Microbial processes in a clay repository

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Abstract

The safety of a deep geologic repository (DGR) for nuclear waste must be ensured for geological times exceeding human imagination taking into account large uncertainties. The long-term effects of complex biogeochemical processes potentially affecting the integrity and the long-term safety of engineered barriers might still be unknown. The aim of this presentation is to give a general overview of some microbial processes which have contributed to shape the Earth since probably billions of years and whose unexpected consequences for nuclear waste disposal should be appropriately tackled.

It is important to identify which safety-relevant processes and properties of a disposal system can be potentially influenced by microbial activity and under which conditions could microbes continue to develop and to be active or not. How to design a robust repository capable of withstanding potential harmful effects of micro-organisms or at the contrary benefiting from their ubiquitous presence in the deep geosphere.

Clay properties such as swelling pressure, sorption capacity, porosity and hydraulic conductivity are important for maintaining safety functions of containment and retardation in engineered barriers and in the immediate near-field of a gallery. Microbial reduction of structural Fe(III) in clay minerals can induce solid-state transformations as observed in unconsolidated argillaceous sediments altering these properties by destabilising the clay structure and releasing Fe(II). Clay dissolution can occur, releasing silica, and in the presence of sufficient soluble potassium, swelling smectite can be converted in non-swelling illite. Similarly, Fe(III) microbial reduction in magnetite passive layer protecting steel overpacks could contribute to depassivate the metallic surface and to maintain their long-term corrosion.

Sulfate-reducing bacteria (SRB) producing sulfide and thiosulfate combined with the formation of biofilms can increase stress corrosion cracking and pitting rate of the metallic barriers if sufficient water and space are available around the canisters to promote their growth. However, sulfate-reducing bacteria and methanogens could also have a potential positive effect on the safety of a deep geologic repository by contributing to strongly decreasing the hydrogen gas pressure induced by the anaerobic corrosion of steel.

Nitrate-reducing bacteria if active at moderately alkaline pH (< 12) in the fissured excavation disturbed zone near disposal cells containing nitrate-bearing bituminised waste could attenuate a nitrate plume in a clay formation and so might contribute to maintain redox-sensitive radionuclides such as ^{79}Se, ^{99}Tc, ^{23x}U in their most favourable reduced states (lowest solubility, highest sorption, lowest mobility of these radionuclides).

Microbes easily adapt to extreme conditions and evolve fast on many generations. It is thus not possible to predict the long-term microbial evolution in a disposal system left open, e.g. for the sake of the reversibility / retrievability of the waste. However, one thing is certain: if space, water and electron donor/acceptor are available under favourable pH conditions, microbes will most likely develop in the future in the spaces filled with water. Harmful microbial effects must then be anticipated and prevented by design, especially for limiting as much as possible the corrosion of overpacks and metallic containers while it is not possible, nor a safe option, to rely in a DGR concept on the positive effects of microbial activity for decreasing the hydrogen gas pressure or for attenuating a nitrate plume because of the too large uncertainties related to microbial development. Microbial life could not be at the rendezvous when we need it most for the safety, but it could cause unpleasant surprises if we ignore it.

To protect the metallic barriers and to decrease their corrosion rate, it is thus essential to ensure "space and water restrictions" to limit the microbial activity directly around the waste containers or to maintain unfavourable high pH conditions for very long periods of time.

An important requirement established now in safety guides in several countries by regulatory bodies is thus to fill all the gaps and the voids in a disposal system and to minimise the pore size of buffer materials in the engineered barriers at the locations close to the waste canisters where microbial activity could produce harmful effects. However, this does not *a priori* exclude to foster microbes development by design in other well-chosen locations where it could improve the overall safety of the disposal system without strict guarantee of success.