Intra-terrestrial Biosorption of Radionuclides and Analogous Trace Elements

Microbial Interference with the 'Water/Rock Interface'

Craig R. Anderson

Department of Cell and Molecular Biology, Microbiology, Göteborg University, Medicinaregatan 9C, Box 462, S-40530 Göteborg, Sweden

ABSTRACT:

Countries utilising atomic energy have a responsibility to dispose of the industry's waste in an economically, scientifically, politically and publicly acceptable way. The Swedish nuclear fuel management company (SKB) has instigated final site investigations for a deep subsurface high level nuclear waste (HLW) repository in granitic rock. This facility will be situated 500 meters below ground level and will isolate the HLW from the environment using an engineered multi-barrier system with a supposed design life of 10^5 to 10^6 years. As microbial life is ubiquitous in intra-terrestrial environments, assessing the subsurface geochemical and geomicrobial influences is critical for predicting the safety and longevity of HLW storage. In the possible event of repository failure, the transport of radionuclides through water conducting rock fractures is the predominant concern but radionuclide migration can be retarded by abiotic and biotic sorption processes.

In this study biofilms were grown under *in situ* pressures and conditions using groundwater sourced from boreholes 296 m to 450m below sea level at the Äspö hard rock laboratory (HRL) in Sweden. Purpose built biofilm reactors were installed and left to develop microbial communities for up to one year. The community genera were then analysed genetically along with the population characteristics. Scintillation, NaI γ-detection, ICP-MS and autoradiography were used to investigate the ability of these biofilms to absorb trace metals from fracture fluids and synthetic groundwater containing Co, Pm, Np, Am, Th, U and Mo. The concentrations of PGE (platinum group elements) and REE (rare earth elements) were also measured by ICP-MS for experiments conducted in aerobic conditions.

Results indicate that aerobic biofilms grown in near neutral pH conditions, with low pressure (1 bar) and oxygen (<1.5 mgl^{-1}; Eh <190 mV), can rapidly attenuate metals to over 1000-fold higher than the levels within the groundwater. In anaerobic conditions biofilms in 1.5 % salt and near neutral pH tend to favour the adsorption of the 3+ valence state (Am, Pm) over other radionuclides such as Co, Th, Np, U and Mo. When compared to the rock surface, the biofilms tend to have slightly less capacity than the rock itself except for 3+ valence metals where the sorption capacity is comparable or greater.

Metal sorption by mixed organic and inorganic phases can occur in any hydraulically conductive fracture. Subsurface biofilms can decrease the adsorption capacity of the host rock for some radionuclides. Biological retardation of radionuclides may not take place until the ground water is more oxidised and closer to the surface. Calculations of biogenic involvement in metal mobilization and immobilization should be considered in the design and safety of nuclear waste vaults. The data presented here indicate that the development of subsurface microbial communities has a significant effect on metal movement when compared to inorganic systems alone.

Keywords: Äspö, contamination, groundwater, actinides, lanthanides, bacteriogenic iron-oxides, *Gallionella*, anaerobic biofilms, metal adsorption

Göteborg 2005 **ISBN 91-628-6691-5**