Optimised Chemical Cleaning of Geothermal Wells: A Laboratory Study

Alan Ferguson[1], Gabby Buchanan[2], Courtney Fox[1], David Fletcher[3], Katie McLean[1], Jonathan Wynands[1], James Asquith[1] and Michael Rosenberg[4]

[1]Contact Energy, Te Aro Rd, Wairakei, New Zealand

[2]Western Energy 132 Rakaunui Road, Taupō, New Zealand

[3]David Fletcher Consulting, Karitane, New Zealand

[4]GNS Science, 114 Karetoto Road, Taupō, New Zealand

alan.ferguson@contactenergy.co.nz

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ABSTRACT

The chemical cleaning of geothermal production and reinjection wells is a helpful maintenance activity in treating formation scale. Removal of this troublesome scale can be used to maximise generation, increase the useful life of wells and defer the drilling of new wells. While we have had several successful chemical workovers of both production and reinjection wells in recent years, there have also been scenarios where the uplift was not as expected, or the recovery was short lived. In an effort to explain the behaviour we have observed, we have undertaken a thorough laboratory study to understand the efficacy of the chemicals typically used to chemically clean geothermal wells and find the optimal chemical mix for both production and reinjection wells. We employed a systematic, statistical experimental design approach to allow testing of a range of variables and chemical types in the smallest number of experiments possible. These baseline results have given us valuable insight into the optimal chemical selection for production and reinjection wells to provide the best chance of success when applied in the field. This paper summarises the results of several hundred experiments across different scale types and formations and discusses the implications of the results for future well workovers.

1. BACKGROUND

1.1 Chemical Cleaning of Geothermal Wells

Chemical cleaning of geothermal wells to remove formation scale has been a recognised maintenance activity for decades. While scaling in the wellbore or surface facilities can be tackled using chemical or mechanical means, chemical cleaning remains the only viable option for dissolving formation scale and recovering the productivity or injectivity of geothermal wells (Figure 1). The most common applications for chemical cleaning are in the dissolution of calcite scale in the near-wellbore formation around production wells or treatment of silica scale in the near-wellbore formation around reinjection wells. While the focus of these interventions is mainly around the removal of formation scale, depending on the choice of chemical there is potential to stimulate the well by dissolving the formation minerals. Most published chemical workovers have utilised hydrofluoric acid (HF), hydrochloric acid (HCl) or a combination of both (Li *et al*, 2022; Charalambous *et al*, 2021; Portier *et al*, 2007). These acids can be used to treat both calcite and silica scale. A variation of the traditional HF/HCl combination was successfully implemented on the Kawerau geothermal field, with formic acid being substituted for HCl, resulting in a beneficial uplift in well injectivity (Goh *et al*, 2020). While many of the HF workovers referenced produced good results, there are some negatives associated with its use, particularly the health and safety aspect of handling this hazardous chemical on the surface.

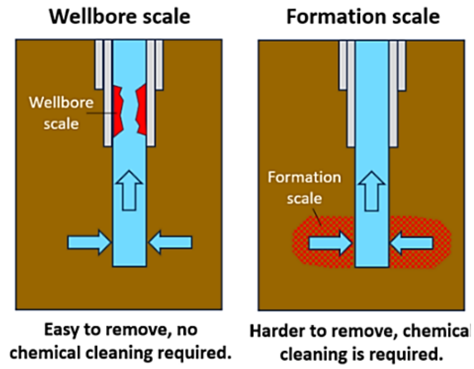

Figure 1: Graphical representation of the typical areas of scaling in a geothermal well.

The use of sodium hydroxide (caustic) to dissolve silica scale has been recognised for some time, although its use has been more limited than the HF mixtures referenced above (Phillips *et al*, 1976; Fukuda *et al*, 2010). It is typically combined with a chelant to improve silica dissolution and reduce the risk of secondary precipitation of metal carbonates, hydroxides or silicates. The chelant binds the available metal ions that can form part of the silica scale or contribute to secondary deposition. Raising the pH of the reinjection fluid using caustic raises the solubility of silica, allowing dissolution of the deposited scale. A recent successful chelated caustic treatment of two reinjection wells in Guatemala highlighted the potential benefit of utilising caustic solutions to dissolve silica scale (Johnson *et al*, 2023), while several reinjection wells have been recovered across the Wairakei and Ohaaki fields using an oscillating acid and chelated caustic regime (Muller *et al*, 2021). Another method that has been proven to be successful in recovering lost reinjection capacity is the use of proprietary chemicals to remove scale deposition in the formation. A field trial using the proprietary chemical GEO991 resulted in the full recovery of a reinjection well following treatment for a period of 49 days over two stages (Monterozo *et al*, 2021).

1.2 Previous Laboratory and Modelling Studies

Given that trialling new techniques in the field can be costly and opportunities to test can be limited, investigation of potential chemical cleaning or stimulation solutions either in the laboratory or through geochemical modelling is a useful method of understanding the most promising chemicals to pursue to field trials. The use of chelants as mineral

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dissolution agents was investigated using TOUGHREACT (Mella *et al*, 2006), while the oscillation of acid and caustic to dissolve silica scale was highlighted as a viable chemical treatment programme using the 1D reactive transport model available within The Geochemist's Workbench software package (Park *et al*, 2006). Chemical stimulation of reinjection wells in a low-permeability granitic reservoir using HCl has been modelled using KIRMAT, highlighting the benefits of permeability improvement but also the risks of secondary mineral precipitation (Lucas *et al,* 2020).

In addition to the modelling studies referenced above, laboratory studies have been used to investigate the impact of using chelating agents to selectively dissolve minerals in the formation (chemical stimulation) or aid the dissolution of typical scales such as silica and calcite (chemical cleaning). The dissolution properties of N-(2-hydroxyethyl)ethylenediamine-N, N′, N′-triacetic acid (HEDTA) and N, N-bis(carboxymethyl)-L-glutamic acid (GLDA) have been extensively studied through core flooding experiments (Watanabe *et al*, 2021 and Salalá *et al*, 2024), revealing significant permeability improvement through the selective dissolution of formation minerals including calcite and quartz. The dissolution of silica scale using a suite of chelating agents and polycarboxylates in a caustic media was highlighted as a viable solution to scale deposition, with several promising combinations being identified on a laboratory scale (McCartney *et al*, 2017). The use of proprietary chemicals to dissolve silica has also been trialled under laboratory conditions (Muller and Rodman, 2014), while the potential of sodium hydroxide and other group 1 metal hydroxides to dissolve silica has been studied in the laboratory extensively in the past (Feranti-Gmati and Jemal, 2011; Hooley, 1961).

2. EXPERIMENTAL SETUP AND DESIGN

2.1 Experiment Design

Prior to beginning the laboratory studies, a number of variables were identified, highlighted in Table 1. An experimental programme was designed using standard factorial experimentation principles, which allowed for the estimation of both the main effect of each factor, and interactions between factors (Mead et al., 2012). The error bars in the data plots below show the 95% confidence limits around each mean and were calculated using a linear statistical model in which both the mean and error variance were modelled in terms of the relevant factors. Figures 15 and 19 show the standard error rather than confidence limits as too few replicates were run for these experiments.

Table 1: Variables tested during this laboratory study.

Production Well Testing	Reinjection Well Testing
Scale/formation type	Scale/formation type
Temperature	Temperature
Acid type	Acid type
Acid Concentration	Acid Concentration
Caustic Concentration	Caustic Concentration
Chemical Sequence	Chemical Sequence
Acid Soak Time	Caustic Soak Time
	Additives
	Caustic Intensifiers

The scales tested were silica and calcite, both sourced from the wellbore or pipeline of our geothermal plants. Ignimbrite and basalt were chosen as formation minerals as they were readily available locally and they represent extremes in terms of silica content in volcanic rocks. Ignimbrite is high in silica while basalt is relatively low in silica. The acids tested were hydrochloric acid (HCl) and formic acid. Experiments were conducted at 20 °C and 100 °C as these were the temperature extremes achievable with a simple experimental setup. Acid concentrations were tested up to 3% w/w. Caustic solutions up to 6% w/w were assessed alongside additives up to 10% w/w. Sulphuric acid was not considered due to the risk of causing anhydrite oversaturation when dissolving calcite scale.

2.2 Scale and formation composition

The silica scale used for the experiments was collected from a reinjection pipeline. The XRF results of the scale suggest the scale is composed of at least 90% amorphous silica and metal silicate material, with a calcite component of up to 10%. This matches well with the geochemical modelling of the fluid in this line, which shows both amorphous silica and calcite being oversaturated at line temperature. The calcite scale was sourced from an air-hammer cleanout of a production well and is almost pure calcite with a minor silica component of around 1-2%. Two types of volcanic rock were selected to represent silicic (Whakamaru Group rhyolitic ignimbrite) and mafic (K-Trig basaltic lava) end member compositions of reservoir rocks. Prepared materials were not hydrothermally altered. The ignimbrite had a silica content of around 73%, with presence of quartz and feldspar, and minor hornblende and biotite (Brown et al. 1998). The basalt had a silica content of around 49%, with aluminium, iron, calcium and magnesium bearing minerals making up the bulk of the rock (Brown et al. 1994; Hiess et al. 2007).

2.3 Experimental Setup

THE EXPERIMENTAL SETUP WAS DELIBERATELY SIMPLE, TO ALLOW RAPID TESTING OF THE HUNDREDS OF PERMUTATIONS IDENTIFIED IN THE EXPERIMENTAL DESIGN TO ALLOW TESTING OF ALL THE VARIABLES (2. EXPERIMENTAL SETUP AND DESIGN

2.1 Experiment Design

Prior to beginning the laboratory studies, a number of variables were identified, highlighted in Table 1.). The scale and formation materials were crushed to a similar particle size (1.4 – 2.8 mm) to ensure consistency across experiments and 5 g of material was used for each experiment. The scale or formation material was treated with 10 mL of chemical solution and heated to the correct temperature using the heating block pictured in Figure 2. The cap of the centrifuge tube was loosely attached to allow any gas generated during the dissolution to escape and avoid building up pressure in the tube. For experiments with multiple steps, the scale was rinsed with water or separated geothermal water between steps. Water was used as the base solution for the production well experiments, while acid-dosed separated geothermal water (SGW) was used for the reinjection well experiments. All experiments were conducted in a fume cupboard.

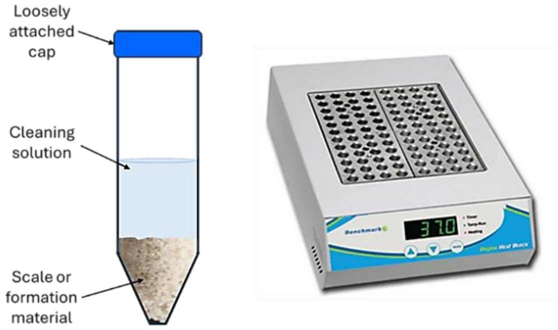


Figure 2: Experimental set up and heating block used for the experiments.

2.4 Limitations

As stated above, the experiments were deliberately designed using simple apparatus to allow the rapid throughput required to test all variables. As such, there are several limitations of the experiments, which should be kept in mind when applying the results to field testing. The tests were all conducted under static conditions. While this represents the soak period of any chemical treatment, it does not allow any assessment of the benefits of chemical treatment under continuous flowing conditions. The maximum temperature of the experiments was 100 °C, so the effects of chemical treatment at higher temperatures could not be assessed. The experiments were conducted at atmospheric pressure, so any effects related to increased pressures could not be observed as part of this experimental programme. To limit the number of experiments required to build a database of baseline chemical treatments, a limited number of formations and scale types were tested. Future work will include comparison of a variety of different scales and formations to assess the applicability of the results across a range of material types. Only two acids were tested during this study, again to limit the number of reactions required. Testing of alternate acid systems is also proposed in future.

Only one type of SGW was used in the testing to keep the number of experiments at a manageable level. Future testing of binary plant SGW or non-acid dosed flash plant fluid is planned to assess any effects related to the composition of the SGW. Despite the limitations highlighted above, we feel the comparative nature of the experiments allows fair assessment of the variables tested and should provide useful information for designing field tests based on the results obtained.

3. PRODUCTION WELL EXPERIMENTS

3.1 Effect of Temperature, Acid Concentration and Acid Type on Calcite Dissolution

These initial results revealed that unsurprisingly, the more concentrated acid solutions dissolve more scale, with HCl performing better than formic acid (Figure 3). The results also show that temperature does not influence the dissolution of calcite.

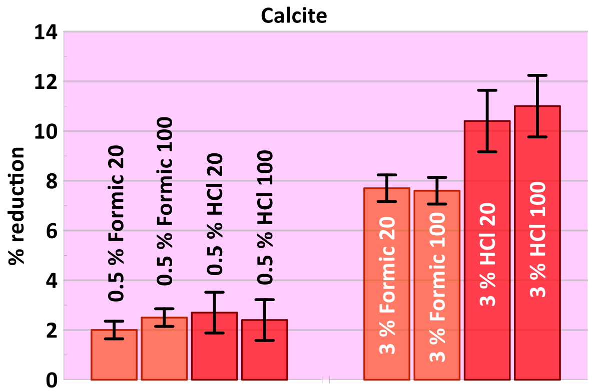


Figure 3: Effect of temperature, acid concentration and acid type on calcite dissolution. Temperature in °C listed after acid concentration and acid type. Reaction time – 10 mins.

3.2 Effect of Reaction Time on Calcite Dissolution

It is clear from the results in Figure 4 that extended reaction times are not beneficial in dissolving more calcite, with secondary precipitation occurring after 120 minutes for HCl and 180 minutes for formic acid. This highlights that employing a soak time for the acid during a production well cleanout would not be beneficial if the primary scale type was calcite. This result is unsurprising given that the pH at the end of the short duration experiments is very close to neutral, indicating most of the acid is spent within the first 10 minutes of exposure to calcite.

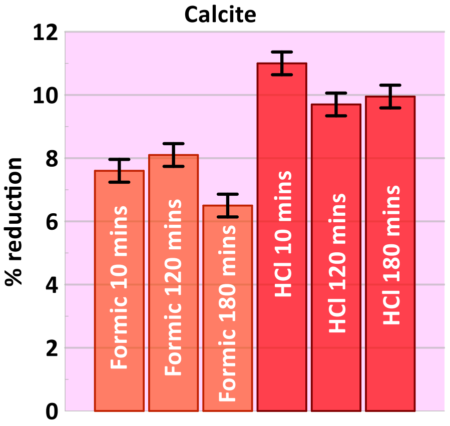
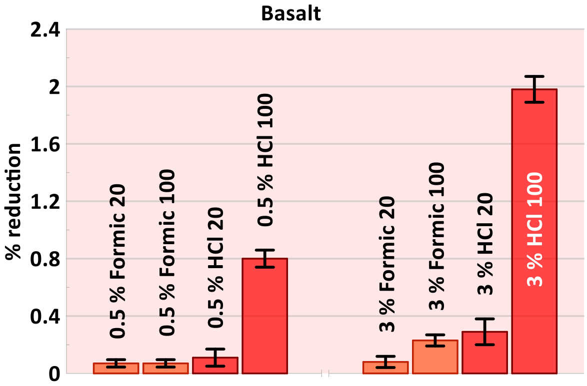


Figure 4: Effect of reaction time on calcite dissolution. Acid concentration of 3% w/w and temperature of 100 °C for all reactions.

3.3 Effect of Temperature, Acid Concentration and Acid Type on Basalt Dissolution

The reaction time for basalt was increased to 180 minutes to allow any meaningful dissolution to take place (Figure 5). Formic acid has very little impact on basalt, while 3% w/w HCl dissolves the most basalt at 100 °C.



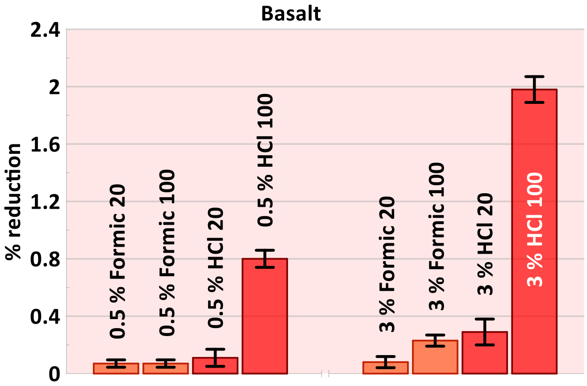


Figure 5: Effect of temperature, acid concentration and acid type on basalt dissolution. Temperature in °C listed after acid concentration and acid type. Reaction time – 180 mins.

3.4 Effect of Temperature, Acid Concentration and Acid Type on Ignimbrite Dissolution

Like basalt, the reaction time had to be extended to 180 minutes to allow measurable dissolution of the formation material. Once again, formic acid has minimal impact on the ignimbrite formation (Figure 6). HCl dissolves the most ignimbrite at 100 °C and 3% w/w concentration. As formic acid has such little interaction with the formation materials may mean it is a good option to take forward to field trials to minimise secondary reactions with the formation itself and focus the acid on its primary job of removing calcite scale from the pore space/fractures of the production well formation.

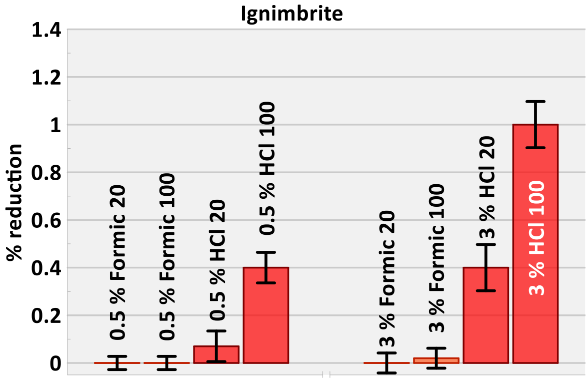


Figure 6: Effect of temperature, acid concentration and acid type on ignimbrite dissolution. Temperature in °C listed after acid concentration and acid type. Reaction time – 180 mins.

3.5 Effect of Chemical Sequencing on Calcite Dissolution

The results in section 3.2 highlight that the acid is mostly spent after 10 minutes, so a multi-step experiment was conducted to assess whether the efficacy of following steps was impacted in any way. The multi-step tests show that successive acid steps provide increased dissolution of calcite (Figure 7). The second acid step gives slightly less dissolution than the first step but still produces a marked overall increase in the amount of calcite dissolved. Unsurprisingly, the caustic step, which includes a chelating agent, provides little benefit due to the poor solubility of calcite in alkaline solutions.

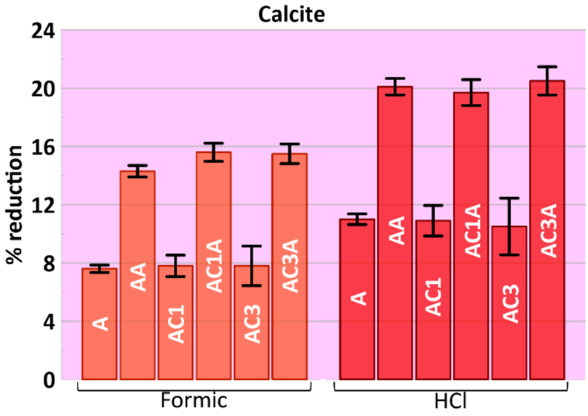


Figure 7: Effect of chemical sequencing on calcite dissolution. A = acid step (all at 3% w/w), Cn = caustic step at n% w/w. Acid reaction time: 10 mins, caustic reaction time: 60 mins, temperature 100 °C.

3.6 Effect of Chemical Sequencing on Basalt Dissolution

The effect of a multi-step reaction on formation materials was also studied. All experiments with formic acid provide little dissolution, even those that include a caustic step (Figure 8). The HCl experiments show increasing dissolution with additional acid and caustic steps. The 3% w/w caustic seems to provide comparable dissolution to 3% w/w HCl when used in combination with HCl. The efficacy of the caustic step is suppressed using formic acid.

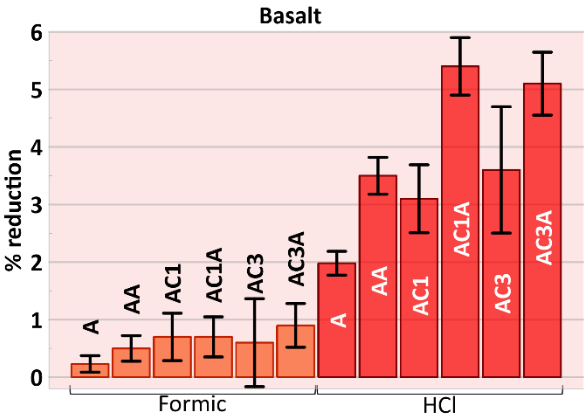


Figure 8: Effect of chemical sequencing on basalt dissolution. A = acid step (all at 3% w/w), Cn = caustic step at n% w/w. Acid reaction time: 120 mins, caustic reaction time: 120 mins, temperature 100 °C.

3.7 Effect of Chemical Sequencing on Ignimbrite Dissolution

The ignimbrite experiments show similar results to those of basalt in that the use of formic acid appears to suppress the effect of the following caustic step (Figure 9). This is revealed by the caustic steps having a much larger impact when employed in combination with HCl. It is also clear that caustic dissolves more ignimbrite than any acid steps and the effect is magnified by the higher concentration of caustic.

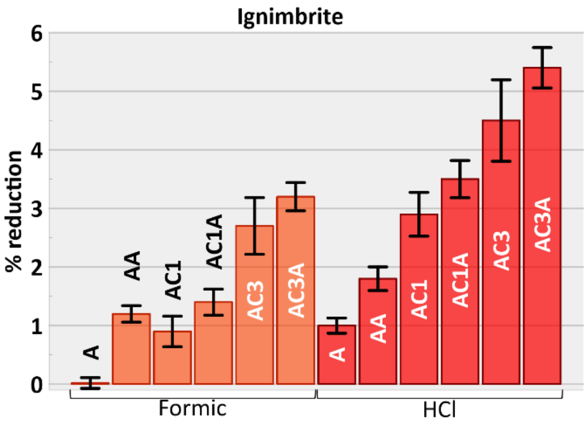


Figure 9: Effect of chemical sequencing on ignimbrite dissolution. A = acid step (all at 3% w/w), Cn = caustic step at n% w/w. Acid reaction time: 120 mins, caustic reaction time: 120 mins, temperature 100 °C.

3.8 Effect of Acid Concentration on Multi-step Calcite Dissolution

To identify the optimal acid concentration, a series of experiments were conducted aimed at dissolving the most amount of calcite with the least amount of acid. From the testing it became clear that a 3% w/w concentration of acid is the sweet spot in terms of efficacy and value (Figure 10). This is especially clear for HCl, where two 3% w/w steps dissolve more calcite than one 6% w/w HCl step. Further testing was conducted on the lower concentrations over multiple steps to assess if lower concentrations provide better value. It was found that the lower concentrations offered diminishing returns, again highlighting that 3% w/w is the optimal concentration.

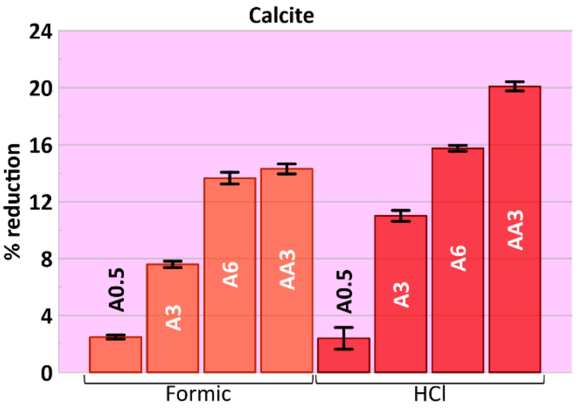


Figure 10: Effect of acid concentration on multi-step calcite dissolution. An = acid step at n% w/w. Reaction time for each step: 10 mins, temperature 100 °C.

3.9 Effect of Using an Acid Mixture

Given that the use of HF in combination with both HCl and formic has been so prevalent in published chemical cleans of geothermal wells, we explored the impact of using an HCl/formic acid mixture in dissolving calcite and formation material (Figure 11). Perhaps not unsurprisingly, for calcite the HCl/formic 3% w/w solution performed somewhere between the 3% w/w HCl and 3% w/w formic acid solutions. The 6% w/w mix dissolved more calcite but not enough to justify the extra cost involved with going to a higher concentration. Once again, 3% w/w HCl proved to be the best option. For formation materials there was little difference between the 3% w/w HCl and the 3% w/w acid mix.

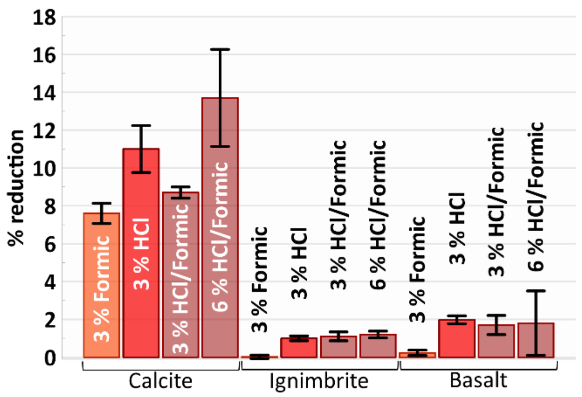


Figure 11: Effect of acid mix on calcite and formation dissolution. Calcite reaction time: 10 mins, formation material reaction time: 120 mins, temperature 100 °C.

4. REINJECTION WELL EXPERIMENTS

4.1 Effect of Temperature, Reaction Time, Caustic Concentration and Additives on Silica Dissolution

Initial testing was conducted at both 20 °C and 100 °C, however, due to the low levels of dissolution at 20 °C it was decided to focus on experiments at 100 °C for the remainder of the reinjection well study. This highlights the importance of temperature when dissolving silica scale. For the short 10-minute reaction time the 1% w/w caustic solutions perform best (Figure 12). For the 60-minute reaction times the 3% w/w caustic solutions perform best. In both cases the presence of EDTA at 1% w/w provides a slight increase in dissolution of silica.

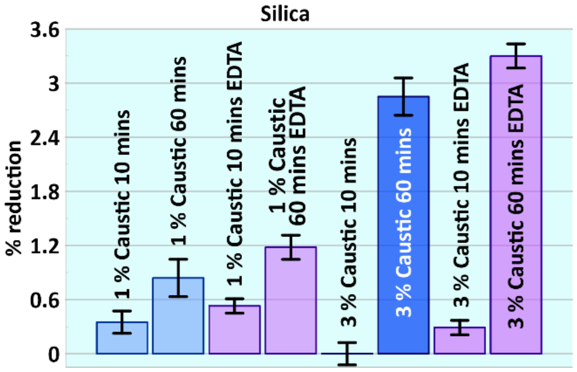


Figure 12: Effect of reaction time, caustic concentration and additives on silica dissolution.

4.2 Effect of Reaction Time, Caustic Concentration and Additives on Ignimbrite Dissolution

Unsurprisingly, the results for ignimbrite are similar to those for silica, albeit with a lesser amount of dissolution (Figure 13). The longer reaction times allow more scale dissolution and the presence of EDTA at 1% w/w slightly increases the amount of formation material dissolved.

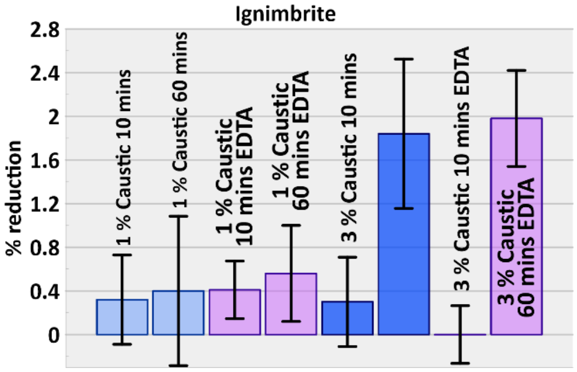


Figure 13: Effect of reaction, time, caustic concentration and additives on ignimbrite dissolution.

4.3 Effect of Reaction Time, Caustic Concentration and Additives on Basalt Dissolution

The experiments with basalt produced quite variable results with replicates producing quite different results. It is hard to pull much information from these findings (Figure 14), although it does appear that the 60-minute reaction time with no EDTA present produces the best result for both concentrations tested.

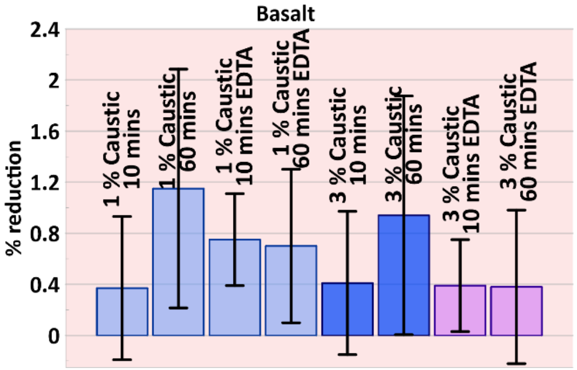


Figure 14: Effect of reaction, time, caustic concentration and EDTA on basalt dissolution.

4.4 Effect of Additives on Silica Dissolution

Given the initial testing had shown a slight beneficial impact on silica dissolution when using EDTA as a chelant, we explored other commercially available chelants, proprietary chemicals and additives. Several different combinations were explored and were tested in concentrations up to 10 % w/w. While some produced a slight increase in silica dissolution, the impact may not be large enough to justify the extra costs associated with dosing these additives alongside a caustic treatment (Figure 15). The use of chelants is a viable option when there is a risk of secondary precipitation of minerals post-job, however, the use of additives to boost silica dissolution was not found to have a significant impact, particularly when considering the extended soak times (Figure 17). This is contrary to some previous articles (McCartney *et al*, 2017), although the concentrations of additives used were higher than tested in this study. The formation of secondary precipitates was limited in our reinjection well testing, suggesting that the use of EDTA may not be required for the dissolution of typical silica scales.

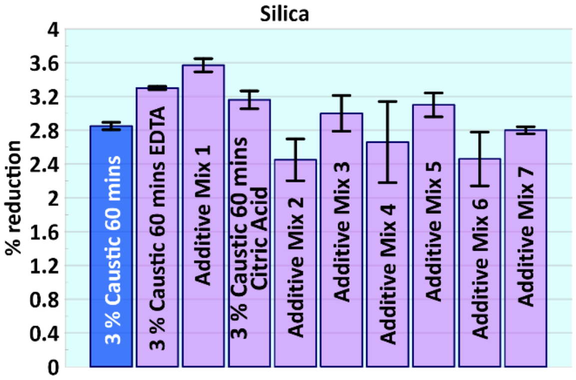


Figure 15: Effect of additives on silica dissolution. All reactions: 3% w/w caustic and a reaction time of 60 mins.

4.5 Effect of Increased Reaction Time on Silica Dissolution

Given that dissolution of silica improved in the experiments up to 60 minutes, a series of experiments were conducted with longer soak times to assess the progress of silica dissolution. No chelating agent was used as it was found to give no benefit for the longer reaction times. As the soak time was increased, so did the dissolution of silica, indicating that addition of a soak time in chemical treatment programmes would be beneficial to allow the maximum value to be extracted from the chemicals deployed.

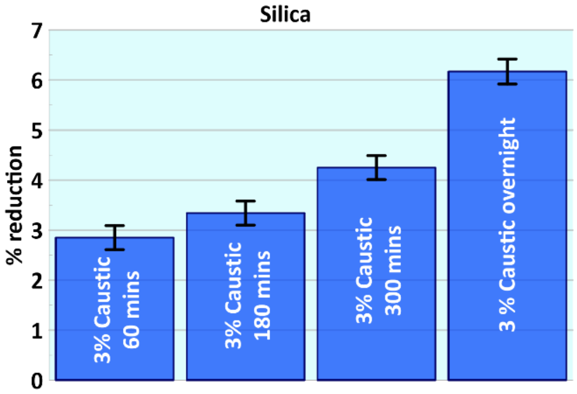


Figure 16: Effect of increased reaction time on silica dissolution.

4.6 Effect of Concentration on Silica Dissolution

A higher concentration of caustic was tested to determine if improved dissolution could be achieved. The results revealed that there is no benefit from using a higher concentration of caustic, although the results did reveal an improved performance at higher concentrations when 1% w/w EDTA was added (Figure 17). As stated earlier, the improvement is unlikely to justify the extra cost of using a chelant such as EDTA to improve silica dissolution, especially given the results of the multi-step reactions in the following section.

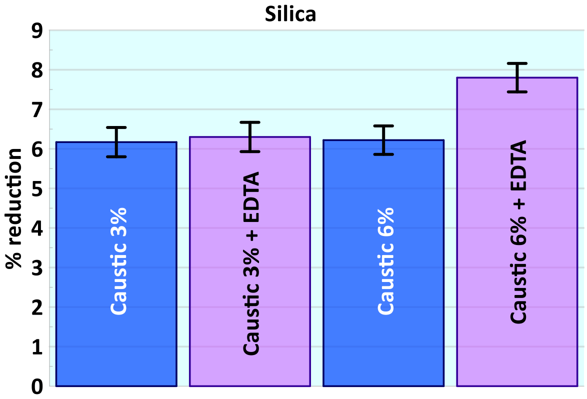


Figure 17: Effect of concentration on silica dissolution. All reaction times overnight.

4.7 Effect of Chemical Sequencing on Silica Dissolution

To assess how receptive the silica scale was to subsequent chemical treatments, a series of multi-step experiments were undertaken. The first acid step provides similar dissolution to one caustic step; however, subsequent acid steps do not provide a similar uplift. This is thought to be due to the presence of calcite in the silica scale. Dissolution of calcite by HCl would account for a large amount of the weight reduction seen for the acid step. Once this has been consumed the amount of silica scale being dissolved in subsequent steps is significantly reduced. For the 2-step experiments the best result is achieved with two caustic steps, while for the 3-step reactions the caustic-caustic-acid sequence gives the most dissolution, helped by the acid step dissolving a large amount of calcite. It is also clear from the 3-step experiments that there is benefit in leaving any acid step until last, possibly due to the calcite present becoming more accessible following the two caustic steps that dissolve large amounts of silica.

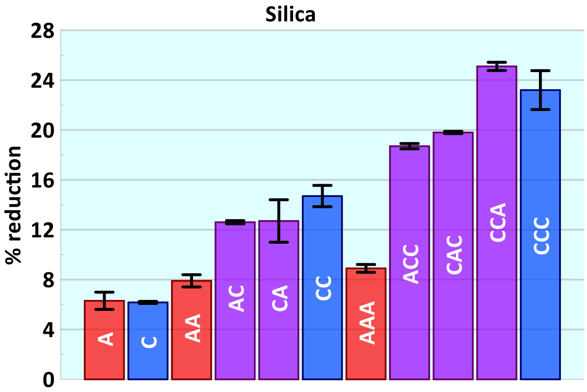


Figure 18: Effect of chemical sequencing on silica dissolution. Overnight reaction time for all chemical steps. Concentration of 3% w/w for each chemical step. C = caustic step, A = HCl step.

Analysis of the reaction effluent and reacted silica scale samples confirmed the above interpretations. The reaction effluent from the treatment of silica with HCl revealed a modest increase in silica concentration of ~200 mg/kg, while the calcium concentration increased by ~6700 mg/kg. This confirms that the acid step is mostly consuming the available calcite present in the scale and explains why further acid steps do not provide much further dissolution once the calcite is consumed. The reaction effluent from the caustic step shows an increase in silica of ~33000 mg/kg, reaffirming that caustic is the best option for dissolving silica-based scales. SEM analysis of the silica scale revealed a significant reduction in aluminium in the reacted sample, suggesting the caustic solution is preferentially dissolving alumino-silicate material, while the purer silica is less soluble.

4.8 Effect of Chemical Sequencing on Ignimbrite Dissolution

Multi-step experiments were conducted to study how the dissolution of ignimbrite progressed with additional chemical treatments (Figure 19). Formic acid provides little dissolution, while 3% w/w HCl provides a similar uplift in dissolution to adding a 3% w/w caustic step.

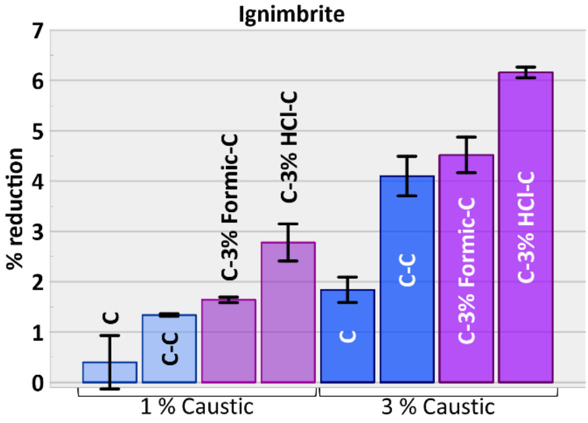


Figure 19: Effect of chemical sequencing on ignimbrite dissolution. All caustic steps: 60 mins; 3% w/w, all acid steps: 120 mins.

4.8 Screening of Caustic Intensifiers

Through our literature research and knowledge of historic chemical cleans, we shortlisted six potential chemicals that could boost the efficacy of the caustic cleaning solutions we had been testing in the laboratory.

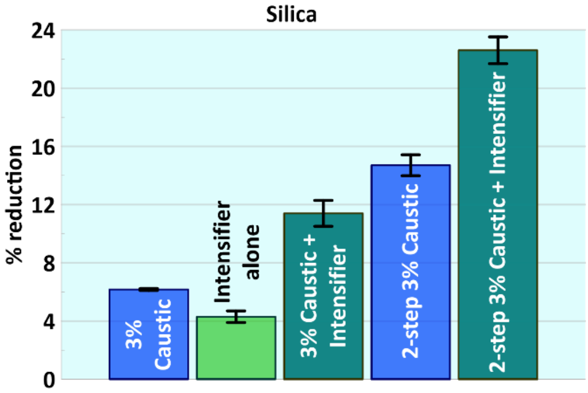


Figure 20: Effect of adding a caustic intensifier to standard caustic solution.

Through a series of comparative tests, we identified one caustic intensifier as the standout performer and worth taking forward to a more extensive testing regime. As seen in Figure 20, the intensifier provides a significant increase in the amount of silica dissolved and suggests it is a good candidate to take forward to field trials.

6. CONCLUSION

The results of several hundred laboratory experiments have provided useful insights into the optimal chemical types and concentrations to give the best chance of success in the field. For production wells affected by calcite scaling, the best solution is treatment with acid. Whilst this is unsurprising, the results have revealed that a 3% w/w concentration gives the best combination of scale dissolution and value for both formic and HCl acid. The formic acid dissolves slightly less calcite than HCl but also has less of an interaction with the formation materials. This highlights the potential of formic acid as an alternative to HCl where interaction with the formation undesirable or there is a risk of formation damage. The multi-step combination of 3% w/w caustic and HCl produced the highest dissolution of the basalt formation. The use of caustic is unlikely to be beneficial in production wells unless silica forms a significant component of the formation scale. For the calcite scale tested in these experiments, this was not the case.

The soak periods utilised in our lab experiments mimicking reinjection well scenarios suggest that the most effective method of removing scale is to allow a soak period, which would require the well to be taken offline for a period. An overnight soak time produced the largest amount of dissolution. Subsequent treatments with caustic provided further dissolution, while the use of an acid step may be useful if the silica scale contains a significant calcite component, as it did in this study. Testing of various additives and chelants revealed that they provide minimal value in terms of further silica dissolution. If secondary precipitation is considered a risk, then their application may be a sensible option. The use of a multi-step acid programme for silica scale is unlikely to provide much value, while the results also highlighted that it would be beneficial to include any acid treatment as the final step in the programme to extract the maximum gain from this treatment. This is most likely to be useful when calcite is also present in the scale. Given its ability to dissolve silica scale, it is unsurprising that the caustic solution had a significant impact on the high-silica ignimbrite formation. This is an unavoidable consequence of dissolving silica scale and may even provide additional benefit in opening up new pathways following a chemical clean, effectively providing both chemical cleaning and chemical stimulation. Finally, the screening of potential caustic intensifiers has uncovered a promising candidate to take to field trials due to the increase in silica dissolution when it was applied.

These experiments have allowed us to create a database of results that makes the testing of new variants faster and easier. Different scale types, formation types or SGW types can be quickly tested and compared against these baseline results, speeding up the process of determining the best chemical solution for a particular problem. The learnings from this laboratory study will now be applied in the field, with results reported in due course.

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