**Performance of aged cement grouts for encapsulating radioactive wastes**

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Funding: EPSRC CDT in Nuclear Energy Futures & Radioactive Waste Management Ltd

The UK Geological Disposal Facility concept for low and intermediate level radioactive wastes is based on encapsulating the wastes in a cementitious matrix, typically a BFS/OPC or PFA/OPC grout, and surrounding the wasteform packages with a specialist high-alkalinity backfill grout known as the Nirex Reference Vault Backfill (NRVB). The backfill buffers inflowing groundwater to a high pH and provides sorption sites to immobilise radionuclides, hence maintaining chemical containment within disposal vaults. However, the cementitious matrix and backfill material will change over time and there is a great need to understand their long-term characteristics under repository relevant conditions.

The National Nuclear Laboratory (NNL) in partnership with Radioactive Waste Management (RWM) have conducted a ten-year hydrothermal ageing experiment to understand the evolution of these materials and the interactions between wasteform grouts and NRVB. The study, reported by Cann et al. [1], characterised the bulk and interface regions using SEM-EDX and XRD mineralogical analysis to study solid phases, selective dissolution to determine the extent of reaction, and acid neutralising capacity to determine the capability of the grouts to maintain a high pH environment. A further study on the remaining samples from this ageing experiment is required in order to fill knowledge gaps surrounding their interactions and evolution over long timescales.

The overarching aim of this PhD project is to develop a deep understanding of the chemical, microstructural and physical changes that occur due to long-term interactions between NRVB and wasteform grouts under repository relevant conditions. We will achieve this via a novel approach that combines thermodynamic modelling with quantitative microstructural analysis and mass transport characterisation. This will produce a rich dataset that will complement and extend the work from previous studies. Ultimately, the new knowledge generated will inform and strengthen the post-closure safety case of the UK Geological Disposal Facility.

The research will be carried out within the *Imperial Centre for Infrastructure Materials* with PhD training provided by the *EPSRC CDT in Nuclear Energy Futures.* The research consists of three interconnected technical work packages that will apply a range of advanced modelling and experimental characterisation techniques. We will use thermodynamic modelling [2, 3] to obtain a complete chemical understanding of the NRVB-grout systems up to ten years of ageing, and determine their long-term chemistry and indicative physical properties (e.g. porosity) at ageing times of 100s years and beyond. We will also perform quantitative microscopy [4], pore structure/solution characterisation and micromechanical studies at the bulk and interface regions. This will provide comprehensive understanding of microstructural gradients (pore structure, microcracking), solid phase assemblage, micromechanical properties and pore solution chemistry. Finally, we will evaluate the integrity of the cement grouts by measuring their resistance to mass transport (permeation, diffusion, absorption, conductivity) in fully saturated and partially saturated conditions [5]. The microstructural data will be used to complement thermodynamic modelling and mass transport properties to form predictive relationships. This will allow us to assess the effects of long-term hydrothermal storage on the barrier performance of wasteform grout-backfill systems.

The ideal candidate will be an enthusiastic and highly-motivated person who meets the academic requirements for enrolment for the PhD degree at Imperial College London. An interest in chemistry, microstructure and properties of cementitious materials is essential. You will have an inquisitive mind, strong intellect and hands-on rigorous approach to research. Good team-working and communication skills are essential.

For further information, please contact Dr Hong Wong (https://www.imperial.ac.uk/people/hong.wong).

References:

[1] Cann et al., 2019, Results from the hydrothermal ageing of BFS/OPC, PFA/OPC and NRVB samples for period of up to ten years, NNL Report #14929.

[2] Lothenbach et al., 2019, Cemdata18: A chemical thermodynamic database for hydrated Portland cements and alkali-activated materials, Cem. Concr. Res., 115, 472–506.

[3] Soler et al., 2011, Reactive transport modelling of the interaction between water and a cementitious grout in a fractured rock. Application to ONKALO, Appl. Geochem., 26, 1115-1129.

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[5] Wong et al., 2007, Mass transport properties of mature wasteform grouts, Adv. Cem. Res., 19, 35-46.