

SILICA SCALE INHIBITION EXPERIMENTS: GEOGARD SX APPLICATION ON GEOTHERMAL BRINE WITH ULTRA HIGH CONCENTRATION OF SiO₂

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Abstract

The Botong sector of the Bacon-Manito geothermal production field have undergone series of experiments to find a proper method of disposing the high silica effluent generated by the Osiao-Pangas (OP) wells. The application of Geogard SX, a chemical inhibitor, was experimented in the field to test its effectivity on the Botong brine which contains > 1100 ppm SiO₂. Two different concentrations of the chemical, C1 and C2, were tested for the hot injection and jar experiments. In the hot injection experiment, concentration C1 was found effective in preventing silica deposition in pipes and formation materials while C2 showed dispersive action to silica polymer but did not inhibit silica deposition. The jar experiments showed significant activity of Geogard SX in stabilizing the colloidal dispersion of polymeric silica formed for both tested concentrations C2 however, showed longer effectivity compared to C1.

1.0 INTRODUCTION

The Botong sector of Bacon-Manito Geothermal Production Field (BGPF) is known for its high silica geothermal resource. The separated water from the first flash separator, using OP-4D well alone, contains > 1100 ppm of SiO₂ which corresponds to a silica saturation index (SSI) of 1.46. The nearly 50% oversaturation in silica is expected to cause enormous scaling along the fluid collection and disposal system (FCDS) if the brine is injected hot and untreated. This silica background hinders the utilization of the OP-wells to generate the projected 20 MWe power for the Botong field.

In previous years a series of effluent disposal scheme have been experimented in the area to manage the bulk of silica slurry generated by the wells during operations. This includes the low temperature injection of separated brine or the cold injection scheme (CIS), brine pH modification, and total cold silica slurry injection into non-producing wells (1,4). Of the three methods, the CIS was found applicable. However, this mode of operation has to be assisted with a dewatering system. This made the process cost ineffective and operationally laborious.

The last disposal scheme which was tested on site is the application of a chemical inhibitor, Geogard SX, directly into the hot brine. This is to prevent silica deposition and scale formation along the FCDS and the reservoir during injection of the treated waste fluid. The experiments were conducted; to test the effectivity of Geogard SX in inhibiting silica deposition using the Botong brine; to investigate the interaction of silica with proppant and formation materials; and to determine the applicability of low temperature injection scheme for the treated brine. The application had been tried and tested and showed promising results in Tongonan, Leyte (2). If effective, the method could simplify the Botong operation and therefore maintenance cost will be largely reduced.

This report discusses the results of silica deposit inhibition and jar experiments and recommends the application of Geogard SX for the utilization of Botong wells.

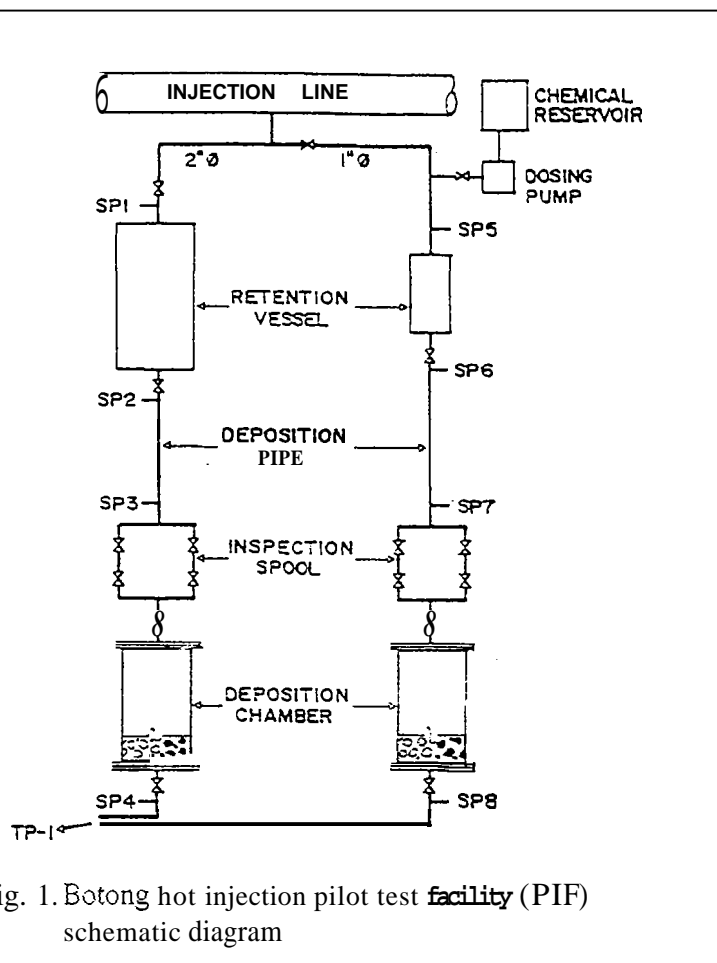
2.0 EXPERIMENTAL - HOT INJECTION EXPERIMENT

Pilot Test Facility

Shown in Figure 1 is the schematic diagram of the hot injection pilot test facility (PTF) for Botong. This facility was designed to simulate the real condition of the Botong FCDS except the pipeline orientation and brine residence time. It is composed of two set-ups, one for the untreated brine and the other for brine treated with Geogard SX. The set-ups were insulated with glass fibers so as to maintain a nearly isothermal (164 °C) and isobaric (6.4 ksc) conditions during experiment. The brine velocity within the lines was held close to about 1.03 m/s towards the outlet.

Each set-up is composed of four major parts: namely the retention vessel, deposition pipe, inspection spools, and deposition chamber. As shown in the figure, the treated line is made of 1" diameter pipes while the untreated is 2" O pipes. The retention vessel was designed for a 10 minute

assumption that silica will deposit after the given period. The deposition pipe was the main source of data for



Several gate valves were placed along the lines to control any activity in the system. Each set-up has a mini-silencer located after the inspection spools for water flow rate measurement. Eight sampling stations (four for each set-up) were installed along the PTF. Each station has a set of thermowell for temperature monitoring, pressure gauge, and coil tubing for sample collection. The sampling stations were located before and after the retention vessel, before the inspection spool, and after the deposition chamber. The untreated line sampling stations were coded SP1 to SP4 and SP5 to SP8 for the treated line. The dosing point for chemical injection was placed near the inlet of treated line to avoid deposition of silica in the 1" O pipe line.

Methods

The OP-4D brine was used for the hot injection and jar experiments. Initially, the brine was monitored for chemical stability in terms of $tSiO_2$, pH, and Cl⁻ prior to the experiment (see Appendix 1). The PTF was tapped at the hot injection line, after the separator vessel of the FCDS. This fluid was then passed through the set-ups and the flow rates measured at the mini-silencers. The chemical inhibitor was then continuously

injected using a dosing pump at the treated line. For this experiment two different concentrations, C1 and C2 were applied. The flow rate was monitored by measuring it at the mini-silencer from time to time. Temperature, pressure, and monomeric and total silica were observed periodically to determine any indication of silica deposition along the line. The spools were also inspected as soon as change in the system was observed and silica deposits were available. The monomeric and total silica concentrations were determined using the standard yellow molybdate method of silica analysis and uv-vis spectroscopy at 410 nm.

3.0 EXPERIMENTAL - JAR EXPERIMENT

The jar experiment was conducted at the BGGF geochemistry laboratory. Treated samples from the hot injection line and mini-silencer outlet were collected. The test was done for both concentrations C1 and C2. For C1, glass jar and rusted metal container were used while for C2 were glass jar and clean metal container. The hot treated brine samples were immediately transferred to the laboratory after collection and cooled conductively at ambient temperature. Sample aliquots for monomeric and total silica determination were collected periodically and analyzed using the method described above.

4.0 RESULTS AND DISCUSSIONS

Hot Injection Experiment

Figures 2 and 3 show the pressure and temperature data obtained for the untreated line against time. The line pressure changed slightly from SP1 to SP3 and drastically from SP3 to SP4. This implied that silica deposition along the retention vessel down to the inspection spool was slower compared to the deposition chamber. The temperature data also showed the same trend. However, the change from SP1 to SP2 is larger compared to SP2 to SP3. This is due to the longer brine residence time in the retention vessel which effectively caused slow cooling of the brine. The large drop in temperature from SP3 to SP4 can be attributed with the large drop in pressure within the chamber. This is due to a slower brine flow along the chamber and deposition of amorphous silica. The monomeric and total silica results, Figures 4 and 5, also showed consistent trend with pressure and temperature. Rapid polymerization and deposition of monomeric silica (Fig. 4) from SP1 to SP2 was observed. This process is due to the long brine residence time within the retention vessel which is around 10 minutes. The almost negligible change in $mSiO_2$ from SP2 to SP3 is due to the short distance between the two sampling points. However, continuous polymerization was observed from SP3 to SP4 as slower brine flow rate was experienced within the chamber. Silica deposition was clearly defined in Figure 5. Much deposition was observed at the retention vessel and deposition chamber as reflected by the large drops in $tSiO_2$ values. This was attributed to the long brine residence time, silica polymerization, and adsorption of silica polymer on pipe walls, formation materials, and proppant.

Data on the treated line (concentration C1) pressure and temperature are shown in Figures 6 and 7. The data trends are more consistent compared to the untreated line and showed negligible indication of silica deposition. The P and T change in SP8 on the other hand is large and due to the slower brine flow rate inside the chamber and possible silica deposition. Silica deposition from SP5 to SP7 is almost negligible as indicated by the monomeric and total silica data (Figs. 8 and 9). Considerable change in silica concentration, about 100 ppm, was observed only at SP8 which further indicates that some silica was deposited in the materials inside the chamber. After inspection of the pipe, silica deposits were already present at the treated line and thus, the experiment was terminated. The PTF was dismantled for further inspection of the line and the silica scales were photodocumented.

The extent of silica deposition for the untreated line is shown in photos A1 to A3. Note the thick silica deposit inside the retention vessel which is ~ 3 cm thick. Hard silica deposit was observed inside the deposition chamber, cementing the pieces of the formation materials and proppant. The treated line showed negligible amount of silica deposit, from the retention vessel down to the deposition chamber (photos B1 to B3). Silica

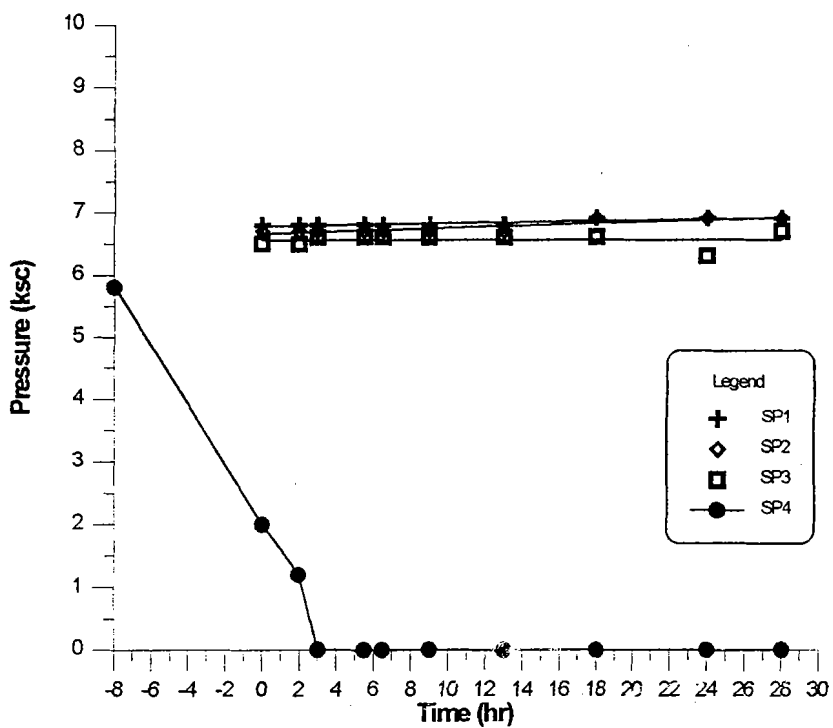


Fig. 2. Untreated line pressures at the different sampling stations as a function of time. Note the negative value for time. This corresponds to the initial 8 hour exposure of the formation materials with the brine prior to the final run.

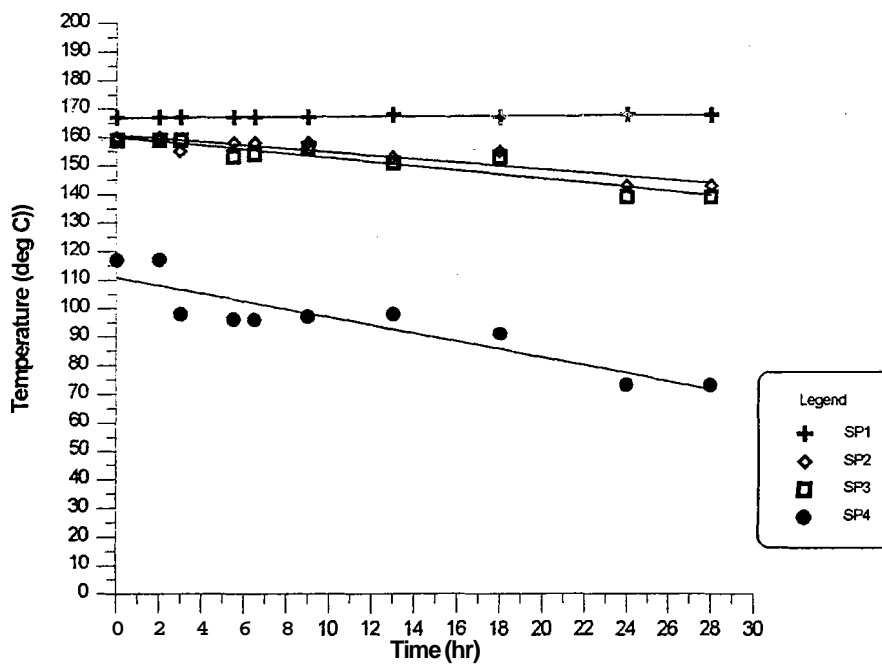


Fig. 3. Untreated line temperature as a function of time. Notice the down trend change in temperature indicating possible silica deposition along the line.

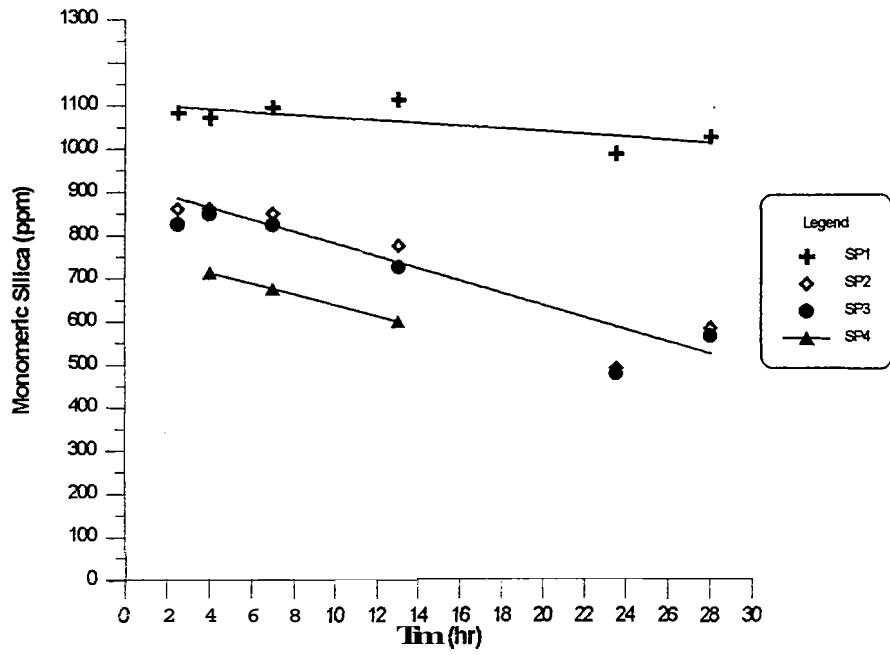


Fig. 4. Untreated line monomeric silica concentrations at the different sampling points as a function of time.

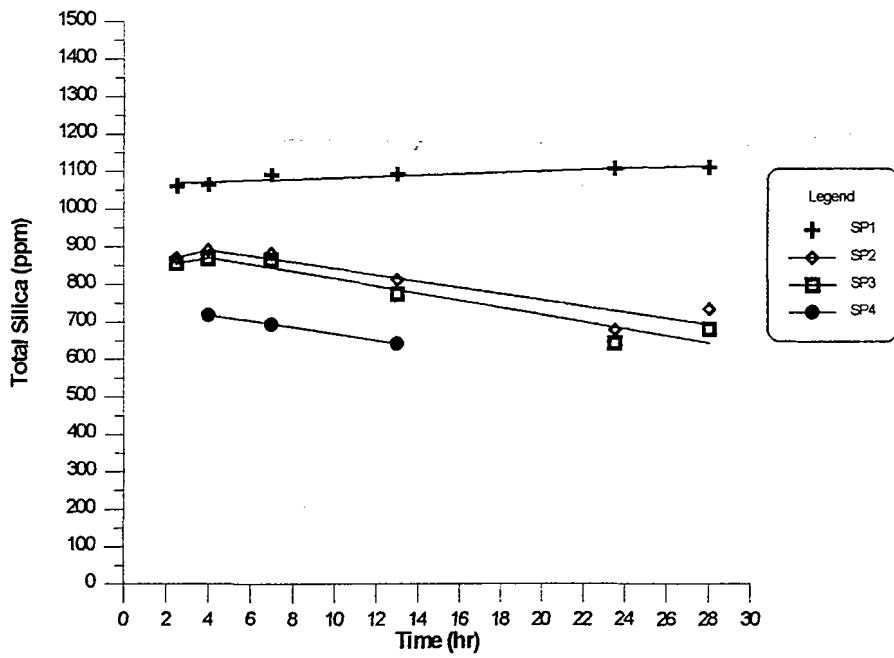


Fig. 5. Untreated line total silica concentrations as a function of time.

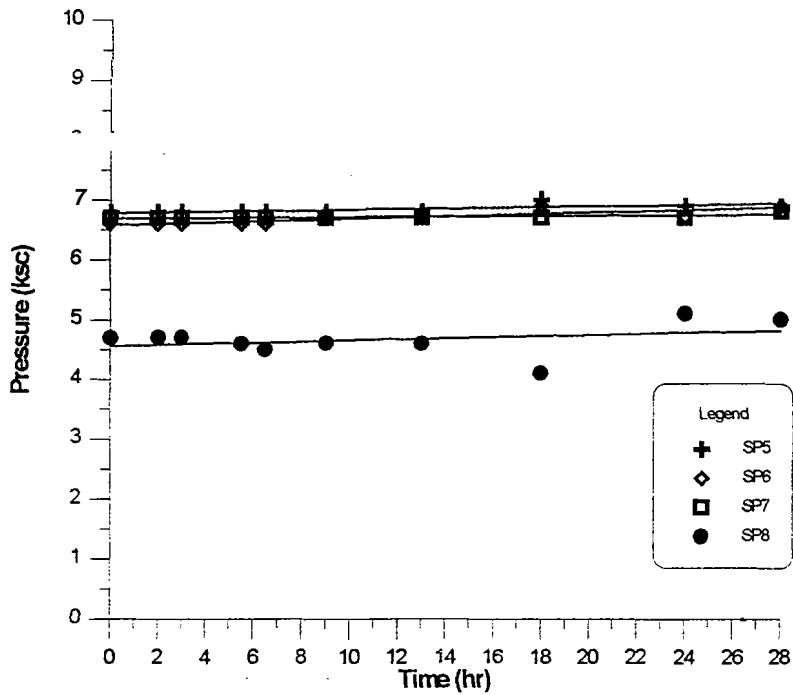


Fig. 6. Treated line pressure data as a function of time for the brine containing Cl concentration of Geogard SX.

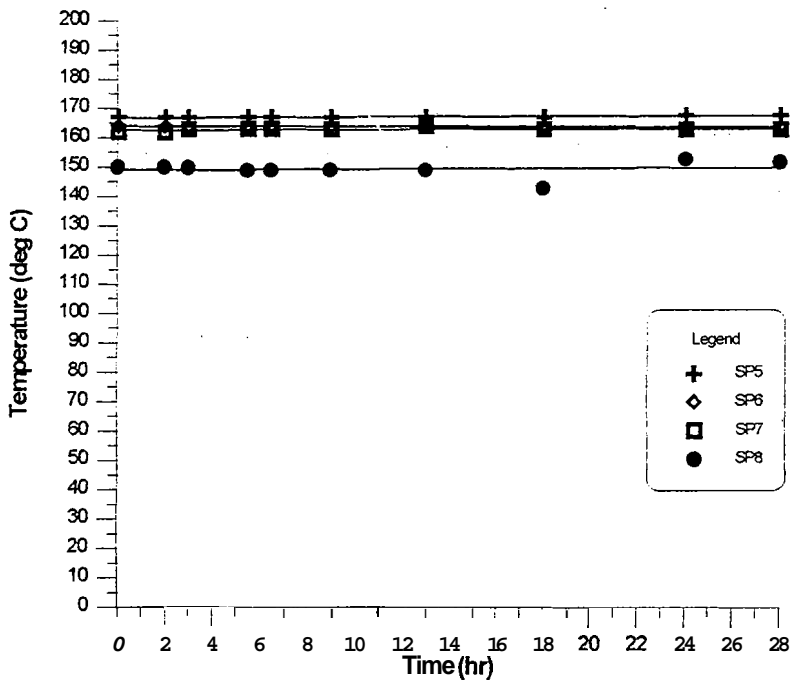


Fig. 7. Treated line (Cl) temperatures as a function of time

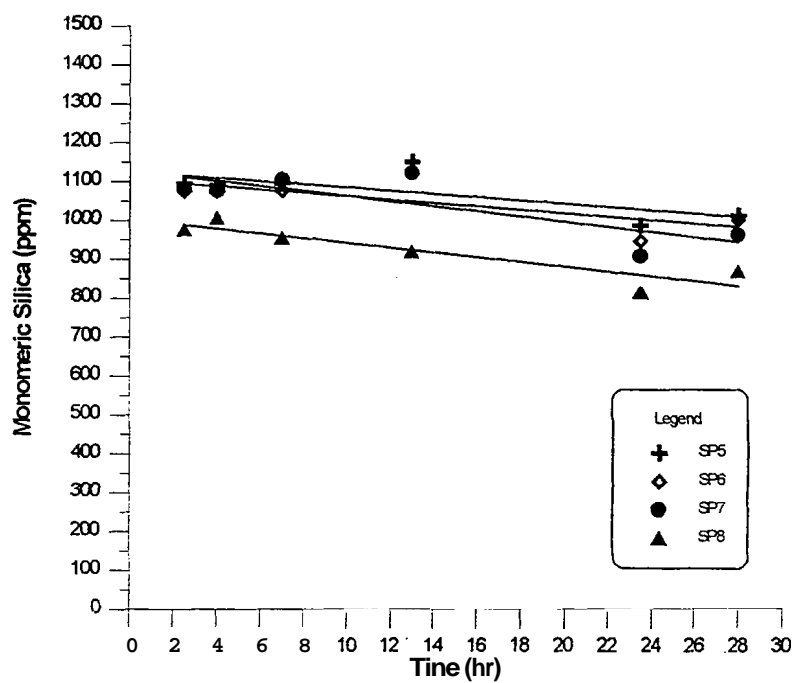


Fig. 8. Treated line (C1) monomeric silica concentrations against time

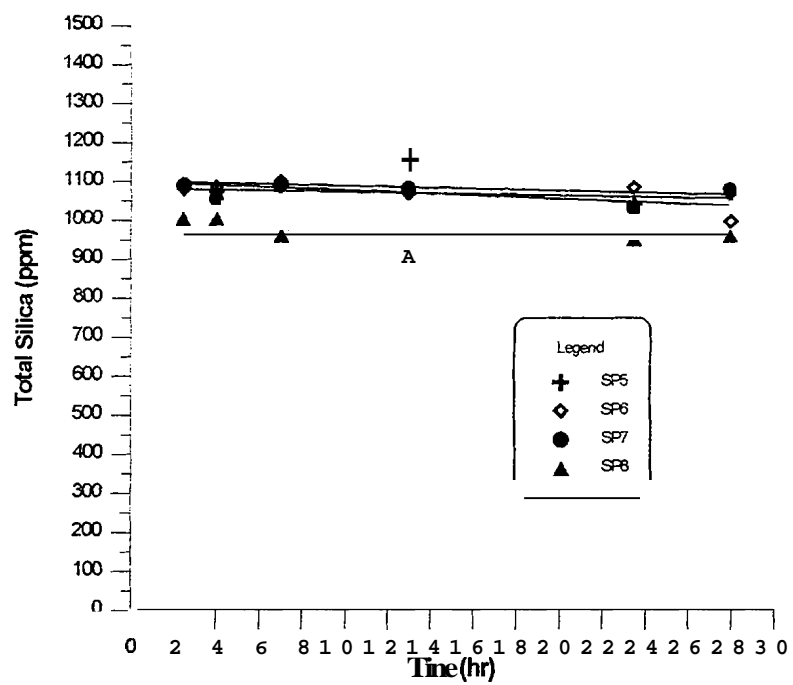


Fig. 9. Treated line (C1) total silica concentrations as a function of time

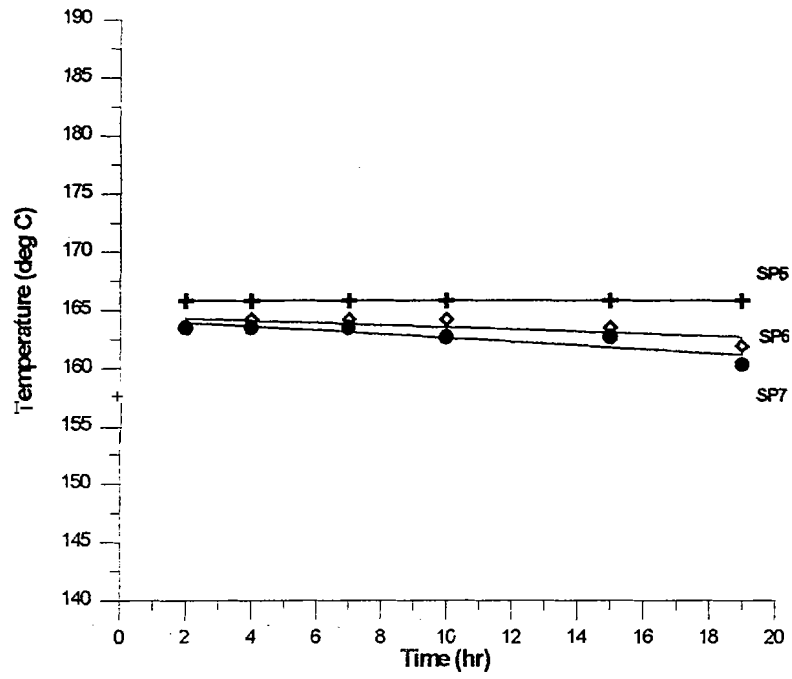


Fig. 10. Treated line (C2) temperatures at different sampling points against time

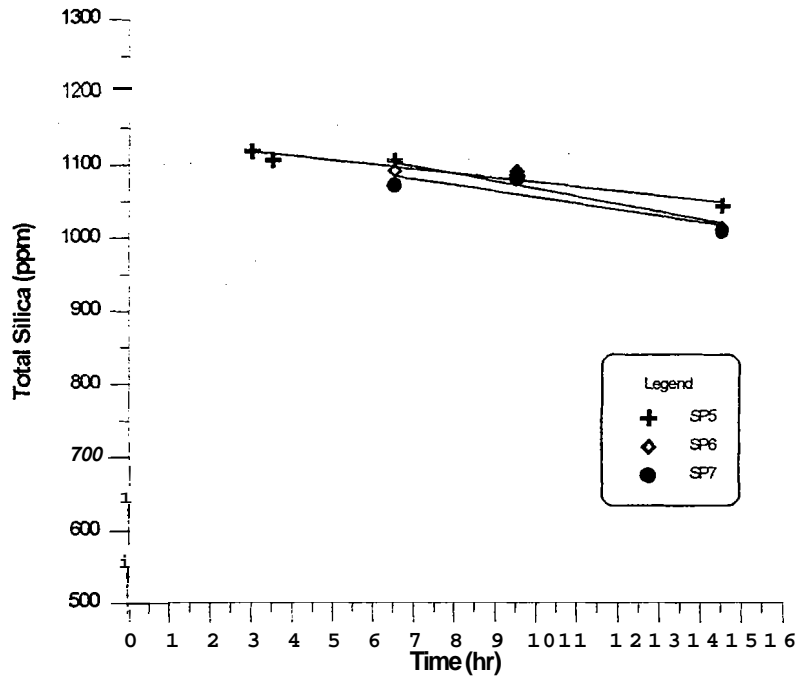


Fig. 11. Treated line (C2) total silica concentrations as a function of time

deposit was found inside the chamber which was earlier indicated by the total silica results. It is however unexpected that much of the silica was deposited in the proppant material and very minimal silica was found deposited on the sedimentary and volcanic rocks (photos B4 to B7). On the chemical point of view the presence of large amount of **aluminum** in proppant may triggered the deposition of silica (3). Few **data** were gathered for the brine treated with C2 concentration of **Geogard SX** due to unexpected fast deposition of silica along the pipeline. Figure 10 shows the temperature profile of the treated line. It is noticeable that drop in temperature was already experienced at the early stage of the experiment. **This** drop in temperature **can** be correlated to **an** early stage of silica deposition. Figure 11, although with minimal **data**, shows slow decline in the total silica concentration with time. This further **suggests** that silica deposition had started as early as the initial exposure time of the corroded metal surface with the brine.

Jar Experiment

The **jar** experiment was conducted under laboratory and static condition. Two different concentrations of **Geogard SX**, C1 and C2, were tested using the brine from the hot line (SP5) and the mini-silencer. These sampling **stations** simulated the separated waters from the first and second separators of the Botong FCDS respectively. For concentration C1, glass and rusted metal containers were used while for C2 were **glass** and clean metal containers. The **rusted** metal container was experimented to determine its effect on silica precipitation and stability of the polymer formed. On the other hand **the** clean metal container represents a clean pipe.

Figure 12 shows the precipitation induction time of polymerized silica for the samples obtained **from** the hot line and mini-silencer. The total silica **values** were monitored continuously for **45** hours. The graph **shows** that precipitation induction **time** for the hot line sample is about 7 hours while 9 hours **was** recorded for the mini-silencer sample. The process **involved** to these effects are not well established but it **was** shown here that the dispersive action of the inhibitor had worked longer for mini-silencer brine sample. In the rusted metal container, the precipitation of silica is very fast for both samples (Fig. 13). This observation indicates the involvement of iron in the precipitation reaction and OH⁻ ions in catalyzing the polymerization of silica. As observed **the** precipitates are colored yellow to yellow-orange. These observations showed that the inhibitor works in two ways, removing the **rust** from and preventing silica deposition on the pipe walls.

Jar test at concentration C2 gave a different silica precipitation trend. It is highly noticeable that the polymer formed in the mini-silencer sample is very stable for 40 hours of observation. The hot line sample showed similar trend with brine treated **with** C1 concentration of **Geogard SX** (Fig. 11). Jar test using the metal container (Fig. 15) gave no different result as compared to the glass container. These findings showed that a clean metal container does not affect the effectivity of the chemical inhibitor.

The results of the tests have some beneficial direct impact for the disposal of silica in Botong. If the observations will hold true on a dynamic system, then it could be applied in low temperature injection of treated geothermal wastewater.

5.0 CONCLUSIONS

The **Geogard SX** have been evaluated on the basis of its ability to prevent silica deposition in the pipelines and on the formation materials. **Based** on the gathered results, its applicability and effectivity in the geothermal system could be controlled and measured. These facts would give us some flexibility on applying the chemical to the different fields and thus, test its economic feasibility. The following conclusions were formulated and could be of use in the actual application of the chemical inhibitor.

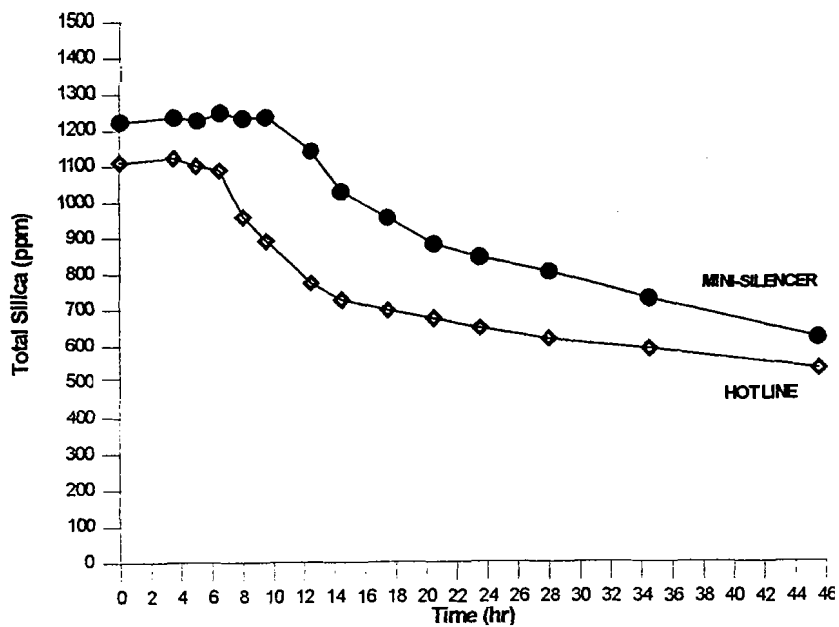


Fig. 12. Total silica concentration in brine treated with Cl concentration of Geogard SX as a function of time (Glass container).

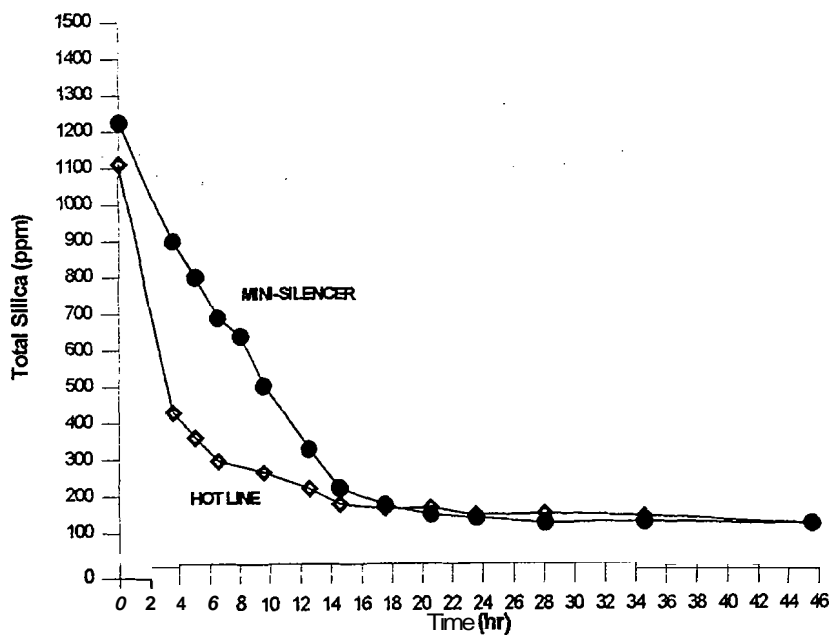


Fig. 13. Total silica concentration in brine treated with Cl ppm of Geogard SX as a function of time (Metal container).

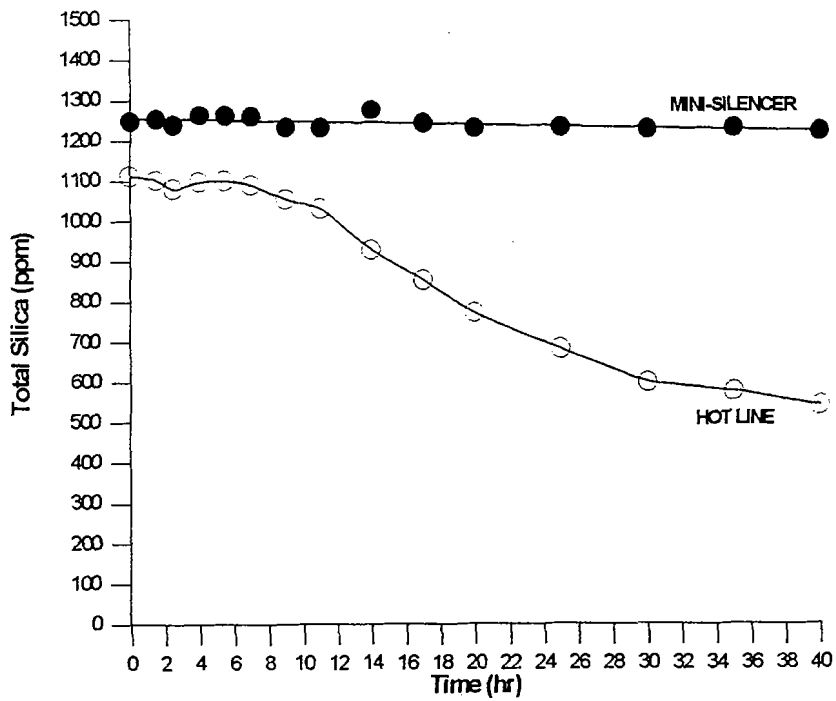
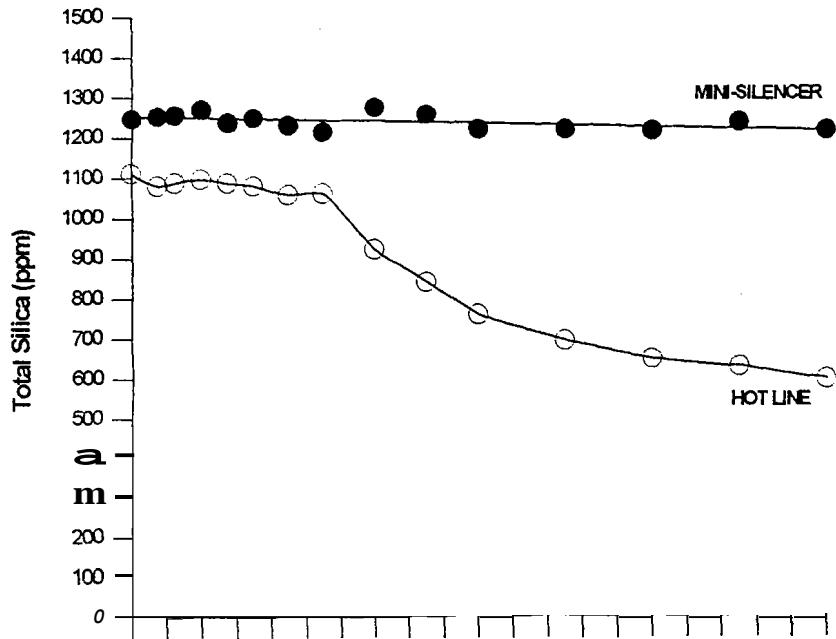


Fig. 15. Total silica concentration in brine treated with C2 ppm of Geogard SX as a function of time (Clean metal container).

- Hot injection of the untreated brine. with > **1100** ppm SiO₂. is not a feasible effluent disposal option.
- Geogard SX. at C1 ppm concentration in brine. effectively inhibits silica deposition on pipe walls and formation materials during hot injection (**- 165 °C**) for 28 hours.
- Geogard SX at C2 ppm concentration in brine is **not** effective in inhibiting silica deposition during **hot** injection
- Hot injection **of** the untreated brine would cause silica deposition in the formation materials
- Hot injection **of** the treated (C1 ppm) brine would cause negligible silica deposits in the formation materials for 28 hours.
- Brine which had been treated with the inhibitor under **high** temperature condition, either at C1 **or** C2 concentration. could be **disposed through** low temperature injection scheme
- Geogard SX is reactive to silica polymer and oxides **of** iron.

6.0 RECOMMENDATIONS

The use of polymeric antiscalant in treating geothermal wastewater is a very young technology. This promising results obtained using Geogard SX would improve the current utilization problem on silica-rich geothermal resource and ease the **disposal** of generated wastewater.

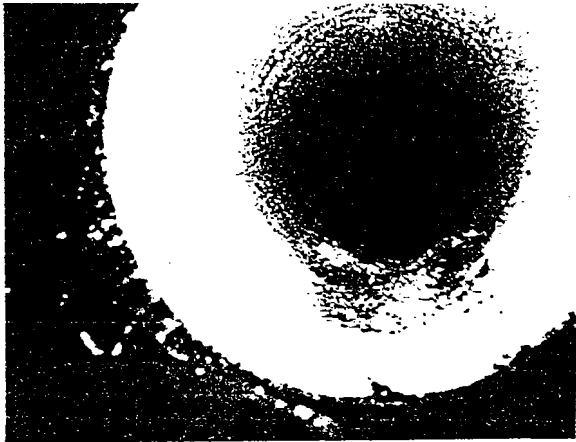
It is therefore recommended to **treat the Botong** brine **with** the inhibitor, at C1 concentration, by injecting it at the separator and dispose the waste **fluid** applying the low temperature injection scheme.

ACKNOWLEDGMENT

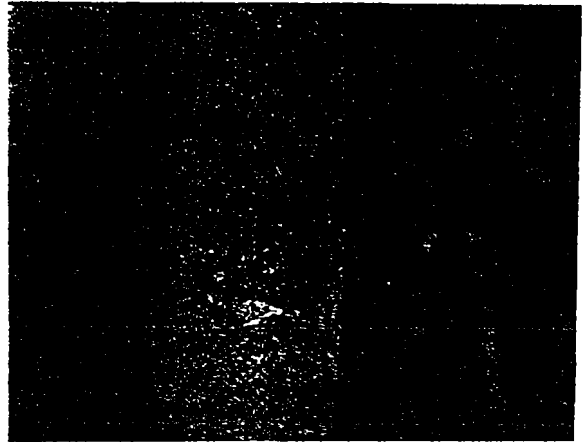
BGPF Geoservices. Maintenance. Production. and Electrical/Instrumentation Groups

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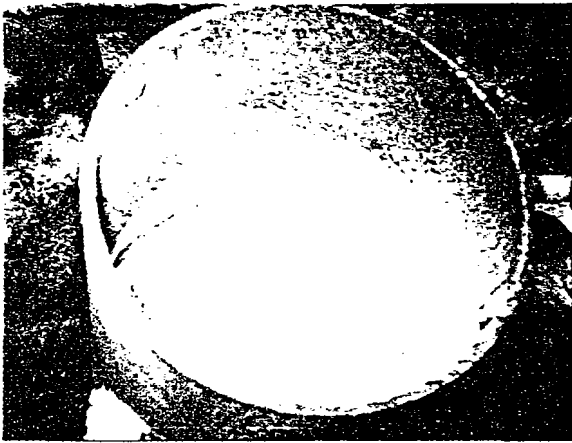
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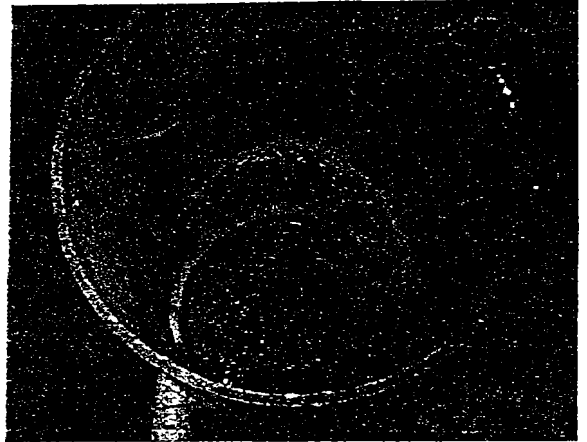
A1. Silica deposit (2-3 cm) inside the retention vessel (untreated)



B1. Residual silica shown as white spots inside the retention vessel (treated)



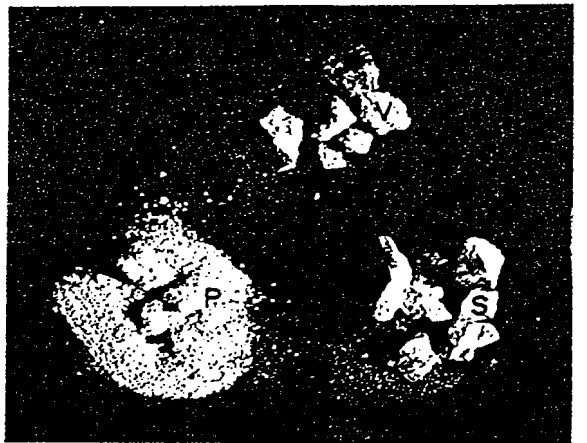
A2. Silica deposit inside the mini-silencer (1-2 mm. untreated)



B2. Minimal deposit of silica shown as white dash lines inside the mini-silencer (treated)



A3. Volcanics (V), sedimentary (S), and proppant (P) materials shown covered with thick deposit of silica (untreated)



B3. Volcanics (V) and sedimentary (S) materials with negligible deposit of residual silica. Proppant is shown with thick silica deposit, but less as compared to untreated.