Risks of microbiologically influenced corrosion in the Finnish nuclear waste repository

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Background

Contaminated **decommissioning waste** is produced during the operation and decommissioning of nuclear power plants. In Finland, this low- and intermediate-level waste is transferred to an underground repository where it will be disposed into concrete silos. This waste consists mostly of **carbon and stainless steel**. In oxygen free water the corrosion of steel is low, unless water is very acidic or there is microbial activity in the environment. At disposal sites, the **concrete** generates a high pH environment, which significantly decreases the corrosion rate of steel. Over the course of time pH starts to decrease again, e.g. due to the carbonization of concrete. It is known that microbes can also decompose concrete and accelerate several corrosion mechanisms, such as general corrosion and localized corrosion. The groundwater at the repository depth contains up to **10^5 microbial cells mL^{-1}** with considerable diversity. The activity of microorganisms attached to the surfaces and the properties of formed biofilms are essential factors when considering the possibility of microbially induced corrosion. Under the biofilm the conditions may differ remarkably from the surrounding environment and thus induce circumstances where the corrosion is locally increased. Indications of **microbially induced corrosion** have also been seen in corrosion studies of carbon steel performed in Finnish groundwater simulating repository conditions, where exceptionally high corrosion rates were achieved. However, the effect of microbial activity on the corrosion of decommissioning waste and the release of radioactive nuclides is still unclear and needs to be studied further.

Aims

1 Design and build suitable experimental conditions
2 Study the effect of microbial functions on corrosion rate and mechanisms of decommissioning waste
3 Study the composition of biofilm formed on surfaces of decommissioning waste

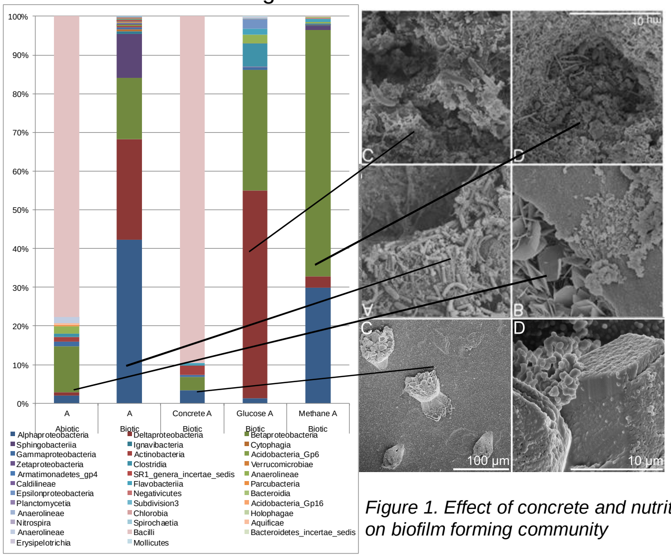

Figure 1. Effect of concrete and nutrition on biofilm forming community

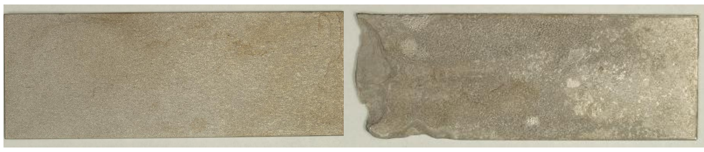

Figure 2. Carbon steel after 3 years of exposure in abiotic (left) and biotic (right) ground water

Results

In this project experimental set-up that enables real-time monitoring of corrosion indicating electrochemical parameters under modified atmosphere was successfully developed. In addition, a set-up that enables simulation of different scenarios and accelerated microbial functions was developed. In this project long-term *in situ* experiment in the **repository cave** and three **laboratory scale** simulation experiments were conducted. **Biofilm formation** on surface of stainless steels and carbon steel was detected to be intensive under repository conditions. The **microbial diversity** of the biofilm was high (Figure 1). The **temperature** had critical effect on the species composition of sulphate reducing bacteria. In addition, organic nutrients affected the composition of the biofilm forming community. Concrete slowed the initiation of, but did not completely inhibit, the biofilm formation. In the presence of concrete the composition of the microbial community differed from that of the natural conditions. In our experiments native microbes from groundwater were shown to benefit from the carbon steel.

In general, the detected **corrosion rates of steels were higher in the presence of microorganisms** compared to the abiotic reference experiments (Figure 2). In the case of stainless steels especially pitting corrosion was induced.

Conclusions

The native microorganisms in the repository environment have the potential to adapt changing environmental conditions and form biofilm on the surfaces of steels. The corrosion rate was higher in the presence of microorganisms than in abiotic reference environment.

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