In-situ testing the corrosion performance of candidate HLW/SF canister materials in contact with bentonite in a crystalline rock environment

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ABSTRACT

The Materials Corrosion Test (MaCoTe) at the Grimsel Test Site (GTS, www.grimsel.com), Switzerland, is designed to assess the effectiveness of engineered barrier components intended for use in a deep geological repository for the safe and long-term management of high-level nuclear waste. The main objectives of the MaCoTe project are to:

- build confidence on the long-term anaerobic corrosion rate of various canister materials (carbon steel, stainless steel, copper, copper nickel alloy, zirconium alloy, etc.) with different surface roughness embedded in compacted bentonite under repository-relevant environmental conditions,
- study the interaction of candidate canister materials with bentonite,
- evaluate the microbial community in compacted bentonite and assess the potential for microbiologically influenced corrosion

The experiment is made up of a series of specially designed stainless-steel modules (Figure 1), 0.3 m in length, inserted into a 10 m long borehole and sealed with a double packer system to maintain anoxic conditions, relevant to the post-closure phase of geological disposal.

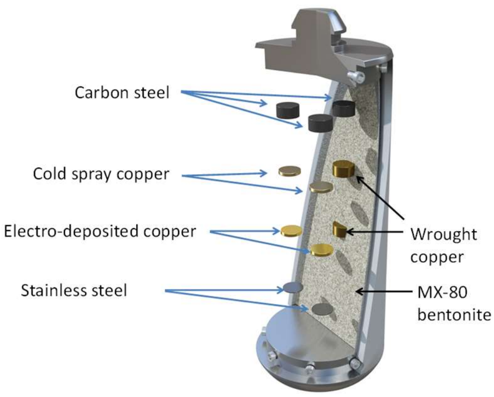

Figure 1. Layout of metal coupons in each module.

The modules have holes and a sintered stainless steel filter allowing the free exchange of porewater with the host rock. In 2014, the first eight modules deployed in the borehole contained metallic coupons made of forged carbon steel, stainless steel, wrought copper, cold sprayed copper and electro-deposited copper embedded in MX-80 bentonite with dry densities of either 1.25 or 1.5 Mg/m^3.

To date modules have been retrieved from the borehole after 1 year, 4.5 years, 7 years and 9 years from the start of emplacement. For the metals, corrosion rates are determined by high precision weight loss measurements, and the chemical composition and microstructure of corrosion products are analysed using Raman spectroscopy, X-ray photoelectron spectroscopy (XPS) and combined scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDX). The roughness of the pristine and corroded metal surfaces is measured with profilometry. Mineralogical and micro-chemical analysis of the bentonite are also carried out to evaluate mineral changes in clay minerals in the altered bentonite zone next to corroded test coupons by comparing with clay minerals in unaltered zones. Microbial populations both in the bentonite and the borehole water are analysed using advanced cell counting and DNA analysis and gene-sequencing to determine microbial populations.

Average corrosion rates were found to decrease from about 1.0 µm/yr down to 0.7 µm/yr for carbon steels and 0.10 µm/yr down to 0.02 µm/yr for copper and copper coatings over the 9-year period. There has been no significant impact of bentonite density on average corrosion rates. Magnetite and iron oxyhydroxides were identified on carbon steel coupons. A layer of Cu_2O was found in the top few nanometres on copper coupons when exposed to 7 years or longer. In the talk, the full results and implications will be presented in brief.