the concentration adjusted to the concentration of 0.05, 0.15, and 0.30%w/v stirred until homogeneous on a hot plate magnetic stirrer. If the reaction conditions are homogeneous (± for 5 minutes) then base $Ca(OH)_2$ is added to reach pH 7, 8, and 9 conditions using a pH indicator. Because at the pH point conditions the solubility of silica experiences the lowest point in the mother liquor (Eikenberg, 1990). Then from the absorbance obtained it is known that silica is taken by decreasing the amount of silica concentration from the mother liquor.

Results and Discussion

The mass of silica obtained was then multiplied by the total volume of the solution for each variation of pH and SLS surfactant concentration under the reaction temperature conditions of 30^{o}C. The results obtained can be seen in Figure 4 below.

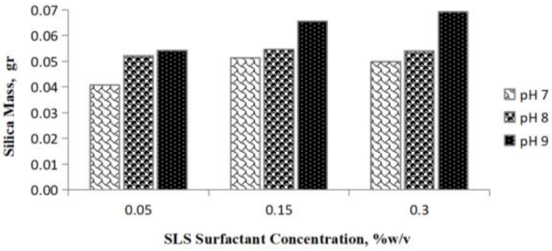


Figure 4. Silica Mass and pH at SLS Surfactant Concentrations

The difference in pH and SLS surfactant concentration can affect the amount of mass silica taken (Fig.4). This can be seen at every increase in pH in brine increasing silica mass, as well as the addition of SLS surfactants at every %w/v. When the addition of base $Ca(OH)_2$, Ca compounds can bind Si so that the concentration of silica in the liquid decreases. With the addition of $Ca(OH)_2$ in the geothermal solution, it will decompose into Ca^{2+} ions and OH^- then Ca^{2+} ions will bind Si directly into the micelle and will propagate continuously in the micelle. The formation of this monomer is very dependent on the presence of micelles for the nucleation of the micellar process. The formation of these micelles will continue to experience growth if the SLS surfactant concentration continues to be added until it reaches the saturation point and until the droplet monomers are consumed. At the pH 7 condition with the addition of a 0.05%w/v SLS concentration is the lowest taken silica mass of 0.0408 gr. If this condition is raised to 8 pH, the difference in silica mass taken is 0.0521 gr, more much from pH 8. Similarly, the addition of pH 9 increases the mass of silica that is taken. These results are also consistent with researchers conducted by Eikenberg (1990) with increasing pH the final concentration of silica decreases. So that with the decrease in silica concentration can be seen the mass of silica taken.

Figure 4 shows the change in SLS surfactant concentration which is very significant, as SLS surfactant concentration increases, the mass of silica is also increase. If the mass of silica is converted into the percent of silica taken, then the percent of silica is taken at the best conditions, namely temperature 30^{o}C, pH 9 and the addition of SLS surfactant concentration 0.30%w/v is 11.609%. (Rofi, 2016) using $Ca(OH)_2$ base was only able to take dissolved silica as much as 5.355% at 40^{o}C, pH 9, and without using surfactants.

Differences in SLS surfactant concentrations as dispersing agents also result in differences in the conditions of the geothermal fluid. Ismiyati (2008) suggested that the different in SLS surfactant concentration is very influential on the percentage of flow values obtained to determine the performance of SLS as a dispersing agent. He addition of SLS as a dispersant in a solution causes a decrease in viscosity so that the surface area becomes larger (dispersed). Dispersing agents that work at the interface between two phases will produce an electric barrier to prevent the dispersing of solid particles (Khouw et al., 2021). Therefore, with the increasingly dispersed geothermal solution by SLS surfactants, it is easier to control and even reduce the silica mass (Sudarmoyo et al., 2018).

The influence of SLS surfactants has been investigated by Ulya et al. (2017) by comparing the brine conditions without using surfactants with the addition of SLS surfactants, which shows that in the brine condition without the addition of SLS surfactant at a temperature of 30^{o}C and pH 9, the resulting dissolved silica concentration was 176 ppm. This silica concentration can drop to 156 ppm after adding SLS surfactant with a concentration of 0.05%w/v, then it can go down to 128 ppm after adding SLS surfactant with a concentration of 0.15%w/v. Additional of SLS surfactant with a concentration of 0.30%w/v, the concentration of dissolved silica can drop even further to 119 ppm. With the addition of an SLS surfactant, it was able to reduce the concentration of dissolved silica in the brine. This indicates that the addition of SLS surfactants is very good to do because there are also Na elements from SLS surfactants that can bind silica and can reduce surface tension to prevent coagulation.

Conclusion

Dissolved silica in the geothermal solution is reduced and can be controlled by the addition of SLS surfactants. The greater the surfactant concentration and pH, the more the mass of silica will be taken. The best conditions were at pH 9 and SLS surfactant concentrations of 0.30%w/v. The addition of base $Ca(OH)_2$ as a pH variable is very influential in decreasing the mass of silica in the geothermal brine. With the addition of $Ca(OH)_2$ in the geothermal solution, it will break down into Ca^{2+} ions and OH^- then Ca^{2+} ions will bind Si causing a decrease in silica mass in the brine. The addition of SLS surfactants is very good to do, because, in addition to being a dispersing agent, SLS surfactants also have the element Na which can bind silica and reduce the mass of silica in the geothermal brine.

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Author Contribution

MRU led the research and provided the outline of the manuscript. All authors contributed to discussion to form the basis of this paper, and provided feedback on the manuscript.

Conflict of Interest

The authors declare that they do not have affiliations with or involvement in any institution with either financial or non-financial interest.

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