Silica scaling depending on SiO_2 speciation in geothermal waters

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Precipitation of amorphous silica (am. SiO_2) scales in the pipelines of geothermal power plants is a common factor limiting the efficiency of energy production. The mechanisms of am. SiO_2 scale formation in such settings are however poorly understood and no universal mitigation strategy to prevent or reduce precipitation is currently available. Here we describe the microtextures of am. SiO_2 scales formed on stainless steel scaling plates inserted into the pipelines of the Hellisheiði power station (SW-Iceland) at 4 locations, over deployment durations of 1 day to 10 weeks. We document two independent mechanisms of am. SiO_2 precipitation: (1) direct deposition of monomeric silica (i.e., molecular deposition), resulting in the formation of dense, ‘bumpy’ layers which grow over time, and (2) deposition of am. SiO_2 particles that have homogeneously nucleated and grown in the fluid, and which aggregate into macroscopic fan- and ridge-shaped structures that grow towards the flow. The growth of the am. SiO_2 scale by molecular deposition (< 0.5 g m^{-2} yr^{-1}) depends on the concentration of total and monomeric silica in the fluid and, to a lesser degree, on fluid temperature and pH. Particle deposition on the other hand is controlled by the concentration of particles in the fluid and decreases along the flow path as the fluid is depleted in particles. Particle deposition as well as the exact structures formed are a function of flow rate. We expect that particle deposition and the resulting 3D structures that form on the inside of the pipelines are more problematic for the efficiency of geothermal energy production compared to molecular deposition as the 3D structures likely result in more turbulent fluid flow and thus likely require higher operational pressures to maintain required fluid flow rates. Our results indicate that by specifically targetting certain mechanisms of am. SiO_2 precipitation (e.g., particle growth or deposition), the effectiveness of mitigation strategies for am. SiO_2 scaling can be maximised.