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FRONTIER FLUID INJECTION MANAGEMENT IN DIENG GEOTHERMAL FIELD TO PREVENT SILICA SCALING: EFFICIENCY FOR GREATER OPTIMAL PRODUCTION

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ABSTRACT

As a severe production issue in Dieng geothermal field, silica scaling has been a major threat in various hydrothermal field dominated with water, thus affecting severely on production and electricity generation of the field. To overcome the damaging effect of silica scaling, an innovative and suitable fluid injection management is a must. This research is conducted by gathering geothermal field data from previously observed fields and comprehensive data analysis in order to achieve the best possible solution. The amount of silica deposition is estimated by calculating the difference between dissolved SiO2 with the solubility of amorphous silica curve. At 180°C and 160°C, the induction time for polymerization was not reached. Scaling rates were 0.2 to 0.3 mm/yr at 180°C (assuming density 2.2), increasing to 0.3 to 0.4 mm/yr at 160°C. At 140°C and 120°C, there was measurable polymer formation, even at the pipe inlet, and the polymer concentration increased through the pipeline; the increase at 120°C was twice that at 140°C. Therefore, scaling in the pipeline decreased dramatically along the length of the pipe, as monomeric SiO2 was removed from solution into the suspended polymer. In all cases, the scale which formed was hard and glassy, with density about 2 gm/ cc. Accordingly, researchers found that the deposition process of silica scaling in Dieng Geothermal Field highly depends on temperature and fluid pH. With those dependence in mind, it is possible to assume low-level scaling confidently enough for purposes regarding production, injection system and mechanism. This can be achieved by suppression technology with the main purpose is to reduce the pH of the fluid by mixing with non-condensable gases and steam condensate. Improved developments in the future on predictive technique will result in uniformity in data collection and experiment design.

Keywords: Fluid injection management, Dieng, silica scaling, temperature, solubility.

INTRODUCTION

Dieng Plateau is located on the border between Wonosobo regency and Banjarnegara regency with an area of 620 hectares surrounded by cluster of mountains such as Mount Sumbing, Mount Sindoro, Mount Perahu, Mount Rogojembangan and Mount Bismo. Dieng Plateau is a caldera with volcanic activity beneath its surface. Dieng geothermal field which is managed by PT. Geo Dipa Energi has two locations of Geothermal Power Plant Complex. The field is located in the Dieng volcanic plateau at an altitude of more than 2000 meters (Layman et al., 2002).

In general, geothermal system is divided into two categories: vapor domination system and water domination system. Dieng Geothermal Field is in the water dominated category with its fluid production composition is 60% water and 40% steam. As a severe production problem at Dieng geothermal field, silica scaling has become a major threat in various hydrothermal fields dominated by water, which greatly affects production and power generation in the field. Scaling is a precipitate or crust derived from mineral salts dissolved in water on a particular contact medium which results in scaling of the contact medium, for example the reduction of pipe diameter or even total blockage of the pipe. Dieng field geothermal fluid production which has a high silica content of ± 900 mg/L. The silica content of high production fluids causes silica scaling problems in geothermal steam production wells and in the brine injection path at Dieng geothermal field.

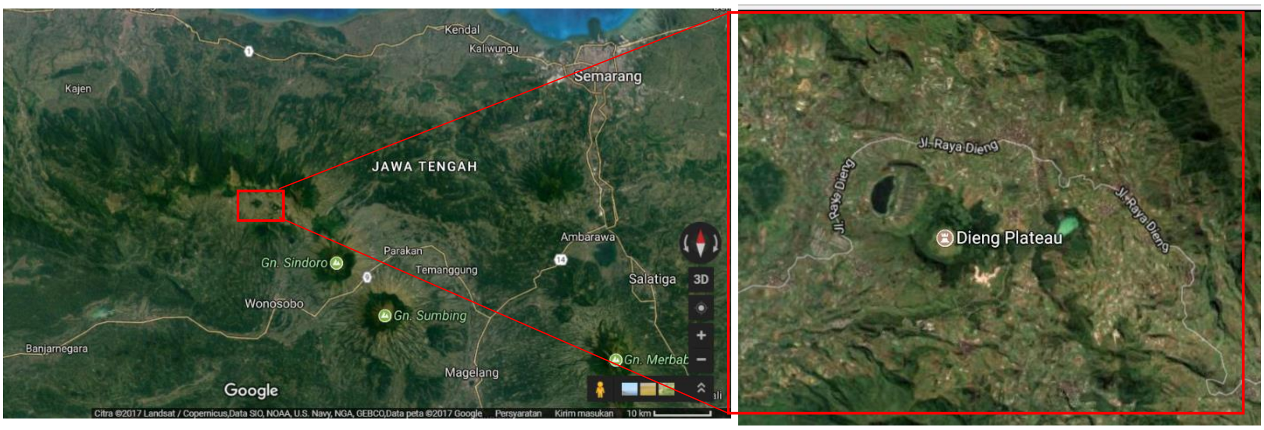

Figure 1: Dieng Plateau Location

Figure 2. Silica Scaling at Dieng field (Felix Arie Setiawan, 2015)

Despite the success of the geothermal industry in learning to manage the severe deposition of hot geothermal hypersaline water in the Salton Sea region of California, United States can show that silica scaling problem can be solved, because to overcome the damaging effects of silica scaling, an innovative and appropriate fluid injection management is a must.

This study aims to implement a concept of fluid injection management based on temperature and fluid pH associated with the rate of pipe diameter reduction process on the brine injection path or production well by silica scaling at Dieng geothermal field. The benefit of this research is to find out suitable method or mechanism to reduce silica scaling so that it can increase production based on the parameters which influence the rate of silica scaling thickening. Where the development of the results of this future-enhanced research on predictive techniques will result in uniformity in data collection and experimental design.

METHODOLOGY

This research is conducted by collecting data obtained from previous studies in the past. Data were obtained from previous literature and researches on silica scaling such as data obtained from the representative wells.

The data has been collected is then processed so that it can be developed to the next phase. In order to create research works that can be utilized widely it is required to do the following stages of data processing which includes:

a) *Examination of data*. The data that has been collected is then checked whether it is complete in order to support the hypothesis to be presented in this paper.

b) *Data analysis*. The data obtained is then analyzed quantitatively or mathematically so as to obtain an objective result which is then continued with a qualitative analysis or conveying interpretation based on data that has been obtained.

c) *Conclusion and further project development*. Data that has been analyzed is then drawn conclusions that can generate a new innovation that may be applied or researched further.

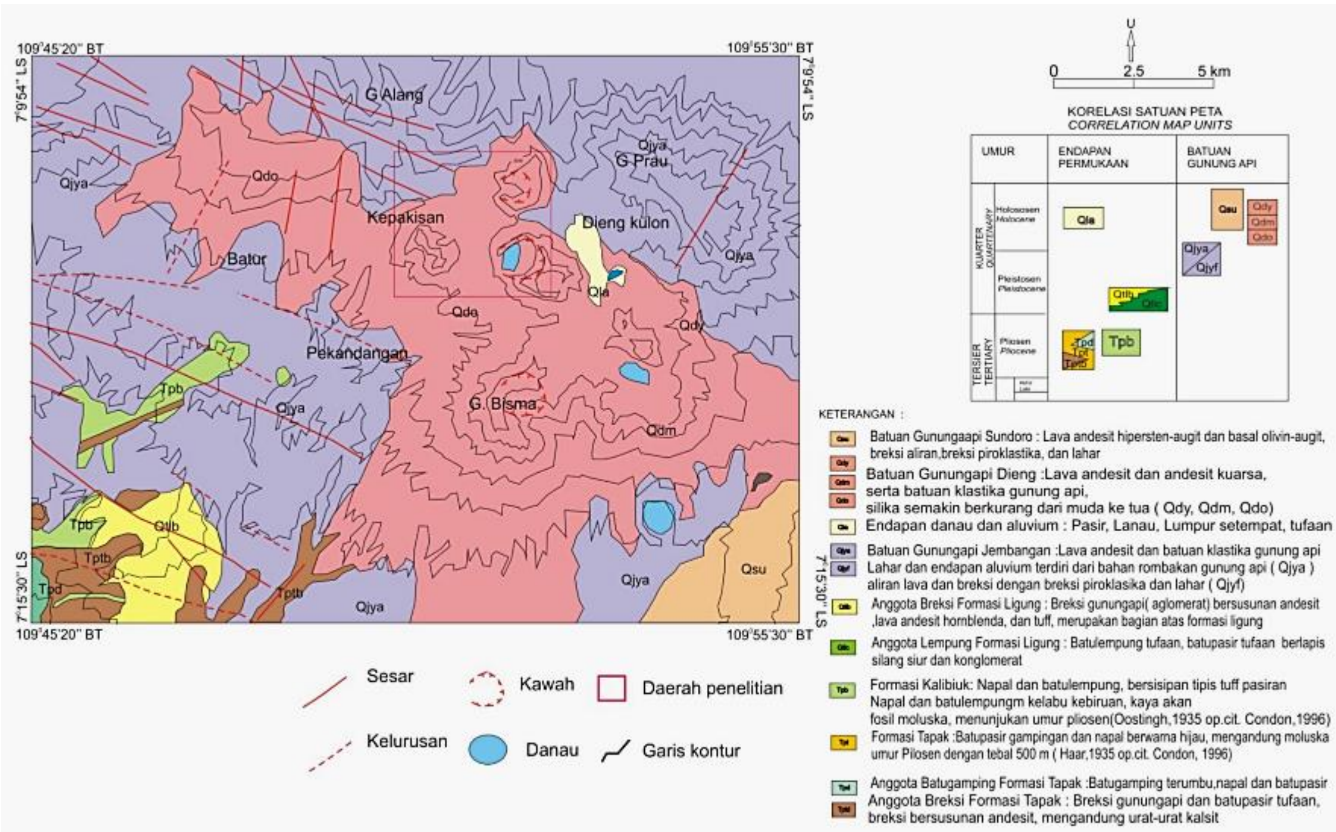

Figure 3. Regional Geology Map of Banjarnegara-Pekalongan (Condon et al, 1996)

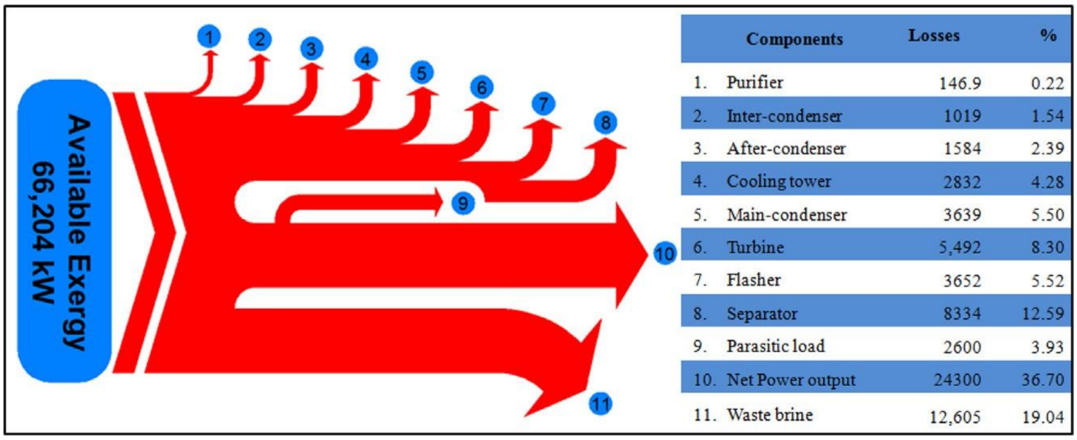

Figure 4. Exergy diagram for exergy flow from the single-flash of Dieng geothermal power plant (Pambudi, 2015)

GEOLOGICAL SETTING

Physiographically, the area of Central Java is divided into 4 East-West trending zones (Van Bemmelen, 1949). These 4 zones are the Central Coast of Central Java, the North Serayu, Serayu Selatan Mountains, and the South Coast Plains of Central Java. Meanwhile, the Dieng Plateau itself is included in the North Serayu zone is limited by its western side Karangkobar and its western area bounded by Ungaran (Van Bemmelen, 1949).

According to Pardiyanto (1970), geomorphology and the area surrounding the Dieng Plateau can be divided into two kinds consisting of mountainous areas and the highlands (Plateau). The mountainous area covers almost all parts of the edge consisting of one straightness of volcanoes (Mount Srodja, Mount Kunir, Mount Pakuwadja, Mount Kendil, Mount Butak, Mount Patarangan, Mount Prahu, Mount Patakbanteng, Mount Djurangsawah, Mount Blumbang, and some domes solitary such as Mt. Bisma and Mount Nagasari). Meanwhile, the plateau area itself is located between rows of volcanoes and dome solitary, generally have filled volcanic material consisting of Dieng, Batur Highlands and Highlands Sidongkal).

Regional stratigraphy in the study area according to Condon et al. (1996), consists of eleven lithologies in the order of old to young is Unit Members Breccia Formation Tapak, Unit Members Limestone Formation Tapak, Unit Formation Tapak, Unit Formation Kalibiuk, Unit Members Clay Formation Ligung, Unit Members Breccia Formation Ligung, Unit Stone Mountain fire Jembangan, Lake and Alluvium Sediment Unit, Unit Dieng Volcano rocks, rocks Unit Volcano Sundoro, Alluvium Deposition Unit.

According to Gunawan (1968) op.cit. Zaenudin (2006) The geological structure of Dieng and its surroundings is influenced by tectonic movements of Quaternary which is still active to date. A great fold does not occur, but clearly there are two Quaternary fractures that can be observed. The first fracture was found in the west part in the formation of Ratamba Block accompanied by fracturing. The second fracture is influenced in the eastern region of Sigedang graben from Tlerep-Butak Volcano and Graben Watumbu from Prahu. Meanwhile, the study summarized by Condon et al. (1996) states that the existing geological structures consist of fault, straightness, and fractures involving rocks aged from Cretaceous to Holocene (Figure 3).

DIENG GEOTHERMAL FIELD

Exergy diagram of the field's single-flash system

The available exergy the power plant received from the fluid and where it is used in the power plant process correlates to the main objective of the power plant which is to convert available exergy into electricity (Figure 4). Although, several losses and waste is expected during this process. The total available exergy in Dieng has been calculated to be around 76,204 kW, which arrives from the reservoir in the form of hot fluid. The net electricity produced is 24,300 kW after reduction by a parasitic load of 2600 kW. This parasitic load is used by several pumps, including the hot well pump (HWP),the auxiliary pump, and the fan. Losses from all the components such as the purifier, the inter-condenser, the after-condenser, the cooling tower, the main condenser, the turbine, the flasher, and the separator are 146.9, 1019, 1584, 2832, 3639, 5492, 3652, and 8334 kW, respectively. The amount of brine sent to the formation uses 12,605 kW in state number 11. This represents 19.04% of the total available exergy that goes to the plant (Pambudi, 2015).

Deposition rate

Previous studies found the estimation of Dieng geothermal field silica scaling deposition rate from representative wells by determining the mass per time units. The higher the potential deposit of silica, the greater the deposition rate. This calculation was done with the assumption that there was no inhibitor liquid has been injected to the brine pipelines. The amount of silica scaling produced are mainly affected by the concentration of potential silica deposits within the fluid and the mass flow rate values.

pH and temperature effect

Utami et al (2014) conducted research on the effects of pH and temperature change in correlation with silica scaling based on two representative wells at Dieng geothermal field. It is found that the process of silica scaling formation at surface facilities in Well A and B are strongly influenced by the very high SiO_2 concentration of resevoir and also the significant change of temperature and pressure which induced flashing to occur and the solution pH. There are only a very slight difference of silica deposition between the temperature-controlled silica solubility curve and pH-controlled silica solubility curve. Beside the abundance of silica concentration within the water, mass flow rate of the fluids also affect the amount of silica deposition. The higher the mass flow rate, the higher the deposition rate over time.

PROJECT DEVELOPMENT

In order to prevent and/or minimize the formation of silica scaling, an understanding, thorough planning and research is essential to establish the suitable fluid injection management.

Scaling mechanism

a well-controlled and documented experimental work to elaborate scaling mechanism by Mroczek and McDowell (1990) was conducted by passing separated brine from a well through a pipeline for 29 to 35 days. Then the pipeline was cut into even sections and the amount of scale in each section determined. Eight experiments were run, two each with separator pressure set for 180°C, 160°C, 140°C and 120°C. At each pressure there was one experiment with a brine f1owrate of 3 I/sec, and another with a rate of 30 I/sec; this produced total residence times of 7 minutes and 0.7 minutes. Total Si02 and monomeric Si02 were measured in water samples collected at the inlet and outlet. Salinity and pH were not reported, but saturation ratios and T-Si02 values suggest that there was essentially no ionized silica (Klein, 1995).

At 180°C and 160°C, the induction time for polymerization was not reached, even at 7 minutes. Scaling rates were 0.2 to 0.3 mm/yr at 180°C (assuming density 2.2), increasing to 0.3 to 0.4 mm/yr at 160°C. At 140°C and 120°C, there was measurable polymer formation, even at the pipe inlet, and the polymer concentration increased through the pipeline; the increase at 120°C was twice that at 140°C.

Therefore, scaling in the pipeline decreased dramatically along the length of the pipe, as monomeric Si02 was removed from solution into the suspended polymer. In all cases, the scale which formed was hard and glassy, with density about 2 gm/ cc (Klein, 1995).

Gas suppression

Hirowatari and Yamaguchi (1990) discussed about gas mixing to lower the solution pH and suppress scale development. A model of dissolving various amounts of CO2 into the injection line brine, after separating the brine from steam at 175°C, is illustrated in figure 5. The particular case modeled starts at 50 ppm oversaturation. Between 25 ppm and 500 ppm total C in solution as CO2, there is a dramatic drop of pH from 7.2 to 5.8, while unionized Si02 climbs from 822 ppm to 850 ppm and oversaturation increases from 50 ppm to 75 ppm. The increase of oversaturation is completely counterbalanced by the lowered pH, and molecular deposition rate drops from 0.15 to 0.01 mm/yr. This should also effectively eliminate any tendency for particle formation and deposition. pH and scaling potential can be lowered further with additional CO2, but this hardly seems necessary. It should be noted that P C02 for 500 ppm is only 1.5 bar. The 500 ppm level is achieved by mixing about 0.025 t/hr non-condensable gases (13 m3 at 1 atm.) per 50 t/hr of water flow.

For comparison with the gas mixing, it is noted that: 1) mixing 50 t/hr water flow with 17.5 t/hr condensate at 60'C also lowers the molecular deposition rate to 0.01 mm/yr; 2) all oversaturation in 175'C water would be removed by mixing with an equal amount of 60'C condensate; and 3) mixing with a combination of gas and condensate may have a beneficial effect by reducing wintertime freezing of vapor in the gas line (Klein, 1995).

CO2 source

The need of CO2 to decrease silica scaling formation by lowering the molecular deposition rate of injection fluid means the need of CO2 resources around Dieng geothermal field. This can be solved either by purchasing from CO2 suppliers or establishing integrated system by transferring CO2 from coal-fired power plants. Pipeline facilities interconnecting the coal-fired power plant with the geothermal field would transfer simultaneously the extracted CO2 into the fluid injection management. In this case, the available nearby coal-fired power plants are PLTU Adipala, PLTU Karangkandri in Cilacap and PLTU Batang, Central Java.

Table 1. The calculation of deposition rate in Well A and Well B at Dieng Geothermal Field. The potential deposit unit mg/L is assumed to be equal with mg/kg to simplify the calculation (Utami, 2014)

Well	Location	Potential Deposits	Mass Flow Rate*	Deposition Rate			
		mg/kg	kg/s	ton/hour	ton/day	ton/month	ton/year
A	Separator	100	2.75	0.00099	0.02	0.71	8.55
	Weirbox	630		0.01	0.15	4.49	53.89
B	Separator	660	9.6	0.02	0.55	16.42	197.07
	Weirbox	600		0.02	0.50	14.93	179.16

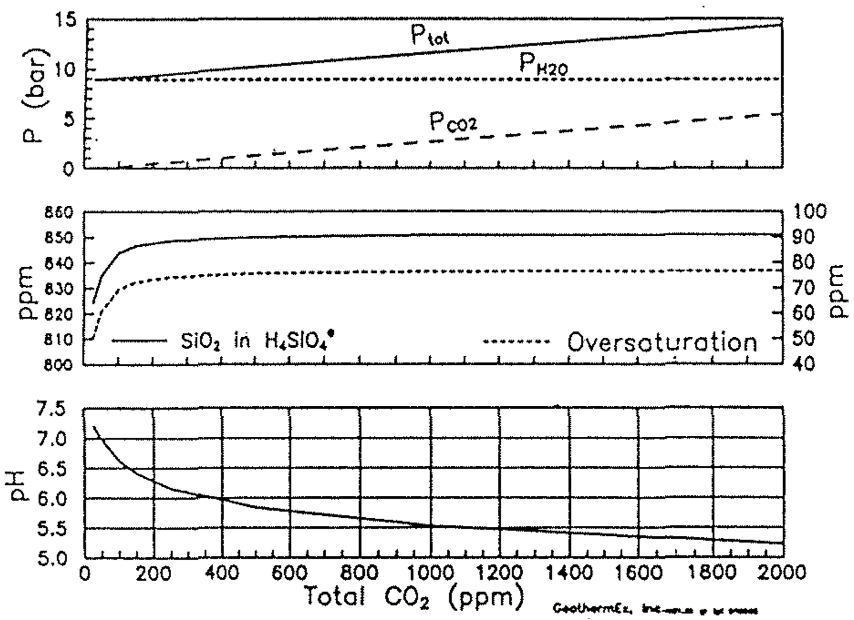

Figure 5. The effect of CO2 mixing into water at 175°C (Klein, 1995)

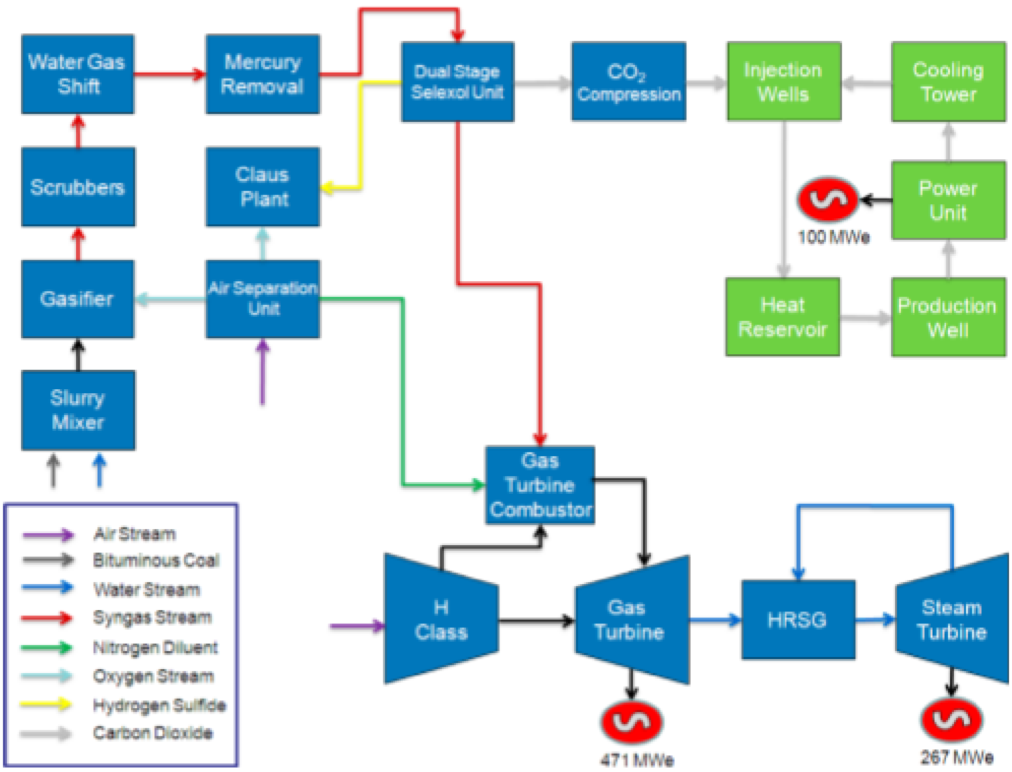

Figure 6. CO2-circulated EGS combined with IGCC system as integrated schematic system of geothermal field and coal-fired power plant (Chandra, 2012)

CONCLUSION

There are several results of this research. First, the amount of silica deposition is estimated by calculating the difference between dissolved SiO2 with the solubility of amorphous silica curve. Silica scaling in the Dieng geothermal field is caused by the influence of fluid pH. From the results of research that has been done previously known that the silica deposit will decrease along with the increase of fluid pH in well A and B at Dieng geothermal field. Where, the solubility of amorphous silica increased significantly at pH > 7 in the separator, and pH > 8 in the weirbox. One way to increase and decrease the pH of geothermal fluid conditions is through fluid management. Fluid management that can be done is by utilizing injection fluid inhibitor (usually sulfuric acid (H2SO4) to reduce the pH unit, or caustic soda (NaOH) to rise the pH unit) into the brine pipeline is able to halt the formation of silica scaling for several hours (Brown, 2011). Alternatively, the separator pressure adjustment can also be applied. But sometimes, this can be unacceptable for the economic power generation.

Second, From the findings above it is known that the higher the temperature of geothermal fluid, the higher the pressure would eventually be resulting in less silica scaling in the pipe. Therefore, the required actions to prevent or minimize silica scaling alternatively are engineering the fluid temperature rise, preserving the pressure of the reservoir and establishing integrated system of geothermal field and coal-fired power plants interconnected by pipeline facilities in order to conduct CO2 suppression into the injection fluid.

Then, using another exploration method in Dieng geothermal field such as by changing the single-flash separation become a double-flash separation is one of possible solution.

The higher the temperature of geothermal fluid, the higher the pressure would eventually be resulting in less silica scaling in the pipe. So, to prevent silica scaling alternatively is to engineering the fluid temperature rise.

The implementation of scCO2 EGS-IGCC will reduce annual emissions by 8,200 tons of NOx, 20,000 tons of SO2, and 4.35 million tons of CO2 over conventional thermal plants in an optimal pairing.

RECOMMENDATION

Establishing integrated system of geothermal system fluid injection management along with coal-fired power plant would be better in the long run as it will continuously supply CO2 by pipeline from the coal-fired power plant while also capturing carbon underneath and reducing CO2 emission to the atmosphere in general.

In addition to scale suppression strategies in Dieng geothermal field, the following is recommended for scale management at low levels of oversaturation (Klein, 1995):

a) Design the injection system to minimize residence time and avoid turbulence.
b) Install pressure ports on injection lines to allow monitoring for scale-related impedance.
c) Install inspection ports and scaling coupon ports
d) on the injection lines.
e) Install ports at both ends of injection lines to allow inserting a clean-out.

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