

Corrosion of steel in contact with bentonite under conditions relevant for nuclear waste disposal

Ashutosh Singh, Nicolas Finck, Dieter Schild, Horst Geckeis

*Institute of Nuclear Waste Disposal, Karlsruhe Institute of Technology,
76021, Karlsruhe, Germany*

Abstract

Carbon steel is considered by many countries as a potential canister material to encapsulate high-level nuclear waste (HLW) before final disposal in a deep geological repository. Depending on the repository concept, compacted bentonite may be used as backfill material. Groundwater will eventually migrate through the barriers and induce steel corrosion. Information on corrosion rates (i.e., service lifetime of the container) and corrosion mechanisms are of high importance for the Nuclear Disposal Safety Case.

A low-alloyed carbon steel and a spring steel of comparable composition, though with higher Si content, were selected in this study. The higher Si content of the spring steel is expected to reduce substantially the corrosion rate by forming of a layer of iron silicates better protecting the surface than for the carbon steel. This hypothesis was tested by performing corrosion experiments in closed vessels under anoxic and water saturated conditions at room temperature (RT) and at 50°C. Coupons were polished and the MX-80 bentonite was pre-equilibrated with synthetic Grimsel pore water prior to use. After 3 months of reaction time, and cooling down to RT where necessary, pH and redox potential (E_h) were measured in-situ and the composition of ultra-centrifuged pore water determined by ICP-OES and IC. Coupons were analyzed by various techniques and corrosion rates were determined from weight loss measurements.

Relatively comparable pH values were measured for the carbon steel (pH 8.40) and the spring steel (pH 8.14) at RT, and lower values were measured in experiments conducted at 50°C. E_h values were not much affected by temperature, but were significantly lower for the carbon steel (around -380 mV). The composition of the pore water in all experiments were relatively comparable. The corrosion rate for the spring steel was larger than for the carbon steel and values increased with temperature. No

presence of corrosion products on the surface of both steel coupons could be detected by XRD analysis. However, morphological changes could be seen at the surface of both coupons by SEM, and a change in chemical composition of the exposed surfaces was evidenced by SEM-EDX analysis. Elemental compositions point to the presence of a thin layer of Fe-silicate covering the coupons. Complementary information on elemental composition and oxidation state of the new-formed mineral was provided by surface sensitive XPS analysis.

Overall, the investigated spring steel is less corrosive than carbon steel under elevated temperature conditions while at room temperature the investigated carbon steel has more corrosion resistance compared to spring steel. The increase of corrosion rate with temperature agrees with reported studies and is expected to decrease with reaction time (e.g., doi.org/10.5006/1.3287691) owing to the development of a more compact alteration layer at the surface of coupons. This assumption is being investigated in experiments with longer reaction time and the comparison of results from both materials will enable to conclude whether Si present in the steel has a significant impact on the corrosion resistance.



Room Temperature (25°C)



Elevated Temperature (50°C)

KEYWORDS: Nuclear waste disposal, MX-80 bentonite, Metallic Corrosion, Anoxic, Carbon steel