Cement / Concrete in Nuclear Waste Management

Karlsruhe Institute of Technology

- 6th FP IP ESDRED: LOW-pH CEMENT FOR A GEOLOGICAL REPOSITORY, 2005
- Workshops on Mechanisms and Modelling of Waste/Cement Interactions
  - Meiringen, 2005;
  - Le Croisic, 2008;
  - Ghent, 2013.
- International Symposium on Cement-Based Materials for Nuclear Wastes, Avignon 2011
- NEA TDB Phase IV: Initiation Report Thermodynamic Data for Cement Minerals, 2012 ➔ State-of-the-Art Report

Collecting Ideas

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- Responses by:
  - AMPHOS21 (E), ARMINES (F), BGS (UK), BRGM (F), BTECH (FI), CEA (F), CIEMAT (E), CTM (E), KIT-INE (D), NRI-REZ (CZ), PSI (CH), SCK·CEN (B), UNILOUGH (UK)
- Proposed Topics:
  - Waste forms (containers, grouts): 21
  - Repository engineering (seals, support, backfill): 13
  - Geology (grouts, alkaline disturbed zone): 4
- Possible approach
  - *Laboratory and Field scale experiments*
  - *Analogues*
  - *Process and system modelling*

Reasons for a TSWG: SRA

- Key Topics 2 Waste forms and their behavior
  - 2.2 Release from ILW and their detailed characterization 2012- 2016, H
- Key Topic 3: Technical feasibility and long-term performance of repository components

3.10 Long-term behaviour of seals and plugs	2011 - 2017	H
3.11 Evolution of cement-based seals	2015 - 2023	M
3.12 Interaction of cement with clays	2016 - 2024	M
3.13 Optimisation of low pH cements	2016 - 2022	M

Issues of the TSWG

- Tentative list of issues for a TSWG:
  - Remaining issues concerning basic understanding the stability of phase compositions under expected conditions
  - Understanding the behaviour and potential reactions under unexpected/disturbed conditions
  - pH and redox buffer capacity in various cementitious environments
  - Radionuclide retention under highly alkaline conditions
- Proposed issues by NDA:
  - Long-term evolution, interactions between barrier materials, and effects on cement properties.
  - Long-term fate of radionuclides in cement based EBS

Basic process understanding to be integrated into models for long-term predictions

e.g.: $4\ H_2 + Ca^{2+} + SO_4^{2-} \rightarrow H_2S + 2\ H_2O + Ca^{2+} + 2\ OH^-$ (Truche 2009, low pH)

Radionuclide retention / Long-term fate of RN

How to proceed?

- Discussion/information with WMOs (ANDRA, ONDRAF·NIRAS, NDA, SKB)
  ➔ Exchange Forum is an adequate chance
- I don't see principle differences, rather general agreement
- Different degrees of details and mapping of topics
- TSWG could design a project by
  - definition of topics/workpackages
  - thematic mapping of topics according priorities, schedules, etc.
  - estimation of time/resources required
  - proposal of partners/contributors
  - clarify organistion, etc.
- Meeting of interested groups?

NDA

- Long-term evolution, interactions between barrier materials, and effects on cement properties.
  - Long-term Cement Studies (LCS) – Grimsel URL
  - Nearfield evolution of cement based systems – long term NRVB performance as backfill and grout, leaching of aged cements
  - Longevity of chemical conditioning
  - Äspö ILW long term experiments, concept optimisation, engineering and design
  - Vitrified ILW durability in cementitious environments
- Long-term fate of radionuclides in cement based EBS
  - Chemical containment demonstration experiments, sorption, (co)precipitation etc
  - Mechanisms of radionuclide uptake to cement based materials, longevity of radionuclide sorption (reversibility)
  - Impact of cement additives and other EBS components on radionuclide mobility (long term, e.g. following cellulose degradation)

Ideas on Waste forms (containers, grouts)

- Impact of saline groundwater
- Changes in pH (high/low alkaline fluids etc)
- Influence on corrosion processes
- Carbonation by the breakdown of organic components in the waste
- Sulphatisation by deep ground waters
- Impact of magnesium (from MAGNOX).
- Impact of sulphatisation / carbonation of CSH/CASH on radionuclide adsorption and retardation.
- Gas generation
- Thermal impacts
- Ground-freezing (permafrost).
- Aging (inc. shrinkage)
- Changes in porosity of the system by formation of secondary solid phases
- Influence of the redox evolution due to scrap corrosion under hyperalkaline conditions
- Speciation of radionuclides under hyperalkaline conditions
- Formation of secondary alteration phases able to retain components of the waste
- Formation of secondary radionuclide solid phases under the hyperalkaline conditions with the development of different redox conditions in the presence of scrap materials.
- Variation of the diffusivity of radionuclides due to alteration of cement based matrices
- Generation of organic complexants
- Complexation of radionuclides by organics, either present or degraded from those in the waste forms, under high pH environments.
- Calcium as a competing metal for radionuclides towards the organic ligands
- Changes in strength, permeability etc

Ideas on Repository engineering (seals, support, backfill)

- Impact of saline groundwater
- Changes in pH (high/low alkaline fluids etc)
- Influence on corrosion
- Carbonation in response to back-reaction with bicarbonate in groundwater and carbon dioxide and bicarbonate generated by the breakdown of organic components in the waste
- Sulphatisation from reaction with sulphate-rich deep ground waters or from oxidation of sulphide minerals in the host rocks
- Impact of magnesium (from MAGNOX).
- Ground-freezing (permafrost).
- Sulphatisation /carbonation of CSH/CASH on radionuclide adsorption and retardation and potential re-release of radionuclides.
- Interfaces
- Cement/bentonite interactions
- Interactions and evolution of properties of low-alkali cements (pH<11)
- Metals/bentonite interactions
- Radionuclide sorption, formation of secondary solids.