Heavy fouling and corrosion risks in the cooling water systems of NPPs and methods for their mitigation (RICO)

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Introduction

Finnish nuclear power plants (NPPs) take their cooling water from Baltic Sea. If a large enough chemical spill happens nearby, it is possible that materials of cooling water systems of NPPs are harmed more than usual by corrosion and fouling. It could be even possible that the heat transfer capacity of the plant is decreased.

In the beginning of this project, an expert panel was organized in order to determine which material deteriorating chemicals are most commonly transported over Baltic Sea and what would be the concentration of the chemical in the water when a chemical spill reaches a power plant. Based on consensus of the expert panel, it was decided to study the effect of ethanol, sodium hydroxide, phosphoric acid, phenol and rapeseed oil (all 0.1-10.0 ppm) on corrosion and heat transfer of heat exchanger tubing material (titanium) and on micro-organisms living in the Baltic Sea water. The effect on micro-organisms were studied because some bacteria (SRB) are known to be able to harm titanium, therefore if chemicals somehow increase the amount of those micro-organisms it might increase corrosion rates.

Methods

Electrochemical impedance spectroscopy (EIS) and linear polarization resistance (LPR) measurements were conducted on titanium samples in artificial brackish water in order to study the effect of previously selected chemicals on the corrosion and fouling. These measurements were compared with measurements that were otherwise similar but there were also micro-organisms from Baltic sea present in the measurement solution. The duration of each measurement was 72 hours which is the time of the emergency shut-down of a nuclear power plant. The test samples were heated on the exterior surface with an external water circulation heated with a heating bath and test solution temperature was kept constant with external cooling water circulation (Figure 1). Water volume in the cell was changed in every 50 seconds. The temperature of solution flowing in and out of the measurement cell was measured to determine whether chemicals changed heat transfer capacity of the samples. In the biotic measurements, the amount of micro-organisms and especially sulfate reducing bacteria (SRB) was measured and compared to the baseline of micro-organisms measured before chemical addition.

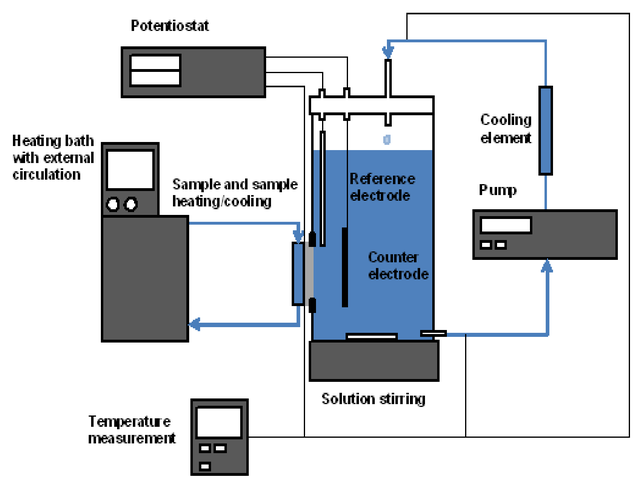

Figure 1. Schematic picture of the laboratory system

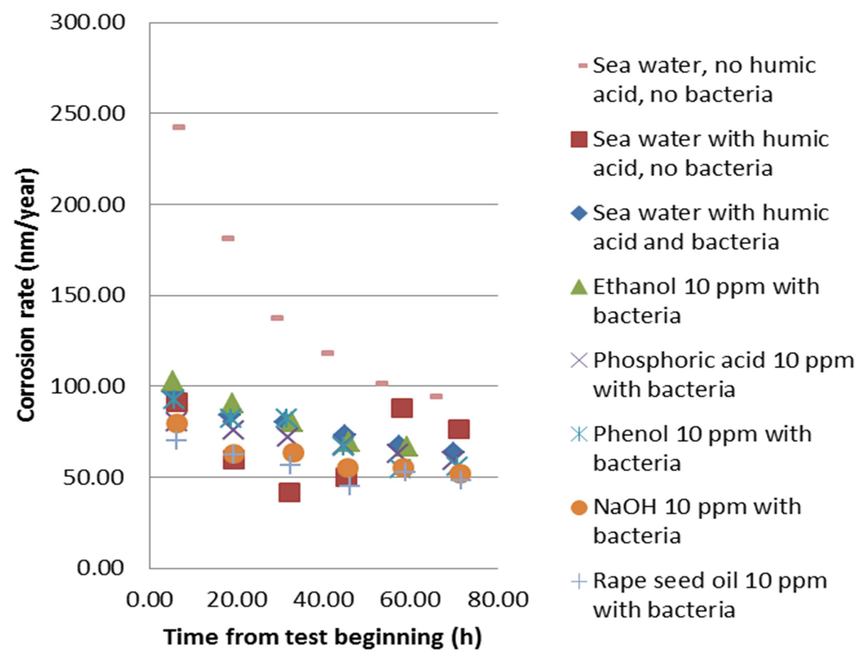

Figure 2. Corrosion rates of titanium samples for biotic measurements compared to abiotic results in artificial brackish water

Results

In abiotic experiments, a white $CaCO_3$ deposit formed on the titanium samples. In biotic experiments, deposit was brownish and consisted of organic substances. The thicknesses of the deposits were evaluated by both calculating from the mass difference of the samples before and after the measurement and also analyzing the electrochemical impedance spectra. The corrosion rates were determined from LPR measurements. Corrosion rates in biotic experiments for different chemicals at concentration of 10 ppm are presented in Figure 2. The corrosion rate stabilized after two or three days with all chemicals. Corrosion rates were higher in abiotic experiments (20-200nm/year) than in biotic measurements (50-70nm/year). The differences in heat transfer rates were so small that no definite conclusions could be made on the effects of the chemicals. Additionally, no clear correlation could be detected between corrosion rate and microbial community. The results suggest that temperature is more important factor than microbes when considering the performance of titanium.

Conclusions

Studied chemicals (ethanol, sodium hydroxide, phosphoric acid, phenol and rape seed oil) are not harmful for titanium parts of cooling systems of nuclear power plants with concentrations estimated to be released from a tanker accident in Baltic Sea. All corrosion rates were in order of tens or hundreds of nanometers per year and decreased over time.

No clear correlation could be detected between the corrosion rate and type or extent of the microbial community in the biotic experiments.

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