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Microbial activity in argillite waste storage cells for the deep geological disposal of French bituminous medium activity long lived nuclear waste: Impact on redox reaction kinetics and potential

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Micro-organisms are ubiquitous and display remarkable capabilities to adapt and survive in the most extreme environmental conditions. It has been recognized that microorganisms can survive in nuclear waste disposal facilities if the required major (P, N, K) and trace elements, a carbon and energy source as well as water are present. The space constraint is of particular interest as it has been shown that bacteria do not prosper in compacted clay. An evaluation of the different types of French medium and high level waste, in a clay-rich host rock storage environment at a depth between 500 and 600 m, has shown that the bituminous waste is the most likely candidate to accommodate significant microbial activity. The waste consists of a mixture of bitumen (source of bio-available organic matter and H2 as a consequence of its degradation and radiolysis) and nitrates and sulphates kept in a stainless steel container.

The assumption, that microbes only have an impact on reaction kinetics needs to be reassessed in the case where nitrates and sulphates are present since both are known not to react at low temperatures without bacterial catalysis. The additional impact of both oxy-anions and their reduced species on redox conditions, radionuclide speciation and mobility gives this evaluation their particular relevance.

Storage architecture proposes four primary waste containers positioned into armoured cement over packs and placed with others into the waste storage cell itself composed of a cement mantle enforcing the argillite host rock, the latter being characterized by an excavation damaged zone constricted both in space and in time and a pristine part of 60 m thickness. Bacterial activity within the waste and within the pristine argillite is disregarded because of the low water activity (< 0.7) and the lack of space, respectively. The most probable zones of microbial activity, those likely to develop sustainable biofilms are within the interface zones. A major restriction for the initial development of microbial colonies is the high pH controlled by the cement solution. Archea are able to survive at high pH, when hydrogen gas is available as an energy sources; they are therefore likely candidates for an initial biofilm formation. It can not be excluded that other micro-organisms such as fungi may develop as well in such conditions. It also needs to be evaluated how conditions change with time and how this affects microbial ecology.

The following is known about the impact of microbes on the waste cell biogeochemistry:

• enhancement of redox reaction kinetics (particularly involving nitrates, sulphate, selenate, pertechnetate, organic matter and H2), thus a faster move towards reducing conditions, important to guarantee the low mobility of critical RN,

• increased retardation of mobile RN in biofilms (i.e. adsorption on microbial cell surfaces and products of possible biomineralization); complexation by embedded extracellular polymeric substances,

• secretion of organic substances (i.e siderophores) known to complex RN and to enhance their mobility,

• biodegradation of dissolved organic substances, such as those released form the waste (organic acids) or generated by microbes,

• production of CO2 or other gases that may affect cement integrity.

Quantification of microbial activity has been implemented into biogeochemical models but the important parameters describing their evolution and metabolism in the real system (ecology, mass, energy sources, metabolites) need to be obtained via specific empirical studies. Such studies require a particular trans-disciplinary approach that brings together the competence of chemical and environmental engineers, microbiologists and system modellers.