Proceedings World Geothermal Congress 2023
Beijing, China, October 9 – 11, 2023

Understanding the underlying mechanism of mineral scaling in the Salihli Geothermal Area, Western Turkey

Deniz Özbek[1], Selin Özdamar[1], Ömer Bozkaya[2], Taylan Akın[2]

1-Sanko Enerji, Istanbul, Turkey

2-Pamukkale University, Geothermal Application & Research Center, Denizli, Turkey

deniz.ozbek@sankoenerji.com.tr, selin.ozdamar@sankoenerji.com.tr, obozkaya@pau.edu.tr, takin@pau.edu.tr

Keywords: Salihli, geothermal field, mineral scaling, triggering mechanism

ABSTRACT

High temperature fluids (>180 C) are being extracted, directed to binary ORC power plants, and reinjected back into the reservoir in the Salihli (Manisa) Geothermal Field, located in the western part of Turkey. Mineral scaling and corrosion behavior of the geothermal fluids treated with scale inhibitor chemicals are constantly being monitored, based on several methods: (1) major ion and total silica analysis, (2) measurements of physicochemical parameters in the field, (3) regularly checking of deposition/corrosion coupons installed on the flowlines. Mineral scaling is observed on the capillary tubing used for injecting scale inhibitors below the flash point, starting from a certain depth below the surface (0-200m), in the production wells. If hard scales are formed and the scale thickness reaches up to 2-3mm, pulling the tubing from the well and wrapping it on a drum becomes problematic. Several types of minerals precipitate in production wells and clog the filters that mounted on the brine pipelines. Therefore, filters are periodically cleaned. In addition to precipitated materials, clastic materials which are transported from reservoir to the surface are also observed inside the tubes and on the walls of the heat exchangers. The main purpose of the study is to understand the characteristics of the scale formation formed under the operating conditions of the power plant. In this context, the mineralogical and geochemical investigations were carried on the scale deposits and classified as: (1) directly precipitated minerals from the fluids, (2) transported minerals that previously precipitated in the deeper parts of the wellbore, (3) detrital/clastic particles belong to the geological units located in vicinity of the production wells. Almost all of the samples collected from filters and tubings are mainly consist of Mg-smectite (80-100%). The sampled materials from the heat exchangers contain small particles (< 2mm) of elemental iron and iron oxide (magnetite), marbles as well as smectite clays. The obtained data indicate that the most significant triggers for scale deposition are: (1) oversaturation of certain mineral phases (SI>5 for Mg-smectite) due to flashing and adiabatic cooling in the well, (2) removal of the steam phase from the geothermal fluid and the consequent drastic change in physico-chemical parameters of the fluid after it passes through separator, (3) alteration of the flow regime due to filter structure and the change in diameter along flowline. By this, the performances of various scale inhibitors are tested for optimum antiscalant treatment of the geothermal fluid. As a conclusion, the routine chemical analysis of geothermal fluid and mineralogical analysis of the scales could be used for evaluating inhibitor efficiency.

1. INTRODUCTION

1.1 Location And Geology Of The Salihli Geothermal Field

Salihli Geothermal field, which hosts a high enthalpy liquid dominated reservoir, is located in Manisa (Western Turkey). The reservoir consists of rocks belonging to Menderes Massif, a metamorphic series of various schists, gneiss, and marbles. Exhumation mechanism, general stratigraphy and structural geology of the massif have been studied extensively. Detailed accounts on the geodynamic evolution of Menderes Massif can be found in the literature, Dora, O. Ö. (2011). General stratigraphy of the Massif is described briefly according to Candan et al, (2011). At the bottom, the series starts with Pan-African and derived sedimentary rocks. The massif itself is treated as two parts, core, and cover series respectively. Paleozoic rocks are overlain by the Mesozoic cover series. The main reservoir lithology cut by the boreholes in the region are mainly the schists.

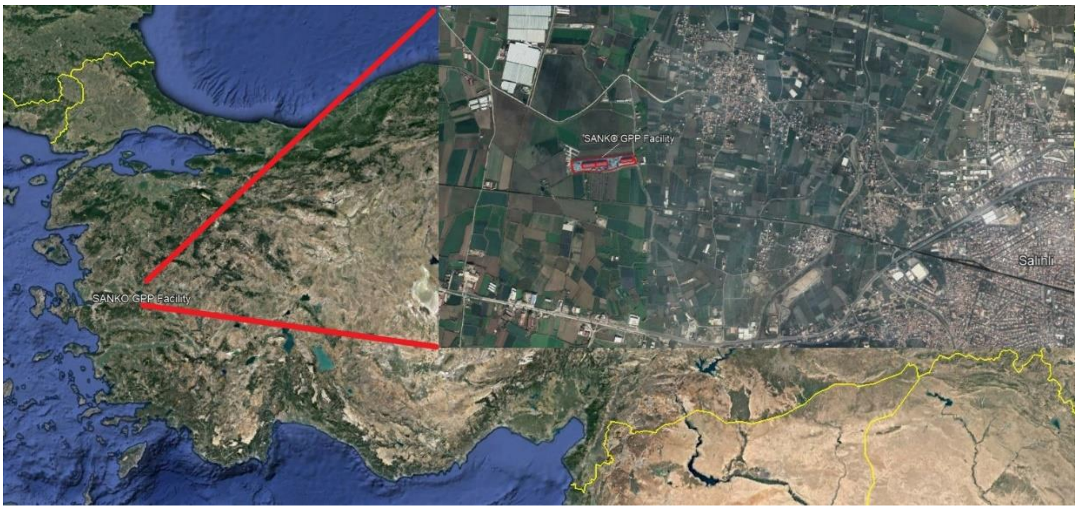


Figure 1: Location of Salihli Geothermal Field and Sanko Geothermal Power Plant

1.2 Salihli Geothermal Reservoir and Sanko Energy Geothermal Power Plant (GPP) Facility

Salihli geothermal reservoir is liquid dominated, supporting high enthalpy (WHT ~200°C, flowrate ~ 250 ton/h) artesian production wells. Total flowrate of production wells ranges between 100-500 ton/h.

A total of 2000 tons of geothermal fluid is being pumped from 10 production wells, diverted to 3 GPP facilities with a total electric capacity of 70MW, and reinjected back into the reservoir from 20 reinjection wells in Salihli Geothermal field. Fluid is seperated into brine and steam at each production well with vertical cyclone type separator. Brine is pressurised with booster pumps to maintain the pressure at the inlet of the vaporizer unit above separator pressure. Steam is transfered to the vaporizer unit directly. The power plant facility has been operating since 2018.

Chemical facies of geothermal brine is $NaHCO_3$. EC25 and pH values of brine ranges from 2150 to 2200 µS/cm and 7.5-8 for injected fluid; 2150 to 2600 µS/cm and 7.5-9.3 for the produced fluid respectively. Total dissolved solids content of the produced fluid has been constantly decreasing since the production started, reaching about 70 to 85 % of its initial value currently.

Pressure and temperature of the system are constantly being monitored with gauges installed/mounted on various key points such as,

next to well heads and also right before seperators on two phase pipeline,

upstream of the booster pumps on brine pipelines and before the bends on steam pipelines

Flow rate of the geotermal fluid is being monitored throughout the system with specific instruments. Brine (Vortex type) and steam (pitot tube) flowmeters are installed on respective pipelines, for each production well after the fluid is separated and for each of the reinjection wells (magnetic type) next to the wellheads. Additional flowmeters are mounted at the entrance of each power plant on steam and brine pipelines.

Dynamic pressure-temperature (P-T) measurement is being conducted in the field for each production well regularly (2-3 months intervals) and P-T profile of the production wells are obtained and updated accordingly. Power plant is operated with 5-6 bar pressure and 165-170 °C inlet temperature. Reinjection temperature is between 75 and 85 °C, varying seasonally. Wellhead pressure for production wells ranges from 8.5 to 25 bar.

Total NCG content of the reservoir is being monitored with the help of Sierra Type portable NCG flowmeter, calibrated according to the dry NCG analysis. NCG content is calculated from gas/steam ratio obtained by steam flow, geothermal fluid flowrate, enthaply of brine and steam in seperator conditions and enthalpy of brine in the production zone. 99.5% of the total NCG is CO_2 and the ratio of NCG to fluid at reservoir is between 0.3-1.5%.

2. METHODOLOGY

Methodology similar to Akın and Kargı, 2019 is followed for the geochemical modeling of the characteristics of fluid chemistry in the reservoir and dynamic evolution of fluid chemistry in the wellbore using properties such as chemical analysis and physical parameters of separated fluid, static and dynamic pressure and temperature profile along the wellbore. Analysis of cations and anions are carried out in Sanko Energy Geochemistry Laboratory with Flame AAS and Ion chromatography instruments. Brine samples were also sent to General Directorate of Mineral Research and Application Center (Turkey) for analysis of major ions and trace elements.

Scale material samples were sent to Pamukkale University, Department of Geology for detailed mineralogical analysis. XRD analysis are conducted in Niğde Omer Halisdemir University Central Research Laboratory.

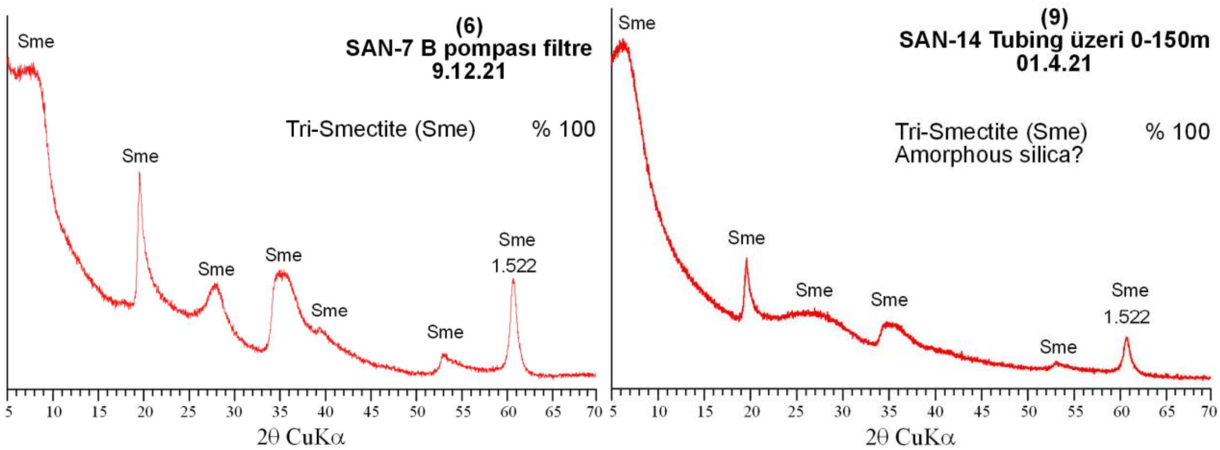


Figure 2: XRD analysis pattern and total percentage of some of the mineral scales sampled from production wells

Elemental and structural inspection of selected scale samples are undertaken with Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy in Adavnced technological application and research center (ILTAM) in Pamukkale University.

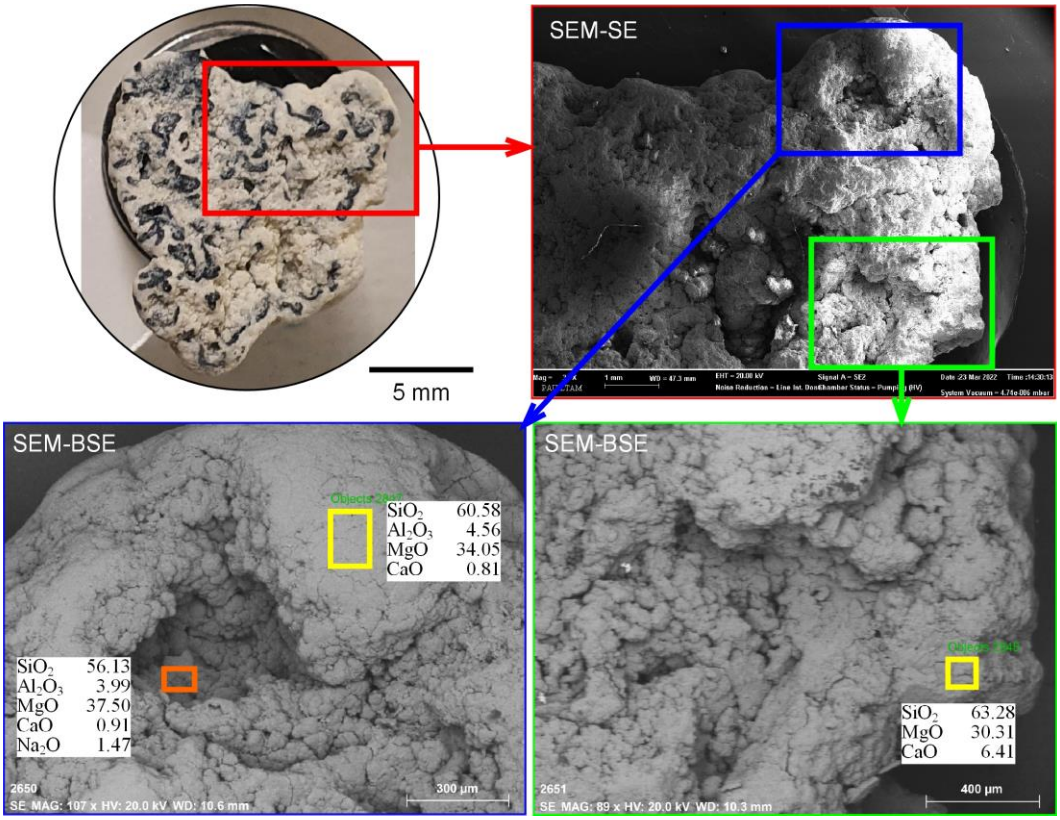
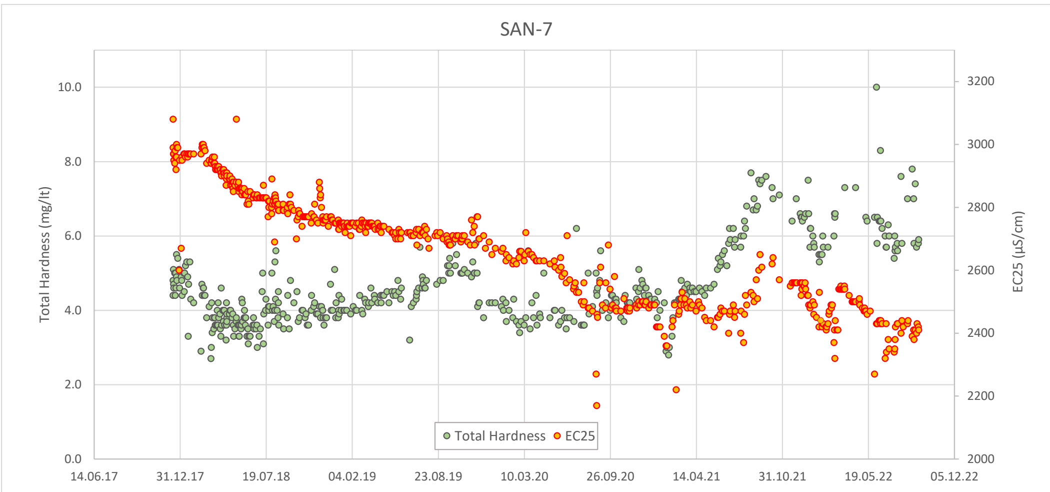


Figure 3: Detailed analysis of precipitated material on booster pump filter drum in SAN-20 production well

Due to the specific characterics of the scales observed (popcorn type structures, different constitution of some cores) in general, it is safely assumed that the precipitation of clay minerals takes place on the surfaces in contact with geothermal fluid directly (insitu), using existing minerals as cores in some instances.

Total hardness (reported as CaCO3) corresponds well with the smectite formation behaviour on casings and accumulation on the filter pumps. Total dissolved solids content of the production wells has been constantly decreasing while total hardness and silica content have increased periodically due to the effect of production and injection rate optimization on flow pattern, meanwhile episodic and constant mineral precipitation is observed.



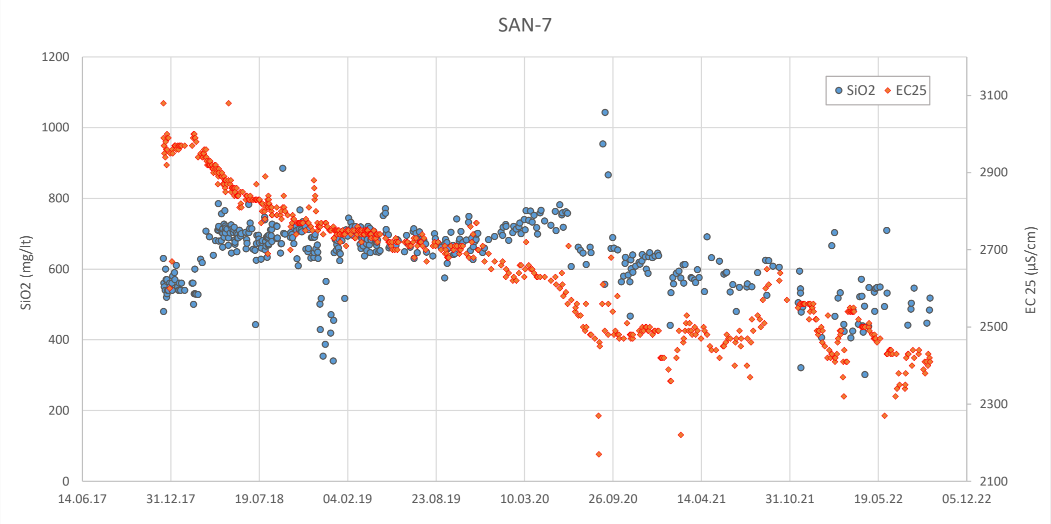


Figure 4: Evolution of water chemistry of a production well with time under constant development of Salihli Geothermal field

4. RESULTS AND DISCUSSION

The main purpose of the study is to understand the characteristics of the scales formed under the operating conditions of the power plant. In this context, the mineralogical and geochemical investigations were carried on the scale deposits and the samples are classified accordingly as: (1) directly precipitated minerals from the fluids, (2) transported minerals that previously precipitated in the deeper parts of the wellbore, (3) detrital/clastic particles belong to the geological units located in vicinity of the production wells.

Almost all of the samples collected from filters and tubings mainly consist of Mg-smectite (80-100%). The sampled materials from the heat exchangers contain small particles (< 2mm) of elemental iron and iron oxide (magnetite), marbles as well as smectite clays.

A trial and error approach is adopted for selection of inhibitor chemical and maintaining optimum dosage to reduce mineral precipitation to a managable level, supported by constant monitoring of physical-chemical parameters and routine analysis of chemical constituents (Si, Ca, Alkalinity, etc) of geothermal brine. For sustainable treatment of geothermal brine, safe concentration range for each constituent (silica and total hardness) are determined, based on time series of each data. Regular check of precipitated material on corrosion coupons and inspection of dosage tubings are part of this procedure.

Triggering mechanism for precipitation of minerals on the surfaces with which the geothermal fluid is in contact, starting from production wells, through the fluid pipelines and heat exchangers to the reinjection wells is closely related to the ratio of total SiO2 and total hardness to total dissolved solids. Total dissolved solids content of the production wells has been constantly decreasing while total hardness and silica content have increased periodically due to the effect of production and injection rate optimization on flow pattern, meanwhile episodic and constant mineral precipitation is observed. Detailed study about how much of the silica is in dissolved or in suspended form has yet to be done, and further studies will involve incorporating total silica analysis in geochemical models and utilization of kinetic behaviour of silica in antiscalant optimization.

Triggers for scale deposition are: (1) oversaturation of certain mineral phases (SI>5 for Mg-smectite) due to flashing and adiabatic cooling in the well, (2) removal of the steam phase from the geothermal fluid and the consequent drastic change in physico-chemical parameters of the fluid after it passes through separator, (3) alteration of the flow regime due to filter structure and the change in diameter along flowline. (4) the effect of flow pattern change in the reservoir due to flow rate optimization.

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