14 Months and Counting

At the time of writing, we have only 14 months to go before the end of the TRANSCEND project in September 2023. Much has been achieved since we started the project in October 2018, and in spite of the global pandemic. Although our researchers at PhD and post-doctoral levels were all affected to some extent by its impact, they have worked tirelessly to achieve the original objectives of their individual projects and those of the collaboration as a whole, with the effects of covid on their work to some extent mitigated by project extensions funded from savings elsewhere on the project, and by the participating universities and key project partners. And despite the pandemic, new collaborations and working practices have been established between researchers at different universities through the sharing of facilities, new joint experimental and numerical simulation programmes of work, and the combination of research to generate novel techniques and strategies for waste management and decommissioning.

Notable achievements to date include (but are not restricted to):

- The development of novel synthesis methods for new materials to remove radionuclides from effluent
- Demonstration that behavioural modification techniques, implemented using additives, are able to improve the flow, mixing and separation of liquid-solid wastes during retrieval and post operational clean out operations
- Confirmation that the application of colloidal silica grout to repair damaged cementitious waste packages restores strength to fractured cement
- Demonstration that electrokinetics form an in-situ barrier that prevents radionuclide migration within soils
- The use of laser-based techniques to develop a spectral database for spent fuel applications which will be shared as an open-access resource for nuclear inspections and decommissioning applications
- Establishment of the properties and release behaviour of products arising from metallic and exotic fuel corrosion under 'partially wet' and post-closure, geological disposal facility conditions
- The use of experimental work to develop novel techniques for the measurement of water adsorption at actinide oxide surfaces (with measurements on PuO2 surfaces imminent)
- The use of comprehensive experimental programmes to reduce uncertainties relating to the use of ceramic/glass-ceramic waste forms for Pu disposal under conditions relevant to a geological disposal facility

Research findings are being comprehensively disseminated into industry and are already being incorporated into strategy developments for UK decommissioning. We also continue to make use of active facilities within the UK and overseas to add value to existing individual projects and provide valuable training for researchers. Flexi-funds have so far supported 9 active projects spread across 5 universities, with a further 2 projects under consideration.

In terms of overall impact, we continue to hold Annual and technical Theme Meetings, and attend other important dissemination events, with a number of challenge-led meetings planned for the near future to harness the collective experience of the consortium in meeting specific industry needs-led research challenges, in particular in relation to Pu management and digital twins. Additionally, the project is impacting on policy through academic membership of key governmental committees, advice to government reviews and the continued secondment of staff to BEIS. We also continue to develop our YouTube channel, and VR activity, exploring nuclear energy challenges and solutions, as well as a public outreach activity aimed at members of the public as well as schools.

Contents

This edition of the newsletter includes reports on various meetings, impact activities, researcher success and, most importantly, project progress. And a date for your diaries. The 3rd Annual Meeting of the TRANSCEND consortium will be held in Glasgow over 1st and 2nd November 2022 and we look forward to seeing you at the event. Updates and further details will be posted on our website (transcendconsortium.org) and on Twitter (@Transcend_epsrc) in due course.

I hope that you enjoy this newsletter.

Mike Fairweather

(M.Fairweather@leeds.ac.uk)

2nd Annual meeting - Harrogate 2021

Our 2nd annual meeting took place in Harrogate over the 10th and 11th November 2021. After nearly two years of online meetings it was a delight to hold the meeting as an in person event and have long overdue catch-ups with colleagues, researchers and industry representatives. For those unable to meet in person we also enabled online attendance.

Over 120 representatives from academia, industry and government bodies learnt about our latest research findings.

Keynote presentations were given by Rick Short (NDA), Katherine Eilbeck (Sellafield), Lucy Bailey (RWM) and Tom Rookes (BEIS).

Twenty-two technical presentations by TRANSCEND researchers covered the latest findings from our 4 themes: Integrated Waste Management; Site Decommissioning & Remediation; Spent Fuels; Nuclear Materials.

The thirty-six posters displayed throughout the proceedings created much interest during the networking breaks.

During the final session of the meeting the audience learnt about the National Nuclear User Facility (NNUF) and the GREEN and Nuclear Energy CDTs.

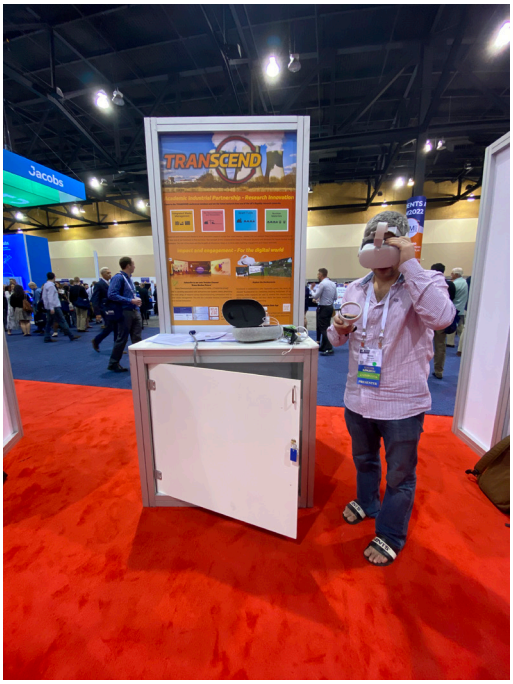
A drinks reception and meeting dinner were held in the magnificant surroundings of The Royal Hall, Harrogate.

TRANSCEND at WM2022, Phoenix, Arizona

WM2022 is the leading international conference for the management of radioactive waste and related topics. A large contingent of Brits attended as the United Kingdom was the featured country.

TRANSCEND once again had its own dedicated session which included seven presentations - providing an overview of the programme, our four research themes, active research and an industry perspective of TRANSCEND.

TRANSCEND also had a number of associated presentations in other sessions which were well received.



We also hosted a stand within the UK pavillion at which Ross Springell (University of Bristol) demonstrated the VR NuclearVerse experience which is currently under development.

TRANSCEND researchers Dominic Laventine and Elanor Murray received 'Superior' ratings for their papers. As did two of our associated students - James Kennedy and Serish Hussain.

Congratulations to two of our PhD students - Elanor Murray (University of Birmingham, Front row 2nd from right) and Angus Siberry (University of Bristol, Back row 3rd from left) - who were awarded Roy G Post Foundation Graduate Scholarships to attend the meeting.

Theme meetings - 2022

The 2022 Theme Meetings were held at Lancaster University over 24th & 25th May 2022.

Ninety attendees learnt about the latest research and developments in our programme and heard from some of our industry partners.

The meetings provided a variety of presentations and generated some stimulating discussions.

Posters from the meetings are on the TRANSCEND website.

Future meetings

The 3rd Annual Meeting of the TRANSCEND Consortium will be held in Glasgow over 1st & 2nd November 2022.

Industry challenge-led meetings are also being planned.

Updates will be posted on the website (transcendconsortium.org) and on Twitter (Transcend_epsrc).

TRANSCEND PhD student reaches finals in UK Young Persons Lecture competition

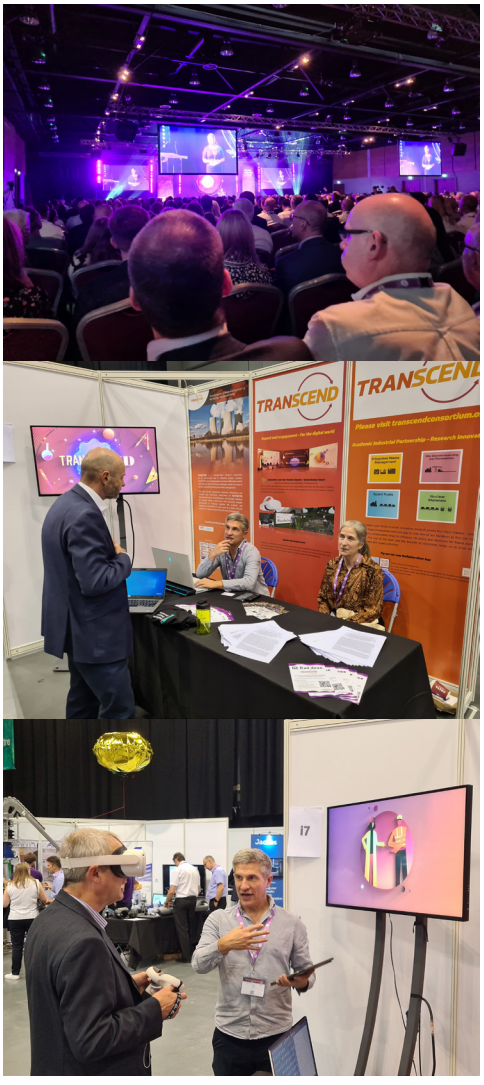
Congratulations to Angus Siberry (University of Bristol) who made it through to the UK final of the Institute of Materials, Minerals and Mining young persons lecture competition on 4th May. He was one of six finalists competing for the opportunity to represent the UK in the Young Persons World Lecture Competition.

NDA Supply Chain Event - Telford

Mike Fairweather, Ross Springell and Lois Tovey manned the TRANSCEND stand at the NDA's 9th Supply Chain Event held in Telford on 21st July 2022.

The event is aimed at attracting new business to the nuclear decommissioning sector and is now the largest event of its kind anywhere in Europe.

As well as raising the profile of TRANSCEND and introducing The NuclearVerse to the 1700 attendees, the event provided a good networking opportunity and a chance to re-connect with old friends.



TRANSCEND Impact

The NuclearVerse

TRANSCEND has a joint venture with AWE and the Royal Society of Chemistry that is funding the development of the 'NuclearVerse' - exploring nuclear energy challenges through VR.

Rad Dose

Research carried out as part of his PhD project has led Angus Siberry to develop an open-source web application - RadDose - a modelling tool to simulate the dose of radiation from radionuclide-containing solids exposed by surrounding media. Further information may be found here http://rad-dose.herokuapp.com/

Green Nuclear Future

TRANSCEND now has a YouTube channel. We will be gradually uploading videos about TRANSCEND and our researchers. https://www.youtube.com/watch?v=jVjX-V4FqspU

rad dose

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TRANSCEND

NATIONAL NUCLEAR LABORATORY

Sellafield Ltd

Project progress

The following pages include updates on the progress of our research projects.
If a researcher has listed something that you and/or your organisation can help with, we strongly encourage you to get in touch. Engagement and collaboration (academic and industrial) remains a priority of the consortium. Please email Dr Lois S. Tovey (l.tovey@leeds.ac.uk) in the first instance.

Electrokinetic remediation application to soils, concretes and other site and process wastes (including EDTA-containing wastes)

Shaun Hemming,
PhD,
University of Southampton

Research:

- Designed, developed and delivered novel series of electrokinetic remediation experiments on difficult-to-measure radionuclides (DTMR) in groundwater simulants and soils
- Will shortly be starting electrokinetic remediation experiments on DTMR contaminated concretes with University of Leeds
- Contributed to design of novel zeolite-based remediation methods for technetium-contaminated wastewaters
- Continuing to liaise with TRANSCEND and external partners to develop electrokinetic remediation technologies

Characterisation of thermal treatment products

Daniel Parkes,
PhD,
University of Sheffield

My project is focused on the thermal treatment of intermediate level waste (ILW). ILW has a wide range of different compositions and a wide range of different potential thermal treatment options. To look at them all is beyond the time scale of this project, therefore several industrial samples have been selected to investigate. Valingar have carried out several inactive trials for the thermal treatment of Plutonium Contaminated Material (PCM) using plasma processing. Two of the five trials had remnant material available for analysis. Initial basic characterisation has been carried out including XRD, XRF, acid-digest and ICP analysis and SEM. The samples have also been crushed and washed ready for PCT dissolution experiments to analyse durability. Future work will involve trying to produce lab simulants of the Valingar melts with the addition of Ce as a simulant for Pu. These will be analysed to assess the concentration and distribution of the Ce across the sample, focusing on the partitioning between the glass matrix and any crystalline phases. PCT tests will also assess the durability and potential leaching of Ce out of the waste form. Geomelt is another major thermal treatment technique that has been trailed in the UK, but it is not currently in the plans as a thermal treatment for ILW. In the USA however Veolia Nuclear Solutions Federation (VNSF) have carried out many inactive trials for both US and international waste including simulants from Fukushima in Japan. Veolia have provided four glass samples, initial basiccharacterisation has included XRD, XRF, acid digest and ICP analysis and SEM. The samples include inactive Cs and Ce, and further analysis will investigate the distribution and partitioning of these inactive simulants. The samples have also been crushed and washed ready for PCT dissolution experiments to analyse durability and the potential leaching of the simulants.

New materials and methods for decontamination of effluent

Anthony Nearchou,
PDRA,
University of Birmingham

Research Progress and Impact

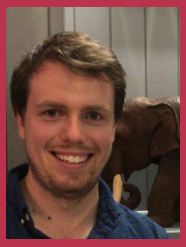
I have been optimising the synthesis of umbite materials for prospective use in abatement of radioactive Cs-137 and Sr-90 from nuclear waste streams.
I have studied how the Cs and Sr exchange properties can be enhanced through a pre-treatment process, much the same as is done for clinoptilolite used commonly in industry. I have successfully integrated umbite and clinoptilolite materials into extruded pellets that will improve mechanical handling and industrial deployment in exchange columns and flow systems. The pellet procedure has been optimised to ensure that the pellets are stable under caustic conditions and retain their selective ion exchange properties. In addition, I have been preparing and characterising some new materials that may be of interest to the nuclear remediation industry.
I have also spent several months working alongside the NNL on a project as part of the Advanced Fuel Cycle Program (AFCP). This included considerable overlap with the work as part of TRANSCEND, researching new materials for selective abatement of Cs-137 from caustic salt solutions. This project provided transferable skills and knowledge which I have fed into my research as part of TRANSCEND. Impact wise, it has fostered new collaborations and resulted in a Case Study article published on the AFCP website and a manuscript in preparation for publication.

Nanotechnology for effluent treatment, radionuclide assay and repair of ageing facilities

Gurpreet Singh,
PDRA,
Imperial College

Previous work has demonstrated a high uptake capacity for selective removal of uranium from solutions using a phosphate-coated magnetic nanoparticle. However, the synthesis process to develop these novel nanoparticles is highly complex and lengthy and the particles can only be used in neutral and alkaline environments, which limits their use within the nuclear sector. The current work is focused on demonstrating similar level of performance (even at acidic pH), by synthesising these novel magnetic nanoparticles using a low-cost and simple work-up procedure. Latest progress on this project has demonstrated successful synthesis of spherical magnetite nanoparticles within a narrow range of 15 to 20 nm, with low polydispersity index. This step can be upscaled to large volumes using cheap raw materials and within a total run time of less than 60 minutes from start. Present efforts are focused on optimising the procedure for coating these magnetite nanoparticles with a well-defined 3 to 5 nm layer of silica coating to withstand acidic conditions. Currently, there are some challenges to achieve this coating uniformly over individual magnetite particles, due to its high surface energy, which causes aggregation and thus form multi-cores. Solutions, such as introducing a surfactant, or altering the coating procedure is under evaluation to mitigate this problem.

Development of Zeolite Composites for Removal of Caesium and Strontium from Aqueous Nuclear Decommissioning Waste



James Reed
PhD,
University of Birmingham

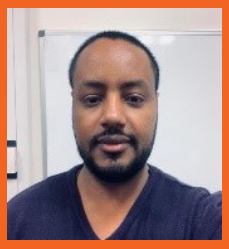
An industry requirement exists to develop innovative materials that have the capability to remove key radioactive species from waste effluent streams. The ability of natural zeolites (clinoptilolite and mordenite) to encapsulate strontium has been shown to increase through chemically-controlled partial phase transformations, where more aluminium-rich frameworks (GIS,CHA) are crystallised. Composites with ~50:50 ratio of phases have been shown to exhibit promising dual-uptake properties: high levels of caesium and strontium uptake are observed. This is a particularly important trait, considering the dwindling supply of Mud Hills clinoptilolite, a natural zeolite material which has been utilised at the UK's Sellafield site for >30 years due to its high affinity for both caesium and strontium. Larger, column ready zeolite composite particles have now been generated and are undergoing active laboratory-scale trials which closely mimic the dynamic effluent treatment process utilised at the Sellafield site.

Particle-laden flow characterisation and prediction

Lee Mortimer,
PDRA,
University of Leeds

- Flows relevant to nuclear waste processing have been shown to be sensitive to various bulk flow chemical and physical properties, as well as the presence of additives such as nanoparticles or polymers. In order to gain insight into and develop such behavioural modification techniques, binary particle interactions have been studied using a high-fidelity immersed boundaries technique alongside direct numerical simulation. The effects of modifying Hamaker constant, ionic strength, coefficient of resitution, temperature and turbulence strength have now been studied, with the results published in Physics of Fluids earlier this year. A novel particle and polymer-laden flow technique based on the finitely extensible non-linear elastic dumbbell model has been developed, implemented, and validated. After using the method to consider the effects of polymer-induced drag reduction on particle-laden flows, the technique has now also been extended to account for polymer-particle interaction. This is presently being used to provide insight into the potential and feasibility of using polymer additives to tune agglomeration and dispersion properties for nuclear waste transport flows. A novel polymer-particle interaction modelling technique based on electrostatic adhesion has now been developed and implemented and is being in the process of being tested and applied, with aims to augment the relevant TRANSCEND experimental projects.

Simulation of complex particle flows



Bisrat Wolde
PhD,
University of Leeds

The overall aim of this study is to address fundamental technical difficulties that are encountered within the nuclear industry. Developing and facilitating approaches for safer, cost-efficient waste management and decommissioning is the focus of the research. Understanding and modelling pond and silo sludge behaviour is essential to the management of radioactive wastes. In legacy ponds and silos, for example at Sellafield, characterising how sludges and slurries containing dense particulates will behave is vital for post-operational clean-out operations. The aim is to establish a predictive tool to support POCO operations through improvements in the flow, mixing and separation of wastes during retrieval and POCO operations.

A direct numerical simulation carried out for a fully developed turbulent pipe flow at three different turbulent bulk Reynolds numbers, Re_b= 3975, 5300 and 11,700. The use of behavioural modifications to fluid and solid particle properties to promote desired outcomes such as reducing particle agglomeration will be considered. This has entailed the implementation of two-way and four-way coupling between the particles and the fluid flow, as well as the incorporation of models for particle collision and agglomeration. Modifications of fluid and solid particle properties present in the inventory can be implemented practically by changes in temperature, ionic strength and pH of the liquid-phase, and injecting additives such as polymers into the liquid phase that will attach to the particles, modifying their surface properties. These modifications will change the way particles interact by affecting van de Waals forces, the restitution coefficient and electric double layer repulsion forces.

Simulations of Processes at and across Nanoparticle-Water Interfaces

Ella Schaefer,
PhD,
University of Manchester

Background: Irradiated nanoparticles (NPs) in aqueous environments have relevance to both the health and nuclear industries. This is due to the chemical changes the irradiated NP can cause in the surrounding media, such as the formation of •OH radicals, low energy electrons and H2.1,2 Low energy electrons and •OH radicals cause DNA damage to cancer cells during radiotherapy,3 and as NP interfaces are present in nuclear waste, the formation of H2 is highly relevant to nuclear safety cases.4 The aim of this project is to cultivate an integrated account of all the processes that can occur at the NP-water interface.
Progress: A simulation method has been developed through the use of TOPAS software, that allows the user to deposit radiation into a NP within a hollow water sphere and calculate the resultant radial dose distribution. This simulation has been run with various NP species (Au, Al2O3, Mg(OH)2 and water) of different sizes, densities and irradiated by a range of both high and low photon energies. Additionally, a process for detecting where an ionisation or excitation occurs in a water sphere, following NP irradiation, has been created.

Durability of Magnesium-Silicate-Hydrate Cements made from Brucite

Mercedes Baxter-Chinery,
PhD,
Imperial College, London

The main focus of my work has been optimising a cement mortar using magnesium hydroxide as a main raw material. Through various iterations and improvements, positive results are starting to be achieved, with the formation of the desired products and requirements being met. These systems are being adapted to fully optimise the formation of M-S-H whilst also maximising the proportion of magnesium hydroxide used.

Long term characterisation, durability and mechanical tests have also begun on the original magnesium oxide – silica system optimised by Zhang (DIAMOND). These will provide comparison for the magnesium hydroxide system and also insight into the influence of time on the properties of M-S-H cements.

Radiation effects on nuclear waste forms

Tamas Zagyva
PhD,
University of Manchester

- The recycling of used nuclear fuel in the UK produces highly radioactive liquid wastes with high molybdenum contents. The final wasteform that is destined for long-term storage is a glass-ceramic material containing powellite ($CaMoO_4$) crystals. The effects of radiation on this high-level waste glass-ceramic wasteform must be understood to be able to predict its durability over timescales of many thousands of years.
- Non-active glass-ceramic samples were provided by National Nuclear Laboratory. X-ray diffraction measurements revealed the presence of 5 common crystal phases. Electron microprobe analysis showed that rare earth elements (surrogates for radioactive actinides) mainly accumulated in powellite, zircon and ceria-zirconia. Nickel and Au irradiation experiments were performed to test the radiation tolerance of all phases. Scanning electron microscope and electron backscatter diffraction measurements showed that ceria-zirconia, zincochromite, and RuO_2 were highly radiation-tolerant phases while powellite and zircon seemed to amorphise and swell considerably. The swelling of crystals was more substantial in the Au irradiated sample. Cracks formed in the samples, presumably due to the thermal expansion mismatch and they became wider after the irradiation.
- Powellite was previously known as a highly radiation-tolerant material. Therefore, further ex-situ and in-situ transmission electron microscope analyses will be performed to fully understand the irradiation-induced microstructural effects on powellite. There are also ongoing Raman and electron paramagnetic resonance spectroscopy measurements on He irradiated glass samples to examine alpha particle irradiation effects in the base glass.
- This research will provide new insights into the behaviour of glass-ceramic nuclear waste under environmentally-relevant conditions.

Process Monitoring of Thermal Treatment of Radioactive Wastes

Alex Stone,
PhD,
Sheffield Hallam University

Wastes selected and loaded into mixture windscale (MW) and calcium zinc (CaZn) glass surrogates over a range of 30-80% WL. Off-Gas analysis and capture system has been developed and validated using impingement method of capture from a heated furnace up to 1150°C. Waste loaded glasses have been tested for caesium volatilisation in this system over 0-2wt% doping with Cs_2CO_3 by capture and analysis by ICP-MS. This is to ascertain the volatilisation behaviour of radioactive waste melts for pollutants such as caesium and some halides. In the future we plan to investigate ways of reducing and controlling these emissions and investigating other pollutant gases from raw ILW.

Understanding glass melt chemistry in thermal treatment of nuclear waste

Lucas-Jay Woodbridge,
PhD,
University of Sheffield

The main body of work has focussed on the vitrification of the ion exchanger ionsiv IE-911 in order to have a proof of concept with the idea that vitrification of ion exchangers is a suitable method of waste form consolidation which exceeds the loading found when batched as a glass from oxides/ carbonates. Otherwise, some work has been done on the vitrification of iodine using calcium-aluminosilicates and a preliminary look into Clinoptilolite to use as ionsiv has been, providing a positive outcome from the ionsiv experiments is seen.

Use of colloidal silica grout for inhibiting airborne and waterborne radionuclide migration

Arianna Gea Pagano
PDRA,
University of Strathclyde

Recent work within WP 2.1 has focused on an experimental investigation to explore the suitability of colloidal silica grouting around radioactive waste prior to removal, to reduce radiation exposure during nuclear waste retrieval operations. Such applications require evidence that colloidal silica hydrogel can maintain its integrity upon exposure to temperatures higher than ambient, typical of the nuclear waste stored within pools and silos.

The experimental investigation was carried out to simulate colloidal silica grouting operations around objects at temperatures higher than ambient, up to a maximum of 120 °C. The effect of the temperature of the grouted object, and of the silica grout properties, on the performance of the gel was explored by carrying out a) microstructural analyses by x-ray imaging, to detect the presence and spatial distribution of temperature-induced cracks within the gel, and b) mechanical tensile and shear strength tests on gel samples at different temperatures and silica concentrations. The experimental results confirmed the potential of colloidal silica grouting for spent fuel removal applications.

Additional work is currently being carried out to assess the feasibility of in-container vitrification of soils grouted with colloidal silica, in collaboration with the University of Sheffield.

Electrokinetic remediation (EKR)

Jamie Purkis,
PDRA,
University of Southampton

Recently completed):

- **year-long experimental series on in-situ barriering technologies (Ferric-iron remediation and stabilisation) in real nuclear site materials for sorption; two papers, one being written and one shortly to appear in press**
- **Work exploring scalable electrochemical degradation methods for PFAS remediation (of relevance to nuclear as PFAS are common fire retardants); paper shortly to appear in press**
- **developing and testing novel sorbent materials for Cs/Sr remediation with University Hospital Lausanne in Switzerland; paper shortly to appear in press**

Ongoing):

- **collaborations with AWE, NNL, NDA, and Universities of Reading and Bristol developing sustainability assessments for electrokinetic remediation, possibly coupled with phytoremediation. Shortly to appear in press**
- **Ongoing collaborations with University of Strathclyde, will shortly be starting silica gel grouting work for borehole engineering at nuclear sites**
- **temporal assessment of radionuclide changes in vulnerable coastal mashes using X-ray fluorescence**
- **development of a decision support tool (DST) to support options appraisal for the nuclear decommissioning process (with NDA/NNL)**

In-situ groundwater monitoring to improve identification of ground/ soil contamination volumes and associated contamination in ground infrastructure that may remain at the Site End State

Soraia Elisio,
PhD,
Lancaster University

- Proposal submitted on Characterisation and monitoring using existing in-ground assets in collaboration with Hybrid Instruments Limited, and first stage accepted on Sellafield Game Changers.
- Design and detector components have been selected. CAD drawing of sensing probe completed and construction/assembly underway.
- Design of the soil pipe arrangement to replicate the in-ground blind-tubes set on site. CAD drawing and selection of components completed and construction/assembly underway.
- Modelling and laboratory experiments are underway to validate the concept and calibrate a single detector in a soil pipe arrangement that replicates the in-ground blindtubes set on site.
- Clearance necessary to have access to Sellafield site and official-sensitive information underway.

Predicting Gamma Dose Rates with Limited Information

Luke Lee-Brewin
PhD,
University of Surrey

- Over the last 12 months my research has explored the use of wavelet analysis and neural networks for nuclear decommissioning radioisotope identification. Wavelets can be a powerful tool for count starved data; I have developed a genetic algorithm which identifies optimal parameter weightings for a wavelet method designed to extract photopeak locations. Separately I have explored the use of neural networks and coded an algorithm capable of identifying isotopes in challenging deployment scenarios. Testing of this algorithm has shown that it can identify the presence of up to 5 isotopes simultaneously from spectra collected in a range of shielding conditions, including those the algorithm has not been directly trained on. Presently a second neural network is in development, the intention is to predict the percentage of counts belonging to each isotope which will support activity determination. Initial results are promising and research into the effect of shielded spectra on the accuracy of this algorithm has begun. I have maintained productive conversations with my industrial sponsors; aspects of my neural network algorithm and research results will be presented as part of the IEEE Nuclear Science Symposium and Medical Imaging Conference 2021.

Assessing the strength of biomineral strategies for concrete repairs

Thanos Karampourniotis,
PhD,
Univerity of Strathclyde

Microbially Induced Carbonate Precipitation (MICP) via urea hydrolysis, is a novel alternative grout that offers the potential to seal small aperture fractures with calcium carbonate. It takes advantage of the mineralization properties of certain types of bacteria where together with a calcium source can form calcium carbonate crystals on their surface. This method has given promising results to fields like ground improvement and sealing fractured rock but has not been extensively researched on repairing concrete cracks.
Research Progress:
During the first year of this project, a Finite Elements Model was developed and calibrated against experimental data on MICP, based on existing literature. In the second year of the project, fractured and degraded concrete cores are treated with MICP. After the treatments, the concrete cores will be tested for their mechanical strength and the collected data will be used to validate the created Finite Elements Model.
Impact:
Currently commercialized concrete repair methods can be ineffective when treating micro-cracking and in need of periodic care and maintenance due to low durability, rendering MICP a promising alternative. The objective of this PhD project is to provide the necessary knowledge to progress in field-scale treatments of degraded concrete, that could eventually lead to the commercialization of the method.

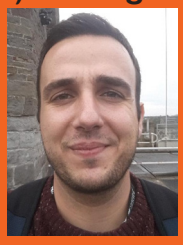
Fungal Biomineralization for Concrete Repair

Jason Erikson,
PhD,
University of Strathclyde

Nuclear sites comprise huge volumes of concrete assets, which are exposed to differing environmental conditions resulting in variable mechanisms, and rates of, concrete degradation. For example, external concrete building facades may be exposed to freeze-thaw and high salinity, whereas some internal concrete structures may be exposed to high temperatures and high levels of radiation. This project is focused on developing a novel technology for repair of concrete on nuclear sites. Traditional and established methods for concrete repair, disposal and decontamination are expensive, time-consuming and can result in the spread of contaminated particulates over large areas. In recent years there has been significant interest in microbially-induced bmineralisation for concrete repair. Biomineral technologies are: non-destructive; durable; and can significantly inhibit radionuclide migration. Although it is referred to as "microbially-induced", research to date, has mostly focussed only on the utilisation of bacteria, with very few resources devoted to studying how other microbes, such as fungus, might be useful in these applications. This research seeks to determine the effectiveness of fungal-induced biomineralisation as an alternative to bacterially-induced biomineralisation, and to assess potential benefits that may be gained from the utilisation of fungus instead of bacteria.

An initial experimental screening programme has been carried out investigating: (i) growth rate and (ii) ureolytic activity of six basidiomycota fungal species, the latter of which is required to precipitate carbonates via the desired pathway. Lyophyllum decastes and Pleurotus cornucopiae were identified as being the most ureolytically active. Preferences in different growth behaviours was also observed among the six fungalspecies (i.e. preference for surface growth
vs subsurface growth). Further research will investigate the ability of these species to precipitate carbonates in terms of both time required for mineral precipitation and total mass of biomineral precipitated.

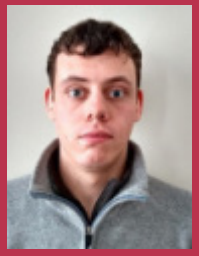
An Investigation of Corrosion and Leaching of Carbide Fuels in a Geological Disposal Facility (GDF) Setting



Dimitris Samaras,
PhD
University of Bristol

A sample disintegrated whilst being cut, revealing its interior to be in powder form, in contrast with the solid surface of the pellet EBSD conducted on the second pellet displayed little to know useful information
X-Ray Diffraction on the salvaged powder revealed peaks that do not match the ones predicted for the monocarbide (usually the most common stoichiometry); however, there seems to be a correlation between simulated peaks for sesquicarbide. A uranium oxide peak was also identified. Further analysis is to be conducted on this.

MOX SIMFUEL - development of simulants



Ian Robertson,
PhD,
Lancaster University

As practice for working with uranic material homogeneous europium doped cerium oxide powders have been produced via the mixed oxalate process.
Both the oxalate and oxide materials have been analysed with XRD, 3-beam Raman spectroscopy and Scanning electron microscopy.
Mixed oxide pellets have been produced via the mixed oxalate co-precipitation route used to produce homogeneous mixed oxide powders. The intended powder composition used to fabricate the pellets was 90 mol.% uranium and 10 mol.% cerium.
These pellets will be compared to pellets fabricated from a heterogeneous mixed oxide powder to compare differences across a variety of analysis.
The pellets are currently undergoing surface analysis and conversion into electrodes as to be used in the measurement of open circuit potentials, cyclic voltammograms and electrochemical impedance in a variety of conditions relevant to geological disposal.

Predicting the Alteration of Spent Nuclear Fuels

Joshua Bright,
PhD,
University of Surrey

Ensuring the safe surface storage of spent nuclear fuel (SNF) over short-term and long-term timescales is difficult. There is significant uncertainty around the alteration and mobilisation of uranium within SNF pools and silos. The alteration products are expected to be similar to naturally occurring uranium minerals, of which more than 250 are known to exist. Understanding the alteration and transportation mechanisms of SNF is key towards providing solutions for the safe storage and disposal of SNF

Aims & Objectives

- This work aims to predict the alteration mechanisms and products of SNF.
- Real time, in situ spectral characterisation and computational modelling of SNF analogues and identification of their alteration products performed under different key environmental conditions (e.g. water, saltwater and water with hydrogen peroxide).
- Experimental characterisation and computational modelling of possible interference from known alteration of Magnox alloys, brucite (Mg(OH)2).

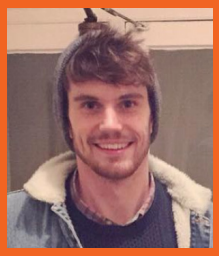
Progress

Experimental characterisation and computational modelling of the Raman and IR spectra of brucite.

Time Resolved Laser Fluorescence Spectroscopy (TRLFS) data obtained for hydrogen peroxide brucite.

- Experimental Raman and TRLFS spectra obtained for a selection of uranyl oxide hydrates.

A Predictive Tool for Spent Fuel Behaviour



Angus Siberry
PhD,
University of Bristol

Multi Scale modelling using COMSOL/FACSIMILIE alongside testing the MOOSE Finite Element framework to predict the behaviour of spent nuclear fuel (SNF) in multiple disposal scenarios. The models will be used to test alongside experiments to better understand scenarios such as failed waste inside legacy ponds to exposed UO2 in a long-term Geological Disposal Facility (GDF).

Aims & Objectives

- Build an improved Radiolysis model incorporating effects from geometrical considerations to H2O2 and H2 profile from the interface
- Incorporate radiolysis model to a suspended particle dissolution model
- Predict chemical behaviour of suspended particles of SNF in legacy fuel pond storage
- Create a comprehensive 2D dissolution model of UO2 in multiple scenarios
- Design and test a Uranium particle dissolution experiment to test surface area to volume effects on rates of dissolution
- Implement work done on UO2 single and polycrystalline thin films to investigate grain size effects on dissolution rates

Progress

Successfully implemented a model based on work by L Wu (2014) of a 1D chemical reaction and diffusion model in COMSOL

Contact Angle Measurements and Wettability of PuO_2 surfaces

Dominic Laventine,
PDRA,
Lancaster University

At the University of Lancaster, we have continued our research into surface chemistry of PuO2 under humid storage conditions using thin-films of PuO2 and PuO2-structural analogue surfaces, particularly CeO2, UO2 and ThO2. Electrochemical experiments have been performed on doped UO2 and PuO2 surfaces in organic electrolytes. Initial results that indicate a change in semiconductor behaviour upon oxidation at potentials that may exist under storage conditions due to radiolytic production of peroxide from water. Further measurements are being undertaken on UO2 SIMFUEL pellets to confirm these results are independent of the electrolyte used and determine whether dissolution into the organic solvent is occurring.

We have designed and built an imaging system capable of visualising thin-film surfaces under controlled humidity and measured the contact angle of water droplets on PuO2 analogue surfaces at a range of humidities and calcination temperatures. Measurements of CeO2 and UO2 contact angles are underway. Funding for alpha particle bombardment to simulate aging of radioactive material at DCF has been approved, allowing the future measurement of contact angle and wettability of ages CeO2 to determine the effect of radioactive aging on these parameters.

Characterisation of AGR Fuel and its Behaviour During Drying

Thomas Bainbridge,
PhD,
University of Leeds

A code has been written which will allow images of a crack to be analysed and allow for the user to determine the length and average width. This is done using the image analysis package in MATLAB. The skeleton function is used to find the path length along the centre of the crack being processed. In doing this the image used is converted to a black and white image. The number of black pixels is counted and divided by the calculated path length. These parameters are then fed into another MATLAB code which models the flow of gas through the cracks. Various approaches have been tried including averaging the predictions of three different methods to produce a model which fits the experimental results as best as possible. In addition to this, rigs have been designed to allow for accurate measurement of flow through both small pinholes as well as the cracks in stainless steel. One of these rigs is built and will be commissioned soon with the aim of using drop evaporation to produce cracks which are representative of those found in the cladding as a result of intergranular stress corrosion cracking.

Development of Micromechanical Testing Methods for Spent AGR Cladding to Examine Effects of Sensitisation and Stress Corrosion Cracking

Kuo Yuan
PhD,
University of Bristol

A new micromechanical testing method based on the standard Small Punch Test has been designed, where circulation of corrosive solution and Digital Image Correlation is introduced in the set-up. With the new design, only a small piece of ex-service fuel cladding material is required to monitor the SCC behaviours in corrosive environment. Additionally, a study on the relationship between sensitisation and grain boundary conditions have been carried out to supplement the main topic of the PhD research, which has been presented at EuroCorr 2020 and EuroCorr 2021.

In-situ Identification of Surface Corrosion Products on Spent Nuclear Fuels

Victoria Frankland,
PDRA,
University of Surrey

Work has continued on the spectroscopic characterisation of potential spent nuclear fuel (SNF) alteration products using laser-based techniques, principally multi-laser Raman and time resolved laser fluorescence (TRLFS). Detailed characterisation of a wide range of uranyl minerals1-4 obtained from national reference collections has allowed a database to be constructed that can now be used in a priori phase identification studies. In the past year, a new laser-induced breakdown spectroscopy (LIBS) system has been commissioned to augment this capability, providing compositional information. A methodology has been devised for application of these methods using sequential analysis for initial identification and subsequent differentiation of similar species at various stages of hydration5-6.

The data outlined above, combined with XRD, SEM-EDXA and crystal structure modelling has allowed us to obtain simulated Raman spectra, Raman modal assignments, projected density of states (PDOS) and band structures. To date, four papers have been published with a further two under review and four more in

Atomistic simulation of Am incorporation into PuO_2

William Nielson,
PhD,
Lancaster University

The project's initial ambition, to understand how Am ingrowth into PuO2 changes the properties of the stored material, has been accomplished. We have combined defect energies, calculated using density functional theory (DFT) and vibrational entropies, determined using empirical potentials, to create a point defect model to predict how the defect chemistry of PuO2 evolves due to the incorporation of Am. This enabled us to make new predictions about the aging characteristics of the material, with full results now published (J. Phys. Chem. C 2021, 125, 28, 15560–15568). Subsequent work has investigated He ingrowth in PuO2, where uniquely we considered the role of Am on the accommodation of He in the PuO2 crystal; this work has been submitted for review. Current work has moved onto simulating PuO2 nanoparticles. This aims to be more representative of the stored material, which is in a powder form, compared to our previous work where only the bulk of the material was considered.

Quantum chemical modelling of PuO_2 surface chemistry

Xiaoyu Han
PDRA
University of Manchester

Recent work has focussed on modelling water adsorption on point-defect ThO_2 111 surface, which we study as a surrogate for PuO_2. Both H adatom and O vacancy surface were considered. We are currently preparing a manuscript entitled "Computational study of water on the point defective ThO2(111) surfaces".

Simultaneously, we have begun studying PuO_2 using the DFT+U approach; the effect of the Hubbard U factor on PuO_2 bulk has been systematically studied. The surface energy, density of states, water adsorption and dissociation are all found to be highly dependent on the choice of the U factor.

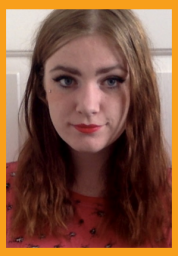
We are also studying the dual molecules, i.e. NO and water on PuO_2 (111) surface, to study the reaction energy and its products.

Gas Generation from the Radiolysis of Water on Uranium and Thorium Oxides

Chris Anderson,
PhD,
University of Manchester

This project aims to investigate modified hydrogen yields when an oxide interface is introduced to radiolytically decomposing water and the processes which govern the modification of said phenomena. The oxides used are not limited to those that are active, encompassing a broad spectrum of those used as surrogate materials of nuclear fuels.
To thoroughly investigate the aforementioned statement, significant time and effort has been devoted to improving experimental systems that measure radiolytic hydrogen yields. As such, a radiation resistant and modular manifold has been constructed. This manifold is capable of exposing samples to very high levels of radiation whilst keeping its functionality and automated control, gaseous control being provided by solenoid valves that have undergone extensive radiation hardness testing. The impact of this apparatus could be very significant for the field of radiolysis as it can provide live monitoring of gaseous production in-situ during irradiation, a first for this form of experiment.
As the mechanism behind enhanced radiolytic hydrogen production is largely unknown, experiments have been planned to explore some of the more commonly cited mechanistic processes. One such experiment being undertook in the project is investigating the band gap of a hydrogen enhancing oxide (ZrO_2) and modifying it via doping to assess changes in the hydrogen yield. The impact of successful data could determine the suitability of such mechanisms in the literature. Upcoming work within the project will explore the hydrogen yield when water radiolytically decomposes on a thorium dioxide interface.

Atomistic Simulation of the ageing of PuO_2



Elanor Murray,
PhD,
University of Birmingham

Have begun using molecular dynamics (LAMMPS) to simulate helium incorporation in PuO_2. Have increased helium bubble sizes in the lattice used the nudged elastic band technique to investigate helium atoms joining and leaving bubbles. Helium diffusion has also been simulated and have found plutonium vacancies to be a trap site for the helium atoms. Will be giving a poster presentation at WM2022.

The Radiolysis of Water over Plutonium Dioxide: A Study of H_2/O_2 Recombination Processes

Cameron Williams
PhD,
Lancaster University

The project has progressed by examining available literature to gain a deeper understanding of the currently proposed mechanisms and the theorised impact of the PuO_2 surface on the recombination process. This information was utilised to construct an experimental regime that could be used to gather data to shed some further light on the mechanism at work in the recombination reaction.
An experimental system is currently under construction and will utilise a sealed pressure vessel which will contain the metal oxide powder (CeO_2 in this initial phase) and the gas atmosphere. This atmosphere will contain H_2, O_2 and Ar gases who's relative concentrations will be varied from very low ratios (0.4:0.0:99.9 and 0.0:0.4:99.9) up to higher ratios (1.0:0.4:98.6 and 0.4:1.0:98.6). This range of concentrations will allow for an examination of the impact of not only the amount of H_2 and O_2 in the system but also the relative ratios of these components. This data will ideally be used to determine if either of the two leading mechanisms are at work – these being the Langmuir-Hinschelwood and Eley-Rideal mechanisms.
Following on from this data collection there are many avenues for further investigation included analysing the morphology and oxidative composition of the metal oxide powder. There are also plans to move on to active work to consider how radiation may alter the mechanism of recombination by providing additional radiolytic reaction pathways.

Disposability of wasteforms for plutonium immobilisation and efficacy of surrogates

Chris Dixon-Wilkins,
PDRA,
University of Sheffield

Work until this point has focussed on examining the durabilities of U and Ce doped zirconolite glass-ceramic composites (CaZr0.9M0.1Ti2O7 ceramic in Na2Al2Si6O16 glass). Cold-press and sinter (CPS) glass-ceramic composites have been produced under air, Ar, and H2/N2 (5% H2 in N2) atmospheres, and the same compositions also produced by hot isostatic pressing (HIP). The durabilities of these glass-ceramic composites have been examined by contacting monoliths of material with different dissolution media (UHQ water, 19 mM NaCl + 1 mM NaHCO3, and 0.01 M HNO3) at 40 °C, with aliquots of the solution removed at regular time points.
Initial analysis of the observed rates of elemental dissolution suggests an early regime of rapid dissolution (from 0 to 0.5 days) followed by a second, slower regime. This is likely caused by the formation of protective layer or secondary phase at the surface, though characterisation of the post-dissolution materials is on-going. Current work is focussed on the synthesis and characterisation of zirconolite ceramics with the same composition as the ceramic phase in the glass-ceramic composites already studied (CaZr0.9M0.1Ti2O7, M = U, Ce). Once suitable materials have been produced, their compatibility with HIP and their aqueous durabilities will then be examined as a comparison to the glass-ceramics composites.

Advanced characterisation for suspension waste pipe flows with acoustic backscatter and behaviour modification polymeric additives.

Joseph Hartley,
PhD,
University of Leeds

Understanding of the acoustic theory and its application to acoustic backscatter systems to determine sediment characteristics, specifically the concentration independent sediment attenuation coefficient, has been undertaken. Training in the use of Python coding language and proficiency in using this platform for data analysis has also been completed. Preliminary acoustic backscatter data for sediment particle size analysis of two sizes of as received spherical glass beads has been collected. As well as some control data on sediment particle size from a Malvern Mastersizer 3000. Sediment attenuation coefficients were calculated for both in situ and ex situ probes for these data which included data gathered at 2MHz and 4MHz frequencies. A sieve shaker has been setup to narrow the particle size distribution (PSD) of as received spherical glass beads to determine the effect of smaller PSDs on acoustic data.

Synthesis and Characterisation of Zirconolite with Charge Compensator Cation for Pu Immobilisation

Merve Kuman,
PhD,
University of Sheffield

Plutonium is formed in nuclear reactors by irradiating the uranium in nuclear fuel. Therefore, Pu is created by reprocessing the spent nuclear fuel. Plutonium is a potentially valuable energy source and there are two different ways for UK Pu management policy. For this purpose, it can be converted to mixed oxide fuel to reuse. However, the separated Pu which is not converted to mixed oxide fuel should be disposed by immobilisation into ceramic or glass host matrix. Zirconolite, which is natural mineral found in geological environments, is a single phase ceramic host for Pu due to its high aqueous durability and radiation tolerance properties. Zirconolite provides 5 cation sites with Ca, Zr and Ti layers for Pu immobilisation, the incorporation of charge compensators and neutron poisons.
The aim of my project is to research and development the zirconolite ceramic structure for treatment of contaminated Pu by investigating the effects of charge compensators and neutron poisons on the zirconolite phase assemblage and microstructure. Therefore, the effect of cation charge compensator (Fe3+) was researched on the zirconolite structure without Pu and its surrogates loading. So far, the charge compensator cation doped zirconolite structures with cold press and sintering method were produced to get dense ceramic matrix. The phase assemblages and microstructures were analysed via XRD and SEM, respectively and zirconolite-2M was found as major phase with minor phases. In addition to these characterisation methods, unit cell refinement was carried out to understand the incorporation of charge compensators into the zirconolite structure. The coordination environment and oxidation state of Fe ion was revealed via Mössbauer spectroscopy and X-ray absorption near edge spectroscopy (XANES) data to understand the Fe substitution in which Ti site. For future work, zirconolite matrix will be prepared with different charge compensators and neutron poisons, utilising HIP method.

Investigation of Pulverized Fly Ash substitutes in Cement: Impact on physico-chemical properties and waste encapsulation performance

Andrea Kowslowski,
PhD,
University of Strathclyde

Plutonium is formed in nuclear reactors by irradiating the uranium in nuclear fuel. Therefore, Pu is created by reprocessing the spent nuclear fuel. Plutonium is a potentially valuable energy source and there are two different ways for UK Pu management policy. For this purpose, it can be converted to mixed oxide fuel to reuse. However, the separated Pu which is not converted to mixed oxide fuel should be disposed by immobilisation into ceramic or glass host matrix. Zirconolite, which is natural mineral found in geological environments, is a single phase ceramic host for Pu due to its high aqueous durability and radiation tolerance properties. Zirconolite provides 5 cation sites with Ca, Zr and Ti layers for Pu immobilisation, the incorporation of charge compensators and neutron poisons.
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Publications

The following are some recent peer-reviewed papers and articles published since the programme started in October 2018.

Synthesis and characterisation of Ca1-xCexZrTi2-2xCr2xO7: Analogue zirconolite wasteform for the immobilisation of stockpiled UK plutonium
Lewis R. Blackburn, Shi-Kuan Sun, Sebastian M. Lawson, Laura J. Gardner, Hao Ding, Claire L. Corkhill, Ewan R. Maddrell, Martin C. Stennett, Neil C. Hyatt
Journal of the European Ceramic Society Volume 40, Issue 15, December 2020, Pages 5909-5919

A systematic investigation of the phase assemblage and microstructure of the zirconolite CaZr1-xCexTi2O7 system
Lewis R. Blackburn, Shikuan Sun, Laura J. Gardner, Ewan R. Maddrell, Martin C. Stennett, Neil C. Hyatt
Journal of Nuclear Materials Volume 535, July 2020

Computational Study of the Bulk and Surface Properties of Minor Actinide Dioxides MAnO2 (MAn = Np, Am, and Cm); Water Adsorption on Stoichiometric and Reduced {111}, {110}, and {100} Surfaces
Jia-Li Chen and Nikolas Kaltsoyannis
J. Phys. Chem. C 2019, 123, 25, 15540–15550

Reactive spark plasma sintering of Cs-exchanged chabazite: characterisation and durability assessment for Fukushima Daiichi NPP clean-up
Liam. C. Harnett, Laura. J. Gardner, Shi-Kuan Sun, Colleen Mann & Neil. C. Hyatt
DOI: 10.1080/00223131.2019.1602484

Safe management of the UK separated plutonium inventory: a challenge of materials degradation
Neil C. Hyatt
npj Materials Degradation 4, 28 (2020)

Preliminary investigation of chlorine speciation in zirconolite glass-ceramics for plutonium residues by analysis of Cl K-edge XANES
Amber R. Mason, Stephanie M. Thornber, Martin C. Stennett, Laura J. Gardner
MRS Advances Volume 5, Issue 1-2 (Scientific Basis for Nuclear Waste Management XLIII)2020 , pp. 37-43

Density ratio effects on the topology of coherent turbulent structures in two-way coupled particle-laden channel flows
L.F. Mortimer and M. Fairweather
Physics of Fluids 32, 103302 (2020)

Near-wall dynamics of inertial particles in dilute turbulent channel flows
L. F. Mortimer, D. O. Njobuenwu and M. Fairweather
Physics of Fluids 31, 063302 (2019)

Agglomeration dynamics in liquid–solid particle-laden turbulent channel flows using an energy-based deterministic approach
L. F. Mortimer, D. O. Njobuenwu and M. Fairweather
Physics of Fluids 32, 043301 (2020)

Enhanced electrokinetic remediation of nuclear fission products in organic-rich soils
Jamie M. Purkis, Andrew Tucknott, Ian W. Croudace, Phil E. Warwick, Andrew B. Cundy,
Applied Geochemistry - in press

Publications

Simulation of Fully Resolved Particle-Particle Interactions in Turbulence with Behavioural Modification
L.F. Mortimer, M. Fairweather and Njobuenwu
10th International Conference on Multiphase Flow – ICMF 2019, Rio de Janeiro, Brazil, 19th-24th May 2019, Paper OC.389, 2019.

A Feasibility Investigation of Laboratory Based X-ray Absorption Spectroscopy in Support of Nuclear
Waste Management
L.M. Mottram, M.C. Dixon Wilkins, L.R. Blackburn, T. Oulton, M.C. Stennett, S.K. Sun, C.L. Corkhill andN.C. Hyatt
MRS Advances Volume 5, Issue 1-2 (Scientific Basis for Nuclear Waste Management XLIII)2020 pp.27-35

Managing our plutonium legacy (2019)
N.C. Hyatt
Science in Parliament, Vol 5 Issue 3

Observation of dose-rate dependence in a Fricke dosimeter irradiated at low dose rates with monoenergetic X-rays
Mel O'Leary, Daria Boscolo, Nicole Breslin, Jeremy M. C. Brown, Igor P. Dolbnya, Chris Emerson, Catarina Figueira, Oliver J. L. Fox, David Robert Grimes, Vladimir Ivosev, Annette K. Kleppe, Aaron McCulloch, Ian Pape, Chris Polin, Nathan Wardlow & Fred J. Currell
Scientific Reports volume 8, Article number: 4735 (2018)

The role of crystal orientation in the dissolution of UO2 thin films
S.Rennie, E.Lawrence Bright, J.E.Sutcliffe, J.E.Darnbrough, R.Burrows, J.Rawle, C.Nicklin, G.H.Lander, R.Springell
Corrosion Science Volume 145, December 2018, Pages 162-169

Rapid synthesis of zirconolite ceramic wasteform by microwave sintering for disposition of plutonium
Zi-JunWei, Lewis R. Blackburn, Laura J. Gardner, Sheng-Heng Tan, Shi-Kuan Sun, Wei-Ming Guo, Neil C.Hyatt, Hua-TayLin,
Journal of Nuclear Materials Volume 539, October 2020, 152332

Solubility, speciation and local environment of chlorine in zirconolite glass–ceramics for the immobilisation of plutonium residues
Stephanie M. Thornber, Lucy M. Mottram, Amber R. Mason, Paul Thompson, Martin C. Stennett and NeilC. Hyatt
RSC Advances Issue 54, 2020

Raman analysis of meta-autunite
V. Frankland, R. Bance-Souhali and D. Read
Environmental Radiochemical Analysis VI: 79-88, 2019. RSC Special. Pub. 354. IBSN:978-1-78801-735-0.

Characterisation of meta autunite: Towards identifying potential alteration products of spent nuclear fuel
V. Frankland, A. Milodowski and D. Read.
Appl. Geochem. 123: 104792, 2020. DOI: 10.1016/j.apgeochem.2020.104792

Publications

Influence of Transition Metal Charge Compensation Species on Phase Assemblage in Zirconolite Ceramics for Pu Immobilisation
L.R. Blackburn, S.K. Sun, L.J. Gardner, E.R. Maddrell, M.C. Stennett and N.C. Hyatt
MRS Advances , Volume 5 , Issue 1-2: Scientific Basis for Nuclear Waste Management XLIII , 2020 , pp. 93 - 101

Synthesis of zirconolite-2M ceramics for immobilisation of neptunium
Zi-Jun Wei, Weichao Bao, Shi-Kuan Sun, Lewis R.Blackburn, Sheng-HengTan, Laura J.Gardner, WeiMingGuo, Fang-fangXu, Neil C.Hyatt, Hua-TayLin
Ceramics International Volume 47, Issue 1, 1 January 2021, Pages 1047-1052

Application of plasma mass spectrometry for half-life measurement of medium and long lived radionuclides.
E. Braysher, B. Russell and D. Read.
J. Phys. Conf. Ser. 1643 012207 (2020).

The use of Raman and TRLF spectroscopy for differentiating early stage alteration products of Spent Nuclear Fuel.
V. Frankland, A. Milodowski, J. Bright and D. Read.
Accepted by Appl. Geochem.

Crystal and Electronic Structures of A2NaIO6 Periodate Double Perovskites (A = Sr, Ca, Ba): Candidate Wasteforms for I-129 Immobilization
Sarah E. O'Sullivan, Eduardo Montoya, Shi-Kuan Sun*, Jonathan George, Cameron Kirk, Malin C. Dixon Wilkins, Philippe F. Weck, Eunja Kim*, Kevin S. Knight, and Neil C. Hyatt
Inorg. Chem. 2020, 59, 24, 18407–18419

The formation of stoichiometric uranium brannerite (UTi2O6) glass-ceramic composites from the component oxides in a one-pot synthesis
Malin C.Dixon Wilkins, Martin C.Stennett, EwanMaddrell, Neil C.Hyatt
Journal of Nuclear Materials, Vol 542, 2020, 152516

Molten salt synthesis of Ce doped zirconolite for the immobilisation of pyroprocessing wastes and separated plutonium
Amber R.Mason, Florent Y.Tocino, Martin C.Stennett, Neil C.Hyatt
Ceramics International Vol. 46, Issue 18, Part A, 15 December 2020, Pages 29080-29089
Volume 46, Issue 18, Part A, 15 December 2020, Pages 29080-29089

The Effect of Temperature on the Stability and Cerium Oxidation State of CeTi2O6 in Inert and Oxidizing Atmospheres
Malin C. Dixon Wilkins, Ewan R. Maddrell, Martin C. Stennett, and Neil C. Hyatt
Inorg. Chem. 2020, 59, 23, 17364–17373

Structure of NaFeSiO4, NaFeSi2O6, and NaFeSi3O8 glasses and glass-ceramics
Mostafa Ahmadzadeh; Alex Scrimshire; Lucy Mottram; Martin C. Stennett; Neil C. Hyatt; Paul A. Bingham; John S. McCloy
American Mineralogist (2020) 105 (9): 1375–1384.

Characterisation and disposability assessment of multi-waste stream in-container vitrified products for higher activity radioactive waste
Sam A.Walling, Marcus N.Kauffmann, Laura J.Gardner, Daniel J.Bailey, Martin C.Stennett, Claire L.Corkhill, Neil C.Hyatt
Journal of Hazardous Materials, Volume 401, 5 January 2021, 123764

Publications

Developing field-scale, gentle remediation options for nuclear sites contaminated with 137Cs and 90Sr: The role of Nature-Based Solutions

J. M. Purkis, R. Paul Bardos, J. Graham, A. B. Cundy

Journal of Environmental Management, 308, 114260, https://doi.org/10.1016/j.jenvman.2022.114620