# Cleaning and Stimulating Geothermal Well with Oil and Tar Residue Downhole

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**Keywords:** *Injection well stimulation, oil and tar residue removal*.

## ABSTRACT

A geothermal company in the Alaşehir region of Turkey contacted Solenis for cleaning an injection well. A significant challenge for this geothermal power producer's plant is that its production wells typically contain trace residues of oil and tar. These residues eventually make their way into the injection wells, thereby reducing the injection capacity of the well and effectively repelling any chemicals aimed at stimulating production and removing mineral deposits.

After studying the composition of the oil/tar residue, Solenis developed a product, a tar solvent, to eliminate the residue downhole. Additionally, a bespoke solution was developed for the specific geology of this well and its fluid dynamics.

In total, 25.6 tons of tar solvent were pumped downhole without suspending the operation of the well. Then the Solenis team completed the online well cleaning, targeting the deposits found downhole and at the formation of the wellbore.

Prior to the online cleaning, this well had an injection pressure of 44 bar at an approximately 125 ton/h injection rate, giving the well an injectivity index of 2.8 ton/h-bar. The final wellhead pressure recorded shortly after the cleaning was 30.6 bar at a flow rate of 409.1 ton/h, resulting in an injectivity increase of 13.4 ton/h-bar. This represents an injectivity increase of 480%.

## 1. HYDROTHERMAL PETROLEUM

In general, hydrothermal petroleum is believed to form or accumulate in association with hydrothermal processes, rather than through the more traditional, long-term burial and thermal maturation of organic matter in sedimentary basins.

### 1.1 Hydrothermal petroleum formation

Petroleum is usually generated at temperatures between 50 and 100 °C in slow heating rate conditions that depend on the rate of subsidence of the basin in which it is located. In contrast, what is known as "hydrothermal" petroleum, is found where hot circulating water plays a role, migrating the source sediments to depths of high temperature (up to 400 °C), where the petroleum is formed at a faster rate.

Worldwide, several locations, ranging from western Turkey graben systems, the Indian Ocean, Japan, Russia, Red Sea, Yellowstone National Park, Lake Tanganyika, New Zealand, the Escanaba Trough off the Pacific coast of the United States, Bransfield Strait, Gulf of California, Lake Chapala (Mexico), have reported the existence of hydrothermal petroleum (Gürgey, 2007).

### 1.2 Turkey's geological context

Turkey is a unique country in many respects, including its combination of geological conditions that allow for the development of geothermal, oil, and gas reservoirs. As shown in Figure 1, the country is within the collision zone of three major tectonic plates: the Eurasian plate to the north, the Arabian plate to the south and the African plate to the southwest.

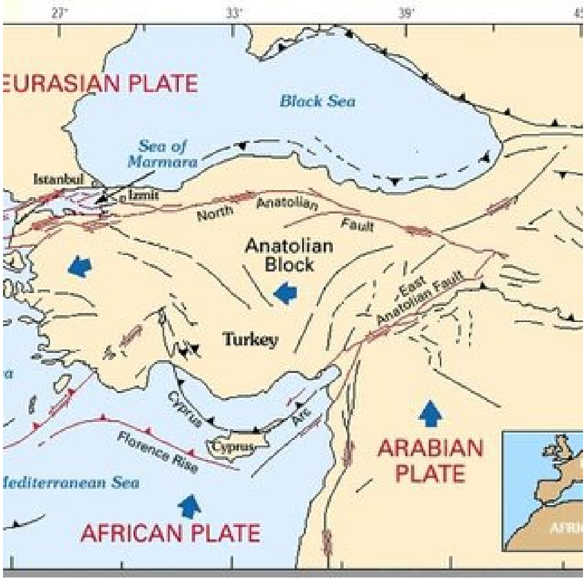


**Figure 1: Turkey, relative to the boundaries of three major tectonic plates.**

Essentially, these land masses were continental fragments that were joined some 20 million years ago (Okay, 2008). Because of the resulting collisions and other geological factors, Turkey has extensive faulting and fracturing, uplift and basin formation, volcanic activity, and high geothermal gradients. The most abundant geothermal activity is concentrated to the western part of the country, in the Manisa

– Alasehir Graben. In the Büyük Menders Graben, located in the Aydin – Denizli province, is where most of the geothermal electricity installed capacity of the country exists. (Mertoglu, et. al, 2020).

By contrast, the southeastern part of the country contains large sedimentary sequences with organic-rich source rocks. This combination of basins formed in more stable settings, marine sediments, and tectonic activity has created structural traps in this region of the country. Because of these formations, this region is ripe for the accumulation of oil and gas (Sami, 2014).

### 1.3 Hydrothermal petroleum in Turkey

The existence of hydrothermal petroleum in a well in the Menderes Graben, which was drilled by a private geothermal water supply company in 2002, was previously reported (Gürgey, 2007). The hydrothermal petroleum was confirmed by the presence of different types of biomarkers discussed in that study.

## 2. INTRODUCTION TO THE SOLENIS GEOSOL™ ONLINE WELL CLEANING PROGRAM

The Solenis GeoSol™ online well cleaning program represents a deliberate departure from traditional oil and gas well cleaning methodologies. Historically, the adaptation of these traditional methods to geothermal applications has been based on two key assumptions: (1) that the geological settings of oil and gas reservoirs are comparable to those of geothermal fields, and (2) that chemical delivery via coiled tubing (CT) at depth ensures direct placement into the target feed zones.

The first assumption overlooks critical differences in mineralogy. Specifically, it fails to account for secondary reactions involving minerals such as calcite and alumino-silicates. These reactions can significantly reduce treatment efficacy, particularly at temperatures greater than 120 °C and in formations with high K-feldspar content.

The second assumption is not universally valid. Low-flow, high-concentration chemical slugs tend to follow the path of least resistance. Consequently, even when injected at depth, the chemicals may migrate upward or downward in the wellbore, thereby bypassing the intended zones entirely.

Solenis' approach addresses each of the flawed assumptions. First, a detailed geological assessment is conducted to evaluate the potential for detrimental secondary reactions to the novel treatment solutions. Second, flowing pressure-temperature-spinner (PTS) surveys are used as part of a comprehensive diagnostic strategy to confirm fluid movement and ensure that the treatment reaches the zones most affected by mineral deposition.

## 3. HISTORY OF INJECTION WELL

This well, located in Alaşehir, Turkey, has a total depth of 3,831 meters. Lithological records indicate alternating formations of conglomerates, sandstones, marls, and low-permeability metamorphic rocks, particularly in the deeper intervals. The lithological profile of this well also reveals a highly heterogeneous stratigraphy. From approximately 2,664 m to its total depth of 3,831 m, the formation consists predominantly of low-permeability metamorphic basement rocks such as micaschists, sericitic schists, and carbonated siltstones, often interbedded with ophiolitic mélange and fractured marbles. This dual composition presented two challenges. The first challenge is that the low porosity and permeability of the metamorphic matrix inhibits fluid penetration and hinders the effectiveness of conventional acid treatments. The second challenge is that the presence of organic-rich shale, silty layers, and carbonate cemented zones favors adsorption or trapping of tar-like substances, thereby limiting both injectivity and chemical mobility.

Since 2017, this geothermal power producer had attempted multiple acidizing cleanings using conventional hydrochloric acid or hydrofluoric acid-based coiled tubing operations. Even after these attempts, the well continued to exhibit poor injectivity. Injection tests showed minimal improvement, most likely due to the presence of hydrocarbon residues (oil/tar) within the formation, which impeded chemical contact and prevented effective stimulation.

Prior to the most recent intervention, the wellhead pressure was approximately 45 bar at an injection flowrate of approximately 110 tons per hour, resulting in a limited injectivity index.

## 4.SCREENING FOR TAR DISSOLVING PRODUCT.

Initial research and laboratory work to develop a product capable of dissolving these types of deposits began months earlier, in a well unrelated to the one discussed in this paper.

In that initial work, two different samples from that well were submitted for analysis. The first one contained mainly long chain hydrocarbons and inorganics in the form of silicon, calcium, aluminum and iron. The second sample contained mainly long chain hydrocarbons. No inorganics were reported in the second sample. Both samples were described as waxy, oily deposits.

### 4.1 Products tested

Three different potential products were tested: Product A, Product B, and Product C.

Product A is an aliphatic solvent-based product, containing an emulsifying surfactant designed to remove organic deposition. The surfactant aids the wetting of the deposits and therefore its removal.

Product B is an advanced water-based micro-emulsion containing vegetable oils, surfactants and dispersants.

Product C is a blend of aromatic hydrocarbon solvents and surfactants designed to remove deposits from bitumen, latex, grease and resins.

### 4.2 Testing and results

Each sample from the initial well was submerged in a test product and heated at 80 °C for 1 hour to test dissolution. Then, the sample was passed through a folder filter and the loss in weight was calculated. Each sample was tested with each product.

Figure 2 shows the samples after filtration and cooling. Products A and C (left and right) proved to have the best weight loss and overall dissolution of the sample, as shown in the yellow-colored liquid layer in the beaker. Product B (middle) did not perform well as A and C.

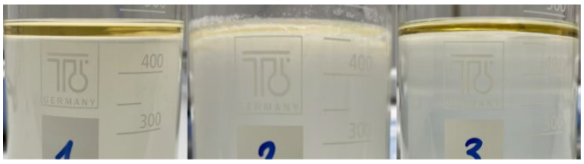


**Figure 2: Results of dissolution testing. Left to right: Product A, Product B and Product C.**

From here, several excipients were added to the product to provide better stability and compatibility with the Solenis well cleaning methodology, particularly as it related to physical characteristics of the final products, such as flash point, viscosity and pH.

## 5. REFINING A PRODUCT SUITABLE FOR DOWNHOLE PUMPING

Since the products cannot be pumped downhole as pure ingredients, excipients, stabilizers and other enhancers had to be included in the formulation to have a product safe for injecting. Two basic formulations were developed; one acidic option with a low pH, and one alkaline option with a high pH.

A testing experiment was built, whereby a known amount of newly collected oil/tar sample was submerged in each of the testing formulations. Surface tension was selected as a variable to be monitored because it is a great indicator of a product's wetting capacity. The surface tension of each test was measured, and their cleaning performance was visually evaluated.

The initial testing showed significantly greater performance of the "alkaline" formulation. Because of this, the team decided to focus on optimizing this formulation and stopped working on the "acidic" formulation.

Although the alkaline formulation showed a better initial performance, there was still room for improvement. For example, the surface tension was relatively high, indicating limited wetting and spreading capacity of the oil/tar. Additional solvents and emulsifiers were added to the mixture, resulting in a single-phase product and more stable structure. The surface tension was measured once again, this time being about 40% lower than the previous formulation.

Finally, the corrosion compatibility of the newly developed product was tested to ensure that the well casing was properly protected. The corrosion testing was carried out at 150 °C for three hours using representative casing materials. The corrosion rate was found to be 0.0001 lb/ft$^2$, confirming its compatibility with the downhole casing.

## 6. FIELD IMPLEMENTATION AND WELL STIMULATION

Prior to any work in the field, the Solenis team completes a rigorous review of the well conditions to determine the best solution.

### 6.1 Product selection and program design

As described previously, the bespoke approach Solenis takes ensures the cost-effective use of products by considering the lithology and well history of each case.

The lithology review of this well revealed a section of the well that contains a highly altered, low permeability zone known to retain oil and tar residues. Further study of the PTS surveys revealed that a moderate mud loss was recorded at a second region, indicating either plugging or a hydrocarbon obstruction.

After all the available information was reviewed, a tar cleaning solution was selected to be used at the onset of treatment. Using the tar cleaning solution reduced the chances of leaving residual, unresolved, oil-based tar in tight zones that could reduce the efficiency of the GeoSol GS1127 cleaning solution and allow re-deposition after the cleaning.

### 6.2 Cleaning execution

Prior to executing the cleaning and stimulation, GeoSol GS1127 cleaning solution was pumped downhole to eliminate calcite deposits present throughout the well. This step exposed the tar residues, thereby maximizing the chance of dissolving it effectively in the second step.

For approximately 20 minutes, the GeoSol GS1127 cleaning solution was pumped at a relative concentration between 51 and 61.2% (of the maximum concentration reached during the later stages of the cleaning process). This step alone provided an increase in the injectivity index from 2.6 to 3.5 ton/h-bar. Figure 3 shows the injectivity index in the hours prior and at the end of the stage along with the relative GeoSol GS1127 cleaning chemistry flow rate used.

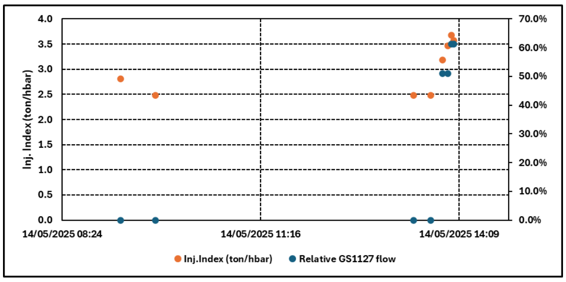


**Figure 3: Step one of cleaning and stimulation program.**

Next, sufficient time was allowed for the volume of GeoSol GS1127 to reach the important feed zone. During step 2, the tar cleaning solution was pumped over the course of approximately one hour and forty minutes. This resulted in an increase in the injectivity index from 3.5 to 5.6 ton/h-bar. Figure 4 shows this change, including the relative flow rate of tar cleaning solution used. Note how the maximum flow rate was achieved near the end of the stage.

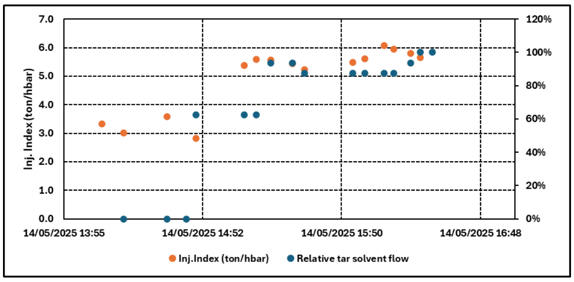


**Figure 4: Step 2 of cleaning and stimulation program.**

To ensure the tar residue was removed, water was pumped downhole at a high rate for approximately 30 minutes. Once this finished, the final step of the cleaning and stimulation program began, which consisted of pumping GeoSol GS1127 cleaning solution at the determined dosage rate to properly target the feed zones in question. This stage lasted approximately 50 minutes and resulted in a significant improvement in the well's injectivity index. The injectivity index, as shown in Figure 5, increased from 5.6 to 13.4 ton/h-bar, the maximum recorded index for this well.

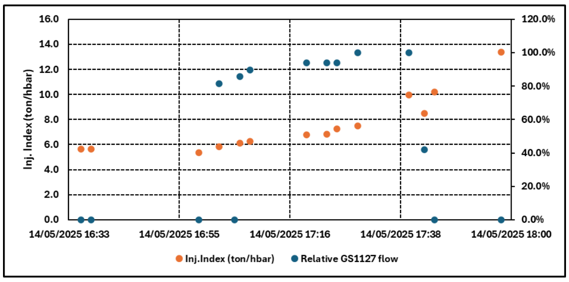


**Figure 5: Step 3 of cleaning and stimulation program.**

## 7. WELL STIMULATION RESULTS

Following the solvent-based tar cleaning treatment, the wellhead pressure dropped to 30 bar while the injection flowrate increased dramatically to 420–430 ton/h. This performance corresponds to a nearly 400% improvement in injectivity, indicating that the oil/tar obstruction was effectively dissolved and removed.

SCADA trends obtained from the plant confirm this improvement, demonstrating a sustained increase in injection flowrate and a reduction in wellhead pressure after the treatment. These results clearly highlight the success of the new methodology compared to previous acid-only attempts, which failed to resolve the issue.

## 8. CONCLUSION

An effective cleaning solution was developed to treat geothermal wells in areas prone to the presence of "hydrothermal petroleum". This novel cleaning solution allowed the well discussed in this study to be stimulated by increasing its injectivity index by 480%. Previous attempts at cleaning and stimulating this well achieved a fraction of the results described here. This current success was mostly attributable to proper due diligence and a thorough understanding of the problem and fluid dynamics.

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