Long-lived radionuclide retention in the alteration products formed from high level radioactive waste glass dissolution

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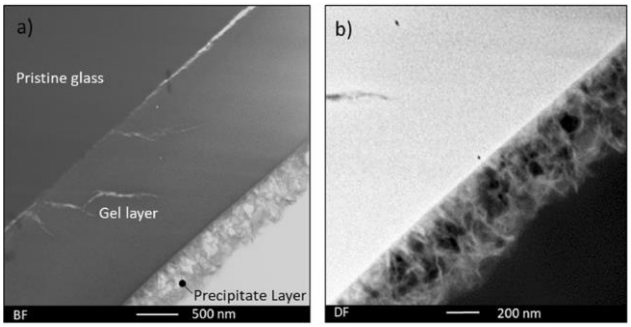
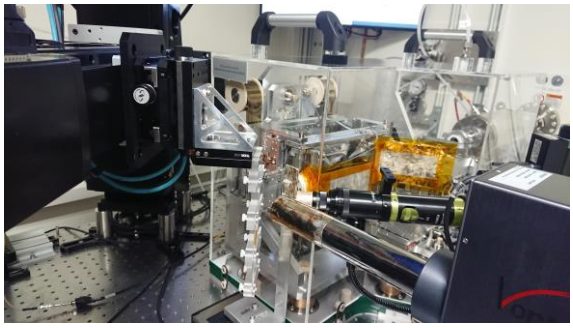


Secondary phyllosilicate minerals formed at the surface of radioactive waste glass upon leaching. Credit: Corkhill et al. Materials Degradation, 6, 67 (2022)



Photograph of the NSLS-II 4BM micro-focus spectroscopy beamline, where state-of-the-art characterisation of radionuclides sorbed to secondary mineral phases will be undertaken. Credit: Claire Corkhill

Project Background

The UK has generated a total of 1,460 m^3 of vitrified high level waste (HLW) from legacy spent reprocessing operations. This material is destined for disposal in a geological facility, where it will be safely isolated from future populations by an engineered barrier system. It is inevitable that, at some time over the next 100,000 years, that groundwater will penetrate the engineered layers of containment and the glass will start to slowly dissolve. Upon doing so, a range of secondary products, akin to rust, will form on the surface of the glass. These mineral phases are silica-based and include phyllosilicate clays, zeolites and amorphous silica. Many of these phases are mined from naturally occurring geological deposits, or are synthesised for commercial use: both are used in industrial processes as sorbents for heavy metals and other element species. This suggests that, when formed at the surface of HLW glass, they may be effective traps for any radioactive elements leached from the glass. This project aims to test this hypothesis and to determine the extent to which secondary mineral phases could retard the release of radioactive elements from the waste into the wider geological disposal facility.

Project Aims and Methods

This project explores the importance of secondary minerals in preventing the release of radioactive contaminants to the geo- and bio-spheres from high level waste in a geological disposal facility for radioactive waste. The proposed research has 4 key tasks:

1. Long-term glass leaching experiments will be established at the beginning of the project, and the fate of specific radionuclides in the alteration layer, formed over a 2 to 3 year period, will be determined using state-of-the-art synchrotron techniques at international user facilities.

2. We will synthesise (or acquire) and subsequently characterise a range of key alteration products known to form on the surface of UK simulant HLW glass, ranging from phyllosilicate clays to zeolites and silica gels. A wide range of mineralogical characterisation techniques will be applied, for example, x-ray diffraction, electron probe microanalysis, and electron microscopy.
3. Using these minerals, we will perform batch sorption experiments to determine the sorption capacity for a suite of relevant radionuclide elements, including anion (Se, I, Mo) and cation (Sn, Cs, Np) radionuclide species. Many of these experiments can be performed using "cold" isotopes (e.g. not radioactive), while others will require use of radioactive species, for which training will be provided. Through a rigorous characterisation campaign, including determination of the speciation and local chemical structure of the radionuclide elements sorbed to the mineral phases, combined with application of geochemical modelling codes, the mechanism of sorption of radionuclides to the mineral phases will ascertained.
4. The extent to which the sorption is reversible will be investigated by leaching radionuclide-contacted mineral phases in groundwater compositions that are representative of the two key geological localities that are currently under consideration for the location of the UK's geological disposal facility (Mercia Mudstone Group and the Ancholme Group).

The successful outcome of the project will be improved understanding of the extent to which secondary mineral phases could retard the release of radioactive elements in conditions representative of the geological disposal facility.

Candidate

This project would suit someone with a 1st or 2:1 Bachelor or Masters degree (or equivalent experience) in any of the following subjects: geoscience, materials science, chemistry, chemical engineering, physics, environmental science or related subjects. You must be prepared to work independently and also as part of a research team, and not be afraid to get things wrong before they go right (that's how the best science works!). You will be interested in problem-solving, learning skills in solid-state and aqueous chemistry and keen to get hands-on in the newly established, stat-of-the-art radiomineral laboratory in the School of Earth Sciences, as well as having a keen eye for identifying trends in data. You will become an expert in wielding a pipette and will get to work on solving a real-life problem with near-term societal benefit.

Training

You will join a cohort of students funded by the UK organisation responsible for safely disposing of the UK's radioactive waste, Nuclear Waste Services. The PhD students in this network are all researching topics related to radioactive waste disposal, from social science-related aspects to geoscience and materials science. As part of this cohort, you will benefit from scientific training sessions (e.g. geochemical modelling software training) with your peers as well as public engagement and science communication training. It is anticipated that you will have the opportunity to use these skills talking to the communities currently part of the geological disposal facility voluntary siting process. You will attend an annual conference of the Nuclear Waste Services researchers, exposing you and your research to a range of future employers.

The project will be supervised by Professor Claire Corkhill, who is one of the UK's leading experts in radioactive waste disposal. She advises the UK Government on matters relating to nuclear waste, and is often found chatting about radioactive waste on the TV (e.g. as a lead contributor to the Channel 4 documentary, Chernobyl: The New Evidence) and radio.

Background reading and references

For an introduction to the topic of radioactive waste management, please see: Corkhill and Hyatt, Nuclear Waste Management, IOP Publishing Ltd (2018). For an overview of radioactive waste glass dissolution experiments, please see: Thorpe et al., Forty years of durability assessment of nuclear waste glass by standard methods. npj Materials Degradation, 5, 61 (2021).

Useful links
http://www.bristol.ac.uk/earthsciences/courses/postgraduate/
Nuclear Waste Services
Nuclear Waste Services Research Support Office

Eligibility
Funding is limited to home students only.

Application deadline: 3rd May 2024 23.59 GMT

How to apply to the University of Bristol: http://www.bristol.ac.uk/study/postgraduate/apply/.

Please select PhD in Geology as the programme in the online application system.