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Effects of heat shocks on biofilm formation and the influence on corrosion and scaling in a geothermal plant in the North German Basin

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Abstract

At geothermal plants, process failures often occur due to corrosion and scaling processes. Especially after heat extraction, sulfate reducing bacteria contribute to corrosion processes by producing reduced sulfur compounds. In biofilms containing scales such as iron sulfides, corrosion processes are enhanced. In a mobile bypass system located at the geothermal plant in Neubrandenburg (North German Basin), the influence of biofilm formation on corrosion and scaling was investigated. Short-term heat shocks were successfully tested in the bypass system in order to reduce biofilm formation and thus to diminish corrosion and scaling processes.

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Keywords: microbial influenced corrosion (MIC); scaling; biofilm; sulfate reducing bacteria (SRB)

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1. Introduction

In geothermal fluids after heat extraction, frequently sulfate reducing bacteria (SRB) are found [1]. SRB contribute to the corrosion process indirectly by the formation of reduced sulfides and/or directly by the uptake of electrons from the metal to the microbial cell [2,3]. SRB form biofilms on the metal surface. The dissolved iron ions precipitate with the sulfides. Thus, SRB do not only contribute to the corrosion process, but also deliver the reactant for the scaling process [4]. Lerm et al. [5] showed a high abundance of SRB at the cold side of a geothermal heat store in Neubrandenburg (North German Basin). There, the submersible pump was strongly affected by pitting corrosion. Lerm et al. [5] concluded that the formation of biofilms on the pump containing corrosion relevant SRB was the main reason for the damages. Würdemann et al. [1] observed a strong reduction in the injectivity and thus, a clogging of the near well area due to scaling products and biofilm formation in the cold store at the Berliner Reichstag. In the joint project "BioKS", measures to diminish biofilm formation are investigated in order to reduce corrosion and scaling processes in geothermal plants. However, the inhibition of microorganisms with biocides is difficult in terms of environmental concerns and local regulations. In addition, high fluid flow rates require high amounts of biocides resulting in high costs. Thus, other measures need to be developed. In this paper, first results of the influence of heat shocks – short-term non-heat-extracting periods – on the biofilm formation in a bypass system are presented.

2. Material and Methods

2.1. Experimental setup

The bypass system was located in Neubrandenburg at a geothermal heat store. The heat store consists of two sides, a "warm" side with a temperature of approximately 80 °C and a cold side with a temperature of around 47 °C. The salinity is 130 g L^{-1}, the sulfate concentration varies between 900 mg L^{-1} at the cold side and 1100 mg L^{-1} at the warm side. More information about the site is given at Kabus and Wolfgramm [7], Obst and Wolfgramm [8] as well as Lerm et al. [5]. The bypass system was installed at the top facility at the warm side. The hot geothermal fluid from the warm side was cooled down with a heat exchanger in the bypass system to 40 °C and flowed through two parallel pipes. In these pipes, unground and ground (120 grit) corrosion coupons were installed. More information regarding the bypass system is provided in Würdemann et al. [6].

The experiment lasted 59 days. Every two weeks, the heat exchanger was switched off for 6 h, while one pipe was closed and one pipe remained open. Thus, in the closed pipe the temperature remained at ~ 40 °C and in the open pipe, the temperature increased to 78 °C due to the hot geothermal fluid. At the end of the experiment, the pipes were removed from the bypass system, transported to the laboratory and the coupons were withdrawn under an anaerobic mobile glovebox to avoid any exposure to oxygen.

2.2. Chemical and molecular biological analyses

In order to determine the corrosion rates, the clean coupons were weighted before and right after the exposure to the fluid. After the fluid exposure, the surface of the coupons was cleaned with 3 M HCl. The material of the coupons was mild steel (1.0038) with a density (ρ_C) of 7.856 g/cm³ and the dimensions of 3 mm x 25 mm x 100 mm. Thus, subtracting the holes in the coupons for its fixation in the bypass tube, the surface area of the coupons (A_C) was 5683 mm². The corrosion rate (CR) was calculated according to Eq. (1).

$$CR = \Delta m / (\rho_C * A_C * t) \qquad [mm/a] \qquad (1)$$

The biofilm layer and scales on the coupons were analyzed using a Scanning Electron Microscope (SEM) from Hitachi S-4700 with a Noran Nordlys II Energy Dispersive Spectrometer (EDS). Bacteria and SRB on the coupons were quantified by quantitative PCR (qPCR). Analyses of bacterial 16S rRNA [9] and *dsr*A genes for SRB [10,11]