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Scale Prevention Technique to Minimized Scaling on Re-Injection Pipes in Dieng Geothermal Field, Central Java Province, Indonesia

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Abstract - Dieng geothermal field including its volcanic geothermal system is dominated by hot water. Brine water is characterized by high salinity, content of chloride (Cl^-), amorphous silica (SiO_2), Na^+, and K^+. The condition of brine water has potential for the formation of amorphous silica scale in the re-injection pipeline which is one of the obstacle in the electrical energy production. The scale prevention on re-injection pipes was performed with non-acid re-injection system. Nevertheless, the scale formed in the re-injection pipe is still relatively thick due to the non-optimal sludge. This research is focused in optimizing the deposition of sludge. The research aim is to apply scale prevention technique on re-injection pipeline by involving engineering technology. The study was conducted through laboratory experiments with factorial design method 2^3 (two levels of three factors). Those three factors are pH, concentrations of coagulants and flocculants concentrations which act as the independent variables. The indicator is the volume of sludge deposition and turbidity of brine water which act as the dependent variables. The result showed that the most significant factor is pH, whereas the concentrations of coagulant and flocculant are preserved to accelerate and stabilize the sludge deposition. The optimal condition is achieved at the level of pH 8, the concentration of 10 ppm coagulant (PAC), and 1 ppm flocculants (Polyamide). These parameters are then used for the preparation of scaling process technology on the prevention of re-injection pipeline by adding some equipments on settling ponds. Therefore, in addition to reduce environmental degradation, it also produces sludge that has potential to be used as raw materials for other industries.

Keywords: rock property, strength criterion, weak rock, shallow underground structure, shear characteristic

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Introduction

Unit I Dieng geothermal field is located in Banjarnegara, Central Java Province, Indonesia (Figure 1). Unit I Dieng Geothemal system is dominated by hot water. Its system is very unique compared to other geothermal systems in Indonesia. The uniqueness is reflected in the form of high content of colloidal silica in the brine water which is the potential source of amorphous silica scale. The scaling problems also occur on the surface equipment such as inside the re-injection pipe.

Scaling prevention in pipelines re-injection is intended to prevent the formation of amorphous silica scale in the re-injection pipes (Figure 2).

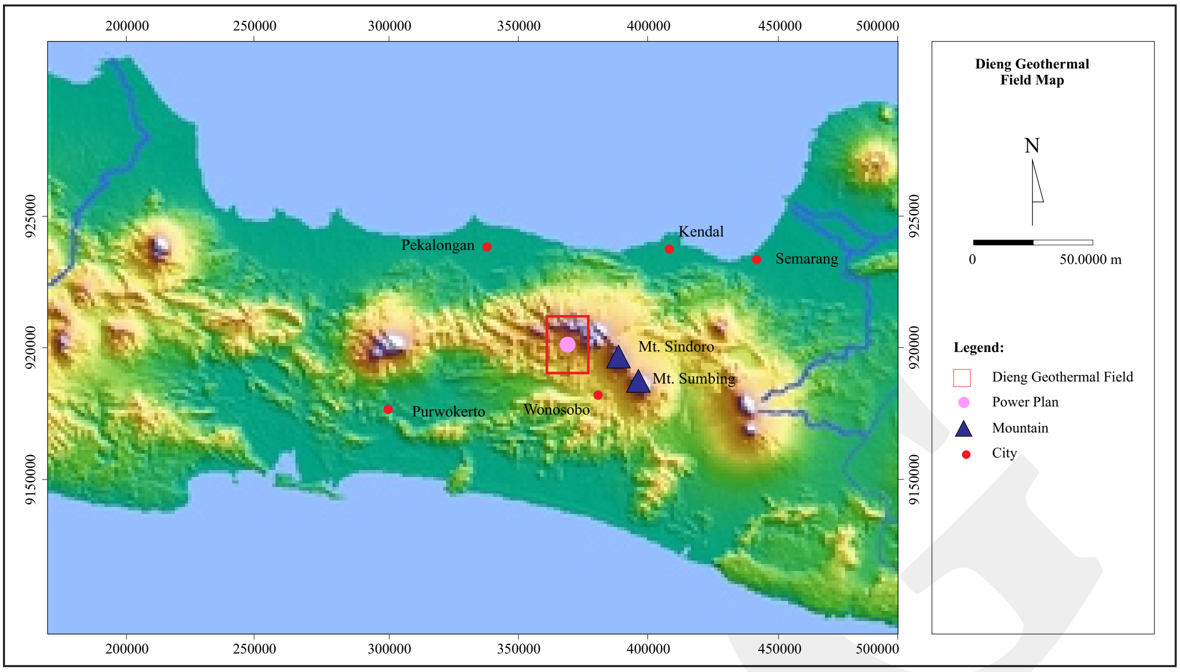

Figure 1. Locality map of the Dieng Geothermal Field.

Figure 2. Amorphous silica scale on re-injection pipes (PT. Geodipa Energi, 2009).

However, this prevention is depending on the characteristics of brine water in each production well. Prevention of scale in the re-injection pipes is applied using a non-acid re-injection system. The process of sludge deposition is done either through open channels or settling ponds, before re-injecting the brine water is re-injected into the earth. However, in fact, the prevention of scale through the deposition process has not lasted optimally. Although the prevention scale system has been implemented, re-injected pipes are already blocked by scale deposit in relatively short period (six months) (PT. Geodipa Energi, 2009).

The purpose of the research is to minimize scaling in the re-injection pipes. The research aims to obtain new preventive techniques on scaling process on re-injection pipes Unit I Dieng geothermal field. In order to achieve these objectives, the comprehensive study about the characteristics of brine water, scale theory, experimental optimalization of the deposition sludge deposition, and engineering technology were undertaken. This study is important to be implemented, because it can provide an effort to minimize scaling in the re-injection pipes, so that the electric energy production targets can be achieved (Ciptadi dan Patangke, 2001; Gunnarsson and Arnórsson, 2005; Ngothai *et al.*, 2012; Utami *et al.*, 2014).

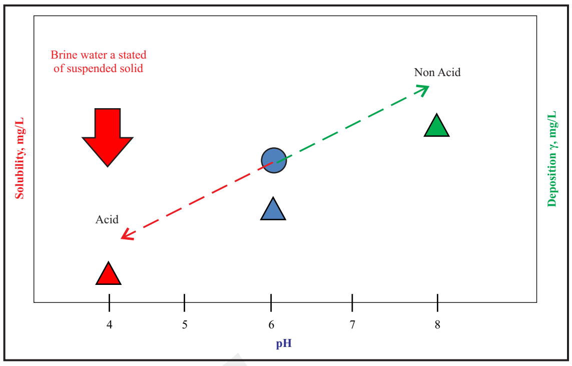

Figure 3. Diagram of acid and non-acid approach of re-injection system.

Methodology

Framework

The formation of colloidal silica in the brine water is the result of interaction between water with quartz at temperature of 200°C. The existence of silica in the production well is always in a state of monomeric (SiO_2). The formation mechanism of amorphous silica scale begins with a silicon element which reacts with oxygen at high temperatures to form silicon dioxide (SiO_2), known as silica (Stapleton, 1989). Ties of some dimeric form cycles which are referred to as cyclic, subsequently formed colloidal (*i.e.*: fine particles floating in the solution). If the particles eventually settle, they will be deposited as amorphous silica scale on re-injection pipe. Gunnarsson and Arnorsson (2003) stated that the prevention of silica scale could be more efficient at a high temperature geothermal fluid. The change in pH and dilution can affect the rate of silica scale (Sigfusson and Gunnarsson, 2011). The statement also supported by the Kiota and Uchiyama (2011) who stated that changing pH is a way for silica scale prevention.

The prevention of amorphous silica scale on re-injection pipes can be done by changing two pH, *i.e.*: (1) acid approach re-injection system and (2) non-acid approach re-injection system. Both are illustrated in the diagram of Figure 3. The diagram shows the basic principles, the first method is through reduction of pH (acid re-injection system), so that the pH of brine water becomes smaller than 4. This aims to maintain the brine water in a suspended solid state, so that amorphous silica can be maintained in a floating position in the brine water. Solubility of amorphous silica (SiO_2) increases with increasing acidity. This condition will reduce the chance for the deposition of silica on re-injection pipes. According to Gill (2011), to prevent the formation of amorphous silica scale on re-injection pipeline can be done by adding additives such as GEO 980 into brine water.

Meanwhile, the principle of second method is conducted by producing precipitate sludge as much as possible before the brine water is injected. Thus, the chance for the formation of amorphous silica scale in the re-injection pipeline can be minimized. This approach is done by raising the pH to around 8 (non-acid re-injection system) to consume the silica deposition process as much as in order to make the littest possibility of colloidal silica particles go into the re-injection pipelines.

The prevention of amorphous silica scale occurrence in pipes was conducted to optimize the deposition of re-injection sludge. Positive ion binding is referred to a coagulant, such as Poly-Aluminium Chloride (PAC) which serves to form the nucleus floc. The greater the precipitating ion valence, the faster the floc core formation is. Flocculant is polyelectrolite such as Polyamide compounds which serves to accelerate the larger formation of floc core. The floc-floc density becomes greater than the density of water, so that the floc-floc will form a precipitate sludge. The rate of deposition takes place gradually through settling hindered phase, transition phase, and compacting phase (Kawamura, 1991). Thus, the water will be relatively clear because of the increasing amount of sediment sludge and the declining water turbidity.

Method

The research method was conducted through laboratory experiments involving engineering technology. The method is illustrated in the form of a flow chart in Figure 4, which shows that the optimization of the deposition of colloidal silica in brine water may occur from various engineering technology variables. Stages of research were performed through the characterization of brine water, experimental optimization of the deposition of colloidal silica in brine water, and preparation of scaling process technology for the scaling prevention of re-injection pipe. Experiments to optimize the deposition of colloidal silica in brine water were carried out by using the factorial design method 2^3 (2 levels of 3 factors) (Sudjana, 1980), namely: coagulant concentration (1 ppm and 20 ppm), the concentration of flocculant (0.1 ppm and 1 ppm), and pH (4 and 9) which act as the independent variables. While factorial design method one factor with six-level-well pH, coagulants, and flocculants were concentrated. The indicators of the experiment, which are the volume of sediment sludge (mg/l) and brine water turbidity (NTU) act as the dependent variables. Furthermore, the experiment results were analyzed statistically for the hypothesis validation and verification.

Results and Discussion

Brine water in production wells Unit I Dieng is characterized by the dominant high content of chloride (Cl) with amorphous silica (SiO_2), sodium (Na^+) and potassium (K^+), and lower content of calcium (Ca^{2+}) and magnesium (Mg^{2+}). The characteristics of such brine water tends to have a positive charge. Therefore, it needs coagulant and negatively charged flocculants. Preliminary experimental research indicates that PAC coagulant had better results than other coagulants, which are satplok and $Al_2(OH)_2$ (Figure 5). Thus, further experiments to optimize the deposition of colloidal silica in brine water were conducted by combining PAC and Polyamide as additive material. These experiments are fairly

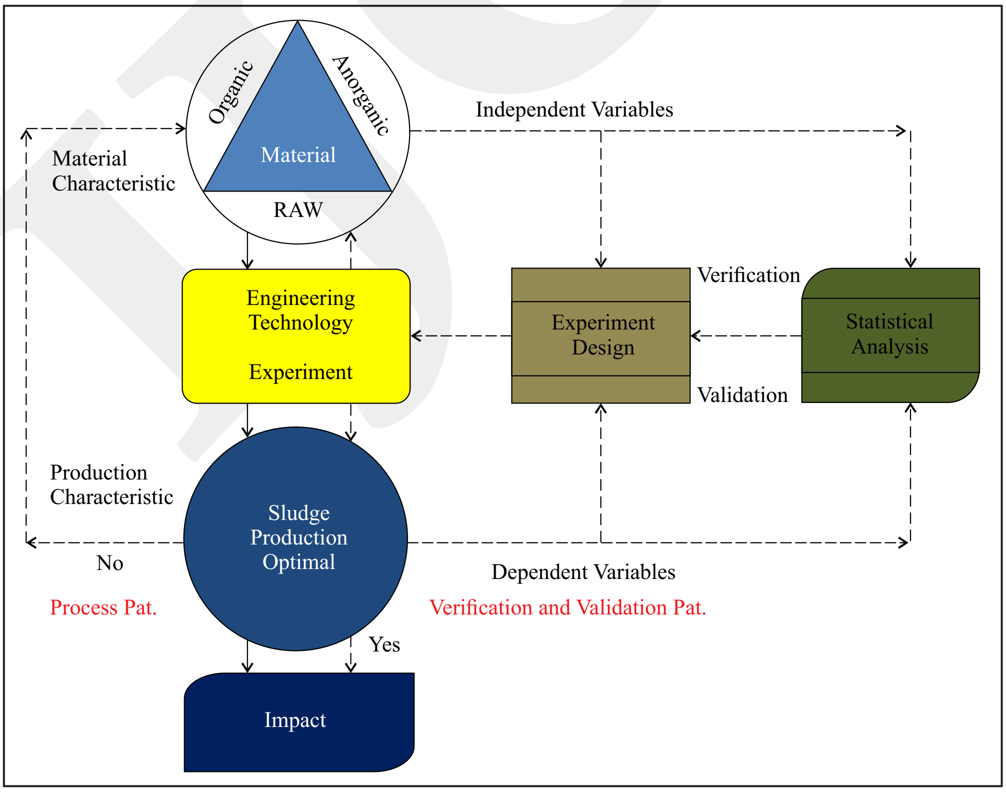

Figure 4. Flowchart of research methodology.

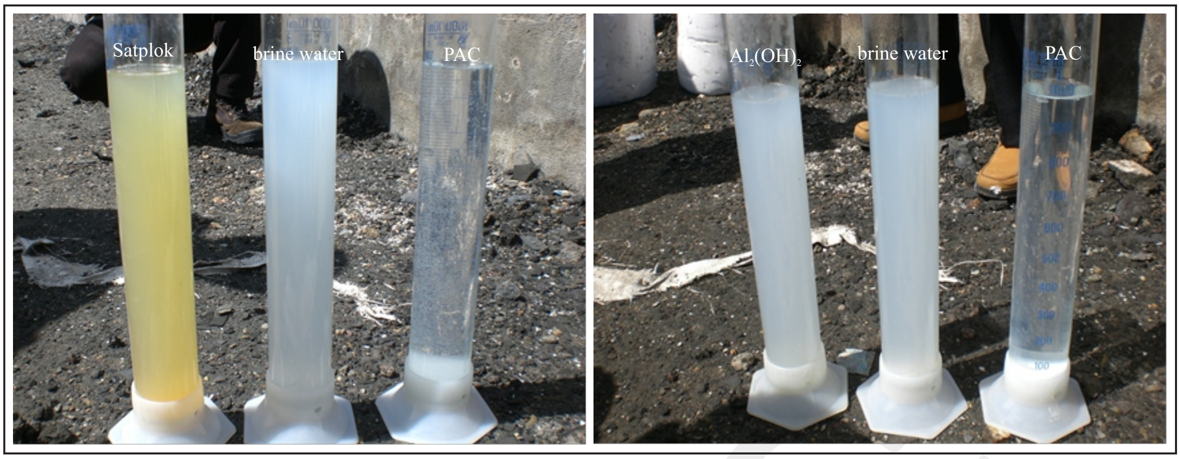

Figure 5. Preliminary experimental of sludge deposition.

represented by combined samples of brine water from production wells in Unit I Dieng.

Optimization of Sludge Deposition

Experimental model of sample is taken from a combination of brine water production wells of Unit I Dieng. The result of the statistical analysis is obtained by using ANOVA method in both directions (Sudjana, 1980). The experimental results are: 1) factorial design method 2^3 (2 levels of 3 factors) showed that among the three most responsible factors, pH is significantly better against the amount of sediment sludge and water turbidity. The condition is indicated by the value of the pH factor significance of both to the amount of sludge sediment and to brine water turbidity (sig?. 0.00 < 0.05). Similarly, the results of the statistical analysis method ANOVA in one direction (Supardi, 2013) to the experimental results; 2) are a factor of factorial design method, consisting of six levels, which also showed that the pH is influenced significantly both in the amount of sludge sediment and turbidity of brine water (sig.? 0.00 < 0.05). The experimental results (2) are presented in a graphical form as shown in Figure 6. It shows that the pH is the most significant influential factor, while the coagulant and flocculant factors showed no significant effect (Figures 7 and 8). However, the precipitate stability of these factors are still needed to be accelerated and maintained. Optimal condition of colloidal silica deposition process in a brine water is achieved at pH 8, while the concentration of PAC coagulant is 10 ppm and flocculant concentration is 1 ppm Polyamide.

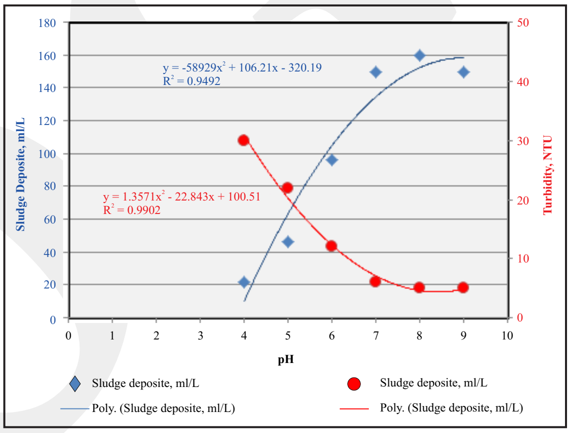

Figure 6. Graphic of the influence of pH factor to the volume of sludge deposits and turbidity.

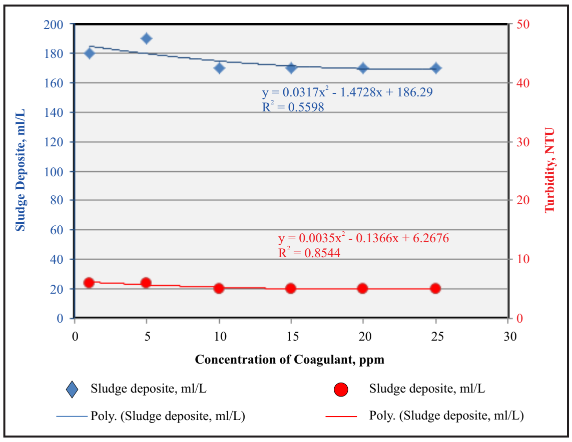

Figure 7. Graphic of coagulant factor influence to the sludge deposits and turbidity.

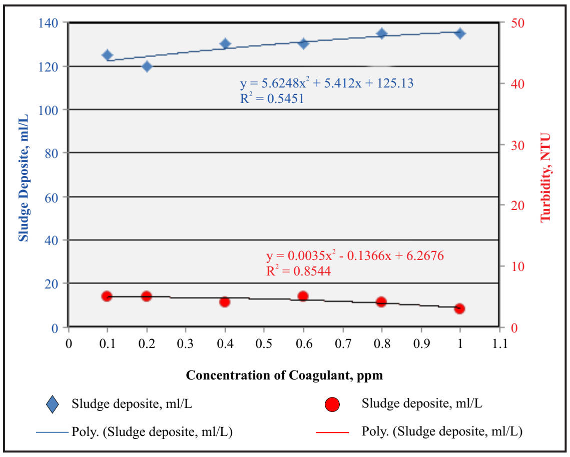

Figure 8. Graphic of flocculants influence factor to the to the sludge deposit and turbidity.

Based on these tested parameters against the value of Total Suspended Solid (TSS), brine water in production wells and pond are mixed both before and after treatments, which shows significant differences in TSS value. The illustration of the difference in the TSS value is presented in block diagram of Figure 9, which indicates that the average TSS after the experiment reaches 11mg/l of about (479 - 1236) mg/l. This means that the TSS is a significant

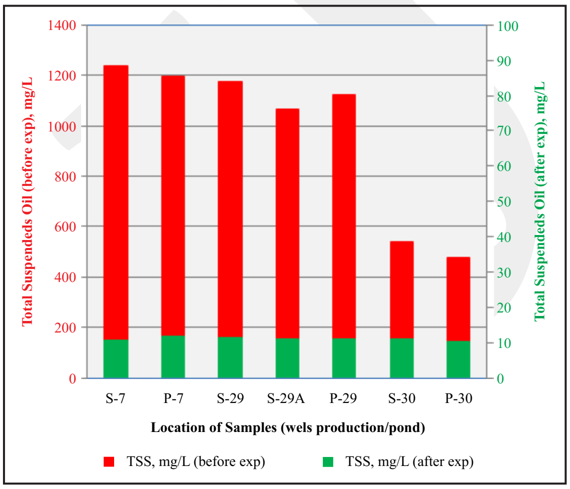

Figure 9. The difference in TSS values before and after the experiment.

impairment. Thus, the potential for the formation of amorphous silica scale in the re-injection pipe can be minimized.

Prevention Scale Technique on Re-Injection Pipes

Technological process of the proposed scale prevention is still using a non-acid re-injection system, but by modifiying the system with the principle of optimally obtaining the sediment sludge in the clarifier. The technological process is a modified version of the US Patent No.4, 900.360 as shown in the diagram of Figure 10. In principle, the process of deposition of colloidal silica in brine water is starting from open channels and settling ponds to reduce the cost of chemicals. Optimization of sludge deposition is done by using the additional facilities, such as a combination of the tank with slow mix, flash mix, and clarifier. Pond as the final container can be used as a equalization for the brine water before its processed, washer tank and filter press for dewatering.

For a discharge capacity of 100 m^3/day, the construction of a reinforced concrete pond with a diameter of 8.0 m with a depth of 2.0 m which can accommodate brine water for 1 day is required. A flash mix cylindrical reactor tank with a diameter of 80 cm, with a height of 100 cm which serves for conditioning pH 8 and as a reaction coagulans (PAC) with brine water is also needed. Brine water residence time in this unit takes approximately 5 minutes. For slow mix in the reactor tank, a cylinder with a diameter of 130 cm and depth of 100 cm serving as a flocculant reaction to form the floc-floc sediment sludge has a residence time of about 15 minutes. A sedimentation basin (clarifier), cylindrical conical bottom with a diameter of 500 cm and a height of 270 cm, serves as a separator for sediment from the water with a residence time for approximately 60 minutes. Pond capacity treatment results shaped pond with reinforced concrete construction with diameter of 5 m and a depth of 2.0 m is essential, to be able to accommodate the water for around 8 hours. A sediment washing tank with a cylindrical sludge diameter of 6.0 m and depth of 2.5 m is required to wash the sludge for about 20 m^3/day. All the sludge washed with water is then introduced into the sludge filter press to obtain a relatively clean

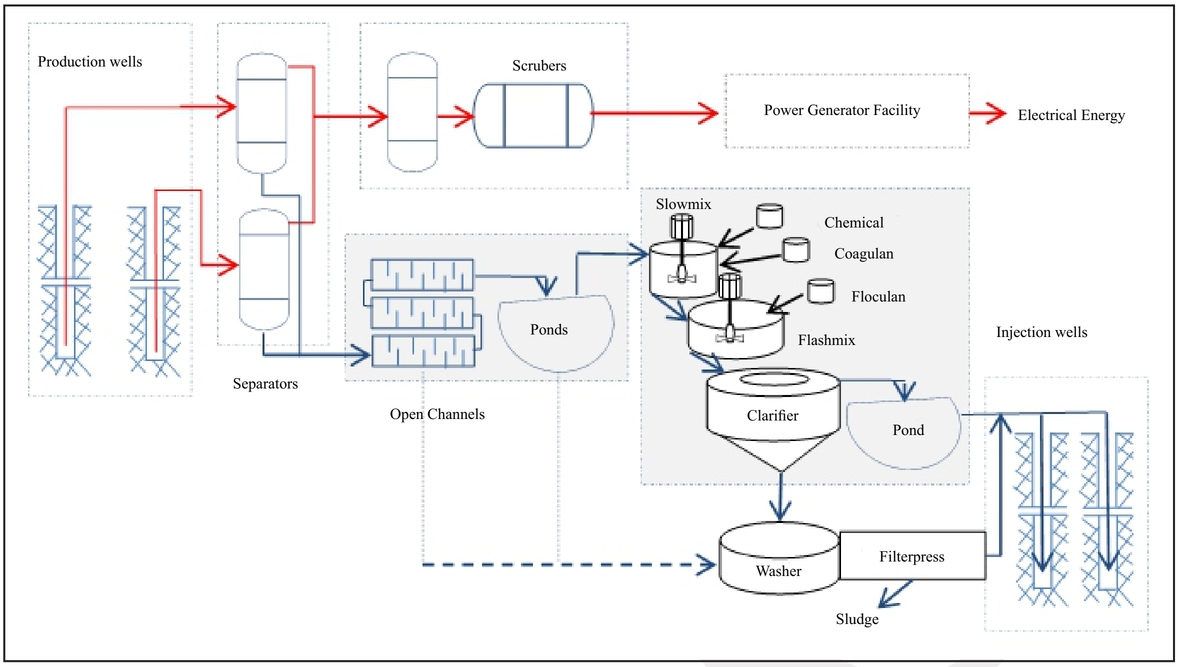

Figure 10. Flow chart of technology processon the scaling prevention of re-injection pipe (modification from US Patent No.4, 900,360).

sludge, so that it can be directly utilized for other raw industrial materials.

Conclusion

The results of the experiment showed that the pH is the most influential factor for both amounts of sediment sludge and water turbidity. Optimal engineering technology parameter obtained at pH 8, the concentration of coagulant (PAC) is at 10 ppm and flocculant concentration is at 1 ppm (Polyamide). From the experiment, it can be predicted that the average of sludge is: [(180 +140)/2]mg/l - 10 mg/l = 160 ml/l - 10 ml/l= 150 ml/l. Based on mass balance, if discharge capacity has 100 m^3/day, sludge content = 150 ml/l x 100.10^3 l x day=15 x 10^6 ml sludge /day= 15 m^3 sludge/day. The sludge can then be utilized as raw material for geomaterial (geopolymer) and Preservation Material Micro-organism. Scale process prevention technology of re-injection pipes is done by modifying the open channel (lamella shaped) and the equipment installation of a pond that added many sludge deposition. Addition of equipment among others classifier, reactor additives, washer tank, and filter press sludge are placed after pond for all of the brine water before it goes into re-injection pipes. Therefore, both the brine water that goes into re-injection pipeline and the products are relatively clean from sludge, so it can be used as raw industrial materials.

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