

# FURTHER SILICA INHIBITION EFFICIENCY TESTING OF GEOGARD SX AT THE SOUTHERN NEGROS GEOTHERMAL PRODUCTION FIELD, PHILIPPINES

Arnel V. Mejorada, Serafin E. Garcia, Oliver T. Jordan, Richard L. Reyes,  
Percival I. Pamatian and Perfecto G. Lim

PNOC Energy Development Corporation, Merritt Road, Fort Bonifacio, Makati City 1201, Philippines

## ABSTRACT

*A phosphino carboxylic acid co-polymer silica inhibitor, Geogard SX™ (GSX), was tested to determine its effectiveness and economic feasibility in the Southern Negros Geothermal Production Field.*

*Using a test facility, that simulates the actual brine conditions along the reinjection line and wellbore, Geogard SX was tested at a 0.50 ppm dosing concentration. After 81 days of continued dosing, the silica deposition rate along the line dropped from 10-13 mm/year to 4 mm/year, which is equivalent to 70% silica inhibition efficiency. The brine flow rate of the untreated line subsequently declined by as much as 40%, while the GSX treated line were maintained within the baseline levels.*

*Based on previous experiences with well OK-3R and cost estimates at 0.50 ppm dosing concentration, the application of GSX is economical compared with conventional pipe and well maintenance procedures at a given time frame.*

## 1.0 INTRODUCTION

The study of using Geogard SX (GSX), a phosphino carboxylic acid co-polymer, silica inhibitor in the Southern Negros Geothermal Production Field, was prompted by the continuing reinjection capacity decline and eventual shutdown of reinjection well OK-3R. This decline in acceptance was attributed to silica deposition in the well bore and formation.

The primary objective of this study was to determine whether the application of Geogard

SX would be effective in controlling silica deposition along the brine pipeline as well as in the reinjection well. The secondary objective was to determine the economic feasibility of using the chemical inhibitor against conventional brine pipe and well maintenance procedures such as well acidizing and mechanical work-over.

Initial testing at 1.0 ppm Geogard SX dosing (Mejorada, et al. 2000) showed that at this dosing concentration, GSX was able to limit the silica particle size, but was unable to completely disperse the deposits. It was also noted that there was more deposit by weight in the untreated line in comparison to the GSX treated line. However, due to the presence of detrital silica (transported silica scales) which clogged up the pilot test facility, accurate measurement of the deposition rate could not be made.

The decision to use a dosing concentration of 0.50 ppm GSX was based on the known chemistry of the Palinpinon Brine and the postulated dispersion mechanism of Geogard SX.

## 2.0 PALINPINON I BRINE CHEMISTRY AND PLANT LOAD CONDITIONS

Prior to testing a complete chemical analysis of the brine was conducted. The result of the analysis is given in Table 1. This shows the typical brine chemistry during the duration of the testing from May 18, 2000 to August 7, 2000.

During the testing, the silica saturation levels of the Palinpinon I brine at reinjection line 318, narrowly ranged from 1.05 to 1.09. The average plant load during the same period ranged from 92.1 MWe to 97 MWe, which corresponds to an average brine flow rate of 304 kg/s to 318 kg/s. There were no major well movements or other

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\* Geogard SX™ is a registered trademark of Biolabs Water Additives

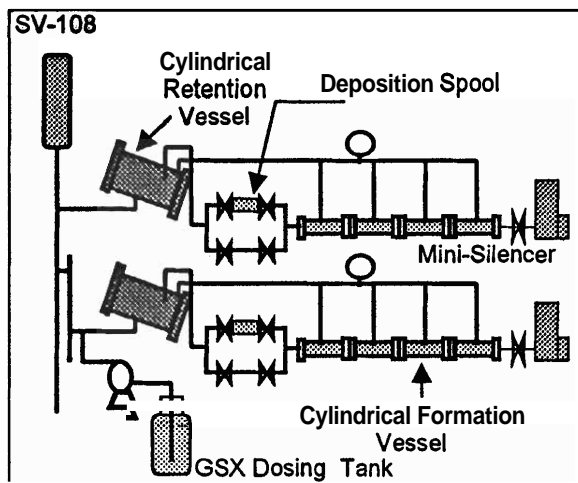
external events that occurred, which may affect the overall results of the field experiment.

**Table 1. Representative Palinpinon I brine chemistry**

Chemical Parameters		Concentration (ppm)
Acidity	pH	6.94
Sodium	Na	4885
Potassium	K	878
Calcium	Ca	265
Magnesium	Mg	0.20
Chloride	Cl	8502
Sulfate	SO <sub>4</sub>	24
Total Silica	SiO <sub>2</sub>	744
Hydrogen Sulfide	H <sub>2</sub> S	4.43
Carbon Dioxide	CO <sub>2</sub>	26.80

### 3.0 PILOT TEST SET-UP

The schematic diagram of the Geogard SX test set-up is given in Figure 1. The pilot test facility is the same as the one used with the 1.0 ppm GSX testing with minor modifications, in order to prevent the interference of detrital silica and smectite scales. This set-up was designed to mimic as close as possible the brine condition from the separator vessel up to the reinjection well. This was done by proportionally scaling down the pipe sizes and brine flows to still attain similar fluid conditions in the main reinjection lines, i.e. the flow regime (Reynold's number) and fluid velocity.



**Figure 1. Schematic diagram of test facility, GSX inhibition efficiency testing**

The cylindrical retention vessel (CRV) is used to simulate the time it takes the brine to travel from the separator vessel to the reinjection pad, previously measured by sodium

fluorescein tracer test to be about 35 minutes. The brine velocity would be slower at this segment but the silica aging time will be similar to the actual line.

The deposition spool (DS) is designed to simulate the brine line condition and also provide an inspection segment, where the silica deposition rates can be compared.

The cylindrical formation vessel (CFV) is used to simulate conditions within the borehole, specifically that of the OK3R formation. This segment is filled up with formation materials representative of the Okoy sedimentary formation. Calcisiltite materials were crushed to approximately one (1) inch pebble size rocks, which are then packed into the formation vessels. This simulates the fluid-rock interaction that may occur in the borehole.

The mini-silencer (MS) is used to channel the fluids and effectively measure the atmospheric flow rate by volumetric method. The actual mass flow at the line pressures of the set-up is calculated using a mass and heat balance equation based on the line and atmospheric pressures.

Two similar lines were used to ensure that the same conditions are happening at both lines for direct comparison. To monitor the progress of the testing, the flow rate, temperature and pressure were routinely measured every two hours.

### 4.0 RESULTS AFTER 81 DAYS

After 81 days of continued operation, the testing was terminated when the brine flow rate of the untreated line was reduced by as much as 40% (Figure 2) relative to the initial flow rate of 180 mL/sec. The slope of the Geogard SX treated brine flow rate showed only a dip of -0.14 ml/day, while the untreated line registered a decline of -0.88 ml/day. This simulation shows the effectiveness of Geogard SX in maintaining the acceptance of a reinjection well.

Following the shutdown of the testing, individual components were inspected. Upon opening of the retention vessels, both components were filled with some cemented detrital silica scales (Figures 3 and 4). It can be noted that more deposits were present on the

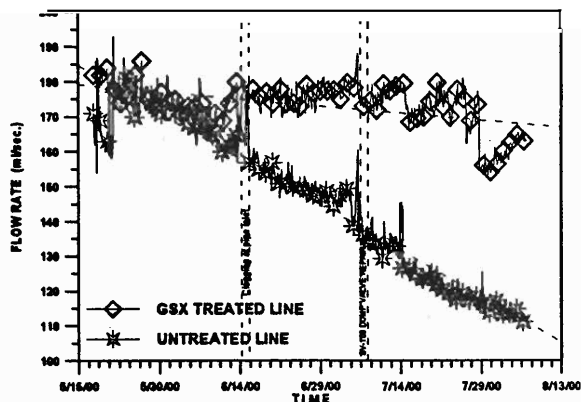


Figure 2. GSX treated and untreated flow rates vs. time



Figure 3. Untreated retention vessel

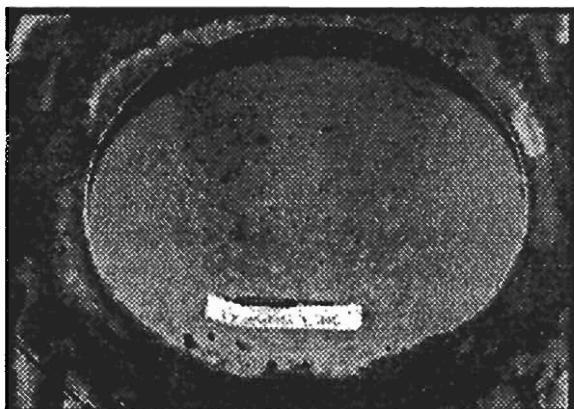


Figure 4. GSX treated retention vessel

untreated retention vessel compared to the GSX treated retention vessel. This can be related either to the line configuration causing the brine to preferentially pass through the untreated pilot test facility before going to the GSX treated pipes, or to the effectiveness of the chemical inhibitor. However, the presence of these materials did not hamper the experiment due to the modifications done in the pilot test facility.

Upon inspection of the deposition spools, the GSX treated deposition spool had a deposition thickness of **0.90 mm** or a deposition rate of **4 mm/year** (Figure 5). In comparison, the untreated deposition spool had a deposition thickness of **2.20 – 2.90 mm** or a deposition rate of **10 – 13 mm/year** (Figure 6). This shows that continuous GSX treatment at 0.50 ppm can reduce the deposition rate by as much as 70%

The deposits on the deposition spools were hard and granular as predicted in the monomeric over total silica ratios (Mroczek and Reeves, 1994, Figure 7 and Table 2.) However there were minor differences in appearance., The GSX treated deposits were dark and grayish, while the untreated scales were whiter. The whiter deposits can be attributed to the contribution of colloidal deposits and the darker deposits to monomeric deposition.

The difference in characteristics of the deposits was elucidated upon using a scanning electron microscope. Under the same magnification at **1500** times, the GSX treated scales (Figure 8) has a smaller particle size than that of the untreated scales (Figure 9). Although both scales have the same morphology, the difference in particle sizes produces the difference in the appearance of the deposits. It could be said that the deposits in the GSX treated scales were generally monomeric in nature, while the untreated scales are made up of both monomeric and colloidal deposits.

Visual inspection of the formation vessels showed that there were more deposits in the untreated vessel (Figure 10) compared to the GSX treated vessel (Figure 11). The drop in flow rate can be attributed to the clogging up of the formation vessel by the silica deposits.

## 5.0 DISCUSSION

Based on these results, application of Geogard SX would be beneficial in reducing the operational and maintenance cost of the reinjection pipelines as well as reinjection wells.

Mechanical work-over and acidizing operations would cost as much as **\$290,990.00**. Using this as a benchmark and **OK-3R** as a model, where, in order to maintain the reinjection capacity of 80 kg/s, well maintenance

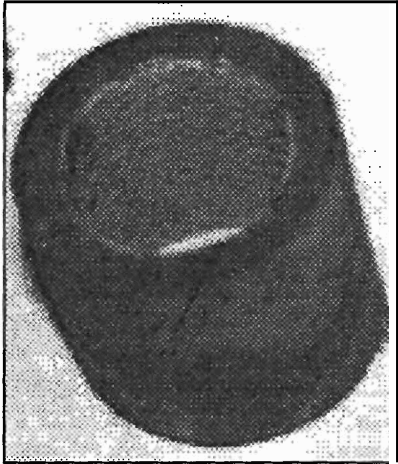


Figure 5. GSX treated deposition spool

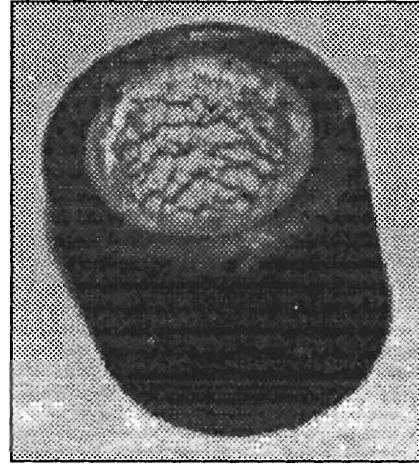


Figure 6. Untreated deposition spool

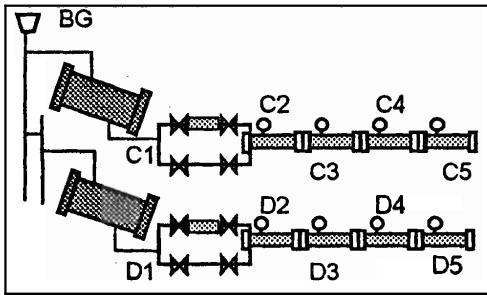


Figure 7. Separated water sampling points

Table 2. Typical monomeric and total silica analysis

Sampling point	mono SiO <sub>2</sub>	total SiO <sub>2</sub>	x's SiO <sub>2</sub>	mono/total
BG	737	744	-7	0.99
C1	753	743	-10	1.01
C2	723	724	1	1.00
C4	764	743	-21	1.03
D1	741	743	2	1.00
D2	755	750	-5	1.00
D4	728	774	46	0.94

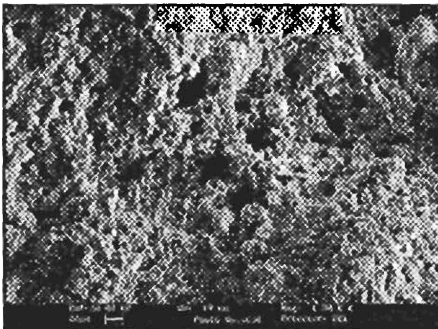


Figure 8. GSX treated silica scales

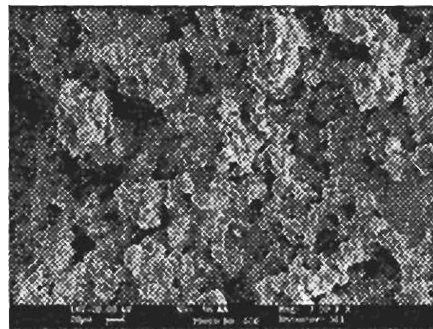


Figure 9. GSX untreated silica scales

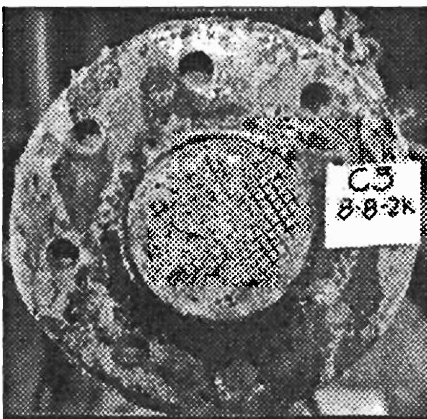


Figure 10. Untreated formation vessel

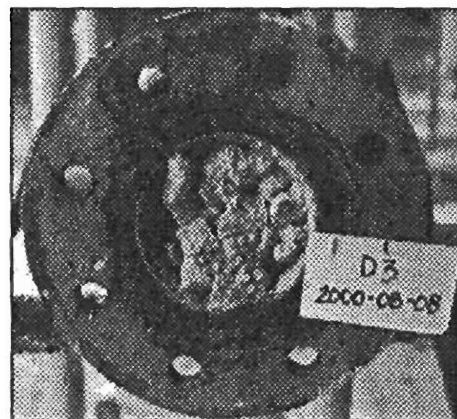


Figure 11. GSX treated formation vessel

operations would have to be performed every **440** days, the economic feasibility of using GSX can be calculated.

Table 3 gives a cost estimate on the silica inhibitor cost for **440** days at a price ranging from \$ 25.00 to \$ 30.00 per kilogram of inhibitor (Estimated maximum commercial price of GSX). GSX dosing at 0.5 ppm will cost around \$ 45,619.00, which is an **84%** reduction in cost compared to conventional acidizing/work-over operations, without any down time in production. Based on these cost estimates, GSX utilization is economical in order to maintain reinjection capacities compared to conventional well maintenance procedures (Jordan, et al., 2000)

**Table 3. Geogard SX cost estimate**

Price / kg	GSX cost 1440 days	
	\$25.00	\$ 30.00
<b>1.0 ppm</b>	\$76,032.00	\$ 91,238.40
<b>0.5 ppm</b>	\$ 38,016.00	\$45,619.20

## 6.0 CONCLUSION

The commercially available chemical inhibitor, Geogard **SX**, is able to control silica scaling of brines with low excess silica. GSX can reduce the deposition rate along the brine pipeline by **as** much as **70%** and maintain the brine **flow** rate within the baseline levels.

Based on the cost estimates at 0.5 ppm dosing, GSX is economical compared to conventional pipe and well maintenance procedures at a given time frame.

## ACKNOWLEDGMENT

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