DISTINCTIVE 2016

2nd Annual Meeting, Bristol, 19th - 20th April

DISTINCTIVE
Decommissioning, Immobilisation and Storage soluTIons for NuClear wasTe InVEntories

A university consortium funded by the Research Councils UK Energy programme

Research Councils UK Energy For a Low Carbon Future

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A university consortium funded by the:

Thank you to our key project partners for their support and significant contributions to the programme:

A special thank you to our event sponsors:

Welcome

On behalf of the DISTINCTIVE Leadership Team, I welcome you to the At-Bristol Science Centre, Bristol, for the 2nd Annual Meeting of the University Consortium.

The 1st conference was held at the Millennium Gallery in Sheffield in April 2015. The event attracted 120 delegates with equal representation from academia, industry and associated stakeholders. It was the first time that all associated organisations were brought together, and the event kick-started valuable interactions for mutual benefit and significantly raised awareness of the programme within the waste management and decommissioning R&D community.

With the help of our International Advisory Group (IAG), the consortium was invited to hold a dedicated technical session at the Waste Management Conference in Phoenix in March. We were delighted with the level of interest in the programme and a number of future opportunities were identified. We look forward to building relationships with the new contacts that we made. I would like to say congratulations to Stephanie Thornber, Luke Boast (Sheffield) and Dimitri Pletser (Imperial) who were awarded the Roy G. Post Foundation Scholarship to attend the conference, and again to Luke who was presented with the 'UK featured Nation' award. Well done to Andre Botha (Leeds) who received the bursary that was kindly provided and managed by NNL. Thank you to all of our researchers who helped make the event successful.

We are now half way through the programme, and it is time to start thinking about recruitment. DIAMOND, DISTINCTIVE's predecessor, was effective in retaining researchers within the nuclear sector. It was through events like this that initial prospects were discussed, and we encourage both parties to take advantage of this opportunity.

I look forward to introducing you to our Invited Speakers, Prof. Rodney Ewing (Stanford University, USA), Dr. John Vienna (PNNL, USA) and Prof. John McCloy (Washington State University, USA) and thank them for contributing to this event. Thank you also to members of our IAG for volunteering to chair the technical sessions with our academic leads.

I would like to take this opportunity to acknowledge funding from the Research Councils UK Energy Programme (EP/L014041/1). I would also like to thank our key project partners, NNL, NDA and Sellafield Ltd., for their continued support and contributions.

Finally, I would like to say a special thank you to our event sponsors, NNL and NDA, for their ongoing support to the consortium.

Prof. Michael Fairweather (Principal Investigator – M. Fairweather@leeds.ac.uk)

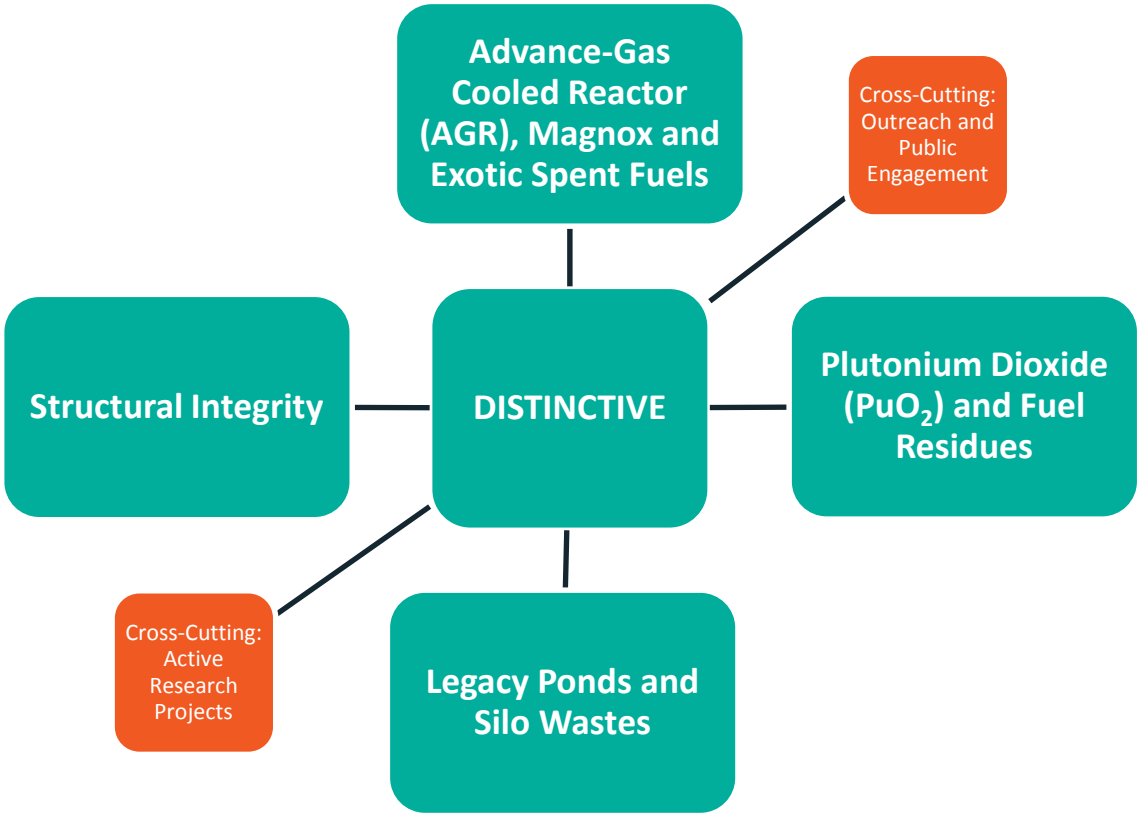
Programme Overview

The structure of this world-class research programme has been aligned with the strategic needs of the UK industry in the area of nuclear waste management and decommissioning.

The aims of the consortium are:

- To carry out internationally leading science and engineering research in the area of decommissioning and nuclear waste management.
- To support research that provides routes to innovative technology developments that can be applied to decommissioning and nuclear waste management.
- To foster and develop new multi-disciplinary research partnerships between academic and industry researchers.
- To train the next generation of UK researchers, equipping them with skills and experiences relevant to nuclear waste management and decommissioning issues.
- To provide a focal point for government, industry and academics through which current and future R&D issues associated with nuclear waste and decommissioning can be discussed.
- To provide a route for public understanding of the underlying research and development needs opportunities and solutions to nuclear waste and decommissioning.

All **53** research projects fall into one of four technical themes which were co-identified with our industrial partners; NNL, NDA and Sellafield Ltd.



Theme 1 - AGR, Magnox and Exotic Spent Fuels

Aim: To provide technical underpinning to the options for the management of the UK's AGR, Magnox and Exotic Spent Fuels

Objectives:

- To understand the evolution of Magnox and exotic SNF during recovery from aqueous storage, drying and repackaging.
- To develop spectroscopic methods for improved determination of SNF dissolution and corrosion rates in water.
- To determine the optimum drying conditions for AGR fuels and the subsequent surface reactivity and alteration of unclad UO_2 in dry storage.
- To determine the consequences of radiation damage in SNF, cladding and other wasteforms for safe long term storage.
- To determine suitable waste management options for spent carbide fuels.

Theme 2 – PuO_2 and Fuel Residues

Aim: To provide technical underpinning to the options for the UK's civil Plutonium inventory

Objectives:

- To understand how the structure and properties of PuO_2 change with time in the presence of H_2O.
- To understand the roles these processes play in gaseous product evolution from PuO_2 in storage.
- To understand radiation induced amorphisation and dissolution kinetics of Pu wasteforms.
- To develop novel, fast neutron based radiometric methods for the quantification, isotopic composition assessment and remote imaging of Pu bearing materials.

Theme 3 – Legacy Ponds and Silo Wastes

Aim: To develop innovative technical approaches to clean up UK legacy wastes.

Objectives:

- To understand durability of heterogeneous ILW glass/ceramic wasteforms from LP&S wastestreams.
- To develop improved ways to remove radionuclides (RNs) from solution, both novel inorganic ion exchange solids and tailored binding superparamagnetic nanoparticles, to treat complex and variable effluents.
- To develop new micro- and ultra-filtration methods for use with sludges.
- To provide three-dimensional modelling and simulation for sludge disturbance, mobilisation and transport, with supportive experimental studies, and manipulation planning for removing corroding nuclear materials.

- To develop a better understanding of gas hold-up in sludges.
- To develop improved techniques for remote monitoring of sludges and heterogeneous wastes.

Theme 4 – Structural Integrity

Aim: To develop reliable systems for infrastructure characterisation, restoration and preservation, that minimise current, and future, radiation exposure to the workforce whilst providing economically viable technological solutions.

Objectives:

- To develop in-situ ground barriers that could act as a 'second skin' surrounding on-site structures, such as silos and ponds, for prevention of subsurface radionuclide migration.
- To develop smart solutions for remote crack detection, infrastructure health prediction and building preservation that can be retrofitted to existing sites.
- To develop autonomous systems with increased functionality and to coordinate them through a CAD-based real-time management system, to facilitate planning and execution of decommissioning works.

Cross-Cutting Themes

The Leadership Team will continue to identify common themes across the research projects to maximise collaboration, training and knowledge/technology transfer across the consortium.

Two cross-cutting themes currently exist; Active Research Projects, and Outreach and Public Engagement.

Active Research Projects

A key component of the DISTINCTIVE programme is the use of world-class active research facilities, both within the UK and internationally. Prof. Simon Pimblott is responsible for ensuring that the consortium receives excellent advice and support in this area, especially relating to the technical needs and duration of the work.

Outreach and Public Engagement

The consortium has identified three distinct groups of non-academic beneficiaries from consortium activities; site license companies and the associate industrial supply chain; Government, regulators and implementation authorities; and, society and stakeholders groups. Over the duration of the programme, DISTINCTIVE will deliver a variety of activities, led by Prof. Neil Hyatt, which will have impact in four key domains:

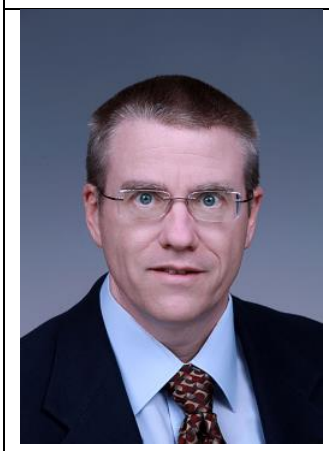
- Knowledge
- People
- Economy
- Society

Introducing the Invited Speakers

Prof. Rodney Ewing (Stanford University, USA)

Rod Ewing is the Frank Stanton Professor in Nuclear Security in the Center for International Security and Cooperation in the Freeman Spogli Institute for International Studies and a Professor in the Department of Geological Sciences in the School of Earth, Energy and Environmental Sciences. Ewing's research focuses on the back-end of the nuclear fuel cycle, mainly nuclear materials and the geochemistry of radionuclides with application to permanent geologic disposal. Ewing has written extensively on issues related to nuclear waste management and is a co-editor of *Radioactive Waste Forms for the Future* (1988) and *Uncertainty Underground – Yucca Mountain and the Nation's High-Level Nuclear Waste* (2006). He received the Lomonosov Medal of the Russian Academy of Sciences in 2006. In 2012, he was appointed by President Obama to chair the Nuclear Waste Technical Review Board, which provides scientific and technical reviews of the Department of the Energy's programs for the management and disposal of spent nuclear fuel and high-level radioactive waste.

Dr. John Vienna (Pacific Northwest National Laboratory, USA)



Dr. Vienna is a materials scientist with 23 years of experience in nuclear waste form development, processing, and testing. John is a Chief Scientist in the Materials Science Team of PNNL's Nuclear Sciences Division. His experience includes serving as the Deputy National Technical Director for Materials Recovery and Waste Form Development, DOE Office of Nuclear Energy (2008-present); National Technical Advisor to the DOE Office of Environmental Management (2008-2012) for waste form and immobilization science; Associate Editor of the International Journal of Applied Glass Science (2010-present); and Adjunct Professor in the Chemistry Department at Washington State University (1999-present). His research has led to more than 250 technical publications (including 33 journal articles, 6 books and book chapters, 98 proceedings articles, and 130 technical reports).

Prof. John McCloy (Washington State University, USA)

Prof. John McCloy has degrees in Materials Science & Engineering from the Massachusetts Institute of Technology and the University of Arizona. He has had a diverse career including 10 years in the defense industry, 5 years in a US Department of Energy national laboratory, and now 3 years in academia. Prof. McCloy joined Washington State University in 2013 as an Associate Professor in the School of Mechanical & Materials Engineering, having previously been the team lead in Glass and Materials Science at the Pacific Northwest National Laboratory. He also holds appointments in the WSU Materials Science & Engineering Graduate program and the Department of Chemistry, and is a Visiting Professor of Nuclear Materials at Sheffield University, UK. His research focuses on nuclear, optical, magnetic, and electronic aspects of materials, particularly in the role of structure and disorder on properties. Most of his current research involves nuclear materials, notably glass and ceramic waste forms for immobilization of radionuclides from legacy defense waste as well as used nuclear fuel reprocessing waste. Other current research involves the development of magnetic sensing methodologies for monitoring nuclear reactor degradation.

PhD Student Awards

A £250 prize will be awarded for the best oral and the best poster presentation given by a DISTINCTIVE PhD student.

Our industry delegates (only) are invited to register their vote at the Registration Desk by **14:50 on Wednesday 20th April**. A voting sheet can be collected from the desk (or from Abby Ward) at any time.

The awards for each category will be presented by Dr. Rick Short on behalf of the NDA, who kindly sponsored these awards, at the end of the event.

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Agenda

Tuesday 19th April		
Time	**Title**	**Presenter**
10:00	Delegate Registration, Poster Board Set Up and Arrival Refreshments	
11:00	Introduction and Housekeeping	Prof. Michael Fairweather University of Leeds
11:10	Projecting Risk into the Future: Failure of a Geologic Repository and Sinking of the Titanic	Prof. Rodney Ewing Stanford University
Structural Integrity *Chairs: Prof. Rebecca Lunn, University of Strathclyde & Dr. Bryony Livesey, Costain*		
11:50	Use of Colloidal Silica Grout for Ground Barriers in Decommissioning: A Project Overview	Dr. Matteo Pedrotti University of Strathclyde
12:10	Hydro-mechanical Characterisation of Colloidal Silica Grout	Christopher Wong University of Strathclyde
12:30	3D Semantic Reconstruction in an Industrial Environment	Henry (Cheng) Zhao University of Birmingham
12:50	Q&A Panel	Session Chairs
13:10	Lunch and Poster Session	
PuO_2 and Fuel Residues *Chairs: Prof. Colin Boxall, Lancaster University & Prof. Nik Kaltsoyannis, University of Manchester & Dr. James Marra, SRNL*		
14:10	Direct Mass Analysis of Water Absorption onto Ceria, Urania and Thoria Thin Films	Dr. Dominic Laventine Lancaster University
14:30	Radiolysis of H_2-O_2 Gas Mixtures of Relevance to Long Term PuO_2 Storage	Dr. Luke Jones University of Manchester
14:50	Water Adsorption on Actinide Oxide Surfaces	Dr. Bengt Tegner University of Manchester
15:10	Real-time Fast-neutron Plutonium Assay for Storage and Ageing Applications	Rashed Sarwar Lancaster University
15:30	Afternoon Break and Poster Session	
16:00	Computational Studies of Water Adsorption on UO_2 and PuO_2 Surfaces	Joseph Wellington UCL
16:20	Ceramic Wasteforms for Actinide Disposition	Dr. Shi-Kuan Sun University of Sheffield
16:40	Q&A Panel	Session Chairs
17:00	Break	

18:30	Drinks Reception	ss Great Britain NATIONAL NUCLEAR LABORATORY
19:15	Call to Dine	ss Great Britain NATIONAL NUCLEAR LABORATORY
23:00	End of Day	

Wednesday 20th April		
Time	**Title**	**Presenter**
08:30	Delegate Registration and Arrival Refreshments	
09:00	U.S. Closed Nuclear Fuel Cycle Waste Management Research	Dr. John Vienna PNNL
Legacy Ponds and Silo Wastes *Chairs: Dr. Joseph Hriljac, University of Birmingham & Mike Angus, NNL*		
09:40	Measurement and Modelling of Sludge Mobilisation and Transport	Dr. Hugh Rice and Dr. Derrick Njobuenwu University of Leeds
10:00	Glass Formulations to Effectively Condition and Immobilise Radioactive Waste – Sheffield MIDAS Facility to B-170 NNL Central Labs	Luke Boast University of Sheffield
10:20	Degradation of International Simple Glass	Dr. Rama Krishna Chinnam Imperial College London
10:40	Morning Break and Poster Session	
11:10	An X-ray Tomography Study of Gas Retention and Release from Nuclear Legacy Waste	Michael Johnson University of Leeds
11:30	Tailored Cs/Sr Ion Exchange in Sn-Umbite by Framework Substitution	Dr. Evin (Tzu-Yu) Chen University of Birmingham
11:50	Q&A Panel	Session Chairs
12:10	Lunch and Poster Session	
AGR, Magnox and Exotic Spent Fuels Chairs: Dr. Tom Scott, University of Bristol & Dr. Carwyn Jones, Nuclear Technologies		
13:10	Thin Film Applications for Investigation of the Evolution of Spent Nuclear Fuel Micro-probe Corrosion, Hydride Formation, Damage Effects and Dissolution	Dr. James Darnbrough and Dr. Leila Costelle University of Bristol
13:30	Microstructural Characterisation of AGR Cladding Materials	Chiara Barcellini University of Manchester

13:50	Immobilisation Options for Exotic Carbide Fuels	Claudia Gasparrini Imperial College London
14:10	Q&A Panel	Session Chairs
14:30	Afternoon Break and Poster Session	
Cross-cutting Themes Chair: Prof. Neil Hyatt, University of Sheffield		
14:50	Basic Research on Technetium in Alkali Oxide Glasses	Prof. John McCloy Washington State University
15:10	An Update on Impact	Prof. Neil Hyatt, Dr. Claire Corkhill and Dr. Matthew Cotton University of Sheffield
15:30	An Overview of the NNL Survey	Mike Angus NNL
15:40	NDA PhD Student Awards	NDA Nuclear Decommissioning Authority Dr. Rick Short NDA
15:50	Closing Remarks	Prof. Michael Fairweather University of Leeds
16:00	End of Day/IAG Meeting	IAG Members Only
17:00	Close for IAG	

Shaded name = eligible for the £250 prize for best oral presentation given by a DISTINCTIVE **PhD** student.

All presentations will be made available to download from our consortium website:

http://distinctiveconsortium.org/category/events/annual-meeting-events/

Posters

The following posters will be presented throughout the event:

Poster Number	Researcher	Poster Title	Leading Institution
1	Dr. James Darnbrough	Evolution of Uranium Metal Oxide Interface in a Hydrogen Rich Environment	Bristol
2	Dr. Leila Costelle	Localized Corrosion Behaviour of Uranium Based Materials	Bristol
3	Sophie Rennie	Dissolution at the UO_2 / Water Interface: The Impact of Crystal Orientation and Ion Implantation	Bristol
4	Claudia Gasparrini	Immobilisation Options for Exotic Carbide Fuels	Imperial
5	Elizabeth Howett	AGR Cladding Corrosion: Investigation of the Effect of Temperature on Sensitised and Unsensitised Steel	Lancaster
6	James Goode	Transitioning of Spent AGR Fuel from Wet to Dry Storage	Leeds
7	Dr. Oliver Preedy	Uranium Speciation by Time-resolved Laser Induced Fluorescence Spectroscopy	Loughborough
8	Matthew Druce	Characterising the Chemical and Physical Properties of Depleted, Natural and Low-enriched Uranium with Regard to the Suitability of Alternative Disposal Routes	Loughborough
9	Chiara Barcellini	Micro-structural Characterisation of AGR Cladding Material	Manchester
10	Andrea Paulillo	A Life Cycle Approach to Nuclear Waste Management	UCL
11	Nathan Palmer	Computational Modelling of PuO_2 Ageing and Fuel Residues	Birmingham
12	Dr. Dominic Laventine	Direct Mass Analysis of Water Absorption onto Ceria, Urania and Thoria Thin Films	Lancaster
13	Rashed Sarwar	Real-time Fast-neutron Plutonium Assay for Storage and Ageing Applications	Lancaster
14	Dr. Bengt Tegner	Water Adsorption on Actinide Oxide Surfaces	Manchester
15	Sophie Sutherland-Harper	Adsorption of Chloride and Water on CeO_2 as a precursor to PuO_2 studies	Manchester
16	Dr. Luke Jones	Radiolysis of H_2-O_2 Gas Mixtures of Relevance to Long Term PuO_2 Storage	Manchester
17	Dr. Shi-Kuan Sun	Ceramic and Glass-ceramic Wasteforms for Actinide Disposition	Sheffield
18	Stephanie Thornber	The Development of Glass-Ceramic Wasteforms for Pu-bearing Waste-Streams	Sheffield
19	Antonia Yorkshire	Understanding Actinide Sorption and Binding to Cement Materials	Sheffield
20	Joseph Wellington	Computational Studies of Water Adsorption on UO_2 and PuO_2	UCL

21	Ryan George	Synthesis and Ion Exchange of Zirconogermanates	Birmingham
22	George Day	Synthesis and Studies of Barium Doped Cs2TiNb6O18 - A New Cs-Waste Form	Birmingham
23	Dr. Evin (Tzu-Yu) Chen	Tailored Cs/Sr Ion Exchange in Sn-Umbite by Framework Substitution	Birmingham
24	Antonios Banos	Uranium Wet Oxidation Under Contained Conditions	Bristol
25	Kate Wyness	Remote Raman Analysis of Storage Ponds	Bristol
26	Dr. Rama Krishna Chinnam	Degradation of International Simple Glass	Imperial
27	Dimitri Pletser	Low Temperature Immobilisation of Spent Adsorbents from Fukushima	Imperial
28	Eleonora Cali	Nanoscale Investigation and Control of Radionuclides in Waste Management	Imperial
29	Olivia Lynes	Computational Investigations into the Effect of Temperature on Hydrated Magnesium, Calcium and Strontium	Lancaster
30	Alastair Tonge	Novel Characterisation of Flocculated Dispersions Using Acoustic Backscatter Systems	Leeds
31	Michael Johnson	Gas Retention and Release from Nuclear Legacy Waste	Leeds
32	Dr. Derrick Njobuenwu	Simulation of Particle-particle Interactions in Turbulent Pipe Flow	Leeds
33	Dr. Hugh Rice	In-line Rheometry and Flow Characterisation of Dense Slurries in Pipe Flow Using Acoustic Methods	Leeds
34	Johannes Andries Botha	A Novel Technology for Complex Rheological Measurements	Leeds
35	Keith Schou	Enhanced Shear Micro and Ultrafiltration	Loughborough
36	Olusola Ayoola	In situ Monitoring of the Legacy Ponds and Silos at Sellafield	Manchester
37	Mel O'Leary	Irradiated Sludges	QUB
38	Conrad Johnston	Hydrogen Evolution in Magnox Sludges	QUB
39	Luke Boast	Thermal Treatment of Plutonium Contaminated Materials	Sheffield
40	Eszter Makkos	Modelling the Interaction of Corroded Magnox Surfaces with Nuclear Fission Products	UCL
41	Henry (Cheng) Zhao	3D Dense Reconstruction in Industrial Environment	Birmingham
42	Toby Lord	Re-use and Volume Reduction of Scabbled Contaminated Concrete from Nuclear Decommissioning	Leeds
43	Ryan Kavanagh	Atomistic Simulation of Cement-Based Materials for Nuclear Waste Disposal	QUB
44	Thomas Mullan	Development of Novel, Low Cost Biomineral Permeable Reactive Barriers for Radionuclide Remediation	Strathclyde

45	Christopher Wong	Mechanical characterisation of colloidal silica grout	Strathclyde
46	Dr. Matteo Pedrotti	Use of Colloidal Silica Grout for Ground Barriers in Decomissioning: A Project Overview	Strathclyde
47	Luca Rizzo	Radionuclide Immobilisation into Calcium Silicate Hydrates	Strathclyde
48	Anthony Collins	Analysis of Partner Engagement in the DISTINCTIVE Consortium	NNL

Shaded name = eligible for the £250 prize for best poster presentation given by a DISTINCTIVE **PhD** student.

Attendee List

First Name	Second Name	Organisation
Anna	Adamska	Sellafield Ltd
Mike	Angus	NNL
Nick	Atherton	Sellafield Ltd
Jonathan	Austin	NNL
Olusola	Ayoola	University of Manchester
Antonios	Banos	University of Bristol
Chiara	Barcellini	University of Manchester
Martyn	Barnes	Sellafield Ltd
Luke	Boast	University of Sheffield
Gary	Bolton	NNL
Johannes Andries	Botha	University of Leeds
Kate	Bowman	EPSRC
Colin	Boxall	Lancaster University
Rob	Burrows	NNL
Ed	Butcher	NNL
Eleonora	Cali	Imperial College London
Colin	Campbell	Environment Agency
Thomas	Carey	NNL
Ray	Chegwin	Knowledge Transfer Network
Evin (Tzu-Yu)	Chen	University of Birmingham
Rama Krishna	Chinnam	Imperial College London
Anthony	Collins	NNL
Andrew	Cooney	Sellafield Ltd
Duncan	Coppersthwaite	NNL
Claire	Corkhill	University of Sheffield
Leila	Costelle	University of Bristol
Matthew	Cotton	University of Sheffield
James	Darnbrough	University of Bristol
George	Day	University of Birmingham
Carlos	De La Fontaine	Nuclear Technologies
Matthew	Druce	Loughborough University

Simon	Dumbill	NNL
Sean	Duvall	INS
Grainne	El Mountassir	University of Strathclyde
Rodney	Ewing	Stanford University
Michael	Fairweather	University of Leeds
Mónica	Felipe-Sotelo	Loughborough University
Claudia	Gasparrini	Imperial College London
Ryan	George	University of Birmingham
James	Goode	University of Leeds
James	Graham	NNL
Keith	Hallam	University of Bristol
Mike	Harrison	NNL
Joanne	Hill	Hydrock NMCL
Jeff	Hobbs	Sellafield Ltd
Elizabeth	Howett	Lancaster University
Joe	Hriljac	University of Birmingham
Timothy	Hunter	University of Leeds
Richard	Hunter	LLW Repository Ltd
Neil	Hyatt	University of Sheffield
Enrique	Jimenez-Melero	University of Manchester
Michael	Johnson	University of Leeds
Conrad	Johnston	Queen's University Belfast
Carwyn	Jones	Nuclear Technologies
Luke	Jones	University of Manchester
Laurie	Judd	Longenecker & Associates
Nik	Kaltsoyannis	University of Manchester
Ryan	Kavanagh	Queen's University Belfast
Debbie	Keighley	Sellafield Ltd
Simon	Kellet	Sellafield Ltd
Andy	Kerridge	Lancaster University
Jorge	Kohanoff	Queen's University Belfast
Dominic	Laventine	Lancaster University
Bryony	Livesey	Costain

Mary	Logan	University of Bristol
Toby	Lord	University of Leeds
Rebecca	Lunn	University of Strathclyde
Olivia	Lynes	Lancaster University
Ewan	Maddrell	NNL
Eszter	Makkos	UCL
Kevin	Malone	MMI Engineering
Jim	Marra	Savannah River Consulting
John	McCloy	Washington State University
Sean	Morgan	Sellafield Ltd
Thomas	Mullan	University of Strathclyde
Derrick	Njobuenwu	University of Leeds
Mel	O'Leary	Queen's University Belfast
Robin	Orr	NNL
Cristiano	Padovani	Radioactive Waste Management (RWM)
Stephen	Palethorpe	NNL
Nathan	Palmer	University of Birmingham
Andrea	Paulillo	UCL
Matteo	Pedrotti	University of Strathclyde
Ian	Pegg	The Catholic University of America
Simon	Pimblott	University of Manchester
Dimitri	Pletser	Imperial College London
Oliver	Preedy	Loughborough University
John	Provis	University of Sheffield
Geoff	Randall	Sellafield Ltd
Sophie	Rennie	University of Bristol
Joanna	Renshaw	University of Strathclyde
Dominic	Rhodes	NNL
Hugh	Rice	University of Leeds
Rodrigo	Rimando	US Department of Energy
Luca	Rizzo	University of Strathclyde
Thomas	Robinson	Sellafield Ltd
Bill	Rogerson	Sellafield Ltd

Rashed	Sarwar	Lancaster University
Keith	Schou	Loughborough University
Thomas	Scott	University of Bristol
Rick	Short	NDA
Howard	Sims	NNL
Ross	Springell	University of Bristol
Helen	Steele	Sellafield Ltd
Carl	Steele	Sellafield Ltd
Shi-Kuan	Sun	University of Sheffield
Sophie	Sutherland-Harper	University of Manchester
William	Tearle	ONR
Bengt	Tegner	The University of Manchester
Paul	Thompson	AWE plc
Stephanie	Thornber	University of Sheffield
Alastair	Tonge	University of Leeds
Divyesh	Trivedi	NNL
Luc	Vandeperre	Imperial College London
John	Vienna	PNNL
Steve	Walters	NNL
Abby	Ward	University of Leeds
Simon	Watson	University of Manchester
Joseph	Wellington	UCL
Rob	Whittleston	Hitachi Europe
Christopher	Wong	University of Strathclyde
Simon	Woodbury	NNL
Kate	Wyness	University of Bristol
Antonia	Yorkshire	University of Sheffield
Henry (Cheng)	Zhao	University of Birmingham

Master Project List

Theme	Title	Leading Institution	Researcher	Type
1	An Investigation of Wasteform Evolution During Wet-recovery and Drying of SNF	Bristol	Dr. James Edward Darnbrough/Dr. Leila Costelle	PDRA
1	UO_2 Surface Reactivity and Alteration – a Fundamental Study of Photocatalytic and Structural Effects Related to Long Term Storage of SNF	Bristol	Sophie Rennie	PhD
1	Options for Exotic Carbide Fuels	Imperial	Claudia Gasparrini	PhD
1	The Behaviour of Used Nuclear Fuel in Wet Storage	Lancaster	Elizabeth Howett	PhD
1	Determination of Optimum Drying Conditions for AGR fuels	Leeds	James Goode	PhD
1	Use of TRLFS to Investigate Dissolution Rates	Loughborough	Dr. Oliver Preedy	PDRA
1	Characterising the Chemical and Physical Properties of Depleted, Natural and Low-enriched Uranium with Regard to the Suitability of Alternative Disposal Routes	Loughborough	Matthew Druce	PhD
1	Grain Boundary Damage Mechanisms in Strained AGR Cladding Under Irradiation	Manchester	Chiara Barcellini	PhD
1	A Life Cycle Approach as a Decision Tool for Nuclear Waste Management and Decommissioning of Existing and Future Plants	UCL	Andrea Paulillo	PhD
2	Computational Modelling of PuO_2 Ageing and Fuel Residues	Birmingham	Nathan Palmer	PhD
2	In-situ Characterisation of Heavily-Contaminated Plutonium Finishing Environments	Lancaster	-	PhD
2	Real-time Fast Neutron Plutonium Assay for Plutonium Storage and Ageing Applications	Lancaster	Rashed Sarwar	PhD
2	Understanding the Interfacial Interactions of Plutonium Dioxide with Water	Lancaster	Dr. Dominic Laventine	PDRA
2	Investigation of Anomalous Hydrogen Production from Water Adsorbed on Oxides	Manchester	Jamie Southworth	PhD
2	Modelling the Surface Chemistry of PuO_2 at the Molecular Level	Manchester	Dr. Bengt Tegner	PDRA
2	Simulation of Low-energy Electron Radiolysis of Water Adsorbed on Oxides	Manchester	Marisa Smith	PhD
2	Understanding Surface Species and Interactions Between Adsorbed Chloride and Water on Stored PuO_2	Manchester	Sophie Sutherland-Harper	PhD
2	Understanding the Interfacial Interactions of Plutonium Dioxide with Water	Manchester	Dr. Luke Jones	PDRA
2	Ceramic Materials for Actinide Disposition	Sheffield	Dr. Shi-Kuan Sun	PDRA
2	Development of Glass-ceramics for Pu Disposition using Hot Isostatic Pressing	Sheffield	Stephanie Thornber	PhD
2	Understanding Actinide Sorption and Binding to Cement Materials for Radioactive Waste Management	Sheffield	Antonia Yorkshire	PhD
2	The Interaction of Water with PuO_2 Surfaces	UCL	Joseph Wellington	PhD
3	New Ion Exchange Materials For Effluent Clean-up	Birmingham	Ryan George	PhD
3	Novel Ceramic Wasteforms for Cs and Sr Encapsulation	Birmingham	George Day	PhD
3	Novel Ion Exchange Materials	Birmingham	Dr. Evin (Tzu-Yu) Chen	PDRA
3	Corrosion of Uranium in Water and Hydrogen	Bristol	Antonis Banos	PhD
3	Development of Raman Spectroscopy Techniques	Bristol	Kate Wyness	PhD

	for the Remote Analysis of Nuclear Wastes in Storage			
3	The Evolution of Grouted Waste Forms Containing Uranium	Bristol	Haris Paraskevoulakos	PhD
3	Durability of Heterogeneous ILW Glass/Ceramic Wasteforms from Complex Wastestreams	Imperial	Dr. Rama Krishna Chinnam	PDRA
3	Glass Composite Materials for Fukushima ILW Immobilisation	Imperial	Dimitri Pletser	PhD
3	Glass Composite Materials for Sellafield LP&S ILW Immobilisation	Imperial	Charles Hutchison	PhD
3	Magnetic Nanoparticles for Waste Separation or Sequestration	Imperial	Eleonora Cali	PhD
3	Computational Simulations of Storage Pond Sludge Disturbance	Lancaster	Olivia Lynes	PhD
3	Characterisation of Flocculated Waste Suspensions with Acoustic Backscatter	Leeds	Alastair Tonge	PhD
3	Gas Retention and Release from Nuclear Legacy Waste	Leeds	Michael Johnson	PhD
3	Measurement and Modelling of Sludge Mobilisation and Transport	Leeds	Dr. Derrick Njobuenwu/Dr. Hugh Rice	PDRA
3	The Development of Characterisation Techniques for Intermediate Level Waste Sludges	Leeds	Andre Botha	PhD
3	Enhanced Shear Micro- and Ultra-Filtration Without Recycle Pumping	Loughborough	Keith Schou	PhD
3	One Step Extraction and Quantification of Radionuclides Using Superparamagnetic Bead and Nanopore Technologies	Loughborough	Laura Mayne	PhD
3	Autonomous Systems for Nuclear Decommissioning in Extreme Radiation Environments	Manchester	Olusola Ayoola	PhD
3	Irradiated Sludges - Experimental	QUB	Mel O'Leary	PhD
3	Modelling Hydrogen Generation from Radioactive Sludges	QUB	Conrad Johnston	PhD
3	Thermal Treatment of PCM and ILW	Sheffield	Luke Boast	PhD
3	The Interaction of Brucite Surfaces with Uranium and its Fission Products	UCL	Eszter Makkos	PhD
4	Production of Real-time Segmented as-built CAD Models for the Planning and Execution of Remote and Human Intervention Tasks	Birmingham	Henry (Cheng) Zhao	PhD
4	The Impact of Recycled Concrete Fines on the Engineering Performance of Cementitious Infill	Leeds	Toby Lord	PhD
4	Simulating Radiation Damage in Cement	QUB	Ryan Kavanagh	PhD
4	Crack Sealing and Water Transport	Strathclyde	Riccardo Maddalena	PhD
4	Development of Novel, Low Cost Biomineral Permeable Reactive Barriers for Radionuclide Remediation	Strathclyde	Tom Mullan	PhD
4	In-situ Ground Contaminant Containment (Physical barrier)	Strathclyde	Christopher Wong	PhD
4	In-situ Ground Contaminant Containment (Physical barrier)	Strathclyde	Dr. Matteo Pedrotti	PDRA
4	Integrated Sensors for Infrastructure	Strathclyde	-	PhD
4	Nano-cracking of Cement Phases: Reactivity and Dissolution	Strathclyde	Luca Rizzo	PhD

Abstracts

Full project summaries can be downloaded from our consortium website:

http://distinctiveconsortium.org/category/events/annual-meeting-events/

The following 19 pages contain the abstracts (in the order of the master project list) from these summaries.

Theme 1 - AGR, Magnox and Exotic Spent Fuels

Corrosion at the surface of nuclear materials

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Abstract

Uranium based thin films have been created and characterised to aid in the fudamental investigation in to modes of corrosion of nuclear materials for storage and disposal. Two projects have shown that the types of damage that occurs to UO_2 in reactor can be simulated separately through He ion or Xe and Cs ion irradiation. This is observed as either an expansion of the lattice or a removal of crystallitity. The measurement of this damage via the 3 omega method and the effect on thermal conductivity are in early stages. Work has been undertaken to look at the formation of pyrophoric uranium hydride on the interface between uranium metal and oxide. Showing that even small partial pressures of 2mbar at 80 degrees centigrade can cause transformation of the uranium metal.

Localized corrosion behaviour of uranium based materials

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Abstract

In the present project, we design uranium microelectrodes using uranium thin films and expose their surfaces to a range of chemical conditions to study the localized corrosion behaviour in uranium-based materials. We use a range of electrochemical tests in order to probe the dynamic changes to the electrode surface and calculate the corrosion rate. The arising experimental results will be used as important parametric input for calculations of the likely long-term degradation of Spent Nuclear Fuels in variety of potential storage and disposal scenarios.

Radiation Driven Reactions at the Surface of Uranium Dioxide

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Abstract

In order to ensure resilient, long-term storage for nuclear material it is critical to have a thorough understanding of the reactions occurring at the surface of stored uranium oxides. This project aims to explore this topic in further detail through studying radiation induced oxidative *dissolution of uranium dioxide thin films*. Building on our previously developed experimental technique, we have expanded upon our initial measurements to investigate the effect of crystal orientation on the dissolution of UO_2. These measurements were conducted on the I07 beamline at the Diamond Light Source in March 2016 and a full analysis of the experimental results is currently underway. However, preliminary analysis has shown crystal orientation to significantly affect the rate of UO_2 dissolution, with the [111] film appearing far more resilient to radiation induced corrosion than either the [001] or [110] orientations.

Oxidation of Carbides Including Carbide Nuclear Fuels

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Abstract

Oxidation of depleted uranium carbide (UC) fuel pellets from Dounreay was investigated using isothermal oxidation of UC pellet fragments crushed in air atmosphere and inert atmosphere in a TGA/DSC for heat of combustion evaluation. Oxidations on fragments performed in a muffle furnace from 873-1173 K were used to investigate the influence of time and temperature on the final oxide product characteristics: conversion, specific surface area (SSA) and oxide stoichiometry and morphology. Preliminary results show that, for a given time, oxidation performed at 873K gives greater SSA and conversion than when higher temperatures are used.

Prior to this work, a preliminary study of oxidation of dense hot pressed ZrC specimens was performed from 1073 – 1473 K. Oxidation in furnaces was performed for kinetics investigations and characterisation of the interface between ZrC/ZrO_2. *In situ* analysis performed on ZrC with an HT-ESEM was used to examine the influence of crack propagation on the Maltese Cross shape development of the oxide.

The Behaviour of Spent Nuclear Fuel in Wet Storage

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Abstract

The project aims to investigate the behaviour of Spent Nuclear Fuel (SNF) in interim storage, specifically AGR fuel in storage ponds at Sellafield. Corrosion behaviour will be studied in order to assess the validity of extended storage periods. Studies will be carried out on UO_2, SIMFUEL and AGR cladding samples separately and in binary systems. Once these initial experiments have been completed, analogous experiments will be carried out on real spent AGR fuel. To date studies have been carried out on the corrosion behaviour of sensitised and unsensitised stainless steel cladding and cladding analogue samples in simulant pond water with varying temperature, chloride concentration and pH.

Transitioning of Spent AGR Fuel from Wet to Dry Storage

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Abstract

Upon removal from a reactor spent AGR fuel (SNF) is placed into water storage to remove decay heat and provide shielding prior to reprocessing. Empirical evidence with long stored fuel suggests that fuel can be stored in caustic dosed ponds for at least 25 years without failures. With the closure of Thorpe and the end of reprocessing the current NDA roadmap has SNF being kept in caustic dosed ponds until 2038 followed by direct disposal to a geological disposal facility in 2075. No decision has yet been made as to how fuel will be stored between 2038 and 2075. One option that is being considered is interim dry storage. This project is investigating whether AGR fuel can be dried suitably for dry storage to be a viable option.

Characterising the Chemical and Physical Properties of the UK's Depleted, Natural and Low-enriched Uranium Stockpile with Regard to the Suitability of Alternative Disposal Routes

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Abstract

The UK owns an estimated inventory of depleted, natural and low-enriched uranium (DNLEU), including that from military and foreign sources, of around 200,000 tonnes. It is classified as a 'zero-value asset' but might be re-classified as waste in the future and would need to be consigned for disposal. The material is stored in a variety of chemical forms and there is currently a lack of data surrounding the secondary phases that might develop under disposal conditions. This project focuses on identifying the paragenetic sequences of minerals that could be formed under different disposal concepts and gathering the necessary thermodynamic and kinetic data. Depleted uranium oxide (UO_3 and UO_2) pellets and uranium metal will be introduced to static solutions of 95% saturated calcium hydroxide, synthetic seawater and synthetic groundwater under both oxic and anoxic conditions. In addition, uranium oxide pellets will be encapsulated using cement-based grouts and surrounded by synthetic groundwater to simulate groundwater interaction with encapsulated DNLEU. Uranyl silicates such as uranophane and the weeksite group are possible secondary phases giving a uranium solubility on the order of 10^{-6} to 10^{-8} mol dm^{-3} and a dissolution rate in groundwater of approximately 10^{-7} g cm^{-2} day^{-1}, though these estimates require confirmation. The results from this project will improve the experimental database and consequently, the accuracy of safety models that are used to predict the fate of DNLEU on disposal. This will clarify whether DNLEU could be disposed of directly in powdered form or requires encapsulation and whether it should be disposed of within specifically designed vaults or may be used in service and transport tunnels in place of backfill.

Microstructural Characterisation of AGR Cladding Material

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Abstract

The safe interim storage of AGR irradiated fuel in water ponds requires a detailed knowledge of the corrosion behaviour of the fuel cladding material. The systematic study of corrosion relies on the availability of sensitised 20Cr25Ni Nb-stabilised stainless steel, ideally with a microstructure close to that produced by neutron irradiation but less radioactive. The aim of this PhD project is the production of sensitised specimens using an intense beam of protons, and to develop thereupon an understanding of the mechanisms driving the radiation-induced segregation of chemical species in the vicinity of grain boundaries. Advanced electron/X-ray techniques are to be used to investigate the damaged structures resulting from the irradiation experiments, in order to compare them with those of claddings removed from the reactor core. A profound knowledge of the behaviour of 20Cr25Ni Nb-stabilised stainless steel under irradiation, however, starts with the characterisation in the pre-irradiation conditions (cold-rolled and annealed). Analytical electron microscopy has been used to investigate the distribution of solute elements, the nature and location of precipitates, together with the crystallographic orientation and grain boundary characteristics of the matrix in non-irradiated specimens. This will constitute the reference for the assessment of the effects of proton irradiation on this material.

A Life Cycle Approach to Nuclear Waste Management

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Abstract

Nuclear waste management has always been a much debated topic and a key driver for decisions within the nuclear industry. A standardised global approach has not yet been developed and at present many countries are re-considering their position. In the UK the reprocessing of Spent Nuclear Fuel (SNF) is projected to stop, but no clear indication about the future approach has been given. This contribution sets out the early stages of an approach to compare the possible alternatives based on Life Cycle Assessment (LCA), which is widely used in other sectors to assess the overall environmental burdens of a product or a service across the whole life cycle – i.e. from cradle to grave. The LCA may serve to support decision-making processes within the nuclear industry and, provided that it is used in an open and transparent way, to improve public attitudes towards nuclear energy. To date few LCA studies within the nuclear industry have been carried out, the main issue being the lack of a standardised methodology to evaluate the impacts of radionuclides. The present study proposes a new framework for this purpose, and aims to demonstrate its application in an LCA study of the current UK approach to the management of spent nuclear fuel based on a mixture of data collated on site and from literature. The final results of the study will eventually show the overall environmental footprint of the

reprocessing of Spent Nuclear Fuel, in terms of both radiological and non-radiological impacts. A "hot spot" analysis will also be performed to highlight the critical processing step.

Theme 2 – PuO_2 and Fuel Residues

Computational modelling of PuO_2 ageing and fuel residues

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Abstract

Static lattice simulations of PuO_2 have been performed using the GULP (General Utility Lattice Program) code in combination with interatomic potentials available in the literature. Simulation results include intrinsic defect energies and mechanical properties of PuO_2, which have been used to select the most appropriate analytical form of the short range potential for further refinement by empirical fitting. The fully ionic model incorporating the core-shell model as used by Read et al. (2014) [1] and Jackson et al. (1986) [2] in modelling PuO_2 is shown to be the most appropriate. The formation energies of intrinsic defects and binding energies of Frenkel pairs and Schottky defects have been predicted. The Uchida et al. (2014) [3] partially ionic model has shown the greatest agreement with experimental data for the oxygen Frenkel pairs. All of the potentials used predict that the formation of oxygen Frenkel pairs are energetically preferred to plutonium Frenkel pairs in PuO_2. Furthermore, they all predict that the formation of Schottky defects where the oxygen ion pairs are further apart are marginally energetically preferred.

Real-time fast-neutron plutonium assay for storage and ageing applications

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Abstract

Nuclear safeguards is the discipline that ensures that civilian nuclear installations are not being misused to pursue weapons and that associated materials are not diverted to illegal usage. The well-established techniques for verifying this include passive/active radiation monitors using one of several detection methods including gamma-ray tomography, neutron coincidence counters using He-3 detectors and the Cherenkov viewing device etc. Each method has its benefits but individual limitations too. Additionally, the development of advanced fuel-cycle material, such as mixed-oxide (MOX) fuel has indicated further limitations of existing safeguard techniques due to presence, for example, of multiple actinides acting like neutron sources having signatures comparable to plutonium. A solution to this can be achieved by using liquid scintillation detectors (LSD) for fast neutron multiplicity analysis or coincidence counting. These detectors are sensitive to both fast neutrons and gamma radiation. The primary advantage of using such detectors is that they enable an extremely short gate time (three orders of magnitude lower than He-3 detectors) to be used, allowing reduced accidental coincidences and thus being able to detect higher orders of multiplicity.

This studentship is supported by the National Nuclear Laboratory as part of the EPSRC DISTINCTIVE consortium along with Lancaster University with the aim of (i) identifying the multiplicity distribution of a sample in real-time using liquid scintillation detectors to discriminate between different isotopes and (ii) exploiting (α, n) reactions to distinguish the uncorrelated events from the correlated neutrons. This report primarily focuses on

the design and development of a real-time system capable of the rapid data processing needed to this end. This is required due to the very short pulse length (in the order of 50-70 ns) originating from LSD when radiation is detected. Moreover, considering practical geometry of an experimental setup (i.e. several rings of detectors surrounding a source within a radius of 50-100cm) and the high speed at which fast neutrons travel, it is expected that fission neutrons will theoretically arrive at the detector after within 20 to 40 ns of the fission event taking place. Hence it is imperative that the system is capable of sampling the detector response at 200 MHz or higher. This feat was achieved utilizing a platform based on System-on-Chip Field-Programmable Gate Array (SoC–FPGA) which combines a dual-core Cortex-A9 embedded core with a FPGA fabric using a high-bandwidth interconnecting link. The system is capable of constructing neutron coincidence distributions in real-time by sampling up to 16 detectors every 5 ns over a user-defined gate-width or coincidence window. This distribution can then be unfolded to carry out neutron multiplicity analysis.

The Behaviour of Used Nuclear Fuel in Wet Storage

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Abstract

We have developed a method which enables direct gravimetric measurement of water adsorption onto CeO2 thin films. Porous CeO2 films were fabricated from a surfactant based precursor solution. The absorption of water onto the CeO2 coating at different relative humidities was studied in a closed reactor. Quartz Crystal Microbalance (QCM) gravimetry was used as a signal transducer, as changes in crystal resonant frequency due to absorbed mass are directly and linearly related to mass changes occurring at the crystal surface.

Water Adsorption on Actinide Oxide Surfaces

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Abstract

The interactions between water and the actinide oxides UO_2 and PuO_2 are important when considering the long-term storage of spent nuclear fuel. However, experimental studies in this area are severely limited by plutonium's intense radioactivity, and hence we have recently begun to investigate these interactions computationally. In this summary we report the results of first principles calculations of the interaction of water with UO_2 and PuO_2. Strongly-correlated effects are taken into account using a Hubbard corrected potential, which enables us to perform efficacious plane-wave density functional calculations of extended systems. In particular, we compare results of water adsorption on UO_2 (111) and PuO_2 (111) with the corresponding results on CeO_2, focusing on the energetics and structural properties of molecular versus dissociative adsorption, for both partially and fully covered surfaces.

Adsorption of Chloride and Water on CeO_2 as a precursor to PuO_2 studies

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Abstract

A quantity of plutonium dioxide powders in storage at the Sellafield site in Cumbria has become contaminated with chloride ions from the degradation of polyvinyl chloride (PVC) within the package, along with moisture from the atmosphere; chloride and water are thus adsorbed to the surface of PuO_2. This `high chloride` PuO_2 must be dried prior to repackaging in welded cans for safe, long term storage. Therefore an interfacial study of water- and Cl^--contaminated PuO_2 is essential to understand its properties and develop a treatment process. Due to difficulties in working with plutonium, using analogues is important to optimise analytical techniques and to provide more complete predictions of the probable behaviour of PuO_2 in advance of plutonium-active experiments. This review summarises recent findings of Cl^--contaminated ceria (CeO_2) as an analogue, using X-Ray Diffraction and Infrared Spectroscopy, Ion Chromatography and Scanning Transmission Electron Microscopy - Energy Dispersive Spectroscopy for analysis.

Radiolysis of H_2-O_2 mixtures of relevance to long term storage of PuO_2

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Abstract

Radiolysis of adsorbed water on the surface of PuO_2 could lead to the build-up of potential detonable atmospheres of H_2 and O_2 during long term storage of this product. This project aims to investigate the radiolysis of H_2-O_2 mixtures to determine the extent of recombination of these gases. This research was undertaken at the Dalton Cumbrian Facility utilising ^{60}Co γ rays and accelerated He^{2+} ions as sources of ionising radiation. Gas chromatography was used to analyse post-irradiated samples.

Ceramic wasteforms for actinide disposition

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Abstract

Pyrochlore ceramic and zirconolite glass-ceramic wasteforms are the potential host phases for actinide disposition. Composition – processing – structure relations in a series of pyrochlore related wasteforms (prototypically $CaCeTi_2O_7$ and $CaUTi_2O_7$) were investigated in this work, using Rietveld modelling of powder X-ray and neutron diffraction data and analysis of Ce and U L_3 edge XANES. An almost single phase Ce pyrochlore

with composition of $Ca_{0.60}Ce_{0.92}Ti_{2.27}O_7$, was synthesised and the first reliable structure determination made from analysis of neutron diffraction data (space group *Fd-3m*, *a* = 10.1462(4) Å). In addition, the synthesis of uranium betafite pyrochlore ceramics, was investigated at 1320°C in flowing N_2 from $CaTiO_3$, TiO_2, ZrO_2 and U_3O_8 as raw precursors. The betafite phase was obtained in high yield (> 85%) and a mean uranium oxidation state of 4.3±0.1 was determined by U L_3 edge XANES; all U_3O_8 was incorporated into the ceramic host phase.

Developing Glass-Ceramic Wasteforms for the Immobilisation of Pu-Bearing Waste-Streams.

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Abstract

The UK has 140 tonnes of separated civil PuO_2 stored at the Sellafield site. The strategy for dealing with this stockpile involves reuse in nuclear fuels, however a significant fraction has been identified as higher activity waste requiring immobilisation into stable wasteforms. This project is fundamental to gaining knowledge and understanding of zirconolite based glass-ceramics as future wasteforms for specific streams of these plutonium wastes. Consolidated using a hot isostatic press, an optimised formulation has been achieved to progress with waste incorporation experiments.

Understanding actinide sorption and binding to cement materials for radioactive waste management

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Abstract

Intermediate level waste (ILW) in the UK is currently immobilised using cementitious encapsulation. Cement hydrate phases, which form during the dissolution of cement clinker and pozzolanic additives, are capable of binding radionuclides on the long timescales required during storage and disposal of ILW. This study is focused in particular on the sorption of plutonium, and other actinides, onto fly ash (FA) and blast furnace slag (BFS) cement grouts associated with the encapsulation of plutonium contaminated materials (PCM) and other ILW, respectively. FA cement was synthesised and analysed using scanning electron microscopy (SEM) and X-ray diffraction (XRD) to establish key hydrate phases that may be involved in the uptake and retention of actinides. Hydrotalcite is a BFS cement hydrate phase that is concurrently being prepared for preliminary sorption studies.

Computational Studies of Water Adsorption on UO_2 and PuO_2 Surfaces

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Abstract

Density functional theory (DFT) and the periodic electrostatic embedded cluster method (PEECM) are used to study AnO_2 bulk and surfaces (An = U, Np, Pu). Water adsorption was investigated on the (111) and (110) surfaces of UO_2 and PuO_2 with 1 to 4 water molecules adsorbing on the cluster dissociatively or molecularly. Water adsorption on the (110) surface is stronger than on the (111). A mixture of molecular and dissociative adsorption is found to be most favourable on the (111) surface, while dissociative adsorption is seen to be most favourable on the (110) surface. Water in a second layer is found to have hydrogen bonding with the surface and hydroxyls present at the surface. Oxygen 1s binding energies show that molecular and dissociative adsorption could be distinguished by X-ray photoelectron spectroscopy (XPS) on the AnO_2 surfaces.

Theme 3 – Silo Ponds and Legacy Wastes

Synthesis and ion exchange properties of zirconogermanates

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Abstract

The synthesis of materials for ion exchange and subsequent disposal of radionuclides will be explored in this work; the concept being the formation of open framework materials with high selectivity for caesium and strontium that can be thermally transformed into dense phases for disposal. The successful synthesis of the germanium form of the natural mineral umbite ($K_2ZrSi_3O_9.H_2O$) and subsequent ion exchange results show both caesium and strontium uptake by Ge-Zr-umbite. Further work focused on the fine tuning of ion exchange properties by partial doping into the material.

Synthesis and studies of Barium doped $Cs_2TiNb_6O_{18}$ - A new Cs-waste form

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Abstract

$Cs_2TiNb_6O_{18}$ has the potential to be an excellent waste form for the immobilisation of radioactive caesium. A previous study revealed that $Cs_2TiNb_6O_{18}$ is the major Cs-containing phase produced when Cs-loaded IONSIV, a commercial ion exchanger, is hot isostatically pressed (HIPed).[1] $Cs_2TiNb_6O_{18}$ demonstrates excellent chemical durability which compared well to the Cs containing phase hollandite in SYNROC.[2]

Tailored Cs/Sr Ion Exchange in Sn-Umbite by Framework Substitution

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Abstract

Stannosilicates consisting of heteropolyhedral structure where the simplest units are SnO_6 octahedra and SiO_4 tetrahedra have been raising considerable interest. Current work has focused on the modification of the crystallographic and electrostatic environment in Sn-umbite ($K_2SnSi_3O_9 \cdot H_2O$) by varying the ratio or species of substitution in the framework (Nb^{5+}, V^{5+}, Sb^{5+}, Y^{3+} and Sc^{3+} for the octahedral site, and Ge^{4+} for the tetrahedral site). The substitutions were confirmed by XRD and XRF. The structural incorporations lead to a slight change of the unit cell volume, suggesting an isomorphous substitution can be achieved. As compared to Sn-umbite, some of the partially substituted phases, for example 25% Nb substituted umbite, show remarkable increases in both Cs and Sr capacity. An increase in ion exchange properties can be explained in terms of their inherent tunnel sizes to accommodate counterions due to partial substitution and bond strengths associated with the charge-neutralising cations and framework oxygens.

Mechanistic studies of uranium corrosion in mixed H_2O-H_2 systems

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Abstract

The main objective of my PhD research is to investigate and develop a better understanding of the corrosion mechanisms and reaction rates of uranium under waste storage conditions. This requirement hinges on the need to implement safe control, monitoring and identification of corrosion products developing on the uranium-rich radioactive waste awaiting to be retrieved from the radioactive ponds and silos at Sellafield. In order to achieve our objective, the main chemical reaction of uranium with water (H_2O) and the interactions between H_2O, uranium and the reaction products (H_2, UH_3) need to be examined thoroughly. Apart from working solely on the combined system (U-H_2O-H_2), it is also wise to investigate standalone reactions; thus the whole subject may be divided into four main areas:

- U + H_2O (saturated/wet conditions).
- U + H_2 (early hydriding stage).
- UH_3 + H_2O (saturated conditions).
- U + H_2O + H_2 (over pressurised conditions).

Concurrently with the experimental work, two separate and comprehensive reports are being produced which detail the current international understanding of uranium corrosion in water and in hydrogen (rates, mechanisms, controlling influences).

Raman Probe Development for In-situ Nuclear Waste Analysis

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Abstract

Sellafield Ltd. is situated in the north east of England and is the UK's nuclear decommissioning site. Within the site, it houses some of the UK's oldest wet storage ponds, with construction from the 1950's. This project seeks to analyse the bottom of the pond environment using Raman Spectroscopy with an in-situ Stand-off probe. Within these ponds a thick layer of sludge (approx. 1m depth) is at the base and is a mixture of nuclear waste, pond infrastructure and organic matter such as algae and windblown debris from its surroundings. This has formed due to decades of corrosion from the aqueous environment. An analysis will dictate the long term strategy for the retrieval and removal of this sludge, so characterising it is essential. The probe geometry and design are imperative for successful data sampling, as organic particulates emit fluorescence when excited by laser interaction, overwhelming the Raman signal the probe is attempting to measure. The probe also has to take data through a body of water. Here is the development to overcome these difficulties by using altering optical set-ups and laser wavelengths.

Glass Degradation in Partially Immersed Water

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Abstract

Glass is one of the potential host to contain nuclear wastes for disposal in deep geological repositories. Water which can potentially access repositories can degrade glass and possibly transport radionuclides from vitrified nuclear waste canisters into environment. Global research efforts to understand degradation of host glass in aqueous conditions and its ability to retain radionuclides for thousands of years is in progress. To assess the long term degradation of glass, there is a need to understand many unknown mechanisms and influences. We at Centre for Nuclear Engineering, Imperial College London are developing experimental methods to understand influences of different realistic conditions on glass degradation. We are currently studying glass cracks degradation, glass surface modifications and colloids formation. The document discusses surface modifications of glass when moisture condenses over glass surface.

Nanoscale Investigation and Control of Radionuclides in Waste Management

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Abstract

The rapid development of the nuclear industry and the associated production of toxic waste has created a large demand for the design of new novel materials aimed at the removal of soluble metals and radionuclides for safe and efficient waste disposal. The recent years' development of magnetic nanoparticles for separation technologies in liquid systems is wide-spread and already in use in medical testing [1–4]. The challenge is to translate this methodology, via surface functionalization to target the species of interest, and to use superparamagnetic behavior for waste form speciation and separation. The potential for magnetic-sorbent

structures to be used in waste form separation or removal of RNs from liquid streams has been investigated. Particle development is being carried out and characterization studies performed using TEM-EDX, ATR-FTIR, XRD, DLS and ζ-potential. Preliminary sorption tests with Sr and U have been carried out to evaluate the sample specificity.

Ab initio Molecular Dynamics Simulations of Magnesium, Calcium and Strontium Hydrates

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Abstract

In order to ensure the safe reprocessing of the legacy waste storage ponds at Sellafield in Cumbria the sludge which has formed at the bottom of the ponds must be characterised. Due to the high radioactivity within the ponds a computational approach offers significant advantages when investigating the behaviour of the various radionuclides which are present and how they adsorb onto the mineral present in the sludge brucite, without the risks associated with working with radioactive materials. This project uses *ab initio* molecular dynamics to quantum chemically study the interactions of magnesium, calcium and strontium ions in a body of water at varying temperatures. The average coordination number and first solvation shell properties have been investigated at 300 K, 350 K and 400 K. Using these methods we have started to develop a picture of the solvation of these ions in order to simulate the behaviour exhibited in the legacy storage ponds.

Developing the use of an Acoustic Backscatter system (ABS) to measure the concentration of nuclear simulants under varying degrees of flocculation

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Abstract

It is proposed here that further research efforts should be made in order to develop the use of acoustic backscatter to measure concentration in flocculated systems. The use of acoustics is generally widespread in marine, food and water treatment industries and has great potential in applications where access to process fluid presents a chemical or radiological hazard. Despite the fact that there have been many developments made recently by various authors to better understand how acoustic models can be developed to further to broaden their applications to measuring particle size and concentration in flocculated or otherwise cohesive systems there is not a robust model relating flocculated particle structure to its acoustic backscatter properties.

X-ray tomography insights into gas retention in nuclear legacy waste

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Abstract

The requirement to evacuate aging legacy facilities at Sellafield represents a multibillion pound challenge and the safety implications of retained hydrogen bubbles must inform the strategy for this legacy waste. This study uses the decomposition of hydrogen peroxide in soft sediments of a magnesium hydroxide test material to replicate behaviour in the magnox swarf storage silos and similar Magnox-era waste, while x-ray tomography is used to gain statistical insights into the retained bubble population. Time dependent x-ray tomograms reveal that bubbles reside only for relatively brief periods of less than an hour in beds of 7 Pa yield stress and that even small bubbles of around 2 mm diameter, with a relatively small buoyancy force, are mobile within the sediment bed. While the larger retained bubbles grow with an increasingly distorted geometry in beds of increased yield stress, the size distribution of bubbles appears largely independent of the bed strength within the 7-234 Pa yield stress range. Each of the beds within this yield strength range have demonstrated the capacity to retain large voidages in the order of 32 %, which would substantially reduce the functional capacity of future waste containers and would reduce the bulk bed density to less than that of a water supernatant, placing submerged beds at risk for rollover events.

Modelling Sludge Mobilisation and Transport

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Abstract

Particle agglomeration can occur during some stages of the decommissioning process (retrieval and transport) of UK legacy nuclear waste, resulting in unwanted effects such as the formation of deposits and plugging of transfer and process pipes. This project, therefore, studies particle-particle interactions to understand particle agglomeration and break-up in turbulent flow using nuclear waste simulant properties.

In-line rheometry and flow characterisation of dense slurries in pipe flow using acoustic methods

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Abstract

The UK's civil nuclear waste inventory is large, diverse and requires processing and disposal but characterisation of nuclear waste slurries during storage, resuspension and hydraulic transport is made difficult by poor accessibility, radioactivity and chemical hazards. The aim of this study is to develop a suite of safe, accurate, versatile and cost-effective acoustic methods for rapid monitoring and characterisation of high-

concentration nuclear waste-analogue slurries, based on existing expertise at the University of Leeds. Results from and proposals for several acoustic methods are described – in-line pipe rheometry, time-domain velocimetry, multi-frequency particle concentration measurement, bed depth and critical deposition velocity determination. A new flow loop laboratory has been commissioned in which these methods will be combined with pumped sampling to investigate horizontal and vertical flow of suspensions of relevance to nuclear waste decommissioning and disposal.

Quartz Crystal Microbalance for *In-situ* Rheology Measurements

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Abstract

Sellafield is currently entering a phase of post-operational clean out where the remediation of the site is anticipated to cost £35 bn over the next 100 years. A substantial portion of this cost is associated with the clean-up, transfer and safe storage of legacy particulate wastes encountered in ponds, silos, highly active storage tanks and other large tanks on site. In order to develop suitable strategies for the transport and removal of these particulate suspensions, the rheology of the sludge should be accurately determined. The current work demonstrates the applicability of a quartz crystal microbalance (QCM) to measure sludge rheology; specifically its shear yield stress. The device is simple to operate with no mechanical parts near the test material, is small and portable which allows for deployment into limited access areas and provides the user with in-situ rheological information on the test sample which eliminates the need for operator sampling. The measurement principle of the QCM relates to the changes in resonance frequency and motional resistance of a piezo-electric gold-coated quartz sensor as it is submerged into the desired test material. The air-to-sample frequency and resistance shifts are shown to correlate well with the shear yield stress of a suspension as measured by conventional vane viscometry. An increase in the suspension yield stress relates to a more positive frequency and resistance shift, where this correlation have been confirmed for a range of particle suspensions.

Cake formation in enhanced shear microfiltration

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Abstract

This project investigates enhancing the flux rate in microfiltration through directed membrane surface shear. This is achieved by reducing the filter cake formed by oscillating the filters either vertically or azimuthally. Control of the filter cake build-up enables a higher flux rate, while maintaining the required particle retention.

In Situ Monitoring of the Legacy Ponds and Silos at Sellafield

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Abstract

The aim of this research is to identify experimental factors that influence the quality of results from sludge sampling and characterisation campaigns, to evaluate their contributions to data uncertainties and to seek ways to optimise the protocol through the use of an in-situ core sampler and analyser. The research involves the use of relevant statistical tools to analyse the results obtained from simulation and laboratory tests. By ensuring high quality in the data obtained from sludge sampling and characterisation campaigns, the quality of decisions taken in the design of sludge transportation and processing systems is further enhanced. The research looks into the measurement of particle size distribution (PSD) as an indicator of the physical properties of sludge.

In this report, the experimental factors considered were the sampling intensity, as represented by the number of samples collected, the sampler device used and the sampling strategy adopted. Other important factors considered were the degree of homogeneity of sludge spatial distribution in the ponds and the method of spatial extrapolation used to predict measured physical properties on non-sampled areas of the sludge bed. Maps showing the confidence limits associated with the resulting spatial extrapolations were also produced.

A useful statistical tool for analysing the influence of different experimental factors on variability of results is the F-statistics. The magnitude of a factor's F-statistics is an indication of the significance of such a factor to variability. From early results obtained from 2D sampling simulations, it was observed that the sampling intensity factor had an F-statistics of about 80,000. This was followed by the sampling strategy factor with an F-Statistics of about 1000. Unexpectedly, the choice of sampler device, which is thought to be an equally significant factor, had an F-statistics of 0. This has led further investigations using a 3D sampling simulation. Analytical factors will also be investigated using the principle of laser diffraction. Another work in progress is the design of a bench-top experiment to investigate the use of an in-situ sampler and analyser for remote characterisation.

Irradiated Sludges

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Abstract

This project aims to identify production mechanisms of important radiolytic products, especially gaseous products for example molecular hydrogen gas, from Magnox sludges at Sellafield sites. We will use the Q14 irradiation platform, in Queen's University Belfast, to irradiate sludge mimics, and then take measurements of the type and amount of different end products, like hydrogen gas, produced by irradiation. These results will then be compared to the predictions of simulations made by the Atomistic Simulation Centre, also at Queen's University Belfast.

Determination of Hydrogen Production from Legacy Fuel Storage Pond Sludges through Molecular Modelling

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Abstract

The First Generation Magnox Storage Pond (FGMSP) represents one of the highest priority targets for risk reduction at the Sellafield Site. This legacy pond has accumulated a deep layer of sludge over many years, formed primarily from corroding Magnox alloy, but also from windblown debris and decaying organic matter. This sludge is of complex and uncertain composition. Additionally it contains dissolved fission products where cladding has failed and split, or even fragments of spent fuel where cladding has corroded entirely. The production of methane and hydrogen gas complicates the future handling and disposal of this sludge. The focus of the modelling project will be on the radiolytic route to hydrogen production through the study of a water-brucite-hydrocarbon system. By studying a simple model system we will develop an understanding of the underlying chemical reactions. Simulations will be carried out using both classical and quantum, ab initio mechanical molecular dynamics.

Investigation of the thermal treatment of waste plutonium contaminated materials (PCM)

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Abstract

Key drivers for the application of thermal treatment processes include the reduced volume, improved passive safety, and superior long term stability, of the vitrified wasteform products. These advantages have led to a renewed interest in thermally treating various UK ILW streams. To support the increased investment in thermal treatment technologies a fundamental understanding of the processes and the impact of waste inventory needs to be established. The research described in this report aims to provide the evidence necessary to support a major investment in thermal treatment of plutonium contaminated materials. The report describes the use of laboratory scale waste simulants to develop an understanding of the waste and matrix interactions during thermal treatment of PCM waste. The report includes the thermal treatment process, characterisation and long term performance of the vitrified product.

A quantum chemical study: Sr^{2+} ion adsorption on the brucite (0001) surface

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Abstract

A quantum chemical model of the brucite (0001) surface is developed using the periodic electrostatic embedded cluster method (PEECM) and used to investigate the adsorption of Sr^{2+} hydroxide and hydrate complexes on the surface. The PEECM model is compared to another well established method, periodic density functional theory (periodic DFT), by calculating Sr^{2+} dihydroxide complexes adsorbed on the bare brucite surface. Relative energies between the different complexes are found to be very similar with the different approaches. Explicit water molecules, whose geometries are based on previous molecular dynamic studies, are introduced above the brucite surface with the PEECM model, allowing the interaction of the Sr^{2+} ion with the hydrated surface to be investigated. Several possible complexes are identified with different Sr-surface distances.

Theme 4 – Structural Integrity

3D semantic SLAM/Reconstruction in industrial environment

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Abstract

In order to facilitate planning and execution of remote handing during the object manipulation of robot arm in industrial environment, every object should be 3D reconstruction and 3D pose tracking in real-time. This research summary proposes a dense semantic 3D reconstruction approach. It also made some preliminary tests in office environment because our nuclear industrial dataset is still under way. Using Kinect like camera, the RGB and depth images can be obtained. Objects and scene can be 3D reconstructed as point clouds in real-time based graph optimization. At the same time, each voxel of point cloud can be labeled to different classes like wall, ground, pipe, metal, robot and etc. based on Randomized Decision Forest classification and 3D Conditional Random Field refinement. Finally, all the recognized objects can be convert to CAD models in order to 3D pose tracking and object manipulation.

Re-Use and Volume Reduction of Scabbled Contaminated Concrete Arising from Nuclear Decommissioning

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Abstract

Around 50% of the UK's classified nuclear waste is building waste including concrete, cement and rubble. While research has gone into ways to minimise the volume of this waste, little has examined recycling of the materials. This research aims to investigate methods to reduce the burden on present and future storage and disposal facilities through re-use and volume reduction of conditioned contaminated concrete. MSc research has shown possible reactivity within the scabbled material enabling the potential for use as a cementitious replacement material. The overall aim of future PhD research is to investigate the use of scabbled contaminated concrete as a replacement material within nuclear waste encapsulation grouts, or at volume reduction of conditioned waste.

Atomistic Simulation of Cement-Based Materials for Nuclear Waste Disposal

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Abstract

The *ab initio* simulation of cement-based materials is a vital task in understanding the processes that will occur in the storage of nuclear wastes in preparation for geological disposal in the future. As cement is an amorphous material whose composition is hotly debated, the problem is as complex as it is important. Initial work building on prior work done by collaborators has shown that while calcium-silicate-hydrate materials are unlikely to be strongly affected by the loss of electrons induced by γ-irradiation. The water contained within the cement is likely to undergo reaction and produce a rich cocktail of molecular species, in particular hydroxyl radicals which may produce hydrogen gas, causing expansion and cracking, or contribute to the Pozzolanic reaction which produces a gel-like layer that compromises the mechanical strength of cements. As such, knowledge of the properties of irradiated cement are necessary for the understanding and safe storage of nuclear wasteforms.

Development of Novel, Low Cost Biomineral Permeable Reactive Barriers for Radionuclide Remediation

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Abstract

The microbial production of phosphate minerals has gained attention as a promising mechanism of *in situ* groundwater remediation. To date, most research has focused on the immobilisation of contaminants by the induced precipitation of insoluble contaminant-phosphate minerals (e.g. uranyl phosphates); however, it is also possible to use this technique to manufacture permeable reactive barriers (PRBs) which are then capable

of mediating long-term, passive remediation of groundwater flow. This project investigates the use of bacteria and fungi to induce the formation of a phosphate mineral PRB *via* the enzymatic hydrolysis of an organic phosphate substrate (phytate). Attention is given to the factors influencing biomineral formation, composition, and characteristics (e.g. enzyme production and activity, secretion of microbial metabolites, other chemical species present, pH, redox potential) and this knowledge used to promote the manufacture of a biomineral with optimal physicochemical properties for deployment in a PRB (large, reactive surface area with a high capacity for contaminant sorption while remaining hydraulically permeable). Additionally, challenges relating to the scale-up and practical deployment of the process will be considered.

Hydro-mechanical characterisation of colloidal silica grout

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Abstract

Colloidal silica based grouts are increasingly being considered as a potential grouting technology for the application of subsurface ground barriers, overcoming several limitations of traditional techniques. Colloidal silica grout has an initial low viscosity, small particle size, and is environmentally inert. Colloidal silica grouts are formed of a solution of silica nanoparticles and a salt accelerator such as NaCl. This summary presents results from on-going research at Strathclyde which aims to develop a greater understanding of the hydro-mechanical behaviour of colloidal silica grouts. Laboratory tests were carried out to investigate the stress-strain behaviour of colloidal silica grout samples considering the influence of curing environment, length of curing time, and gel time. A series of one-dimensional oedometer consolidation and direct shear tests were conducted on colloidal silica samples. Additionally, the soil-water retention behaviour of colloidal silica grout was determined.

Use of Colloidal Silica Grout for Ground Barriers in Decommissioning: A Project Overview

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Abstract

Over the last three decades, colloidal silica has been investigated and more recently adopted as a low viscosity grouting technology (e.g. for grouting rock fractures within geological disposal facilities nuclear waste). The potential of colloidal silica as a favourable grouting material exists due to: its initial low viscosity; its low hydraulic conductivity after gelling (of the order of 10^{-7} cm/s); the very low injection pressures required; its controllable set/gel times (from minutes to several days); the fact it is environmentally inert; its small particle size (less than hundreds of nanometres) and its cost-effectiveness. Colloidal silica can be destabilised by the addition of a salt accelerator compound and a change to pH, resulting in a rapid increase in viscosity (i.e. gelation) and formation of a rigid solid gel. This behaviour allows for low injection pressures to be used during the grouting process due to the initial low viscosity; with the resulting gel forming the contaminant ground barrier. This study aims to investigate the use of colloidal silica based grouts for formation of ground barriers at the Sellafield site. Potential applications include pre-treatment of the ground beneath, and surrounding, legacy structures prior to the retrieval of hazardous wastes and the formation of horizontal and vertical barriers surrounding unlined waste disposal trenches. The programme of research includes the successful completion of a large scale laboratory experiment, followed by field trials, to demonstrate the reliable application of colloidal silica for near-surface ground barrier formation. Here we summarise results to-date on colloidal silica gelling behaviour, grout-site interaction, the colloidal silica grout injection process, injection monitoring and the mechanical characterisation of the colloidal silica grout.