

The impact of microbial metabolism on the geodisposal of radwaste in multibarrier systems

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Expectations

3.1 Key Topic 1: Safety case

3.1.1 Definition, scope and rationale

IGD-TP Strategic Research Agenda (SRA)July 2011

Definition – A safety case demonstrates safety by providing a clear reasoning based on sound scientific and technological principles /3-1/. The safety case should be simple to understand and robust. The safety case is a major set of efforts to achieve the approval of a license application for a specific nuclear waste disposal facility and has to comply with the requirements set up by the national authorities. Attention should also be paid to the recommendations made by international organisations such as the International Atomic Energy Association (IAEA) and the Nuclear Energy Agency by OECD (OECD/NEA).

The safety case must be able to describe the evolution of the repository in a way that can be seen as a reasonable representation of what might happen and that also gives a clear indication of uncertainties in the description.

Safety of construction and operations addressing safety at shorter term is treated in Key Topic 5, see Section 3.5.

Objectives - The objectives are to:

- Develop a broad view on the basis for long-term safety assessments and thereby the scope and contents of safety cases relevant for all participants of the IGD-TP.
- Develop and refine concepts and models for improving long-term safety assessments.
- Improve the treatment of sensitivities and uncertainties.

Address key microbial uncertainties in nuclear waste disposal safety case Decrease conservatism (see also Long-term performance, Topics 9–17)

Scientific Background: Manchester Geomicrobiology Group

Broad interest in nuclear fuel cycle microbiology ≈£9M funding (NERC, BBSRC, EPSRC, US-DOE, EU, NNL, WMOs) Cross-disciplinary (spectroscopy, post-genomic studies, imaging) 20 yrs of work on radionuclide biogeochemistry (U/Tc/Np/Pu etc.) in natural and engineered environments Cross-cutting role in £3.5M NERC BIGRAD consortium (alkali disturbed zone)



Main components of MAVL (medium activity long lived) waste cell (ANDRA concept)



Microbial activity plays an essential role in catalysing most of the key redox reactions, particularly those including oxyanions (nitrate, sulphate, carbonate), organic matter (plasticisers, cellulose, organic acids, polymers) and hydrogen gas, thus controlling redox potential and RN speciation and mobility

Substances likely to participate in redox reactions

Reducing element (oxidation state)	Waste cell component	Oxidising element (oxidation state)	Waste cell component
C(-IV), C(0)	organic matter	O(0)	0 ₂
Fe(0), M(0)	steel	N(V)	NO ₃ (nitrates)
Fe(II)	pyrite, siderite	Fe(III)	Clay minerals, hydrogarnet
S(-I), S(-II)	sulphides	S(VI)	SO4 ²⁻ (sulphates)
H(0)	H ₂	C(IV)	CO ₃ ²⁻ (carbonates)

GDF gas generation

- Generation processes
 - corrosion
 - radiolysis
 - microbial action
- Bulk gases
 - hydrogen, methane, carbon dioxide
- Trace radioactive gases containing
 - tritium
 - carbon-14
 - radon 222
- Microbial gas metabolism (especially methane and hydrogen) largely uncharacterised in GDF/EBS



Illustrative calculation of gas generation from Unshielded- ILW (2004 Inventory) for higher strength rock UK concept Hydrogen (and C14) peak - corrosion of reactive metals Long-term H₂ generation; steel corrosion & radiolysis of water CO₂ trapped due to cement carbonation (NDA Report NDA/RWMD/037)



Upper pH limit for microbial metabolism

- Succession of electron acceptors: Nitrate > Fe(III)-citrate > ferrihydrite > SO₄²⁻
- In accordance with the calculated free energy yields and Eh values
- No microbial activity at pH 12





Blogeochemical Gradients

and RADionuclide transport





Ferrihydrite





Blogeochemical Gradients and RADionuclide transport BIGRAD

Magnetite



Microbial Reduction of Fe(III) under Alkaline Conditions Relevant to Geological Disposal

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High pH U, Tc, Np biogeochemistry





EXAFS bioreduced uranium

The University of Manchester MANCHESTER

Enzymatic U(VI) reduction by novel Gram +ve bacteria



Microbial metabolism of CDPs: ISA biodegradation at high pH





- High concentration of ISA formed during cellulose hydrolysis at high pH
- Water soluble and can mobilise wide range of radionuclides

ISA degradation at pH10: aerobic=nitrate-reducing >Fe(III)-reducing conditions

Deep disposal of intermediate level waste: possible scenario



Engineering, chemical and natural barriers to achieve long-term containment Ref: UK Groundwater Forum, British Geological Survey.

"Remaining issues"

- Biogeochemical evolution of EBS (bentonite/EDZ/ADZ/ Geosphere)
- Microbial impacts on key radionuclides, gases (e.g. H₂ and CH₄) and CDPs (often positive!!)
- Thermodynamic data base on key biogeochemical reactions in situ or from analogues (used for modeling)
- Limits of life; incl temp/pH/radiation/pore size and accessibility e.g. in clays
- Biocorrosion impacts
- Gradient systems and heterogeneity
- Common theme- biogeo coupling to hydrogen?
- Better comparison of data from URLs and analogue sites (network)?