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Silica Scaling Control in the North Reinjection Line of the San Jacinto Tizate Geothermal Field, Nicaragua

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ABSTRACT

San Jacinto Tizate is a high temperature geothermal field (~310 °C) with a serious operational issue of silica scaling formation from production wells that are in PAD 12 and have high silica content between 900 and 1000 ppm with a silica saturation index (SSI) of 1.35.

Due to technical problems related to silica deposition, mainly occurring in surface equipment, reinjection pipeline and injection wells in the North zone of the field, field trials were performed using a silica test skid followed by online testing at the end of 2016. In both scenarios, pH buffer, citric acid and acetic acid were tested to assess the effectiveness of these chemicals to control the silica polymerization process by modifying the brine pH in a range of 4.5-5, which usually delayed silica precipitation long enough to be disposed in injection.

From the trials carried out in the silica skid test, it was determined that citric and acetic acid allow modification of the brine pH in the desired range to delay silica polymerization. The same results were obtained with the online test, and so it was decided to use acetic acid because there is a local supplier, low cost, and stock availability.

These pilot and online tests were very useful for finding the best chemical option, based on cost-benefit, to control silica scaling. From 2017 to the present, acetic acid has been used to modify the brine pH coming from cyclonic separator HPS-3, and ongoing monitoring shows that silica polymerization is prevented in the injection pipeline. Furthermore, the injection capacity of wells SJ11-1 and SJ11-2 have been maintained.

1. INTRODUCTION

The brine of San Jacinto Tizate Geothermal field has high levels of dissolved silica, which reflects the high temperatures (greater than 290 °C) in the production wells (PAD 12). Steam and water phases are separated in the cyclonic separator at 4.9 bar_g and 158 °C. Silica concentration in the separated brine varies between 900 and 1000 ppm. The average Silica Saturation Index (SSI) is 1.4. Chemical equilibrium requirements indicate that brines with SSI above 1.0 will eventually deposit excess silica and form scales.

The Silica Skid Project was constructed with the purpose to study the silica polymerization process in separated brine from HPS-3 unit, considering that this brine has a high scaling potential (ISS = 1.4). Untreated and treated brine scenarios were carried out in the Silica Skid using different pH control products at different concentrations, such as buffer solution (acetic acid, sodium hydroxide, sodium acetate and water) at 30, 50, 70 and 120 ppm, 50% citric acid at 70, 100 and 120 ppm, and 99.85% pure acetic acid at 40, 50 and 60 ppm.

Low rates of silica polymerization were achieved in the dosage ranges of 70, 100 and 120 ppm citric acid, and 50 and 60 ppm of pure acetic acid. The pH was controlled with these two-organic acids in the range of 4.2 - 4.9. According to Silica Skid test results and cost-benefit analysis, 50 ppm of pure acetic acid seems to be the most suitable alternative to control the silica polymerization process in separated brine coming from HPS-3. Additionally, online tests were carried out in order to verify the silica behavior and effectiveness of acetic acid and citric acid.

2. KINETICS OF SILICA POLYMERIZATION

The kinetics of silica polymerization depends on several factors, such as pH, temperature, degree of supersaturation, and ionic strength. These are the same factors that control silica deposition. Increased rates of silica polymerization imply increased risk of silica scaling (Brown, 2013).

One of the treatments to cope with silica deposition is the inhibition of colloid formation by decreasing the pH to lower values of 4.5 -5.0. At this pH, the polymerization process can be halted for several hours, but the silica will eventually polymerise and possibly deposit (Brown, 2013). Based on that, buffer solution, citric acid and pure acetic acid were tested to adjust the brine pH of the San Jacinto production wells (PAD 12).

Induction time in the silica polymerization process is very important because silica deposition cannot occur unless the brine is supersaturated with silica at any temperature. Deposition proceeds after monomeric silica has begun to polymerize. Figure 1 shows the silica deposition mechanism.

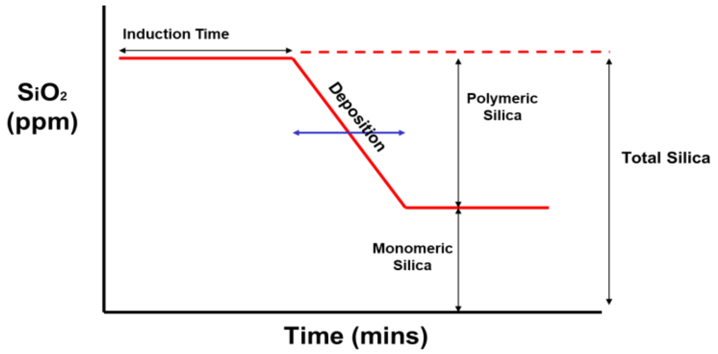

Figure 1: Silica deposition.

3. SILICA FIELD TRIALS

Silica raises a serious operational issue in high temperature geothermal fields due to scale formation in surface pipework and injection wells. A set of trials with buffer, citric acid and pure acetic acid were carried out, firstly in a pilot level (silica skid) and secondly in the north reinjection pipeline of the San Jacinto Tizate Geothermal Field (online test).

3.1 Pilot Test

The silica skid consists of two main parts: the chemical injection or dosing system, and the polymerization tank that simulates the residence time for the brine, allowing the test to run at quasi-constant temperature (150 °C) with a reduction of approximately 5°C for one hour.

To run the polymerization test, it is first necessary to ensure stable brine flow, temperature and chemical treatment conditions. Then, brine is fed to the polymerization tank, and the dosing pump is started, and pH is monitored until a stable measurement is achieved. Once we have this condition, the polymerization test starts inside the polymerization tank, containing the brine in a static condition for one hour. Samples were taken at 10-minute intervals.

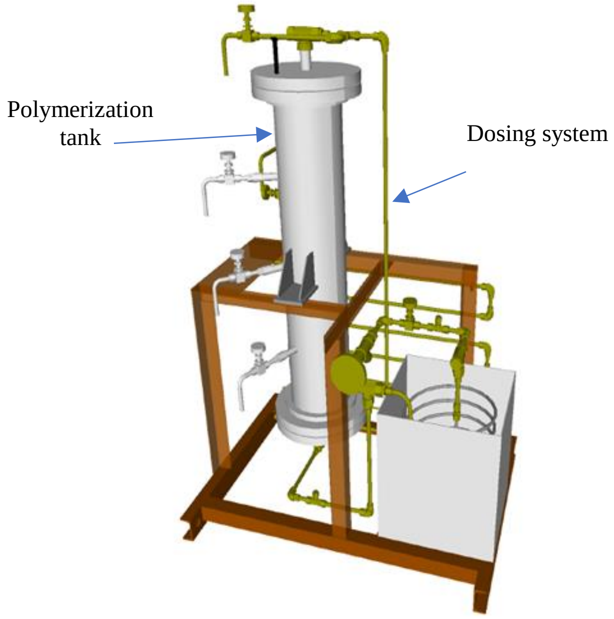

Figure 2: Silica Skid scheme.

3.1.1 Buffer Solution

Buffer solution is a mixture of a weak acid combined with base (acetic acid and acetate) which was formulated to 5 pH desired for silica scale control. The composition is: acetic acid (60.05 Weight g/mole (%)), and sodium hydroxide (40.01 Weight g/mole (%)).

The silica skid test with buffer solution was carried out with dosing at 30, 50, 70 and 120 ppm. The test results of polymerization are shown in Figure 3. It can be observed that at doses of 30, 50 and 70 ppm of buffer, brine pH is modified slightly from 7.4 to 7.0. On the other hand, at 120 ppm, brine pH was modified to 6.1. An induction time of only 10 minutes was obtained with 50, 70 and 120 ppm; after this time polymerization starts. At 30 ppm no induction time was observed, indicating that monomeric silica starts to form polymers from zero time. Scaling potential is present at almost all doses, with the exception at 120 ppm, where only 9 ppm polymerized.

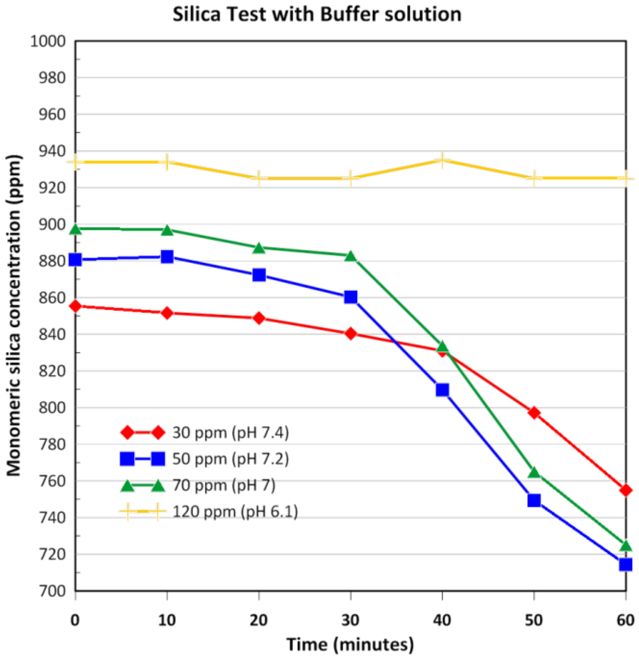

Figure 3: Silica skid test results with buffer solution.

3.1.2 Citric Acid (50%)

A silica skid test with citric acid was carried out with dosing of 70, 100 and 120 ppm. Test results of monomeric silica are shown in Figure 4. A good result was obtained with all doses because the brine pH was modified to between 4.23 and 4.85, and slowed the rate of silica polymerization, increasing the silica polymerization induction time. This means that few polymers were formed during the one-hour test.

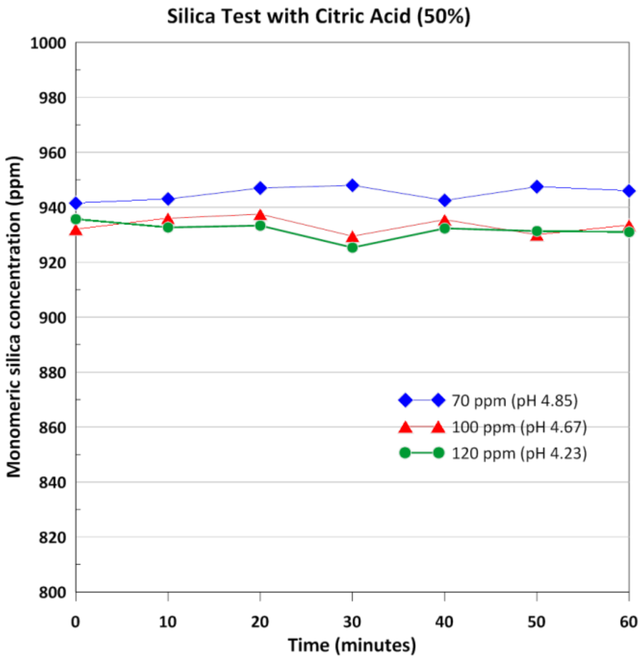

Figure 4: Silica skid test results with citric acid.

3.1.3 Pure Acetic Acid (99.85%)

The silica test was carried out with pure acetic acid dosing at 40, 50 and 60 ppm. The results obtained are shown in Figure 5, and it can be observed the brine pH is modified to between 4.49 and 4.86, and this slowed the rate of the silica polymerization reactions, increasing the silica polymerization induction time; few polymers were formed during the one-hour test.

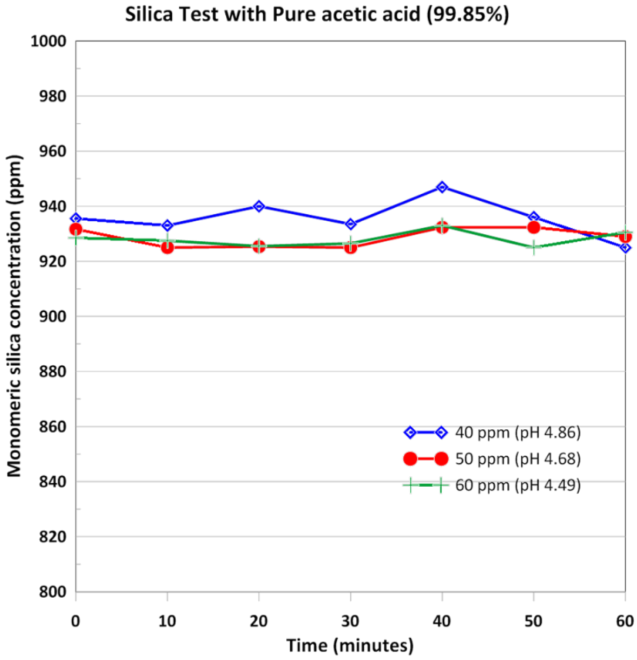

Figure 5: Silica skid test results with pure acetic acid

3.2 Online Test

Based on the results obtained in the silica skid test mentioned before, and to evaluate the behavior and effectiveness of buffer solution, citric and pure acetic acid to regulate the brine pH to delay silica polymerization along the North Reinjection line, an online test was carried out with buffer solution (at 120 ppm), citric acid (at 50 and 70 ppm), and pure acetic acid (at 40 and 50 ppm), for one month for each brine pH regulator. In the North Reinjection line, four sampling points were monitored at the PAD12, mixing point (brine coming from HPS-2 with an average silica concentration of 545 ppm causing some dilution effect), Coupon 12 and SJ11-1 and figures 7, 8 and 9 show the results obtained.

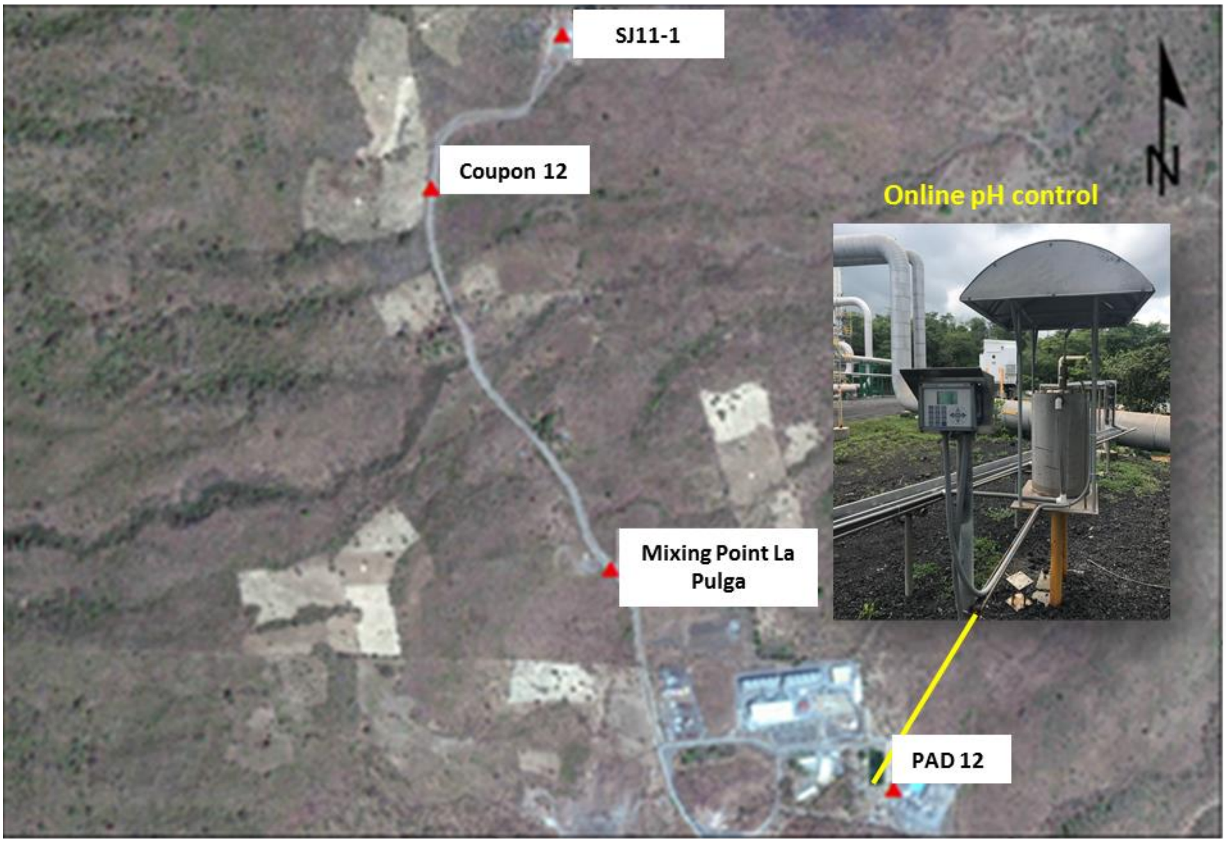

Figure 6: Map of sampling point along the North reinjection line

3.2.1 Buffer Solution at 120 ppm

Online test results using buffer solution at 120 ppm are show in Figure 7. Four set of samples were collected, and it can be observed that the largest decline of monomeric silica concentration was 40 ppm along the North reinjection line, and the pH obtained was in the range of 5.61-5.84 (PAD 12). After the mixing point at SJ11-1, the pH increased slightly to between 5.77 and 6.

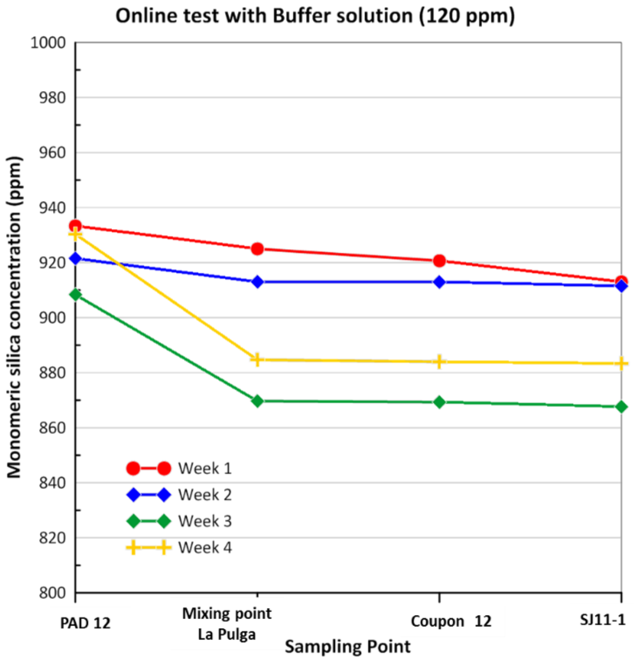

Figure 7: Online test results with buffer solution

3.2.2 Citric Acid at 50 and 70 ppm

Citric acid dosing was applied at 50 and 70 ppm. It can be observed in Figure 8 at 70 ppm dosing monomeric silica drops an average of 30 ppm along the North reinjection line, and pH values obtained were in the range of 4.0-4.2. With 50 ppm dosing, monomeric silica concentrations declined ~61 ppm from PAD 12 to the mixing point, and after this point, toward SJ11-1, only declined an average of 8 ppm, with pH in the desired range of 4.5-4.6.

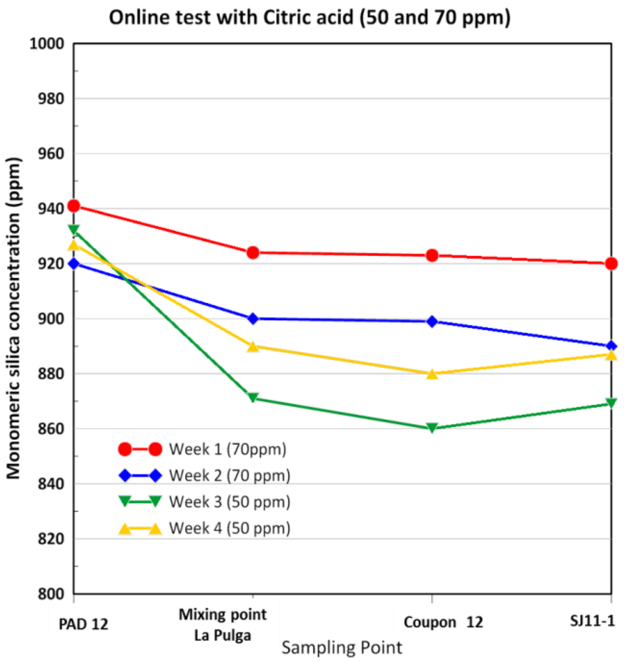

Figure 8: Online test results with Citric Acid

3.2.3 Pure Acetic Acid at 40 and 50 ppm

Pure acetic acid dosing was applied at 40 and 50 ppm. The results obtained are shown in Figure 9. Acetic acid provides a significant delay in silica polymerization along the North reinjection line. The pH obtained was in the range of 4.4 – 5.0. It can be observed that at the point called mixing point "La Pulga" that monomeric silica decreases or increases due to brine from HPS-2 mixing with the brine from HPS-3.

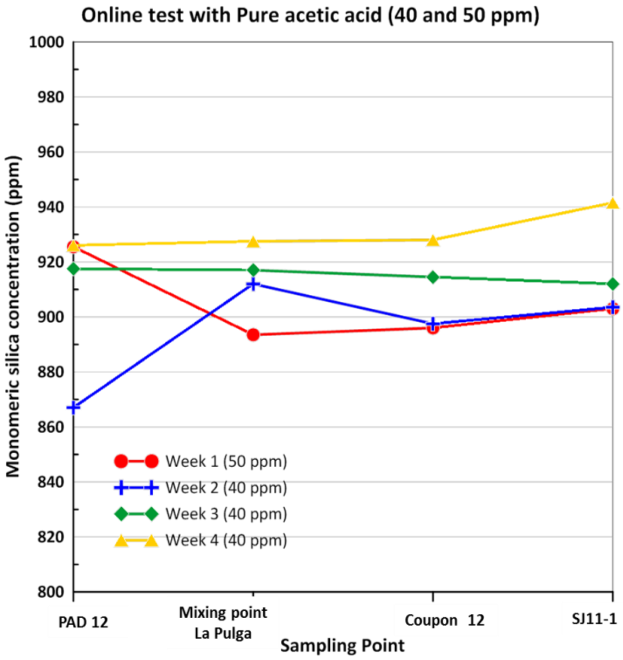

Figure 9: Online test results with pure acetic acid.

3.3 Pure Acetic Acid Injection

After the finished test period with buffer, citric and pure acetic acid to control silica reaction in the North Reinjection line, it was decided to inject pure acetic acid at 40 ppm. Figure 10 shows monomeric silica behavior results; it can be observed that pure acetic acid delays monomeric silica reactions controlling the polymerization process as these concentrations remain almost at the same value along the entire pipeline. Acetic acid doses, controls and maintains the brine pH in the range of 4.6-5.0 and helps it hold silica in suspension to prevent polymerization.

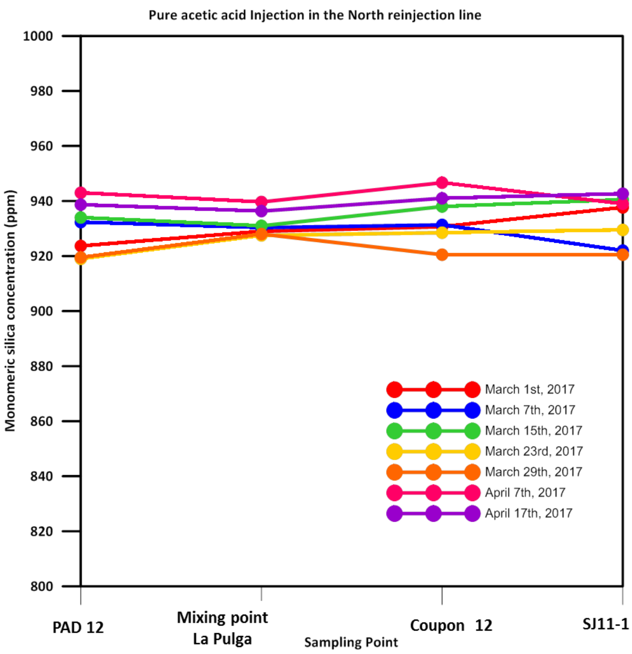

Figure 10: Silica concentration results along the North Reinjection line.

In order to ensure chemical treatment and monitoring the modify brine pH at the desired value of 4.5 – 5.0, an online pH-meter was installed in PAD 12 (see figure 6).

3. CONCLUSIONS

San Jacinto Tizate has a serious operational issue of silica scale formation from production wells that are in PAD 12 and have high silica content between 900 and 1000 ppm, with a silica saturation index (SSI) of 1.35.

Brine acid treated using Silica Skid Test show that citric and pure acetic acid provides excellent delays in silica polymerization at a temperature of 148°C and a pH range of 4.20 - 4.9. Citric acid and pure acetic acid allow modification of the pH to a desired value (between 4.5 and 5). Less effective control of silica polymerization was achieved using buffer solution at a dose rate of 120 ppm. Doses greater than 120 ppm represent a non-economic option. In the online test, citric acid (70 ppm) and acetic acid (40 ppm) produced the necessary pH adjustment.

It is expected that the monomeric silica remains in a range of stability in which the polymerization reactions and scaling deposition in the pipe will be low, and it is expected that this will prevent or delay the decline of the injection well capacity.

In all experiments with different tested acids, a slight change in the pH of the brine and silica concentration was observed at the point called "Mixing Point La Pulga" due to brine coming from HPS-2 being mixed with the brine that is coming from HPS-3. The pH values remained within the recommended range (4.5-5.0), which prevents corrosion problems in the line and rapid polymerization of monomeric silica.

After completing tests with buffer, citric acid and pure acetic acid to control silica reaction in the North Reinjection line, it was decided to inject pure acetic acid at 40 ppm because this is a less costly option and is available in the local market.

These pilot test and online tests were very useful to find the most cost-effective chemical option to control silica scaling. From 2017 to the present, pure acetic acid is used to modify the brine pH coming from cyclonic separator HPS-3, and ongoing monitoring shows that silica polymerization is prevented in the injection pipeline.

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