TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Theme 1: Integrated Waste Management Theme Overview

Joe Hriljac, University of Birmingham

& Diamond Light Source

TRANSCEND Thematic Meeting 1

11 November 2019
Lancaster

Energy
For a Low Carbon Future

Programme Overview

TRANSCEND: Collaborative Research Programme in **Tran**sformative **Sc**ience and **E**ngineering for **N**uclear **D**ecommissioning

- Follows on from DISTINCTIVE nuclear consortia (Feb 2014 to Feb 2019)
- Project started 1st October 2018, runs until 30th September 2022
- £4.59M EPSRC → £5.73M (at FEC), plus £3.70M from industry = £9.43M

Programme Overview

- University Partners on EPSRC grant

- Industry Partners

Programme Objectives

- To carry out internationally leading science and engineering research in area of decommissioning, immobilisation and management of nuclear waste
- To undertake research that leads to innovative technology developments that can be applied in industry
- To develop new multi-disciplinary research and innovation partnerships between academic and industry researchers
- To train next generation of UK researchers with relevant skills and experiences that can be applied in sector
- To provide focus for all stakeholders, including government, industry and academics, through which current and future research and innovation requirements can be discussed
- To provide route for public understanding of research and development needs, opportunities and solutions

Themes

Theme 1. Integrated Waste Management (Leads: Claire Corkhill / Joe Hriljac)

Theme 2. Site Decommissioning and Remediation (Leads: Becky Lunn / Luc Vandeperre)

Theme 3. Spent Fuels (Leads: David Read / Tom Scott)

Theme 4. Nuclear Materials (Leads: Colin Boxall / Nik Kaltsoyannis)

Themes

Theme 3. Spent Fuels (Leads: David Read / Tom Scott):

- Properties and Reactivity of Bulk Corrosion Products
- Pressing Fuel Barrier Corrosion
- In-Situ Identification of Nuclear Fuel Materials and Surface Corrosion Products
- Prediction of Long-Term SNF Behaviour

Theme 4. Nuclear Materials (Leads: Colin Boxall / Nik Kaltsoyannis):

- Surface Chemistry of PuO_2 under Conditions Relevant to Interim Storage
- Plutonium Immobilisation in Advanced Ceramic Wasteforms

IWM Theme Topics

1. Application of the waste hierarchy and categorisation
2. Novel waste treatment to achieve passive safety and volume reduction including orphan wastes
3. Material decontamination, effluent and gas treatment
4. Process control, product monitoring, prediction and handling
5. Waste package design and optimisation

These came out of the Bristol meeting and align with various strategy documents including the Technology Opportunities from the *NDA Technical Baseline* (Oct 2016) and NNL *Nuclear Industry Guidance for Research in Academic Institutions* (Sep 2017)

IWM Theme Technical Challenges

Research in this theme will focus on underpinning science and engineering in three areas of relevance to **hazard reduction and decommissioning**:

Removal of radionuclides from effluent

Enhanced characterisation and modelling the behaviour of sludges in the Sellafield ponds and silos

Development and evaluation of new wasteforms

IWM Research Objectives

This theme aims to develop an **enhanced understanding of materials, processes and wasteforms used in hazard reduction and decommissioning**. The ultimate goal is to underpin new technologies for safe and efficient management of legacy waste. The objectives are to:

Develop new materials for the removal of radionuclides from effluent that can be deployed in plant, e.g. to replace or supplement the clinoptilolite in SIXEP at Sellafield, or on site.

Develop first principles modelling techniques on particle-laden flows that can be used to improve their flow, mixing and separation properties.

Transform the understanding and predictive capability of the role of radiation-driven processes in nuclear waste sludges

Develop a better understanding of the production & physical properties of a toolbox of wasteforms including cementitious, vitrified and ceramic materials

Theme Researchers

4 Postdoctoral Researchers:

University of Birmingham	University of Leeds	Imperial College London	Manchester 1824 The University of Manchester
3 year PDRA	3 year PDRA	3 year PDRA	2 year PDRA

12 PhD researchers over 7 Universities:

University of Birmingham
University of Strathclyde Glasgow
The University Of Sheffield.
Manchester 1824 The University of Manchester
University of Leeds
Imperial College London
Sheffield Hallam University

7.5 PhD projects funded by Universities. 4.5 from industry:

NDA Nuclear Decommissioning Authority
Sellafield Ltd
LLWR Ltd

Work Packages Overview

WP1: New Materials and Methods for Decontamination of Effluent

- x1 PDRA at Birmingham University
- x1 PDRA at Imperial
- x2 PhDs at Birmingham (1 sponsored by Sellafield Ltd.)

WP2: Modelling and Experiments for Understanding Pond and Silo Sludge Behaviour

- x1 PDRA at Leeds University
- x1 PDRA at Manchester University
- x2 PhDs at Leeds, x 1 PhD at Manchester

WP3: Wasteform Development

- x7 PhDs at: Imperial (1); Manchester (1); Sheffield (3); Strathclyde (1); Sheffield Hallam (1) (2 sponsored by NDA, 1 by SL, 0.5 by LLWR)

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

j.a.hriljac@bham.ac.
uk

Transformative Science and Engineering for Nuclear Decommissioning

TRANSCEND: Site Decommissioning and Remediation

Professor Becky Lunn

2019, TRANSCEND Theme Meeting

Nov 2019
University of Lancaster

For a Low Carbon Future

Theme Technical Challenges

Decommissioning nuclear sites

- Waste retrieval
- Decontamination & deconstruction
- Where necessary, containment and/or remediation of the remaining structure and surrounding land

Research Aims

To develop **new technologies for monitoring, remediation and containment**

that serve to **minimise the volume** of radioactively contaminated **waste for disposal**,

for application **prior to**, **during** and **after** retrieval, deconstruction and decontamination operations.

Research Objectives

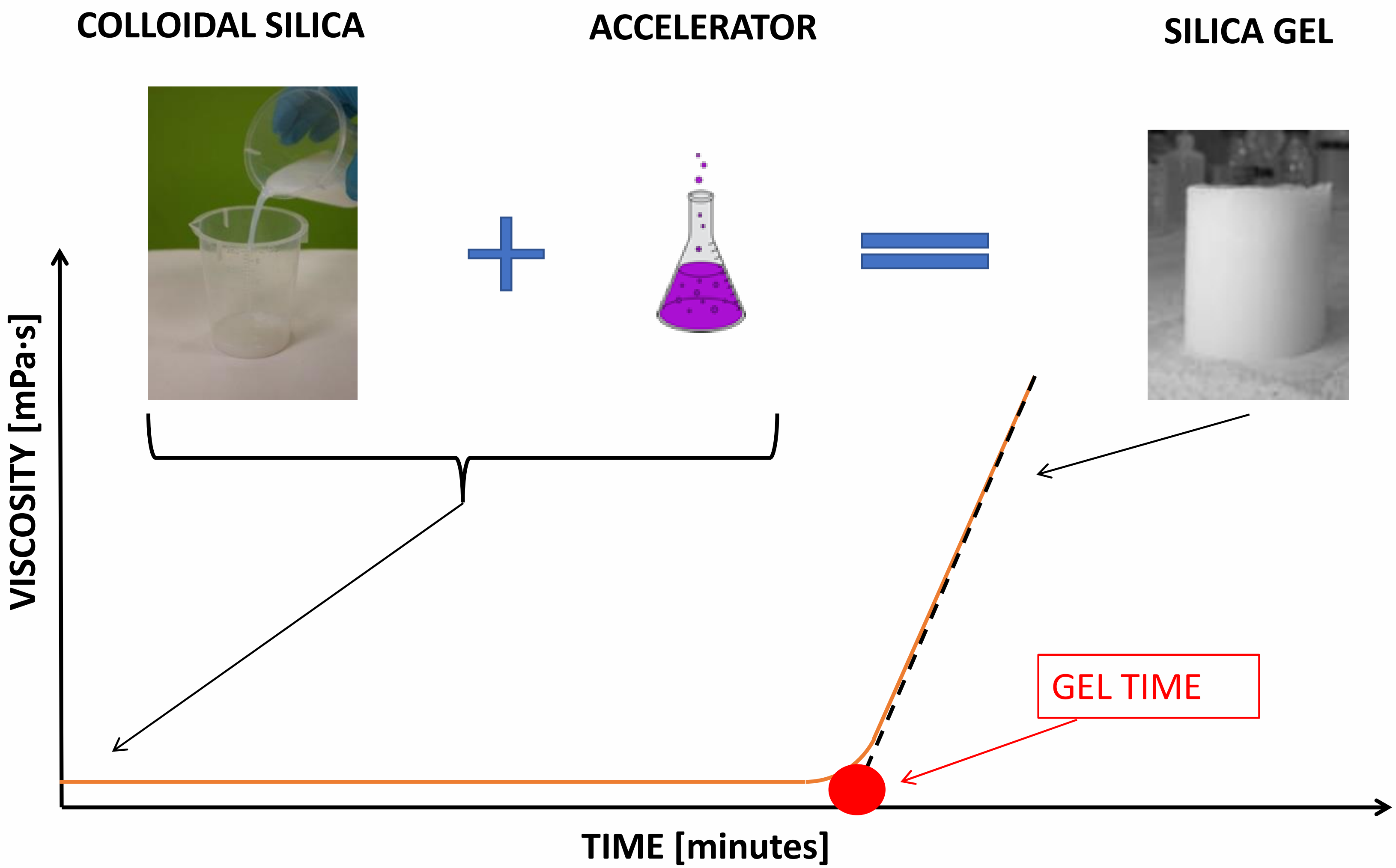
1. **Develop silica-grout soil/infrastructure grouting strategies** that minimise airborne and waterborne hazard and environmental risk;
2. **Develop viable in-situ and ex-situ wasteforms for silica-grouted soils/cements such that the silica is redeployed** within wasteform;
3. Adapt and develop **low-energy electrokinetic remediation** for waste volume minimisation and to combine these with silica-based in-situ grouting/vitrification
4. **Develop rapid non-invasive geophysical techniques for the assessment of radiological soil contamination** and structural degradation (including reinforcement).

WP2.1 Colloidal-Silica Grout

Main research aim :

- **Treatment of soils to inhibit air- and water-borne radionuclide migration**

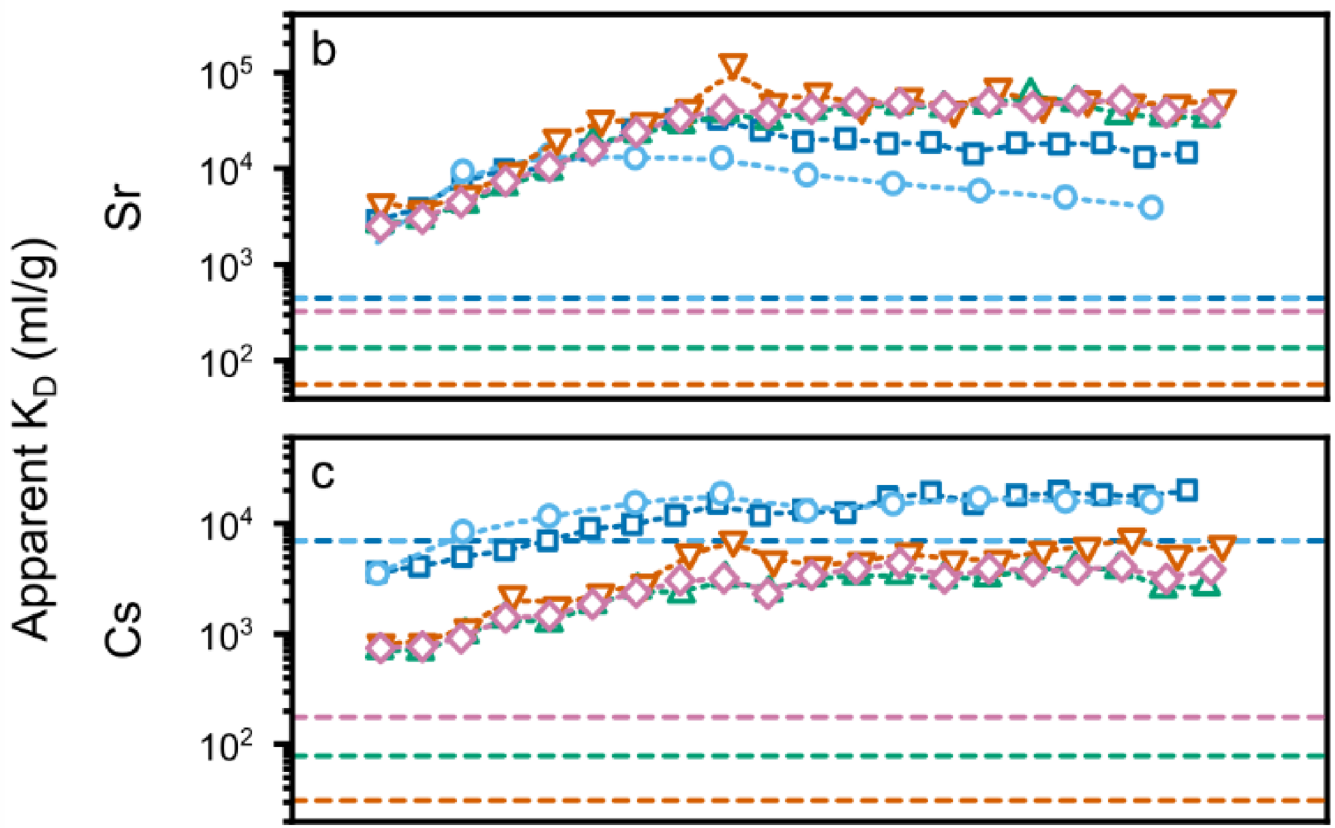
Colloidal Silica Hydrogel



Sorption Capacity – Leaching Tests Sr and Cs

- Grout is a hydrogel – need to inhibit diffusion
- All grouted samples have higher sorption capacity

Adsorption coefficients plotted against time



Straight lines are values for ungrouted samples

Gea Pegano (PDRA) Strathclyde

Specific objectives :

Soil stabilisation and barrier formation

Optimisation of sorption/desorption grout properties

The feasibility of in-situ and ex-situ vitrification/cementation of grouted soils,

Colloidal silica as a strategy for repair of existing degraded cementitious waste packages;

combining colloidal silica grout containment and in-situ vitrification with the electro-kinetic technique in WP2.2.

NDA-funded associated PhD
David Morrison, Strathclyde

Erosion testing

Contact : Becky Lunn, University of Strathclyde

WP2.2 Electrokinetic Ground Remediation: Low voltage current

EK test cells at laboratory and intermediate(m)-scales

- remove, focus or degrade contaminants
- direct subsurface water, chemical and colloid flow

Numerical models of EK processes

- to inform full-scale on-site application by nuclear site holders

Specific objectives:

- adapt low-energy ex-situ electrokinetic remediation and volume minimisation techniques already proven on AWE legacy wastes to other UK nuclear legacy wastes and sites;
- develop in-situ **low-energy electrokinetic fencing** (for groundwater) **and remediation** (for soils and sediments), to limit the spread of active contaminants, and minimise soil volumes for subsequent treatment; and
- combine EK with colloidal silica grouting to minimise soil contamination for in-situ vitrification.

Contact : Andrew Cundy, University of Southampton

Jamie Purkis (PDRA) + 1 PhD

WP2.3 Non-Invasive Monitoring of Soil Contamination, Structural Degradation, Assessment and Repair.

- Muon scattering tomography for the detection of chloride corrosion in structural reinforcement

  1 PhD @University of Strathclyde, UoS

  Contact : Marcus Perry, University of Strathclyde

- Tools for improved identification of ground contamination associated with contaminated in-ground infrastructure that may remain at the site end state

  Soraia Elisio, PhD @Lancaster University, NDA

  Contact : Malcolm Joyce, Lancaster University

WP2.3 Non-Invasive Monitoring of Soil Contamination, Structural Degradation, Assessment and Repair.

- In-situ bio-remediation of damaged concrete structures

Thanos Karampourniotis, 1 PhD @ University of Strathclyde, Cavendish Nuclear

Contact : Becky Lunn, University of Strathclyde

- Algorithms to determine gamma dose rates based on restricted information

Luke Lee-Brewin, PhD @University of Surrey, Sellafield

Contact : David Read, University of Strathclyde

Theme Summary

2 PDRA's and 4 PhD students + 1 associated PhD working to:

Develop **new technologies for monitoring, remediation and containment**

that serve to **minimise the volume** of radioactively contaminated **waste for disposal**,

for application **prior to**, **during** and **after** retrieval, deconstruction and decontamination operations.

Thank you

Contact Details

Site Decommissioning and Remediation- Context, Challenges and Opportunities

James Graham

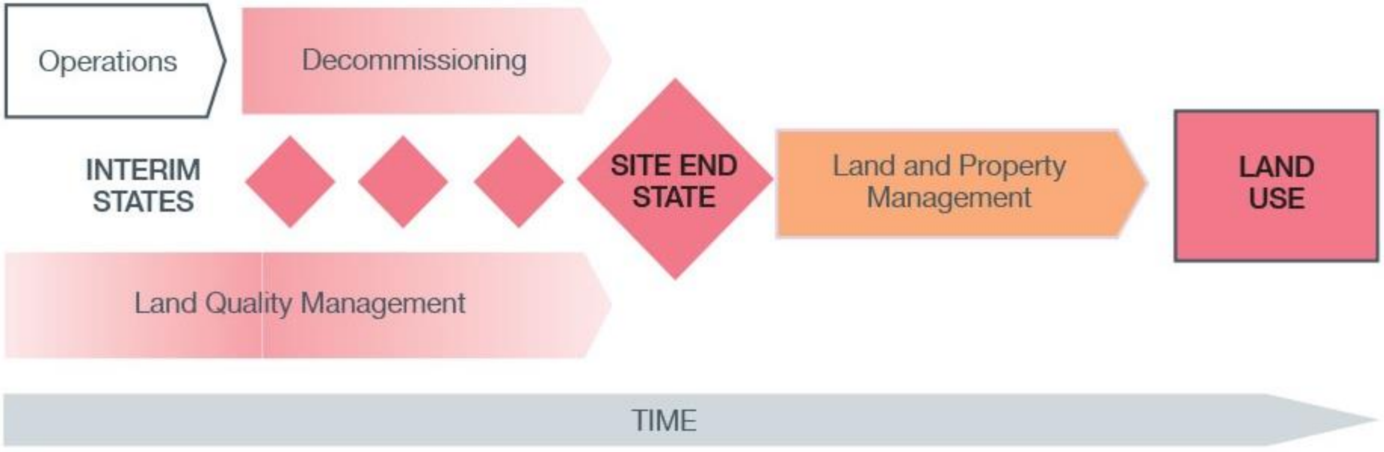
11th November 2019

NATIONAL NUCLEAR LABORATORY

Contents

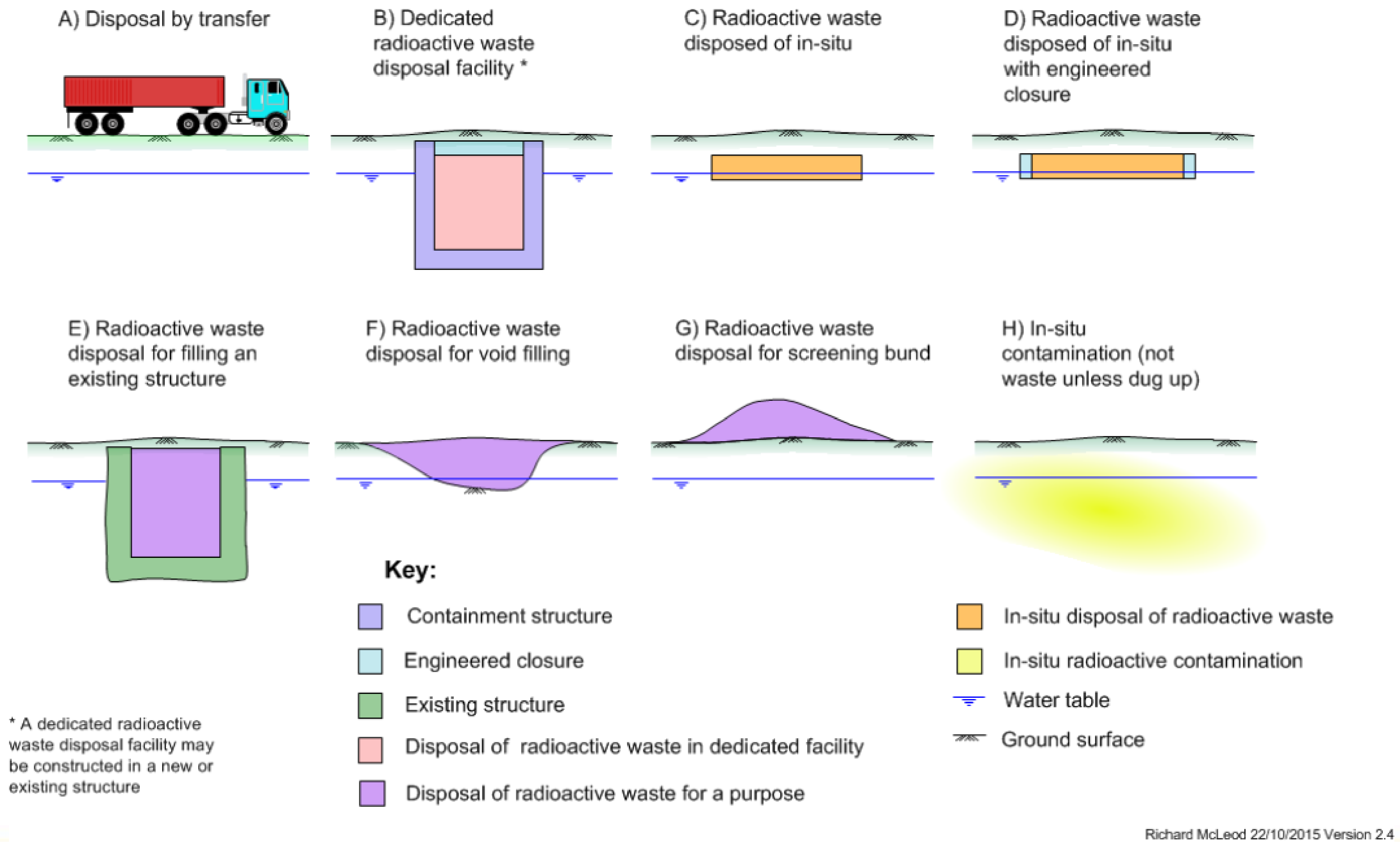
Site Decommissioning and Remediation : Context

- Reflects one of Five NDA Themes
- "Site decommissioning and remediation is our primary focus and all other strategic themes support or enable its delivery." NDA Strategy, 2016
- SD&R Objective:
  - "To decommission and remediate our designated sites, and release them for other uses."



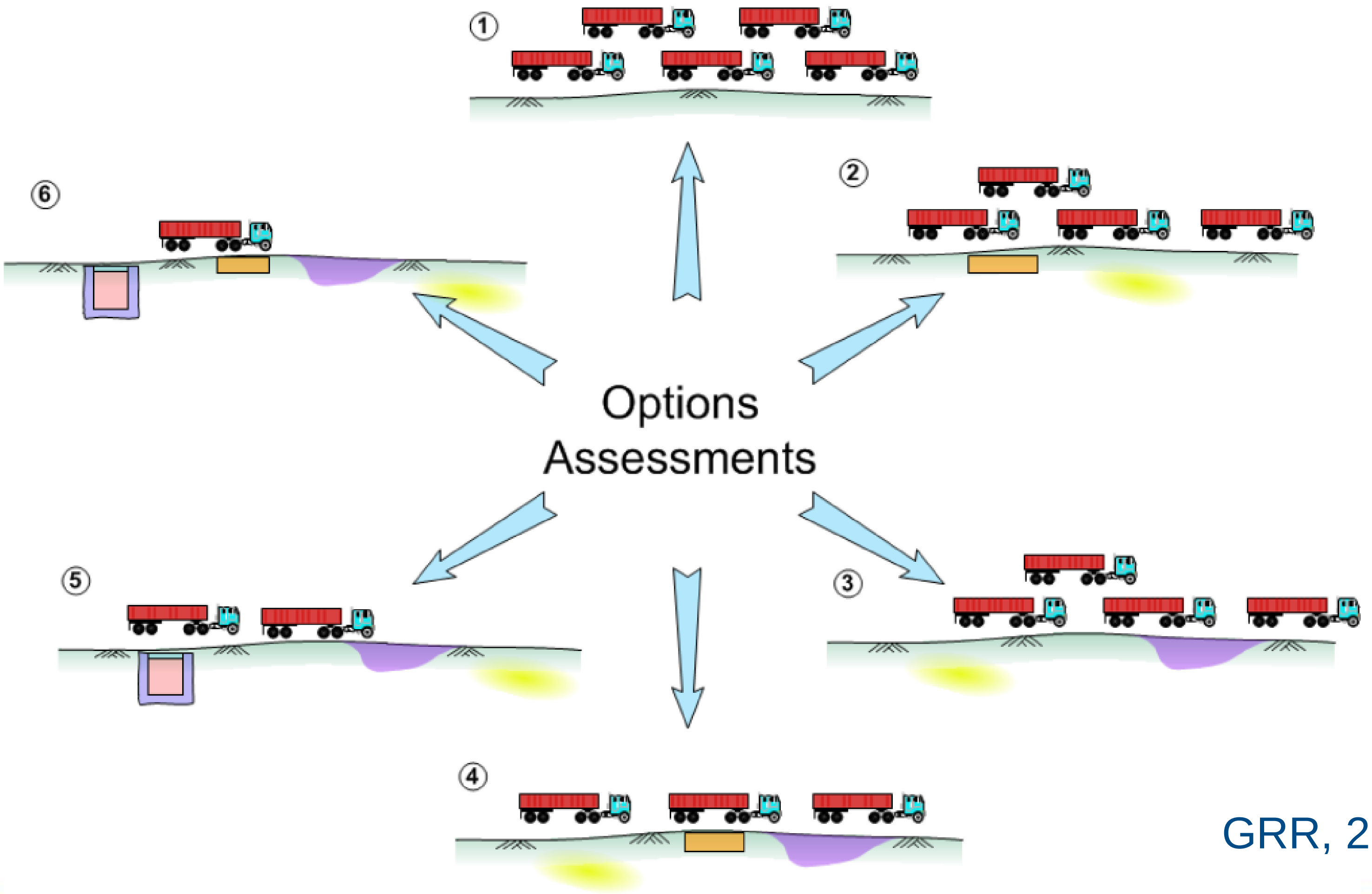
Site Decommissioning and Remediation timeline (NDA, 2016)

Disposition options for radioactivity from a decommissioning nuclear site



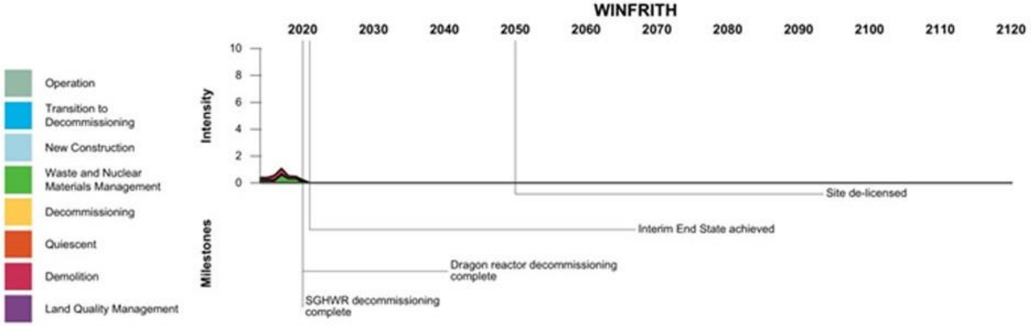
GRR - Guidance on the requirements for the release of nuclear sites from RSR (July, 2018)

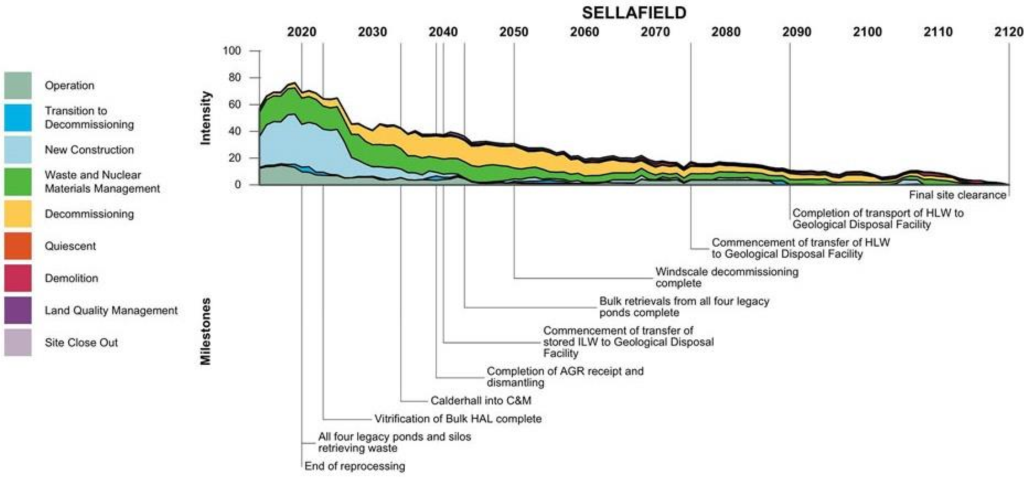
Options Assessment



GRR, 2018

Site End State Examples





SD&R Challenge Summary

- Major challenges in SD&R (NDA, 2016):
  - legacy plants in excess of 60 years old containing significant quantities of corroding radioactive material which represent some of our largest hazards and our highest risks
  - deteriorating infrastructure
  - ground and groundwater contamination resulting from a variety of past uses, including non-nuclear activities

Sellafield FGMSP

- Role for R&D and innovation in SD&R
  - Reduce lifetime costs (currently >£100Billion)
  - Increase Safety
  - Accelerate programmes
  - Reduce uncertainty
  - Underpin decision making
  - Improved confidence
  - Develop and maintain expertise and capability

Photo: https://www.gov.uk/government/news/game-changing-progress-in-sellafield-pond

TRANSCEND SD&R Programme

Theme Objectives:

- Develop soil/infrastructure grouting strategies, for application prior to and during decommissioning, that minimise airborne and waterborne hazards and environmental risk
- Develop viable in-situ and ex-situ wasteforms for silica-grouted soils/cements such that the silica is redeployed within the vitrified or cementitious wasteform
- Adapt and develop low-energy ex-situ and in-situ electrokinetic remediation/waste volume minimisation approaches, already proven on some legacy wastes, to other UK nuclear sites, and to combine these with silica-based in-situ grouting/vitrification
- Develop rapid non-invasive geophysical techniques for the assessment of radiological soil contamination and structural degradation (including reinforcement)

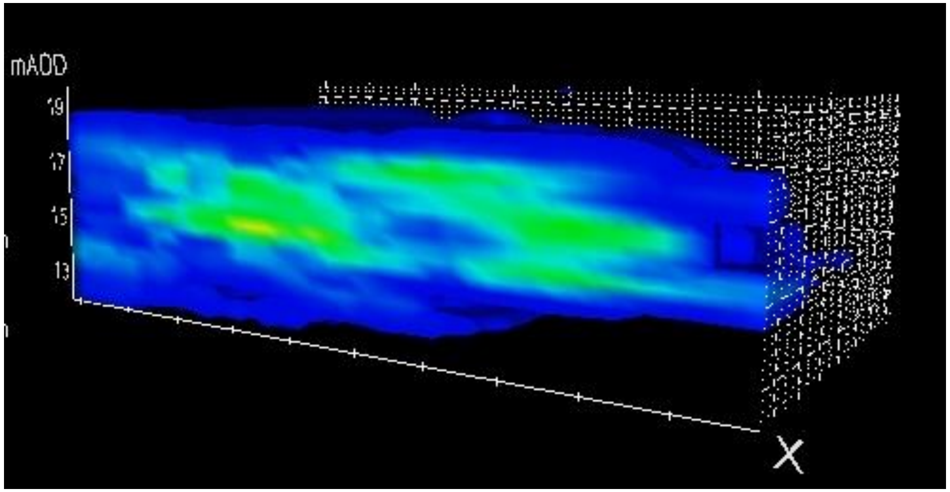
Work Packages:

- Colloidal-Silica Grouting
- Electrokinetic Ground Remediation
- Non-Invasive Monitoring of Soil Contamination, Structural Degradation, Assessment and Repair

Grouting Case Studies

Waste Plant Source Zones/Leak Mitigation

- Waste plants undergoing retrievals for decades
  - History of leakage causing significant ground contamination and GW plume
  - Potential for new leaks in inaccessible locations
- Requirement for tool box of techniques for limiting migration of contamination away from historical/new leak sources
- Concerns in these areas of:
  - Sensitive structures (no ground displacement)
  - Remobilisation of existing contamination
- Colloidal silica
  - Chemically and biologically inert
  - Non swelling
- Opportunities
  - Significant existing characterisation of case study systems by industry
  - Analogue materials



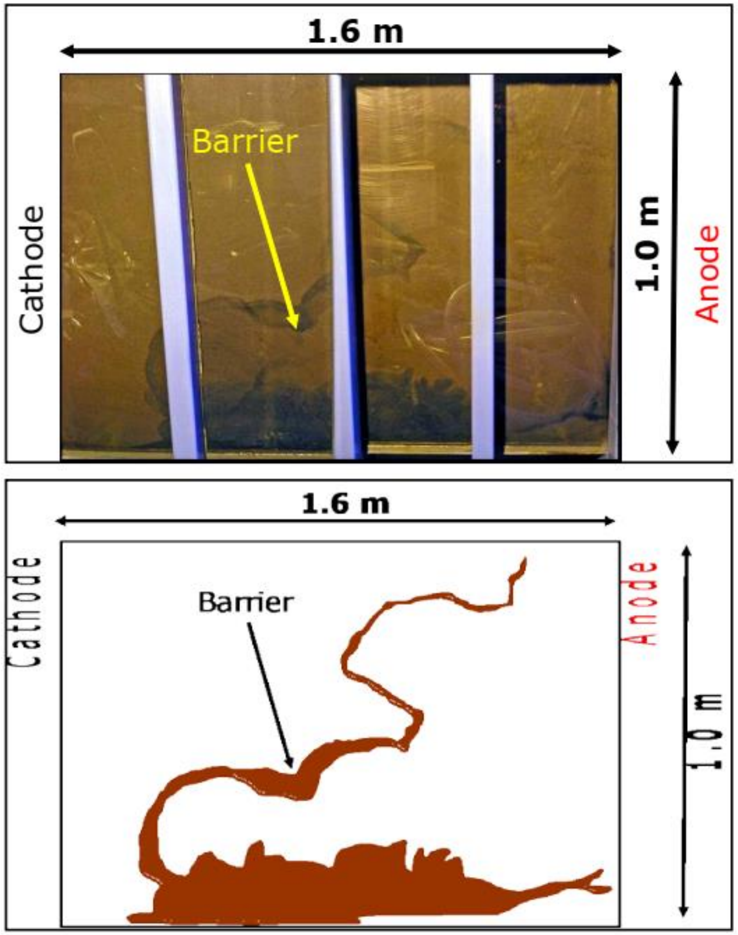
Remediation Case Stuies

Less Intrusive Contaminated Land Remediation

- Growing case for in-situ management of contaminated land/structures; but
  - Some contaminants may disperse leading to greater soil volumes/plume migration
  - Some areas too active to leave in-situ
  - Long lived radionuclides may also need removing
- Need for techniques which prevent migration and or remove contamination without soil
- Potential role for electrokinetic ground remediation

Opportunities

- Significant knowledge of key UK case studies and radionuclide behaviour
- Previous work by Industry on electrokinetics can form basis for new focussed work

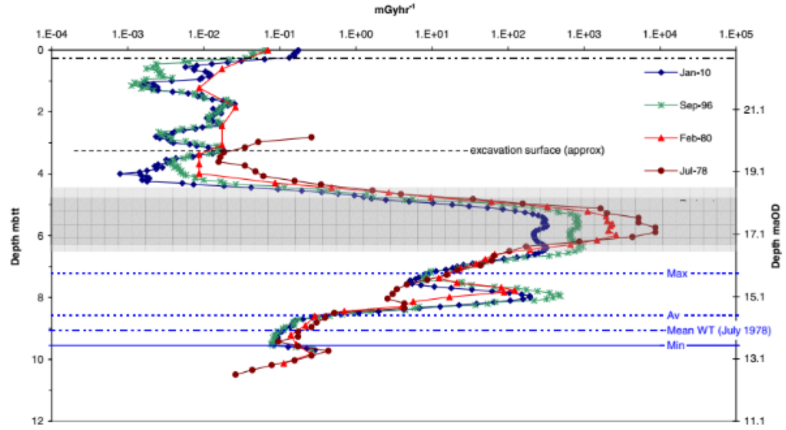


Fe Barrier EK Results, 2006. (Nexia, 7143)

Monitoring Case Study 1

Gamma Monitoring in leak zones

- ‘Blind-tubes
- GM tube technology
  - Pros - robust and reliable; but
  - Cons - Radiation intolerant->operator dose, & no rad discrimination
- In situ management required for decades
- Looking for monitoring solutions which
  - ➢ Lower worker dose
  - ➢ Continual reassurance
  - ➢ Conceptual uncertainty reduction (spectrometry/directionality?)
- Opportunities
  - Engaged facility
  - Background Info on system and
  - Opportunities for site trialling



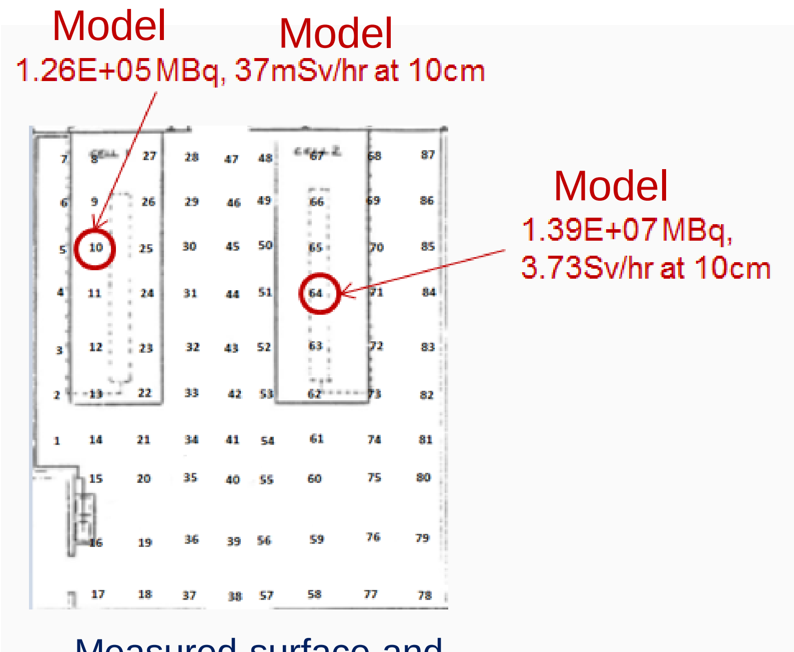
Monitoring Case Study 2

Buried Pipelines

- Nuclear sites require effluent discharge.
- Commonly sea discharge by pipeline of varying size, construction etc
- Limited characterisation data shows these are heterogeneously contaminated.
- Decommissioning/Disposal options need developing e.g. remove, decontaminate, in-situ-disposal
- Challenges:
  - Distribution and extent of contamination not clear
  - Long (e.g. Winfrith 6 miles)
  - Buried
  - Difficult to access
- Opportunities
  - Background data on UK pipelines
  - Testing on real sites

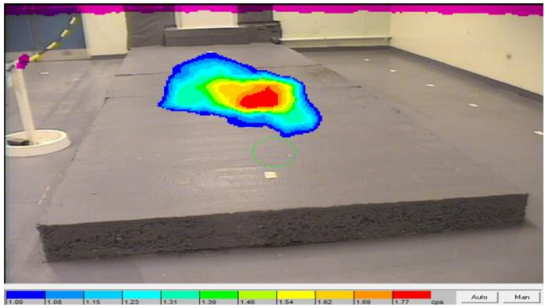
Monitoring Case Study 3

Dounreay Labs Subsurface Contamination

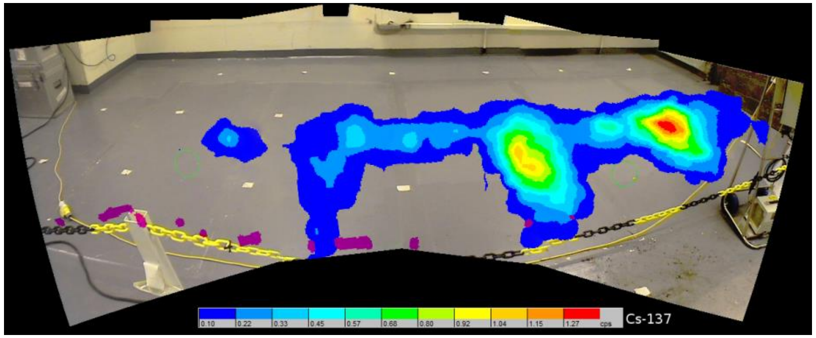


Measured surface and modelled subsurface results

Gamma Imaging



East plinth



West Duct Panoramic View

Figures Courtesy of DRSL

Dounreay Decommissioning excellence

Conclusions

- Role for R&D and innovation in SD&R to meet Industry Challenges:
  - Reduce lifetime costs (currently >£100Billion)
  - Increase Safety
  - Accelerate programmes
  - Reduce uncertainty
  - Underpin decision making
  - Improved confidence
  - Develop and maintain expertise and capability
- Opportunities in TRANSCEND to link to relevant Case Studies

Transformative Science and Engineering for Nuclear Decommissioning

ElectroKinetic Remediation (EKR)

Jamie Purkis

University of Southampton

11-11-19
TRANSCEND 2019 Theme Meeting
Lancaster

Energy
For a Low Carbon Future

Transformative Science and Engineering for Nuclear Decommissioning

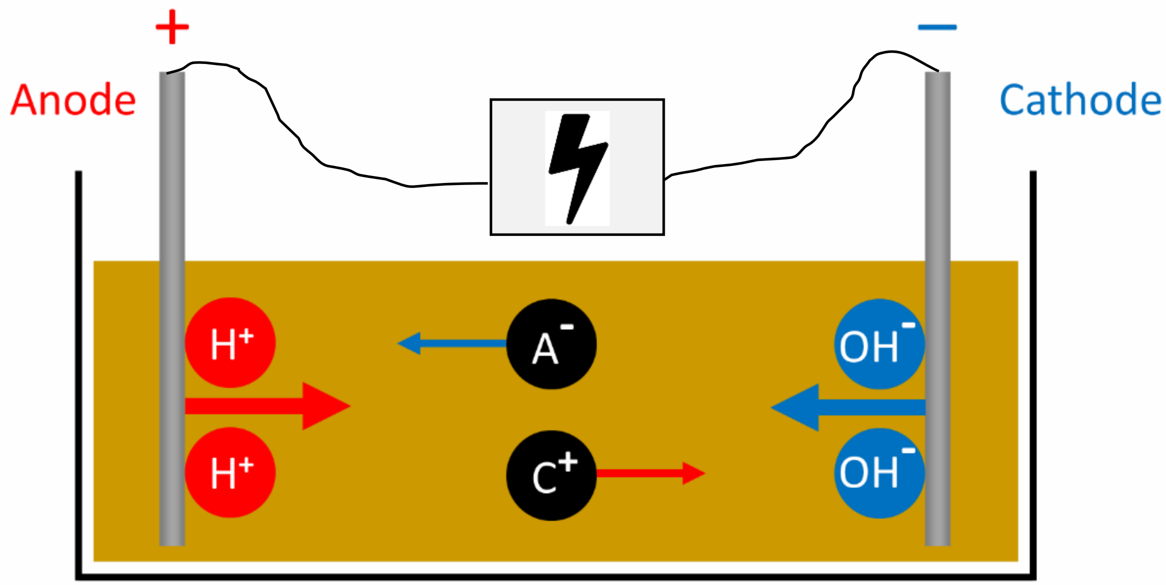
What is Electrokinetic Remediation?

electro kinetic

Electrically induced → electro

movement (of ions, …) → kinetic

- Soil/groundwater/concrete
- Electro-osmosis
  → *movement of water*
- Electromigration
  → *movement of ions*
- Electrophoresis
  → *movement of particles*



$H_2O \rightarrow 2\,H^+ + ½\,O_2\,(\uparrow) + 2\,e^-$

E^0 = - 1.229 V

$H_2O + 2\,e^- \rightarrow 2\,OH^- + H_2\,(\uparrow)$

E^0 = - 0.828 V

How Does EKR Compare?

	Target?	Energy use?	Duration?	Cost?	Challenges?	How can EKR help?
Bio- and Phyto-	Organics, Some metals Organics, Metal(-loid)s	Low	≥ years	Generally low	Long remediation time	**Faster nutrient movement**
Redox (ZVI)	Oxidisable contaminants	Low	Short	V high (nano-ZVI - £££)	Cost, mass transport of ZVI	***In-situ* ZVIs? (FIRS)**
"Dig and dump"	Heavy metals, Radionuclides	Medium-high (excavation)	Years+ (half-life)	Low	Just 'moving' contamination	**Dewatering (lower size)**
Thermal	Volatile organics	V high (heat)	Short (< months)	High (energy cost)	High energy cost	**Not amenable**
EKR	Organics, Most metals	Variable (5 to > 100 V)	Short-medium (weeks – months)	Variable	**Unproven on site**	**-**

Chemosphere, 2017, 181, 122; FIRS = Ferric Iron Remediation and Stabilisation; ZVI = Zero-Valent Iron

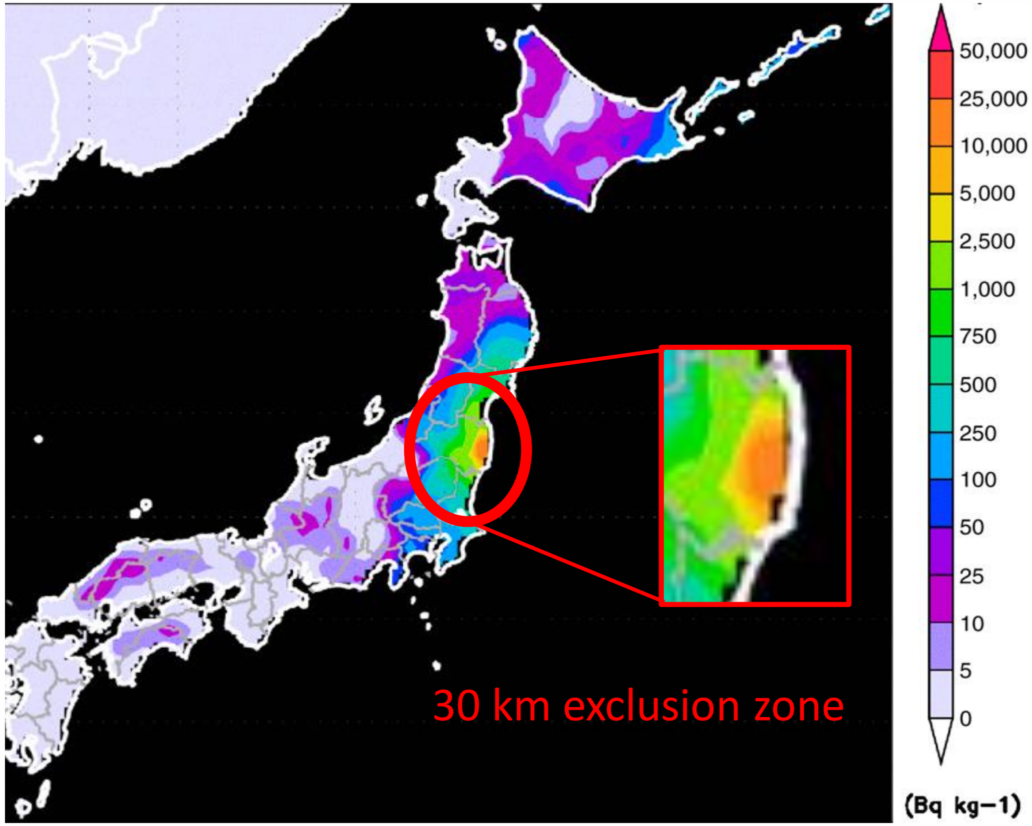
EKR Case Study – Fukushima Simulant

Fukushima, 2011

~ 3 PBq ^{137}Cs & ^{90}Sr in soil (30 km)

160,000 t soil at > 8 KBq/kg (2014)

$50 – 150 billion (2016)



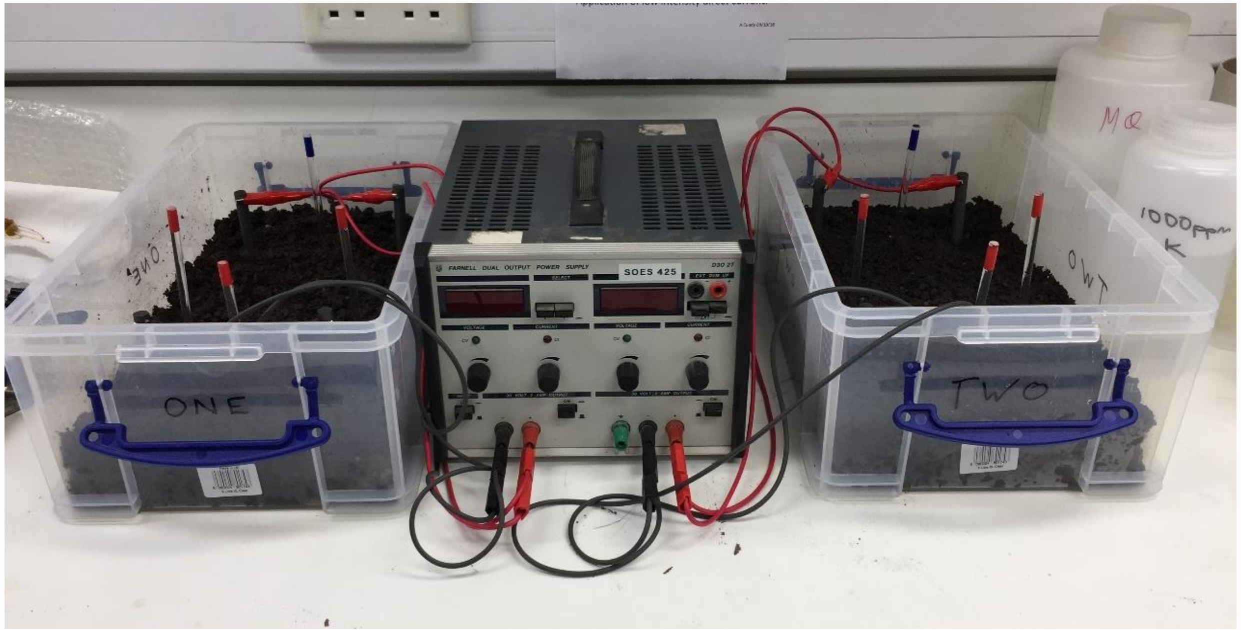
[^{137}Cs], Japan, 19/04/2011

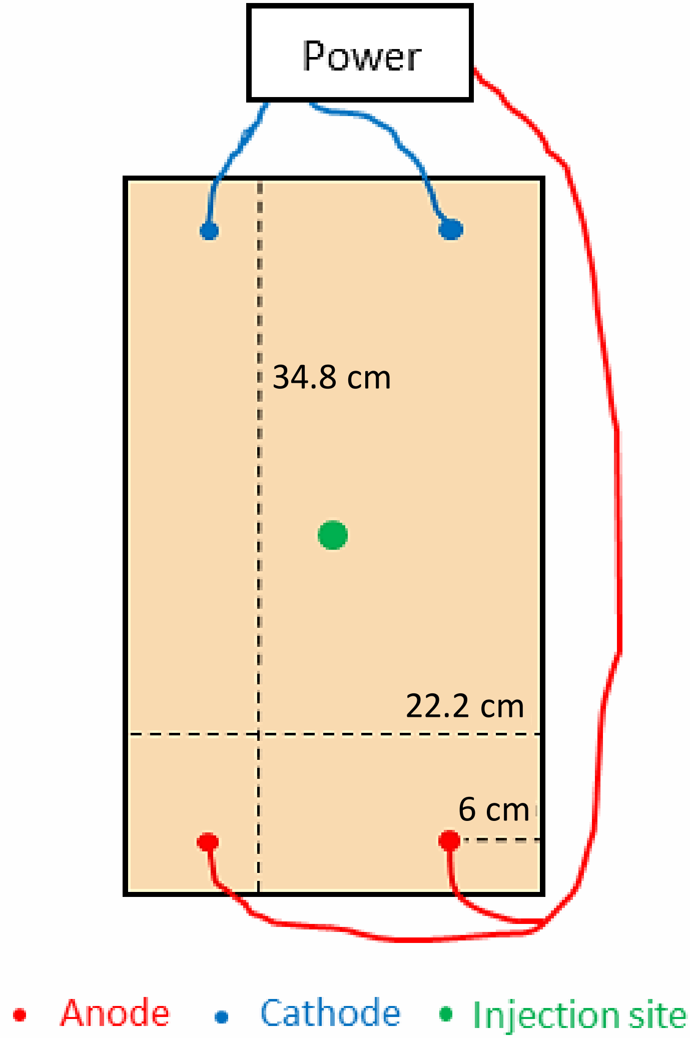
Fukushima: 11/03/2011

PNAS, 2011, 108, 19530; Environ. Sci. Technol., 2014, 48, 13053; J. Environ. Radioactiv., 2016, 151, 512

EKR Case Study – Fukushima Simulant

- 6:1 clay-peat soil (TOC = 11.6 %, pH 5.4)
- 15 or 20 V (0.5 V/cm) → low energy EKR
- Monitor: pH
  [Cs] and others by XRF





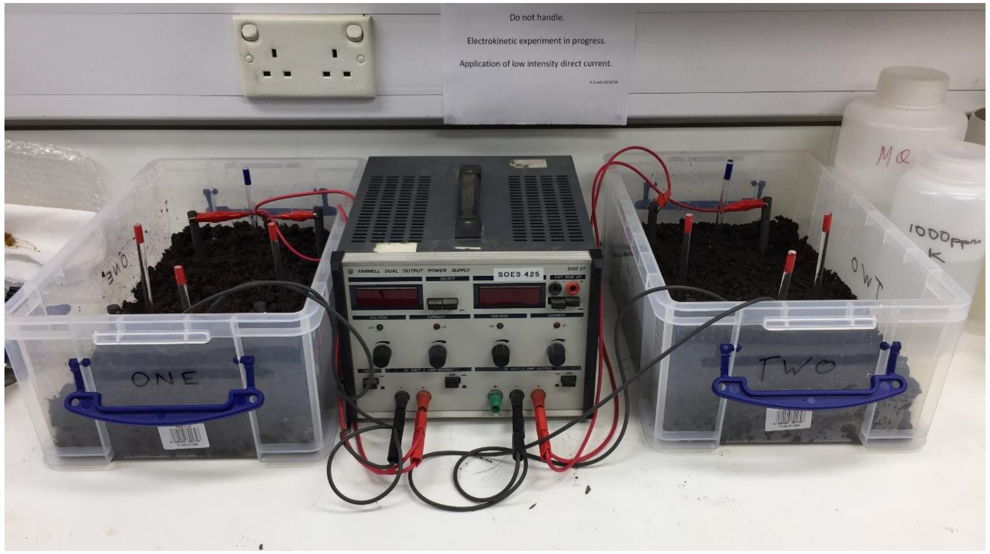
Purkis, Tucknott, Cundy, Warwick, manuscript in prep.; J Soil Contamin., 1999, 8, 617

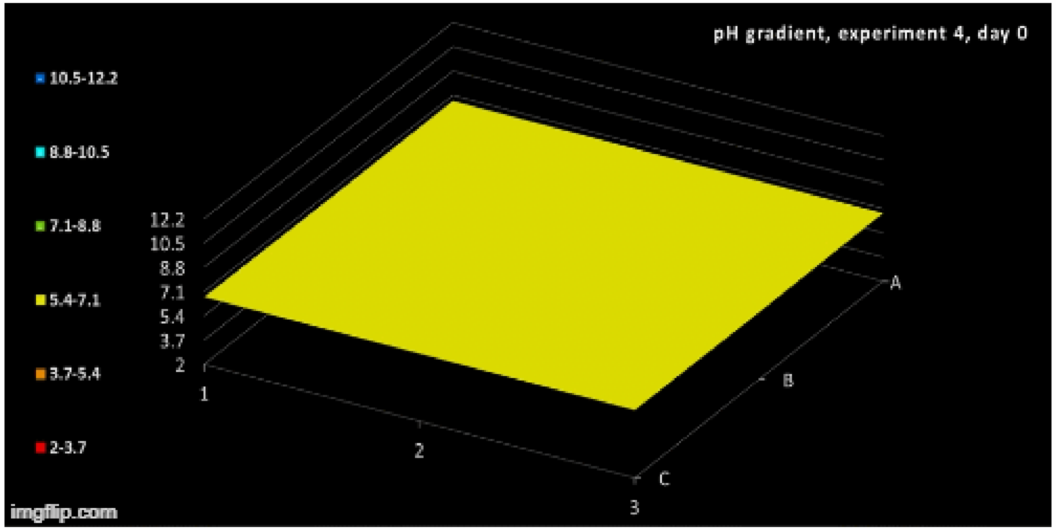
TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

EKR Case Study – Fukushima Simulant

- 6:1 clay-peat soil (TOC = 11.6 %, pH 5.4)
- 15 or 20 V (0.5 V/cm) → low energy EKR
- Monitor: **pH**
  [Cs] and others by XRF



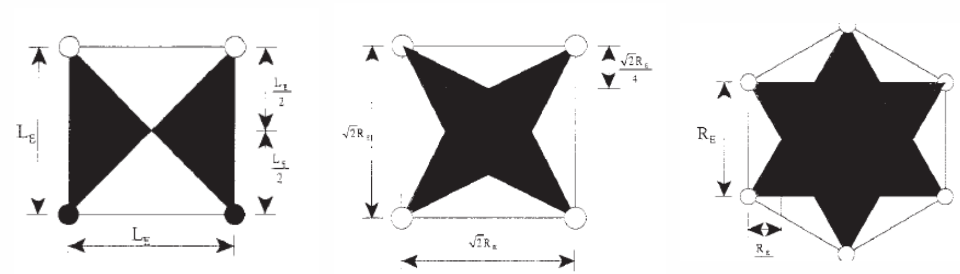


Anode

$H_2O \rightarrow 2\ \mathbf{H^+} + \frac{1}{2}\ O_2\ (\uparrow) + 2\ e^-$

Cathode

$H_2O + 2\ e^- \rightarrow 2\ \mathbf{OH^-} + H_2\ (\uparrow)$



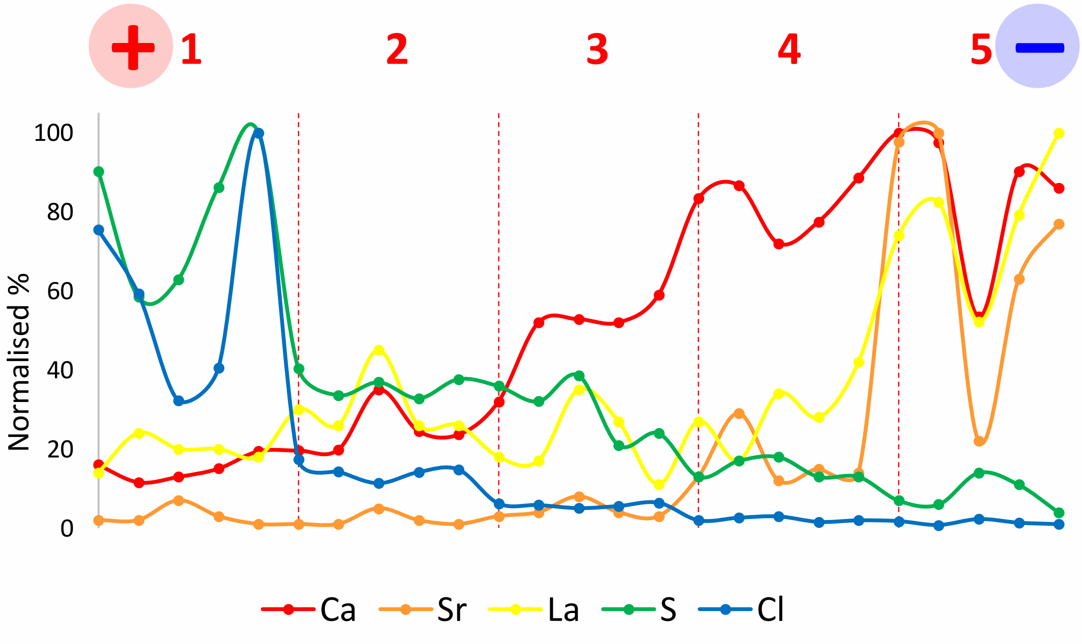
Purkis, Tucknott, Cundy, Warwick, manuscript in prep.; J Soil Contamin., 1999, 8, 617

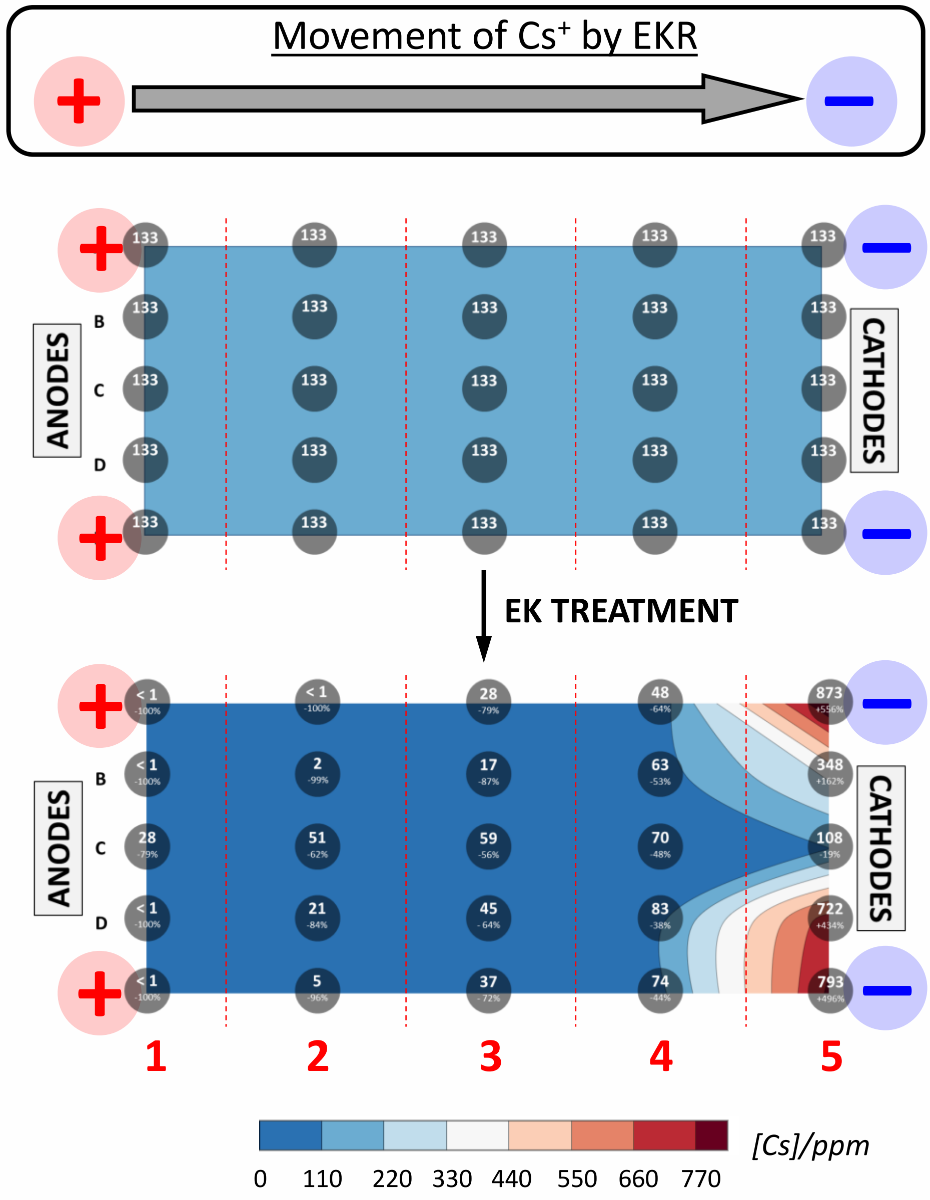
Transformative Science and Engineering for Nuclear Decommissioning

EKR Case Study – Fukushima Simulant

- 6:1 clay-peat soil (TOC = 11.6 %, pH 5.4)
- 15 or 20 V (0.5 V/cm) → low energy EKR
- Monitor: pH

[Cs] and others by XRF

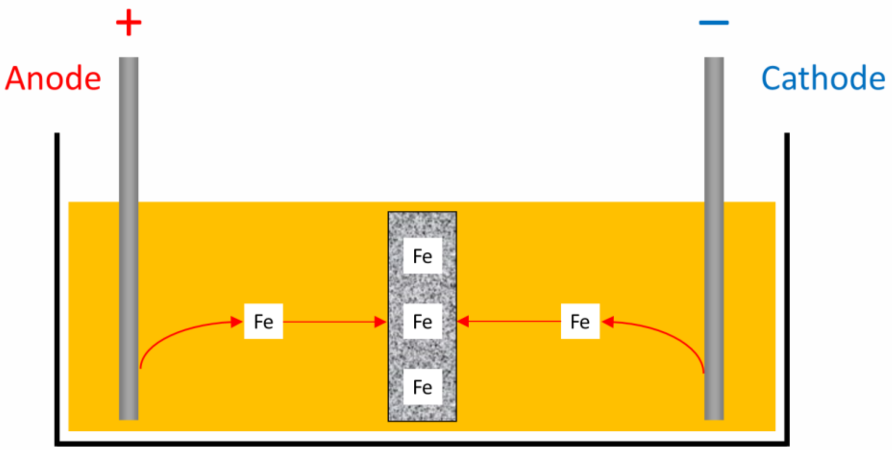




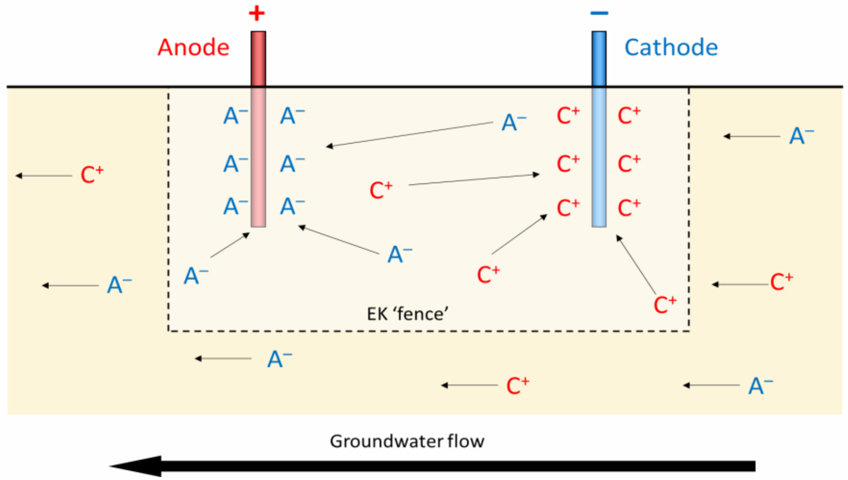
Purkis, Tucknott, Cundy, Warwick, manuscript in prep.

Transformative Science and Engineering for Nuclear Decommissioning

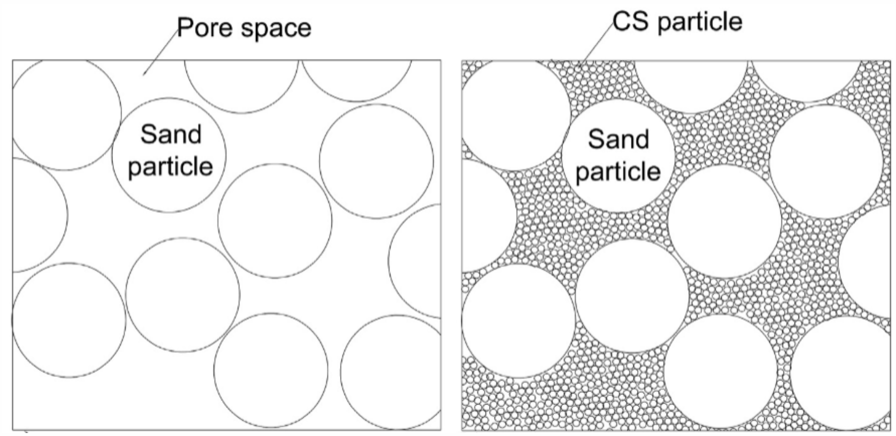
EKR for TRANSCEND



FIRS

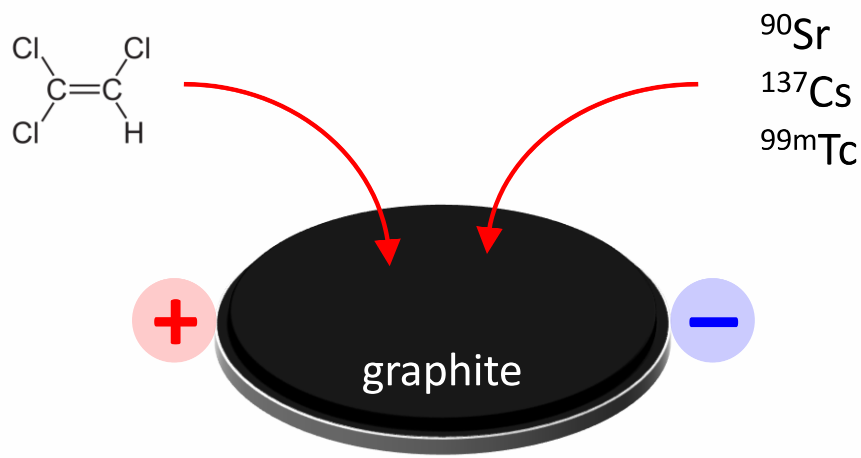


EK FENCING



SILICA GROUTING – Prof. Becky Lunn

Engin. Geol., 2018, 243, 84



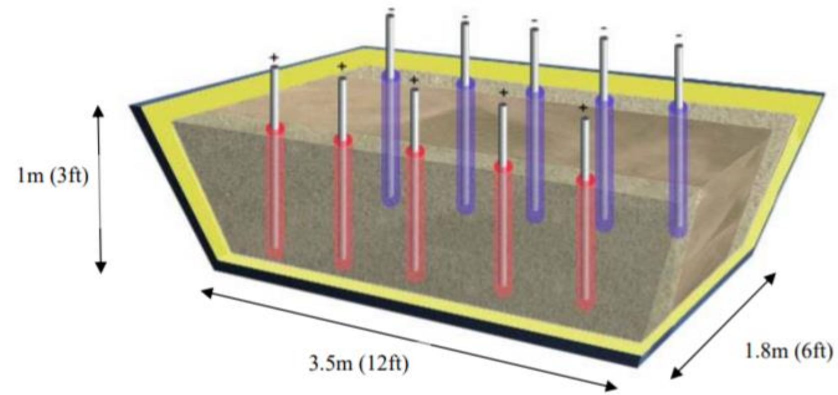
MIXED WASTE? – Prof. Dmitry Zherebtsov

Transformative Science and Engineering for Nuclear Decommissioning

EKR Case Study – AWE

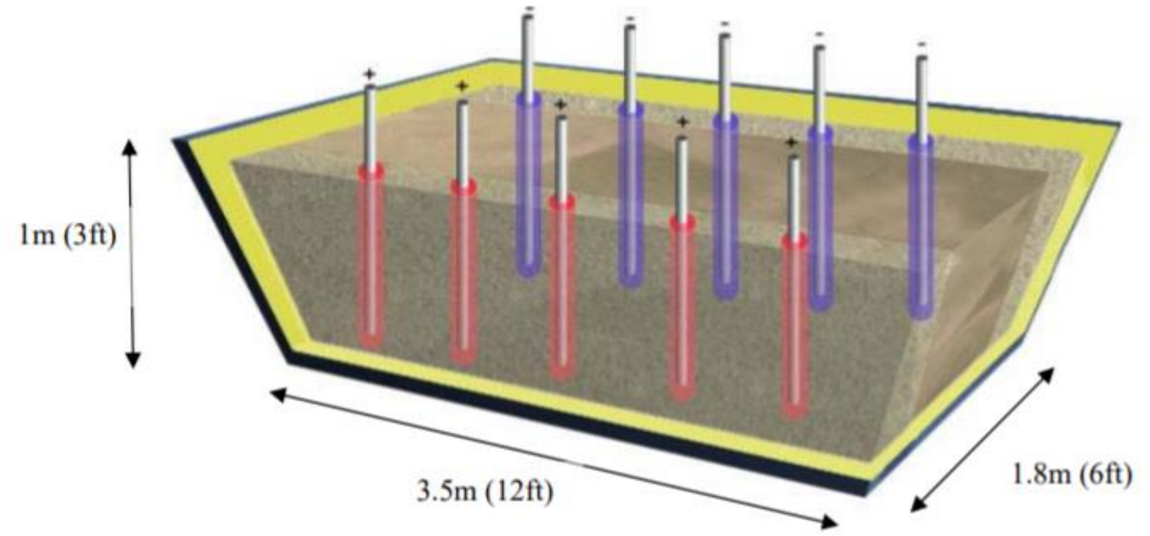
- Atomic Weapons Establishment (1950 –)
- Nuclear weapons manufacture
- Plutonium contamination

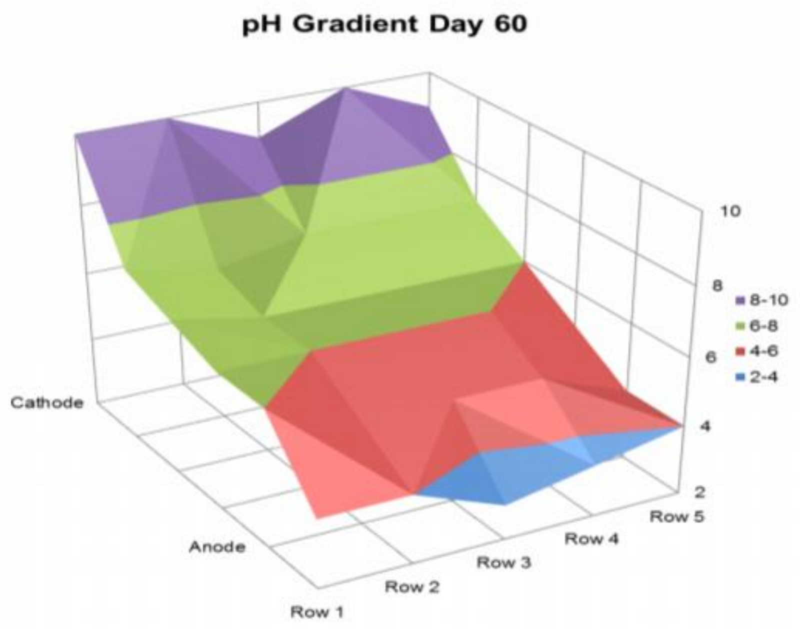
Containment failure → *ex-situ* remediation?



a

EKR Case Study – AWE

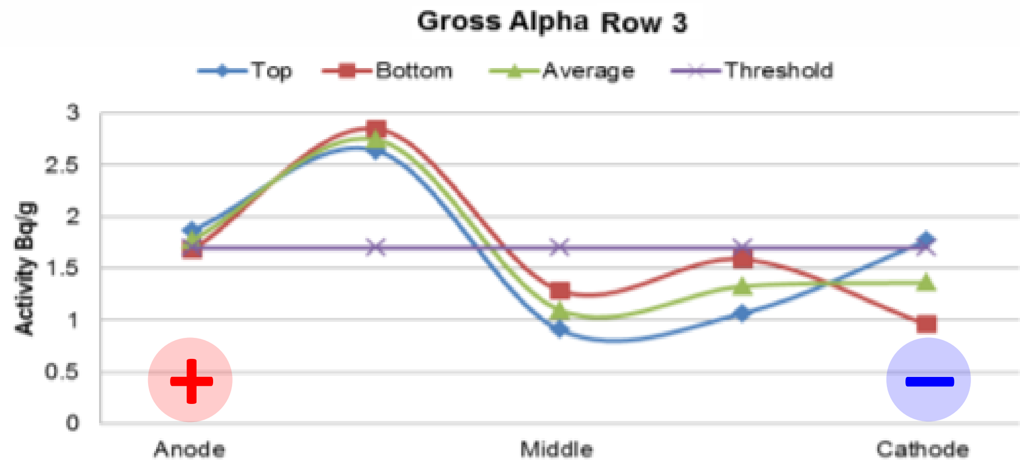




- 10 steel electrodes
- 12 V battery (0.08 V/cm), 60 days
- AWE soil and groundwater
- "Free release" = 1.7 Bq/g

  Landfill
- Citric acid added

Picture of plutonium citrate here



Transformative Science and Engineering for Nuclear Decommissioning

New materials and methods for decontamination of effluent

Antony Nearchou, University of Birmingham

TRANSCEND Thematic Meeting

11/11/19

Lancaster University

My Background

Currently:
PDRA – Hriljac Group at University of Birmingham

Previously:
PhD – University of Bath
“Zeolites fit for a crown”
Sartbaeva Group
Researching the role of metal cations and organic templates in zeolite crystallisation.

MChem – University of Bath

UNIVERSITY OF BATH

UNIVERSITY OF BIRMINGHAM

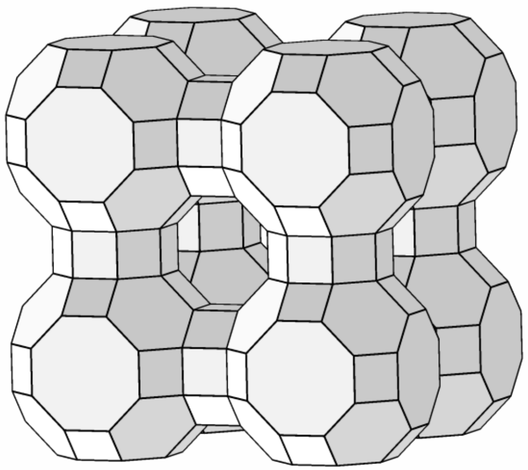
Zeolites: the "hole" story

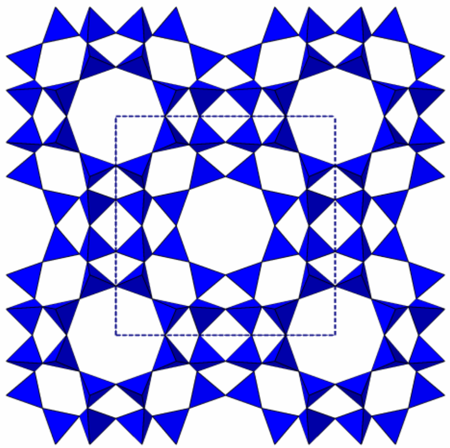
Zeolite: '*zéō*' '*líthos*' Greek for '*boiling stone*'

- Crystalline, microporous (< 2 nm) aluminosilicates
- Formed of interconnected SiO_4 and AlO_4 tetrahdedra
- 3D framework
- Regular cages and channels

Applications:

- Catalysts – hydrocracking petroleum
- Molecular sieves
- Gas adsorbents/separators
- Drug delivery
- **Ion exchange – sequestration of radionuclides**

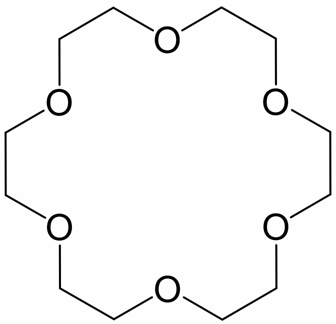




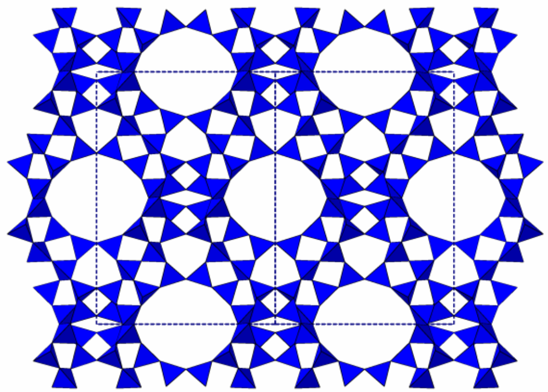
http://www.macleans.ca/wp-content/uploads/2014/10/oil-sands-refinery-wishes.jpg

PhD – Zeolites fit for a crown

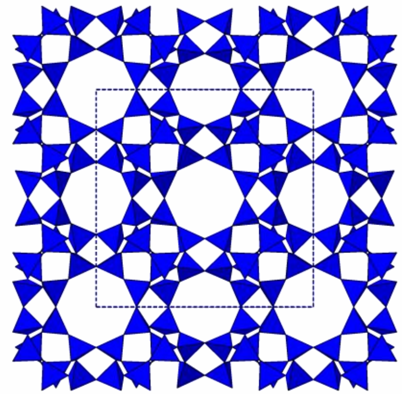
One template, four zeolites



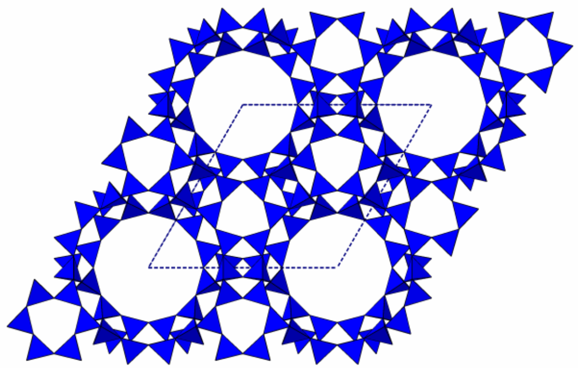
18-crown-6 ether



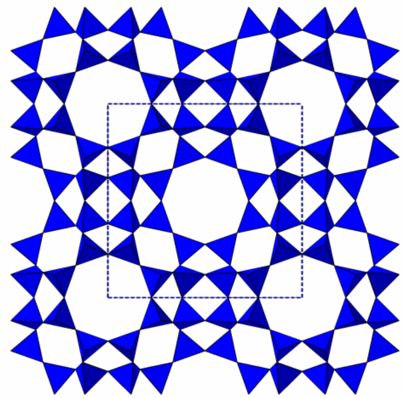
Zeolite Na-X



Zeolite ZK-5



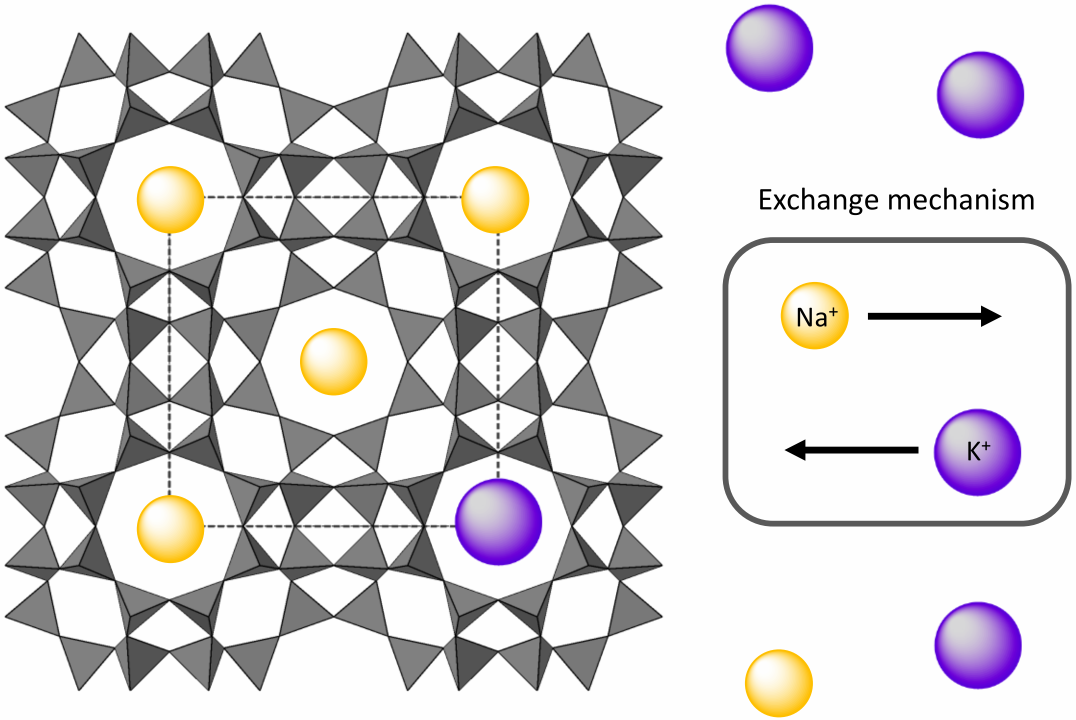
Zeolite EMC-2



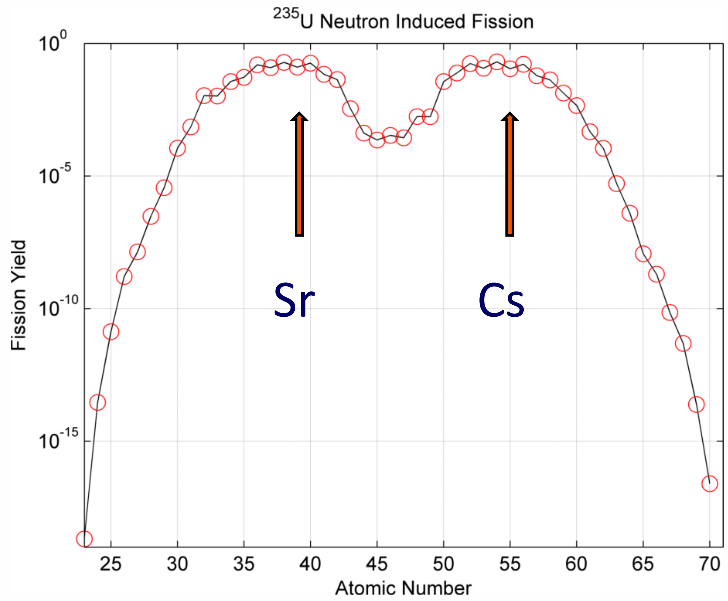
Zeolite RHO

Ion Exchange

- Due to $[AlO_4]^{5-}$ the framework retains a negative charge
- Balanced by extra-framework cations – which can be exchanged
- Can be used to extract unwanted cations from solution
- Water softening, **sequestration of radionuclides** for nuclear clean-up.

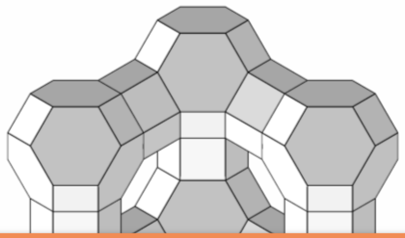


Nuclear Fission



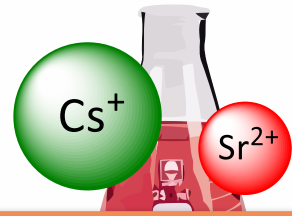
The fission reaction in ^{235}U produces fission products such as Ba, Kr, Sr, Cs, I and Xe with atomic masses distributed around 95 and 135. ^{137}Cs and ^{90}Sr have half-lives of ca. 30 years and produce most of the medium-lived radioactivity in spent fuel. Require removal from liquid waste.

Hriljac Group's Focus



Microporous Inorganic Materials

1. Improved Synthesis for Industry
   - Lower temperatures/time
   - Seeding
   - Microwave synthesis
2. Improved Material Properties
   - Structural defects – doping
   - Mesoporosity
   - Morphology
3. Alternative Remediation Processes
   - Magnetisation



Ion Exchange Experiments

4. Batch Ion Exchanges
   - Bulk exchanges
   - Competitive ions
   - Influence of high pH
   - Simulant solutions
5. Column Experiments
   - Exchange under solution flow
   - Ion breakthrough
   - Bulk and simulant solutions

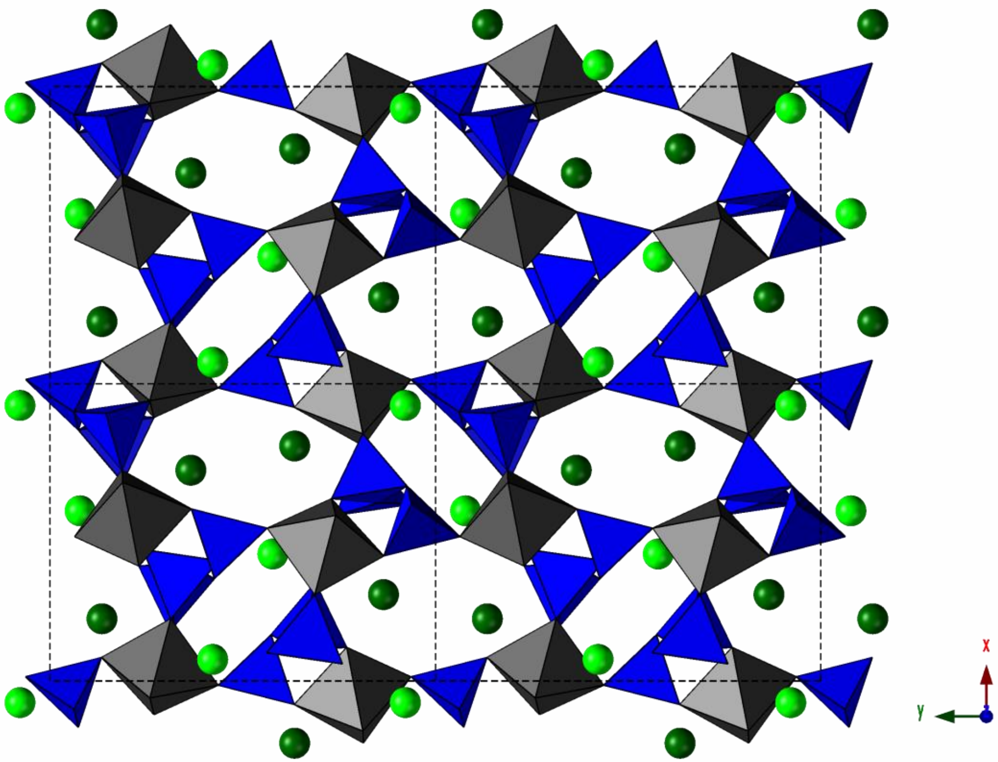
Transformative Science and Engineering for Nuclear Decommissioning

New Material for Cs^{+}/Sr^{2+} uptake: Umbite

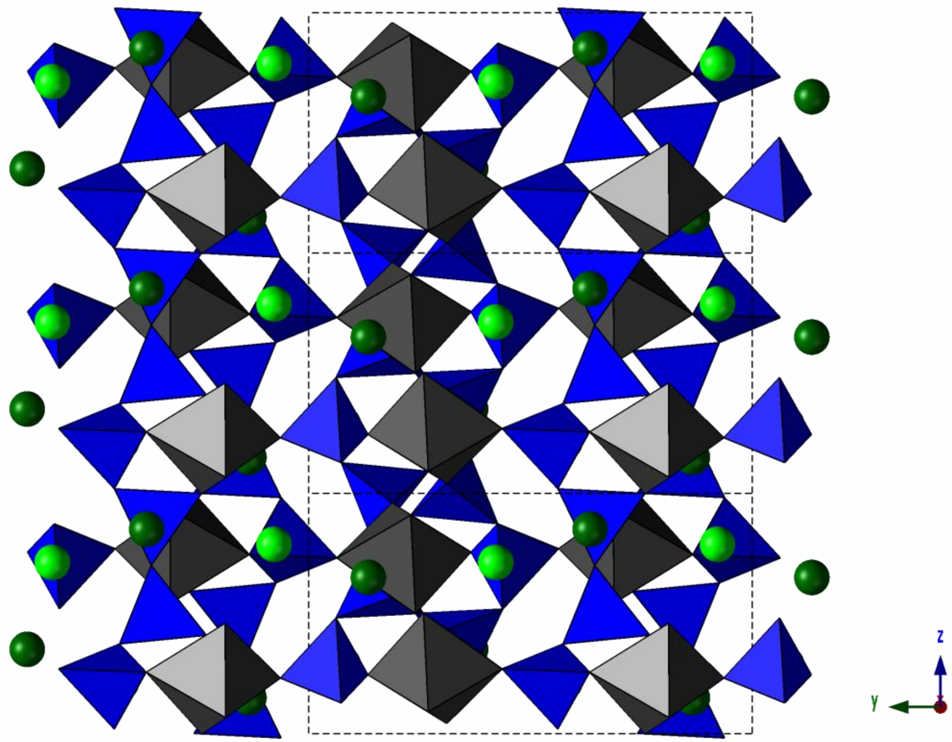
$K_2SnSi_3O_9 \cdot H_2O$ *Zeolite? Zeotype? Zeo-like?*

6-ring and 8-ring channels along c axis
7-ring windows between them

Grey octahedra: $[SnO_6]^{8-}$
Blue tetrahedra: $[SiO_4]^{4-}$
Green spheres: K^{+} Cations



View down c axis



View down a axis

Substituted Umbites

$$K_2Sn(Si,Ge)_3O_9 \cdot H_2O \quad \text{or}$$

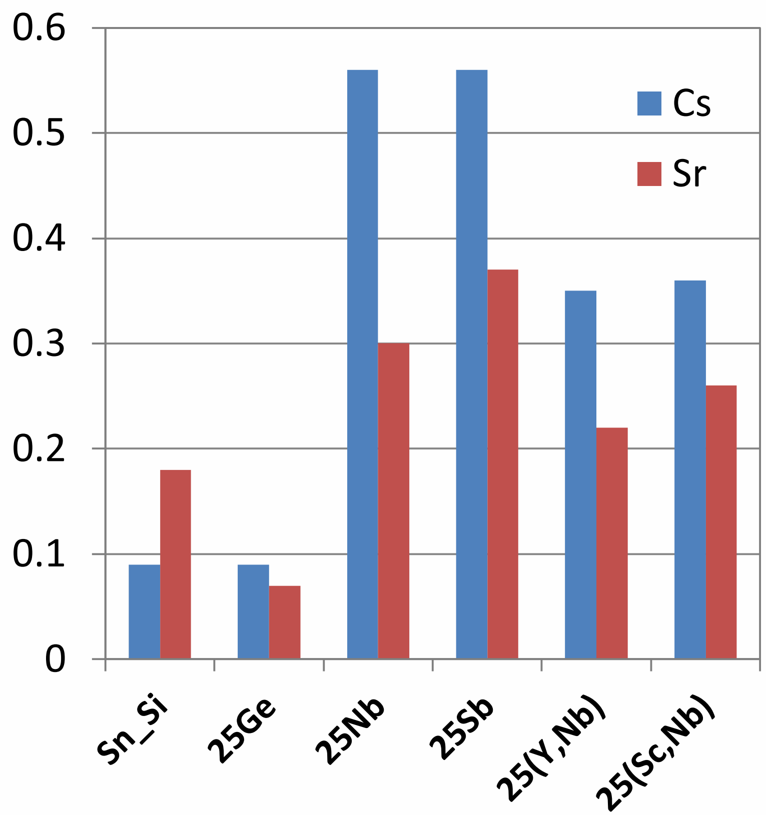
$$K_{2-x}Sn_{1-x}M^{V}{}_{x}Si_3O_9 \cdot H_2O$$

	Substitution	
25Ge	T-site:	25% Ge^{4+} for Si^{4+}
25Nb	O-site:	25% Nb^{5+} for Sn^{4+}
25Sb	O-site:	25% Sb^{5+} for Sn^{4+}
25(Y, Nb)	O-site:	12.5% Y^{3+} and 12.5% Nb^{5+} for Sn^{4+}
25(Sc,Nb)	O-site:	12.5% Sc^{3+} and 12.5% Nb^{5+} for Sn^{4+}

- Replacement of Sn^{4+} with M^{5+} creates a deficiency of K^+ in the material.
- Deficiency of K^+ cations in channels suspected to increase ion mobility – and hence ion exchange

Static batch ion exchange tests

Normalised molar ratio of Sr/Cs uptake to octahedral elements



Competing Ions

- Typical cationic species in untreated effluent streams at Sellafield.
- All effluents are/intended for processing in SIXEP using ion exchange.

- Interested in how ion exchanger performs with competing ions.
- Of particular interest and issue is Cs vs K.

High Potassium

Analyte	Case A	Case B	Case C	Case D
pH	11.2	11.0	10	> 10
^{137}Cs (Bq/ml)	3000	1.2×10^6	1×10^6	5×10^6
^{90}Sr (Bq/ml)	80	8.1×10^3	3×10^4	1.7×10^5
Na (µg/ml)	70	130	60	210
K (µg/ml)	0.20	10	20	250
Ca (µg/ml)	0.20	3	1.2	60
Mg (µg/ml)	< 0.10	3	140	30
U (µg/ml)		2	200	

S. Kellet, Data on cationic species in untreated supernate at Sellafield, DISTINCTIVE collaboration, Sellafield Ltd., 2014

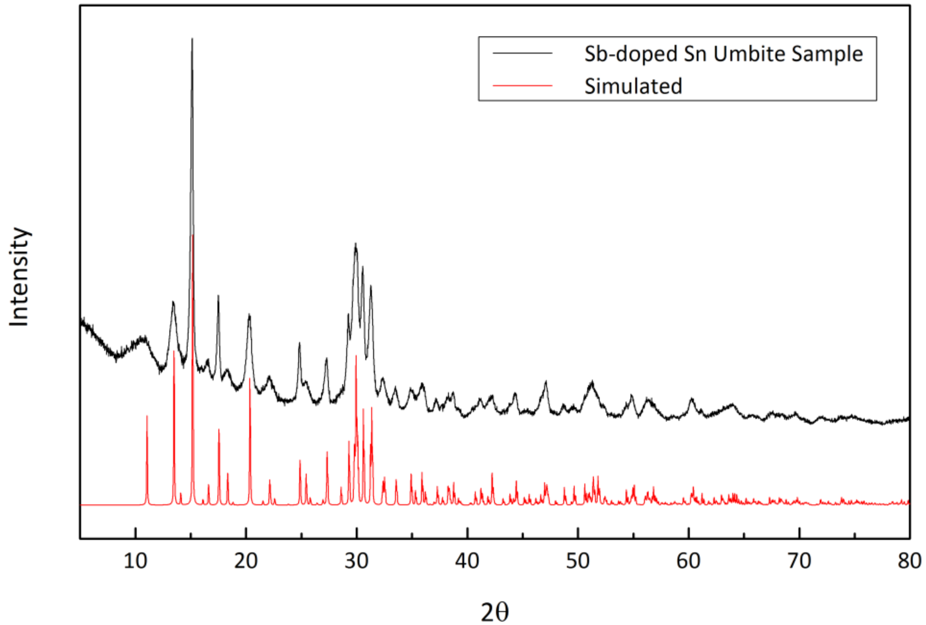
Sb-doped Sn Umbite Synthesis

- 25% Sb-doping in Sn umbite.
- Hydrothermal synthesis: 200˚C 24hrs

$$K_{2-x}Sn_{1-x}Sb_xSi_3O_7 \cdot H_2O$$

	% K^+ exchanged for Cs^+
$K_2SnSi_3O_7{\cdot}H_2O$	~10%
$K_{1.75}Sn_{0.75}Sb_{0.25}Si_3O_7{\cdot}H_2O$	~33%

Bulk exchanges 1M $CsNO_3$



XRF	Wt. %
Sn	35.7%
K	24.5%
Si	20.2%
Sb	9.4%
Cl	0.6%
O	not measured

J. Reed, *Synthesis of Magnetised Tin Umbites for Removal of Radionuclides from Water*, School of Chemistry, University of Birmingham, 2019 (Project Report)

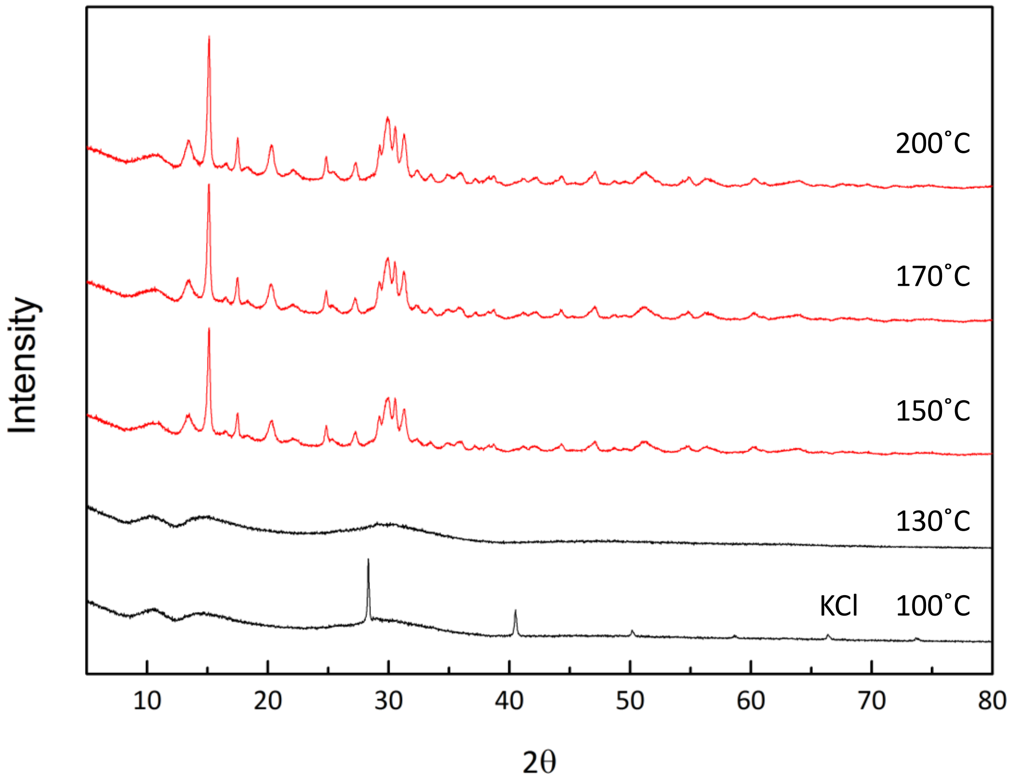
Transformative Science and Engineering for Nuclear Decommissioning

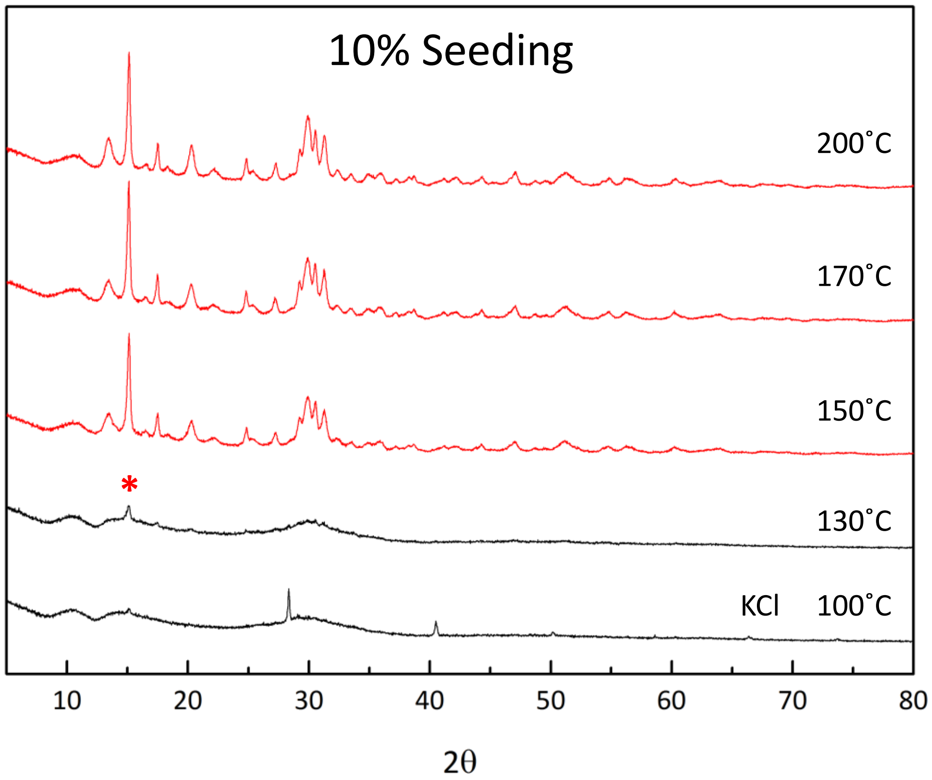
Reducing Synthesis Time/Temperature

Seeding

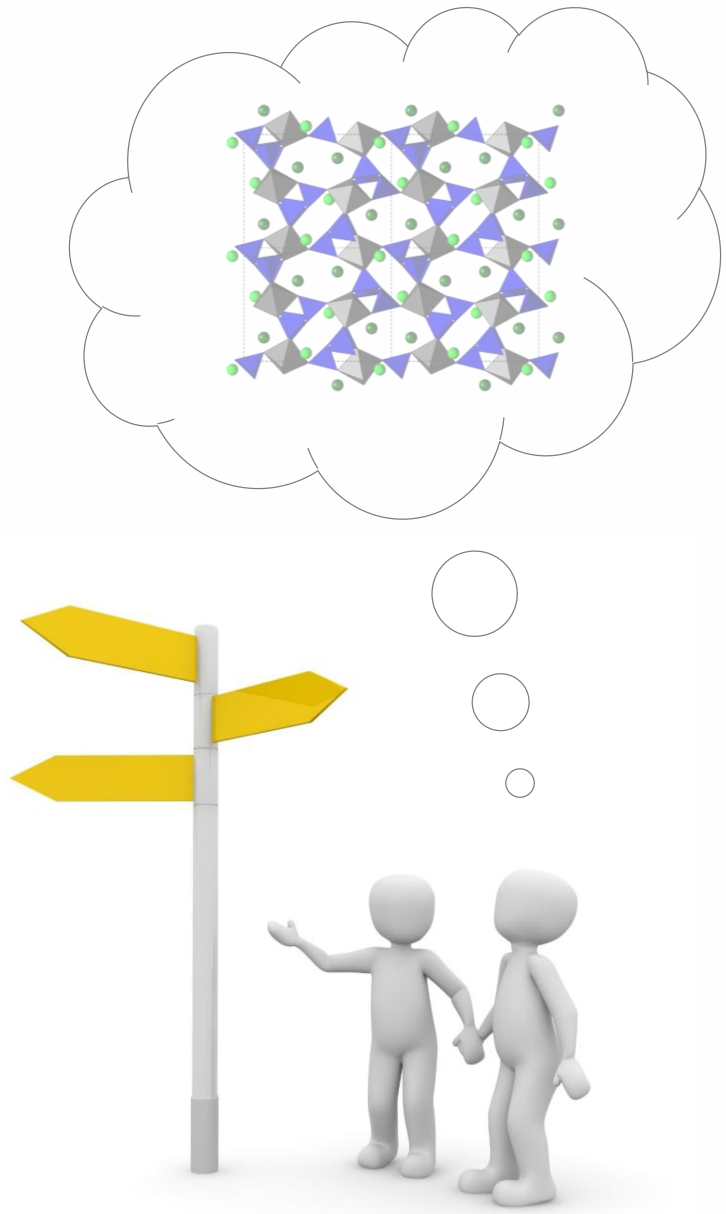
- Introducing previously made umbite crystals.
- Reduces the need for spontaneous nucleation.

- Umbite structure crystallises ≥ 150˚C
- KCl precipitates at 100˚C
- Potentially formation of umbite at 130˚C (*)





What Next?



<u>Synthesis Modification</u>

- Seeding
- Lower temperature
- Microwave synthesis

<u>Ion Exchange</u>

- Testing competing ions: Cs^+, K^+, Na^+, Ca^{2+}, Mg^{2+}
- Sr^{2+} exchange capabilities
- Simulant effluent solutions
- Column/flow studies

<u>Magnetisation</u>

- Exploring synthesis by different routes
- Currently conceptualising a magnetic separation rig

Acknowledgements

Birmingham: Tzu-Yu (Evin) Chen, Dan Parsons, Ryan George, James Reed, Joe Hriljac.

EPSRC
Pioneering research and skills

TRANSCEND

UNIVERSITY OF BIRMINGHAM

Research Councils UK
Energy
For a Low Carbon Future

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

Email: A.Nearchou@bham.ac.uk

Transformative Science and Engineering for Nuclear Decommissioning

Particle-laden Flow Characterisation and Prediction

Lee Mortimer, University of Leeds

TRANSCEND THEME MEETING 2019

11th November 2019
Lancaster, United Kingdom

For a Low Carbon Future

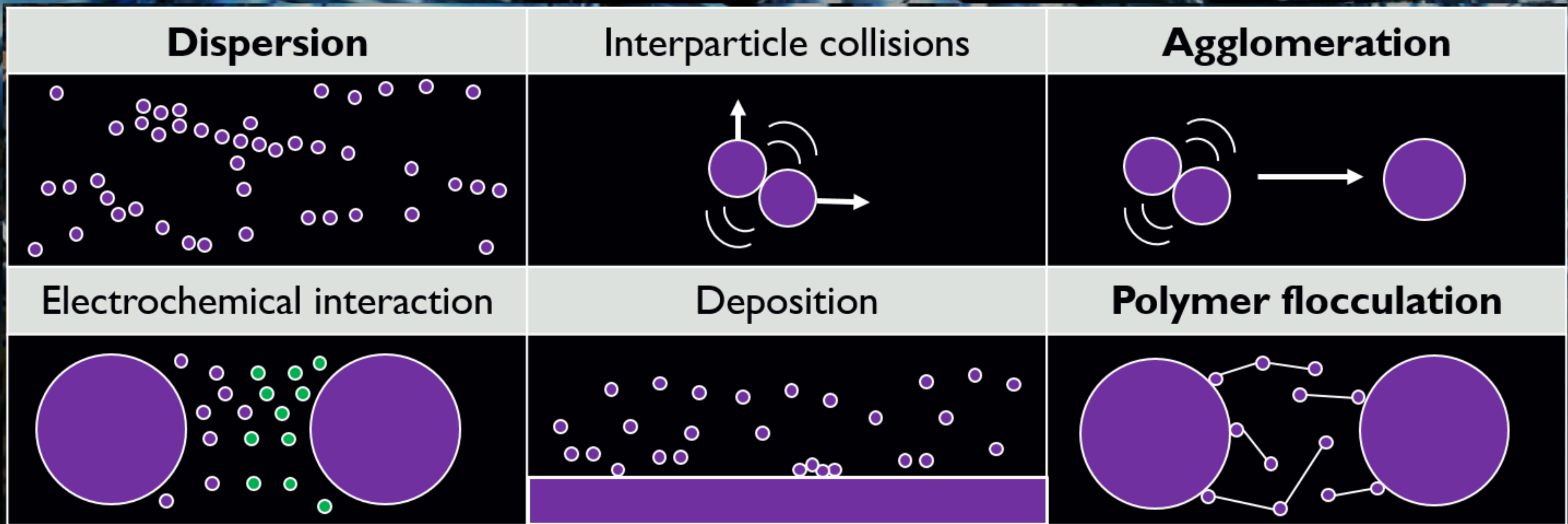
Motivation - decontamination of legacy ponds and silos

- Waste suspension flows transport legacy material from historic ponds to other interim locations where they are stored safely.
- Present designs perform inefficiently, with the potential for blockages and poor flow conditions.
- Current transportive systems won't function adequately for long timeframes.
- Knowledge must be developed surrounding behaviour of waste sludges.
- Presence of high flow rates means systems are usually turbulent.
- Generation of this knowledge will lead **to accurate predictive capabilities** and **enhanced control over multiphase turbulent flows**.

Behavioural modification

Development of behavioural modification techniques

- Use high-fidelity simulation to predict system response to modification-capable properties.
- Temperature, ionic strength, pH, material coating, presence of other phases (particles/polymers), flow rates, turbulence.
- Explore fundamental dynamics surrounding interaction mechanisms such as:



Multiphase fluid simulation techniques

- Range of technical tools for both the fluid and particle phases

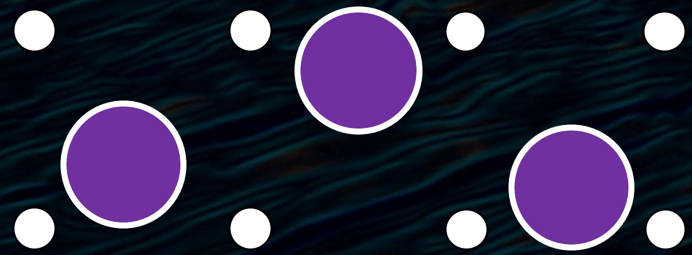
FLUID PHASE

Direct numerical simulation (DNS):

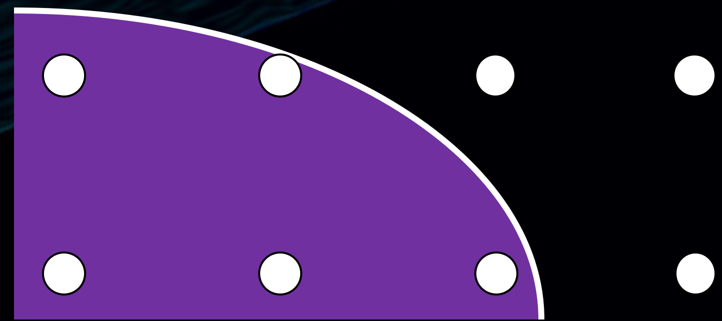
- All relevant turbulent length and timescales are resolved.
- Accuracy and high-fidelity allows for investigation of fundamental dynamics.
- Computationally intensive but code is parallelised (HPC at Leeds).
- NEK5000 open source spectral element method solver.

PARTICLE PHASE

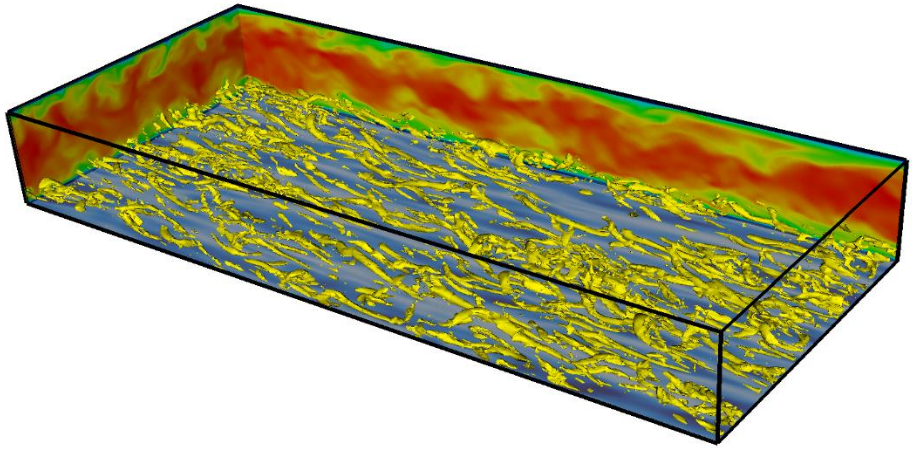
Lagrangian particle tracking (LPT):



Immersed boundaries method (IBM):

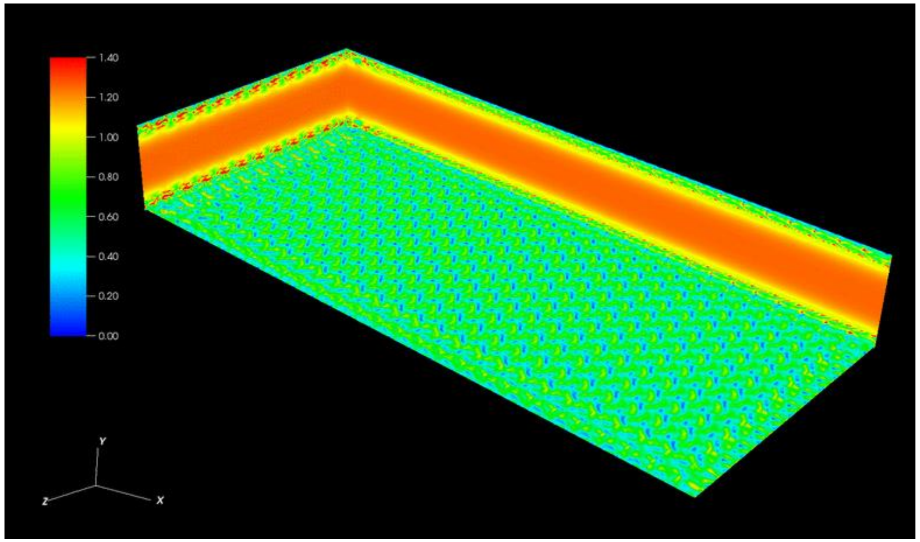


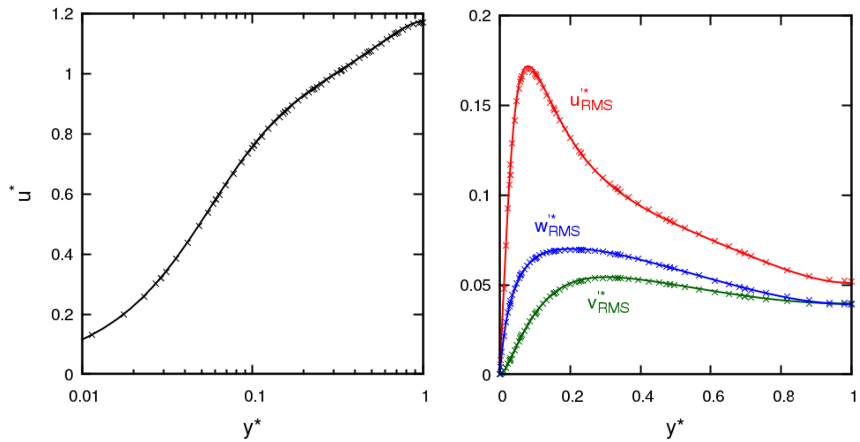
Single phase turbulent channel flow at Reτ = 180



NEK5000 SEM SOLVER

(27 x 18 x 23) 7th order spectral elements



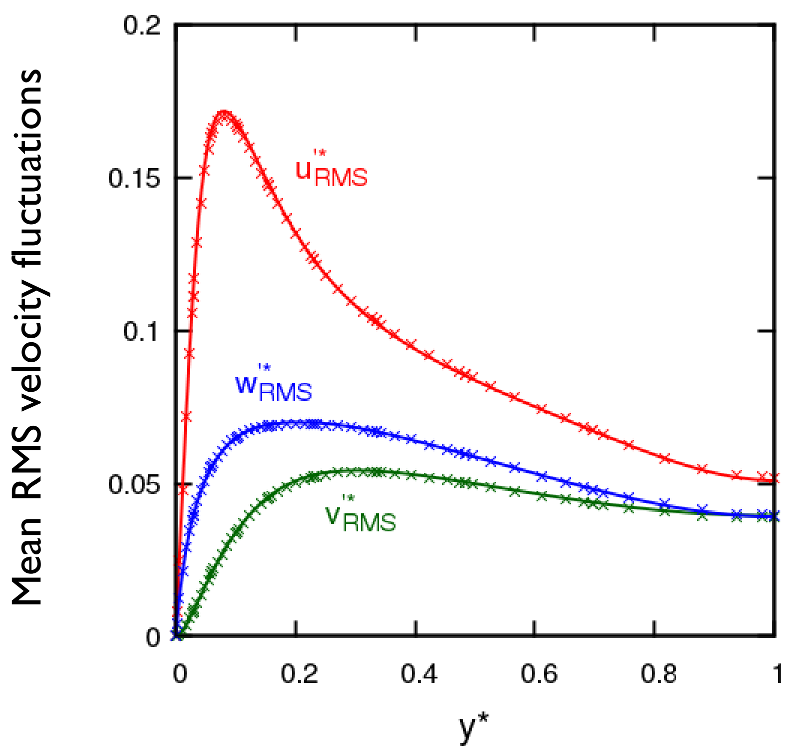


Crosses: Present work

Solid line: Vreman and Kuerten (2014) [1]

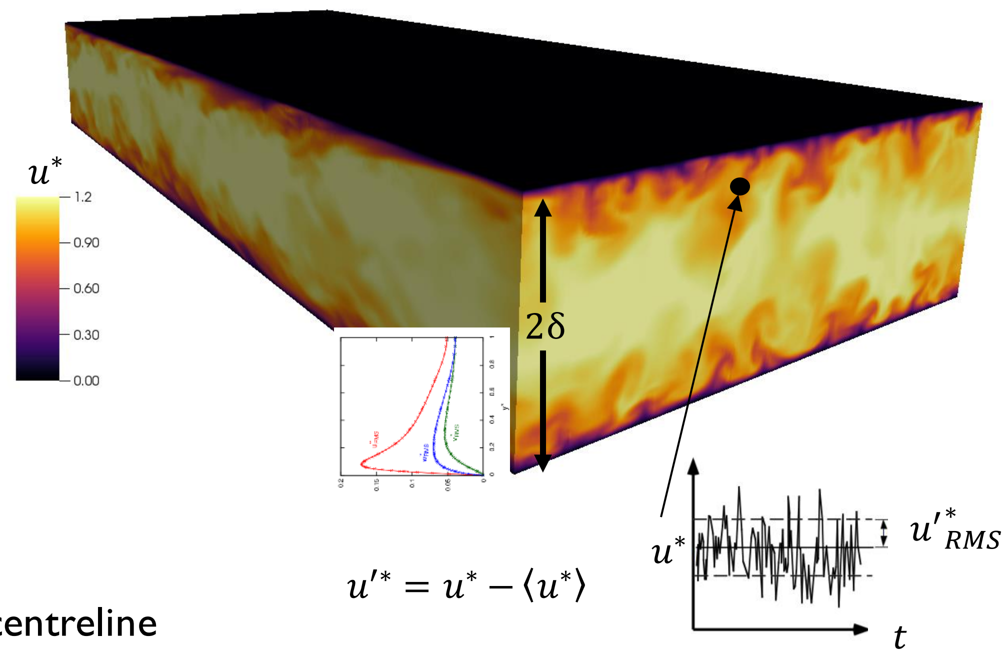
[1] - Comparison of direct numerical simulation databases of turbulent channel flow at Re_τ = 180. *A.W. Vreman and J.G.M. Kuerten, Phys. Fluids* ***26****, 015102 (2014).*

Second-order flow statistics: Mean RMS velocity fluctuations profile



δ: Channel half-height

U_B: Bulk velocity (mean across entire channel domain



$u'^{*} = u^{*} - \langle u^{*} \rangle$

Distance from wall, $y^{*} = y/\delta = 1$ is the channel centreline

Crosses: Present work

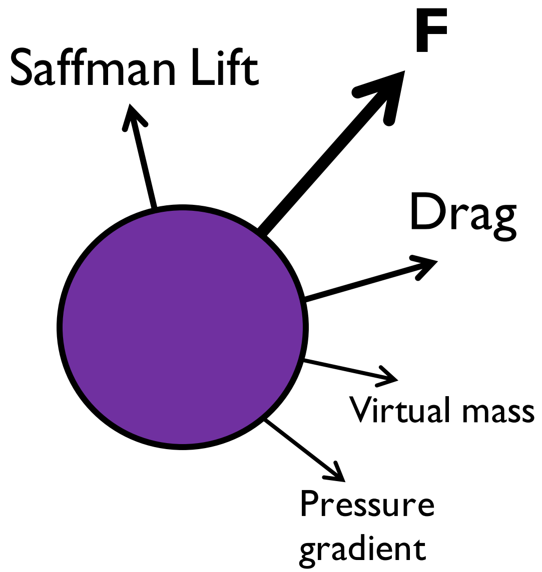
Solid line: Vreman and Kuerten (2014) [1]

Also referred to as 'turbulence intensities' when normalized in this manner.

[1] - Comparison of direct numerical simulation databases of turbulent channel flow at Re_τ = 180. *A.W. Vreman and J.G.M. Kuerten, Phys. Fluids* ***26****, 015102 (2014).*

Lagrangian particle tracking methodology

- Particle dynamic properties updated each timestep due to inertial effects of the surrounding flow field, obtained via spectral interpolation.
- Resultant force is the summation of individual forces acting on the particle.
- Runge-Kutta 4th order integration algorithm.
- Momentum coupling using particle source in cell (PSIC) method (two-way coupling).
- Elastic/inelastic hard-sphere collision model (four-way coupling).
- Deterministic energy-based agglomeration model.



$$\frac{\partial u_P^*}{\partial t^*} = \underbrace{\frac{3C_D|\mathbf{u}_s^*|}{4d_p^*\rho_P^*}\mathbf{u}_s^*}_{Drag} + \underbrace{\mathbf{g}^*(1-\rho^*)}_{Gravity/Buoyancy} + \underbrace{\frac{3}{4}\frac{C_L}{\rho_P^*}(\mathbf{u}_s^* \times \boldsymbol{\omega}_F^*)}_{Lift} + \underbrace{\frac{1}{2\rho_P^*}\frac{D\mathbf{u}_\mathbf{F}^*}{Dt^*}}_{Virtual\ Mass} + \underbrace{\frac{1}{\rho_P^*}\frac{D\mathbf{u}_\mathbf{F}^*}{Dt^*}}_{Pressure\ Gradient}$$

Published work on fundamental dynamics in particle-laden flows

Mortimer, L.F., Njobuenwu, D.O., Fairweather, M., "Near-wall dynamics of inertial particles in dilute turbulent channel flows," *Phys. Fluids*. **31**(6), 063302 (2019).

How does density-ratio or inertia affect particle dispersion behaviour in turbulent flows?

Stokes number $$St_\tau = \frac{\tau_P}{\tau_{F\tau}} = Re_\tau^2 \frac{{d_P^*}^2 \rho_P^*}{18\, f_D}$$

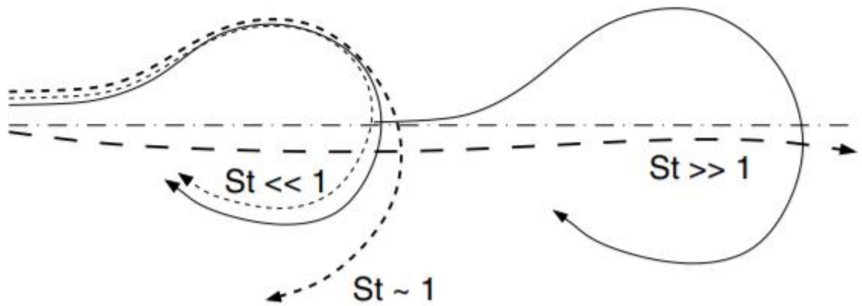


FIGURE FROM: Soldati, A., 2005. Particles turbulence interactions in boundary layers. ZAMM J. *Appl. Math*. Mech. 85, 683–699

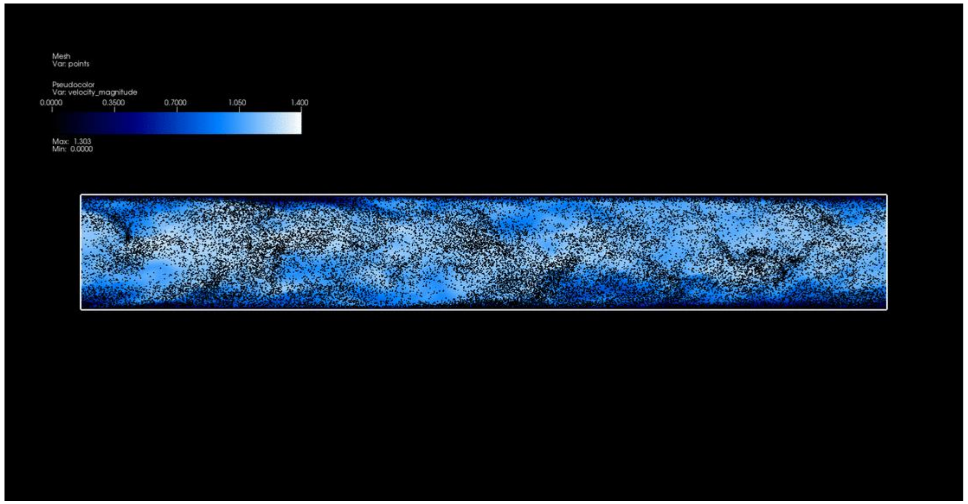


Fig. 1 Influence of particle relaxation time on particle trajectory. Small inertia particles follow precisely the flow; large inertia particles filter the space changes of velocity; intermediate inertia particles respond to the flow structures (see also [13]).

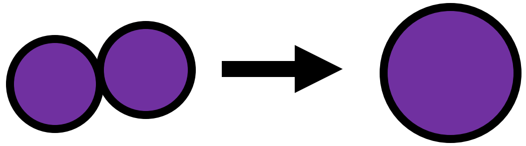
Energy-based agglomeration dynamics in turbulent flows

Mortimer, L.F., Njobuenwu, D.O., Fairweather, M., "Agglomeration dynamics in direct numerical simulations of liquid-solid particle-laden turbulent channel flows using an energy-based deterministic approach," (Submitted)

How and under what conditions do calcite spheres in water (simulant for nuclear waste material) undergo agglomeration?

Agglomeration condition

Upon collision:



$$\boldsymbol{u}^{*2}_{P,r} - \frac{\left(1 - e_n^{*2}\right)\left(\boldsymbol{u}^*_{P,r} \cdot \widehat{\boldsymbol{n}}\right)^2}{\left|\left(\boldsymbol{u}^*_{P,r} \cdot \widehat{\boldsymbol{n}}\right)\right|} \leq \frac{H^*}{6\delta_0^{*2}}\left[\frac{6\left(1 - e_n^{*2}\right)}{\pi^2 \rho_P^* \bar{\sigma}^*}\left(\frac{d_{P,1}^{*3} + d_{P,2}^{*3}}{d_{P,1}^{*2} d_{P,2}^{*2}\left(d_{P,1}^{*2} + d_{P,2}^{*2}\right)}\right)\right]^{\frac{1}{2}}.$$

$\boldsymbol{u}^*_{P,r}$ - Relative particle velocity vector

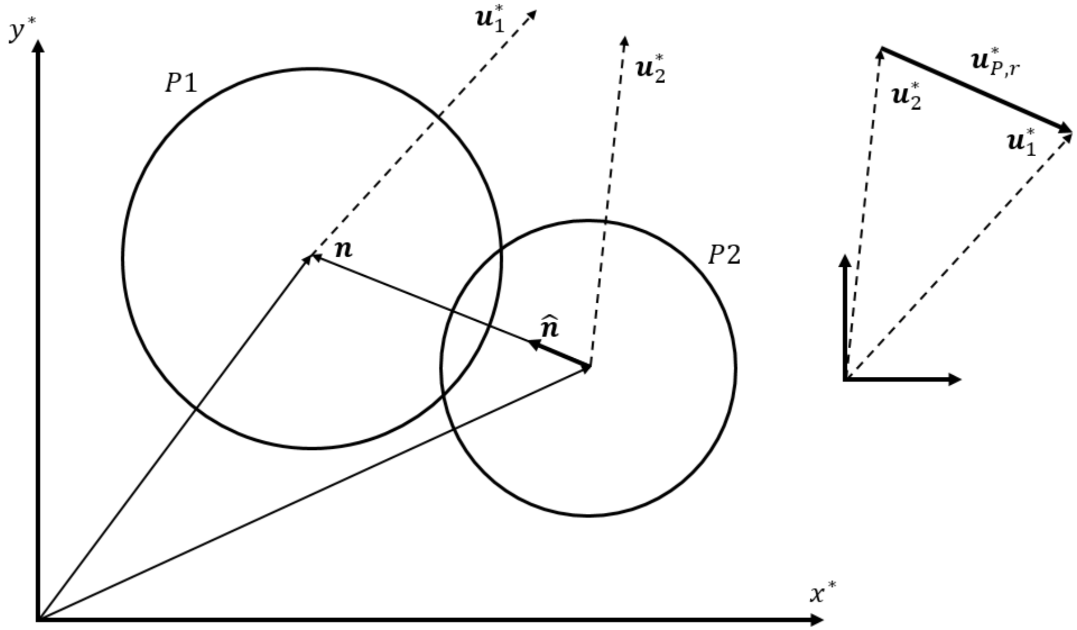
$\widehat{\boldsymbol{n}}$ - Normalised relative position vector

H^*- Non-dimensionalised Hamaker constant ($H^* = H/\rho_F U_B^2 \delta^3$)

δ_0^* - Non-dimensionalised minimum contact distance ($\delta_0^* = \delta_0/\delta$)

$\overline{\sigma^*}$- Non-dimensionalised yield pressure ($\bar{\sigma}^* = \bar{\sigma}/\rho_F U_B^2$)

e_n - Coefficient of restitution



Collisions

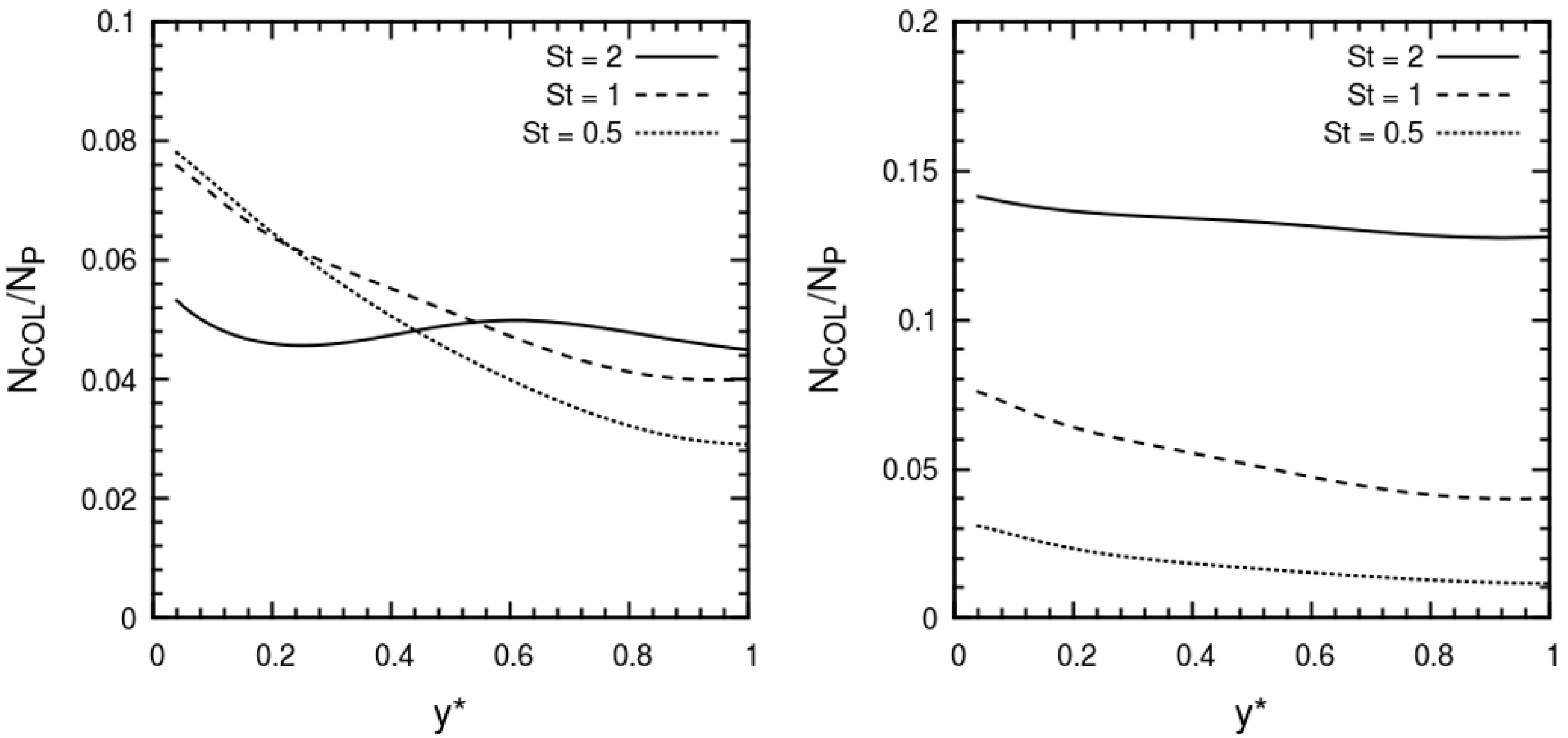


Figure 10 Effect of Stokes number on mean particle collision rate normalized by the initial number of injected primary particles across wall-normal direction of the channel. Sample time is $0 \leq t^* \leq 100$. Left: Fixed volume fraction; Right: Fixed particle number.

Agglomerations

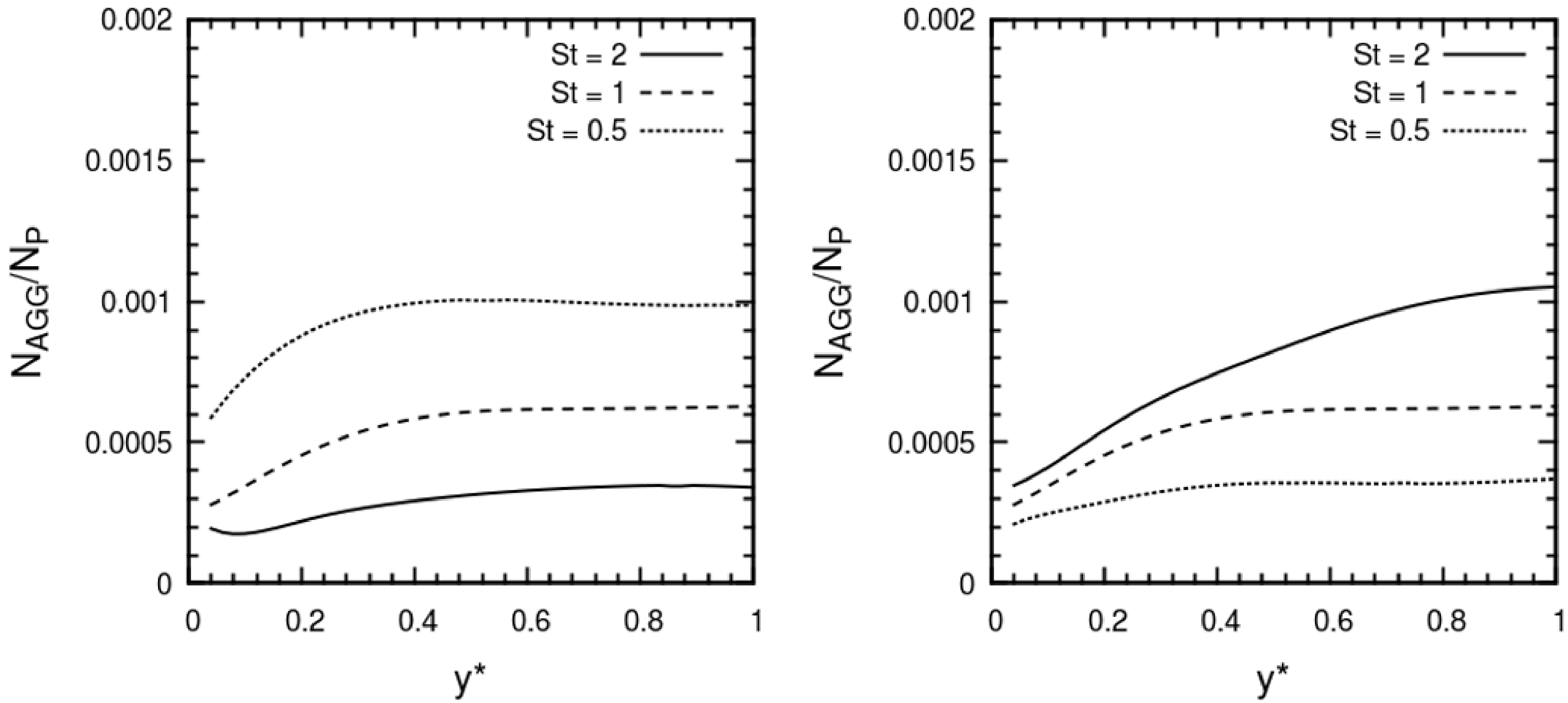


Figure 11: Effect of Stokes number on mean number of agglomeration events per timestep normalized by the initial number of injected primary particles across wall-normal direction of the channel. Sample time is $0 \leq t^* \leq 100$. Left: Fixed volume fraction; Right: Fixed particle number.

Agglomeration rate / efficiency

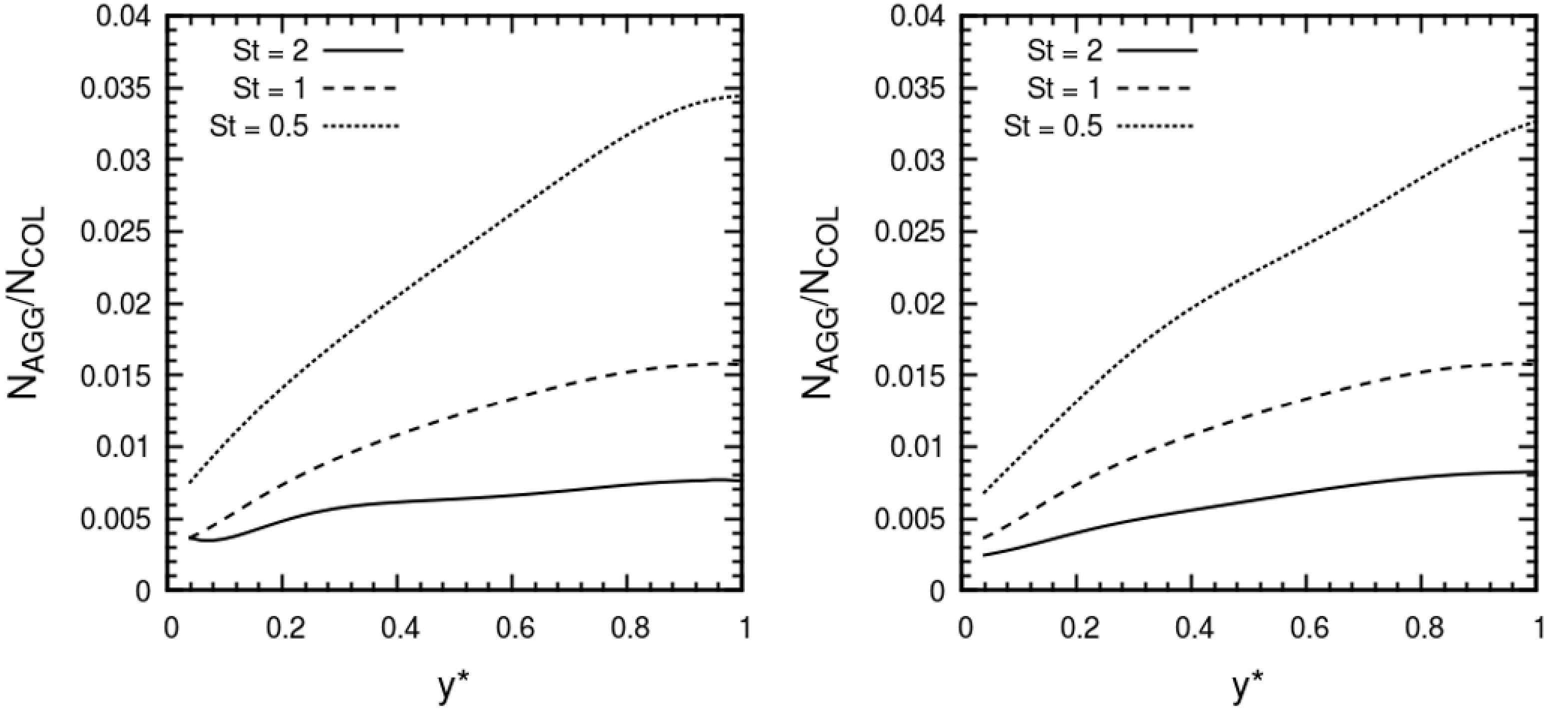


Figure 12: Effect of Stokes number on mean particle agglomeration rate across wall-normal direction of the channel. Sample time is $0 \leq t^* \leq 50$. Left: Constant volume fraction; Right: Constant particle number.

Relative particle velocities

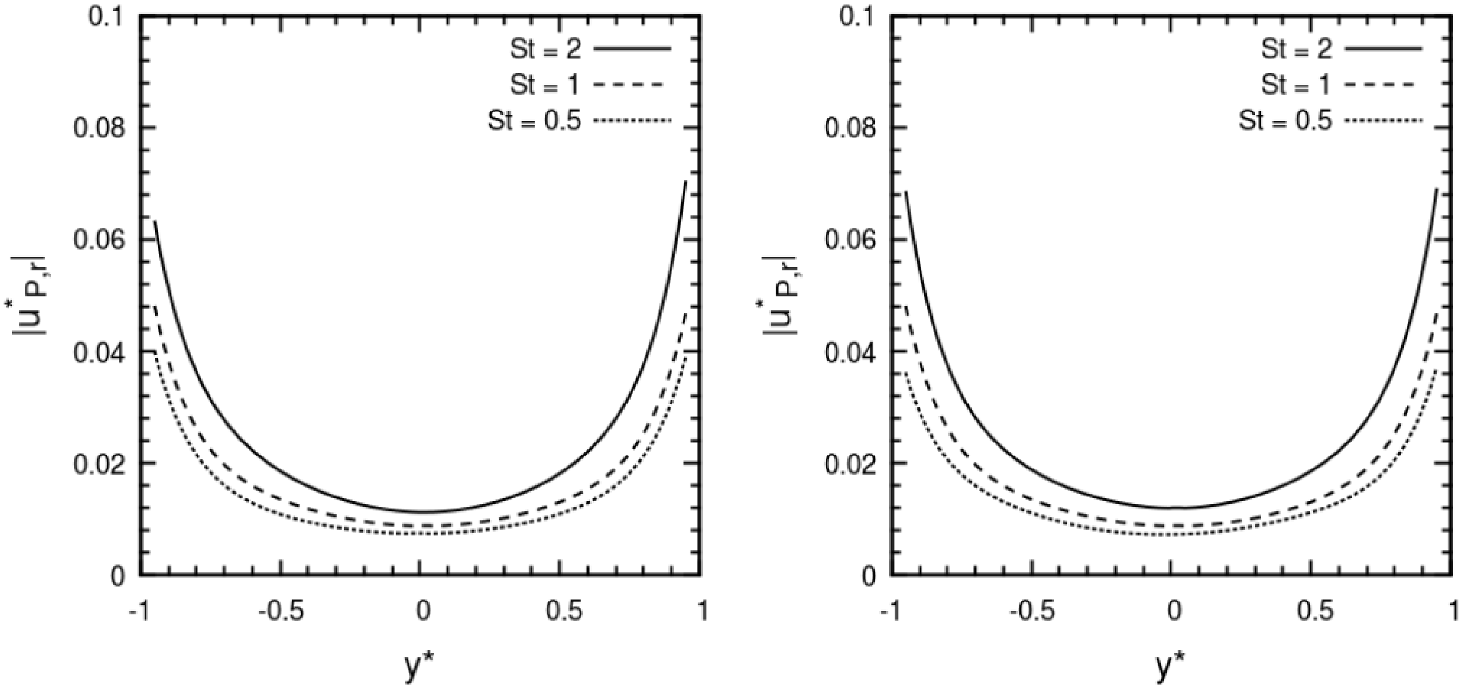
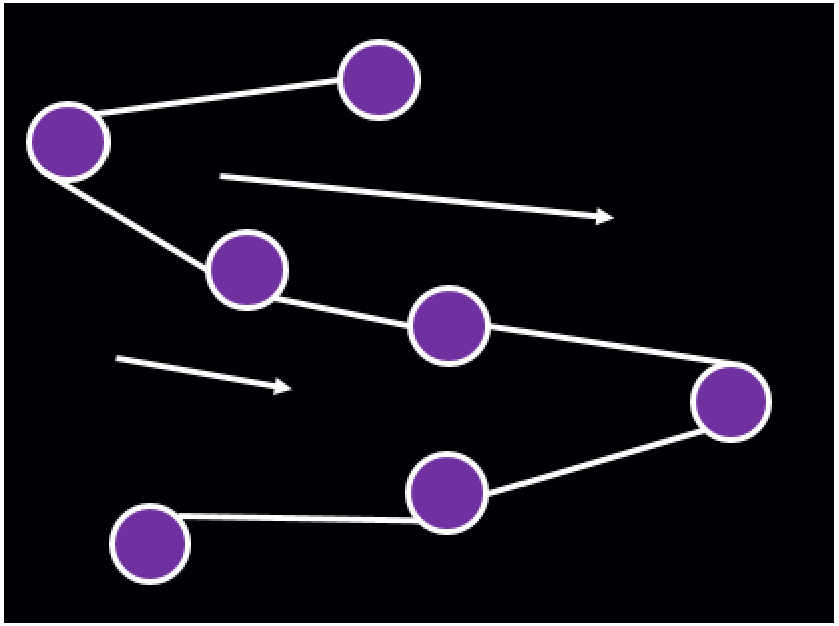
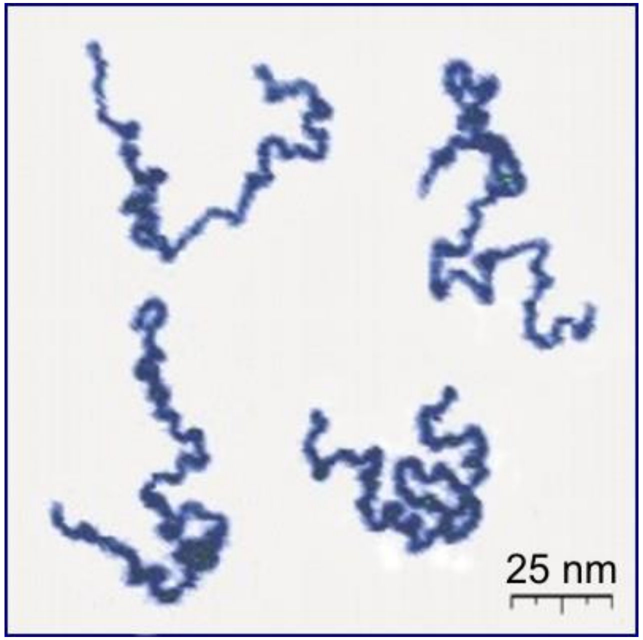


Figure 13: Effect of Stokes number on mean relative particle collision velocity across wall-normal direction of the channel. Sample time is $50 \leq t^* \leq 100$. Left: Fixed volume fraction; Right: Fixed particle number.

Polymer-laden shear and turbulent flows

Computational investigation into the use of polymer additives for beneficial modification of slurry flow behaviour

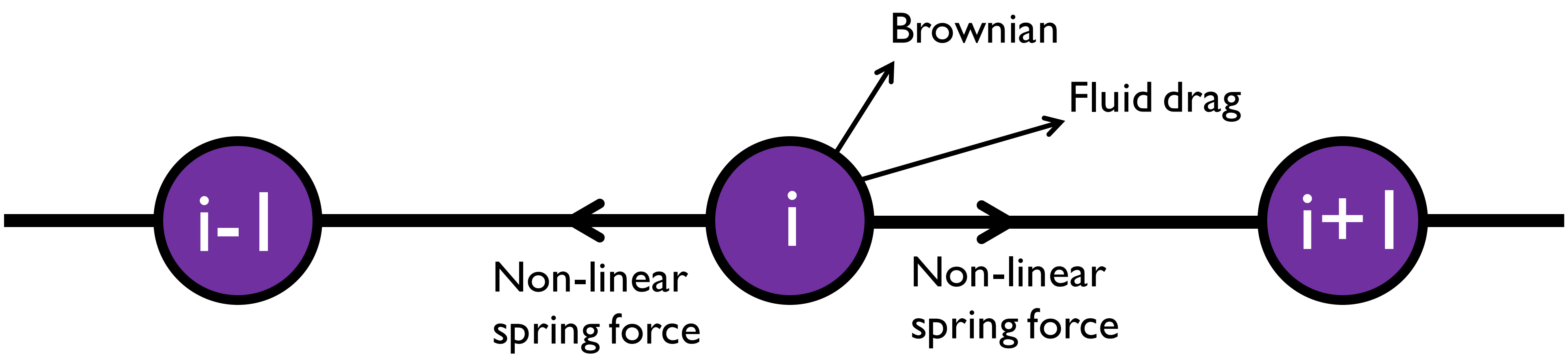




Polymer modelling

- FENE-P (finitely extensible nonlinear elastic) dumbbell model represents the polymer as a sequence of beads connected by nonlinear springs.
- Springs used to model individual Kuhn chains

$$\zeta\left[\boldsymbol{v}_0^* + \boldsymbol{\kappa}^* \cdot \boldsymbol{r}_i^* - \frac{\mathrm{d}\boldsymbol{r}_i^*}{\mathrm{d}t^*}\right] + (\boldsymbol{F}_i^* - \boldsymbol{F}_{i-1}^*) + \sqrt{2k_\mathrm{B}T\zeta}\,\frac{\mathrm{d}\boldsymbol{W}_i^*}{\mathrm{d}t^*} = 0$$



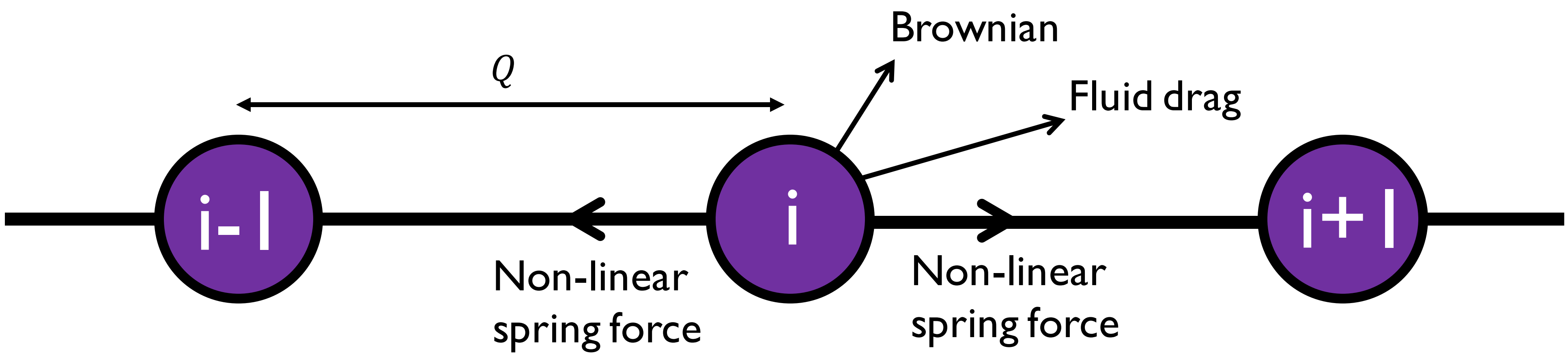
Spring forces

$$F^*(Q) = HQ$$

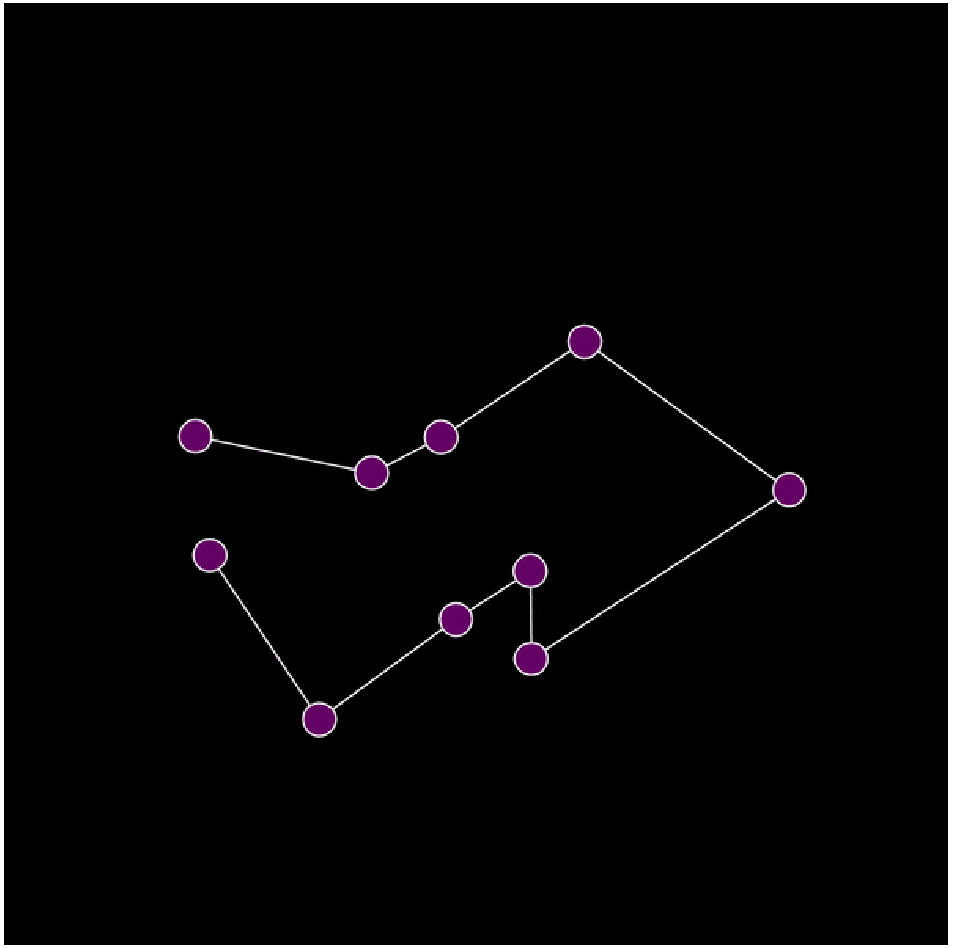
$$F^*(Q) = \frac{HQ}{1 - |Q|^2/Q_0^2}$$

$$F^*(Q) = \frac{HQ}{1 - < Q^2 > /Q_0^2}$$

H: Hertzian spring constant
Q: Spring extension
Q_0: Maximum spring extension
$< Q^2 >$: Root-mean-square extension for full chain.

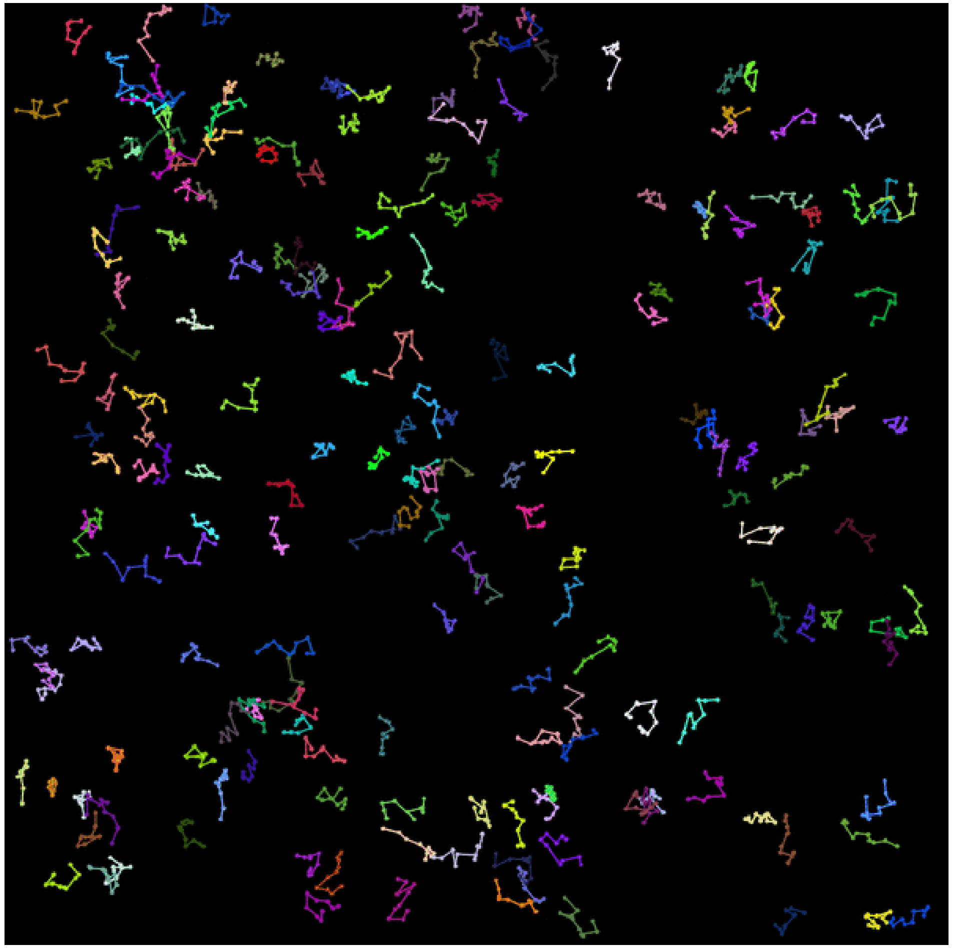


Polymer in equilibrium conditions



- 1 polymer chain ($N_B = 10$)
- Δt = 1×10^{-5} s
- Properties chosen to match λ-phage DNA strands for validation purposes.
- Kuhn length = 0.132μm
- Maximum spring extension = 2.33μm
- Contour length = 21μm

Ensemble of polymers in equilibrium conditions



- 200 polymer chains simulated for 6s ($N_B = 10$)

Observables compared with work of (Chopra and Larson, 2002)

- Equilibrium stretch: $< Q^2 >/Q_0$ (μm)

Measured: 1.15 Literature: 1.26

- End-to-end distance: $< R_0^2 >$ (μm)

Measured: 1.45 Literature: 1.66

- Radius of gyration: $< R_G^2 >$ (μm)

Measured: 0.66 Literature: 0.68

- $< R_0^2 >/< R_G^2 >$

Measured: 2.19 Literature: 2.44

Experimental validation data: M. Chopra and R. G. Larson, *J. Rheol.*, 2002, 46, 831–862

Next steps

Extend to polymer-laden turbulent flows

Newtonian / non-Newtonian

Polymer drag reduction

Polymer-turbulence interaction

Polymer-particle interaction

Subsequent flocculation

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

Lee Mortimer
PhD, MPhys
Research Fellow
Office 2.22 Chemical and Process Engineering Building
School of Chemical and Process Engineering
University of Leeds

Transformative Science and Engineering for Nuclear Decommissioning

In-Situ X-Ray Diffraction Studies of Ion Exchange in Zeolites

Hannah Parish, University of Birmingham

TRANSCEND Theme Meeting

11th November 2019
The Conference Centre,
Lancaster

For a Low Carbon Future

- MSci Chemistry at University of Birmingham (2014 – 2018)
  - Master's project with Joe Hriljac (2017-18) looking at Sn-umbite materials for use in nuclear waste clean up
- PhD at University of Birmingham (2018 – 2021)
  - Crystallographic studies of zeolites and related zeotypes, with a particular focus on these materials in nuclear waste remediation

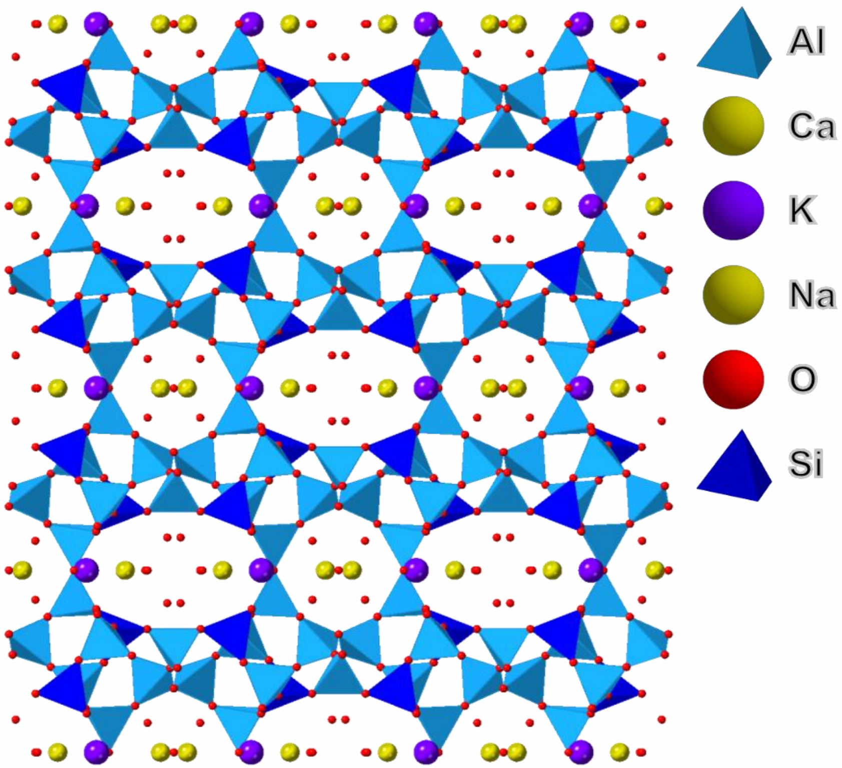


Figure 1 – the crystal structure of clinoptilolite along the c-axis[1]

- Zeolite clinoptilolite is already used in nuclear waste clean-up
  - Excellent selectivity for radioactive ^{137}**Cs** and ^{90}Sr
  - Clinoptilolite from Mud Hills, California, used in the SIXEP plant at Sellafield
- In-situ powder XRD studies used to monitor Cs ion exchange
  - Subsequent analysis will hopefully give chemical and crystallographic insight into the exchange process

[1]J. R. Smyth, A. T. Spaid and D. L. Bish, *Am. Mineral,* 1990, **75**, 522 – 528

- Two samples of Mud Hills clinoptilolite used – untreated and Na-exchanged
  - Exchanged with 0.5 mM $CsNO_3$, flow rate 0.2 ml min^{-1}
  - XRD patterns recorded
  - Analysis using Pawley and Rietveld methods

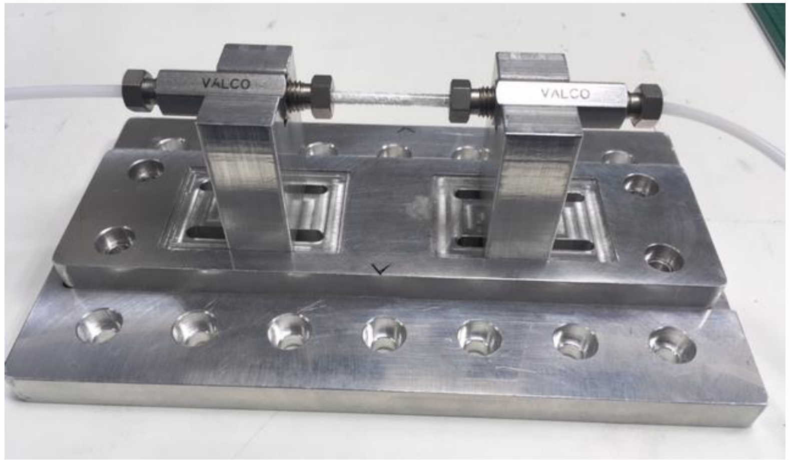
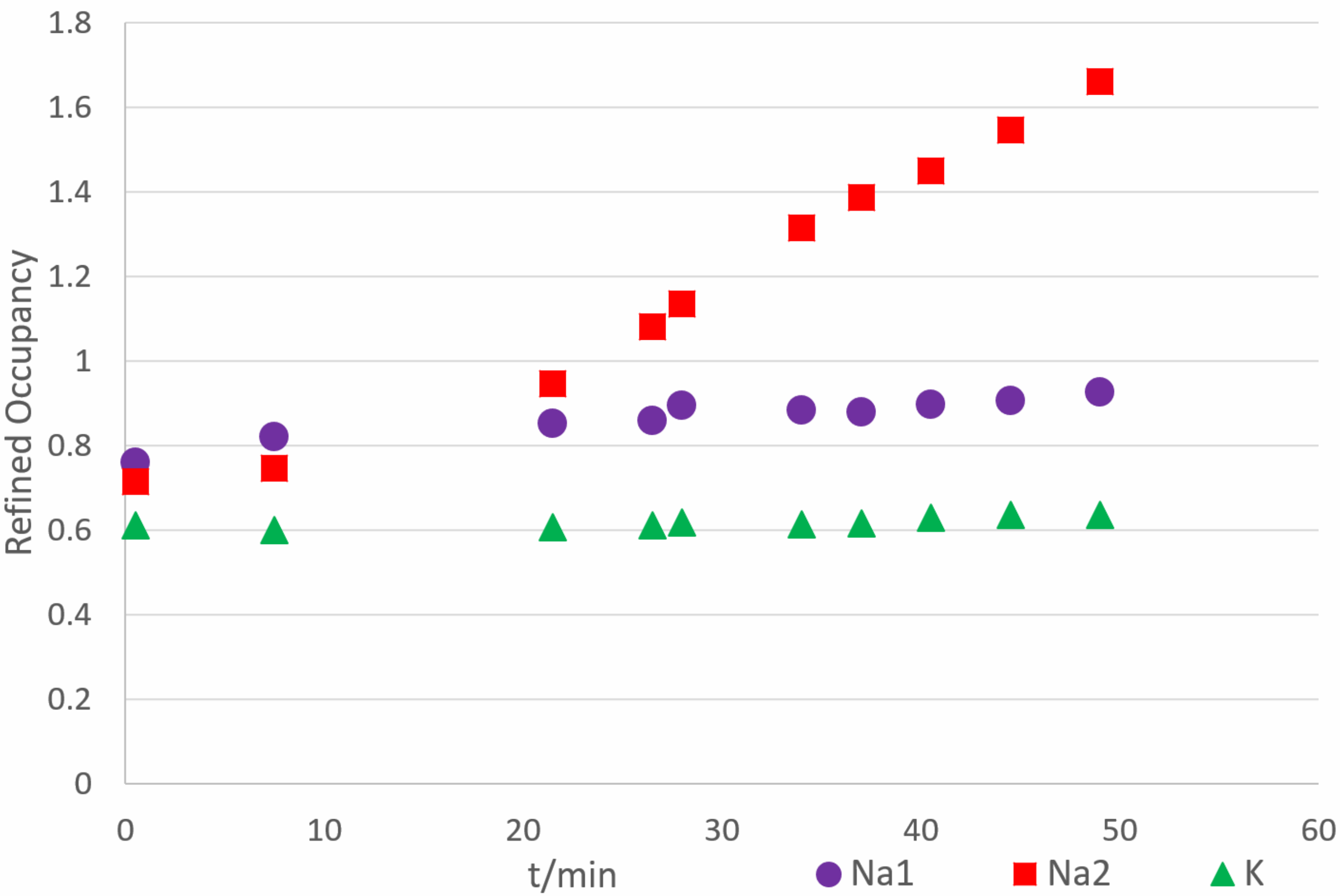
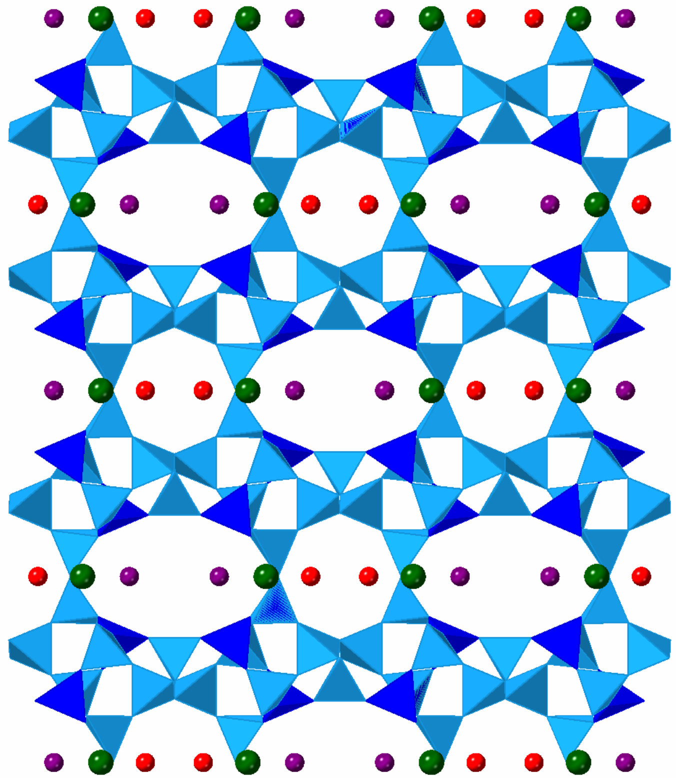


Figure 2 – the in-situ flow cell used for the exchange experiments


Refined Occupancy
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
t/min
Na1
Na2
K



TRANSCEND

- **Dr Joe Hriljac**, University of Birmingham/Diamond Light Source
- **Dr Geoff Cutts**, BAE Systems
- **Dr Chiu Tang**, Diamond Light Source

Thank you

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Scoping Studies of New Ion-Exchange Materials

James Reed, University of Birmingham

TRANSCEND theme 1&2 meeting 2019

11th November 2019
LancasterUniversity

Energy
For a Low Carbon Future

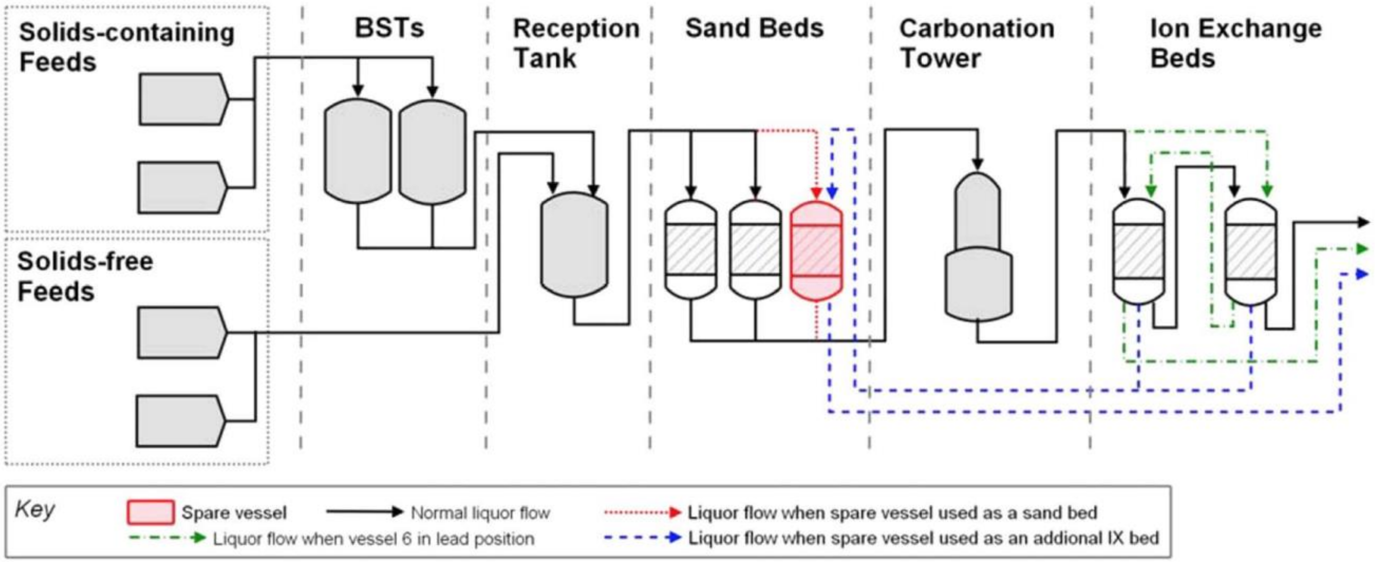
About Me

2019 graduate from University of Birmingham with an MSci in Chemistry.

- Development of ligands for metal complexes aimed at treatment of peridontitis (summer 2018).
- Synthesis of magnetised tin umbites for removal of radionuclides from water.
- Showed highly selective caesium uptake.
- Refined magnetisation procedure.

Background

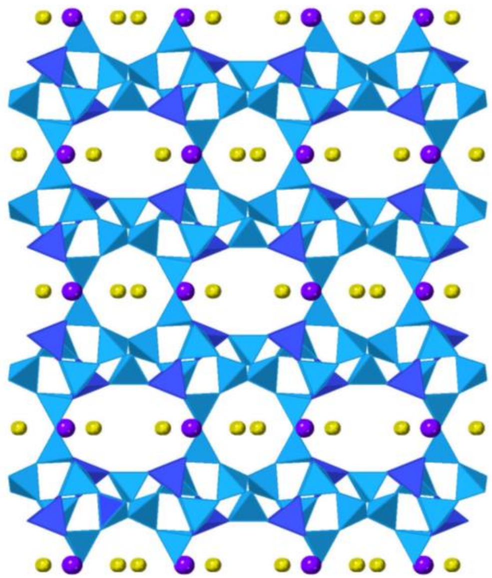
- SIXEP plant at the Sellafield site removes radioactive caesium and strontium from effluent.



- Mud hills clino used in ion exchange beds.
- Estimated to last 100 years.

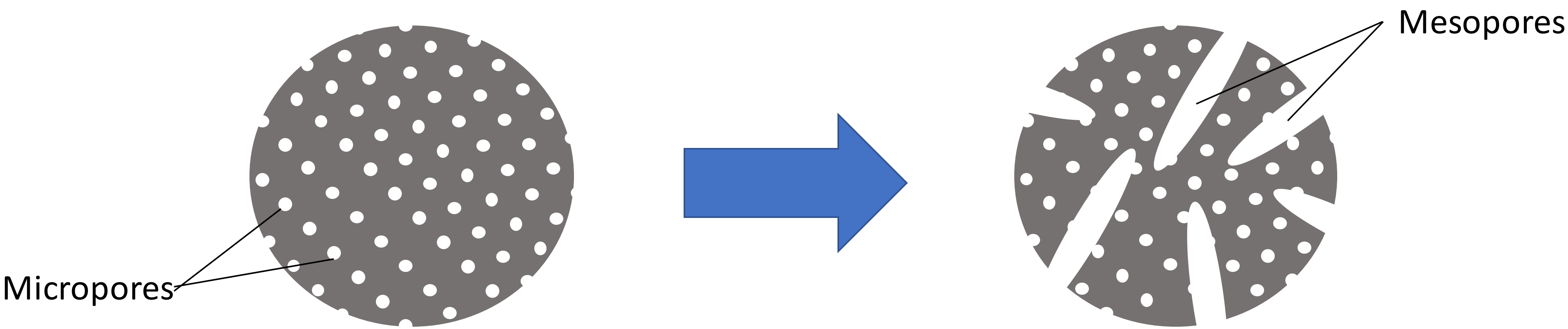
Project Aims

- Characterisation of material currently used in SIXEP plant at Sellafield (Mud Hills Clinoptilolite).
- Explain why Mud Hills variant superior to others.
- Scope other natural / readily sourced zeolite materials.
- Explore treatments that improve properties.



Treatments on existing zeolites

Faster Exchange → Introduction of mesoporosity → Partial breakdown of framework (acid or base treatment)



Thank you

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Durability of Magnesium-Silicate-Hydrate Cements made from Brucite

Mercedes Baxter Chinery,
Imperial College London

Theme meeting, Lancaster, November 2019

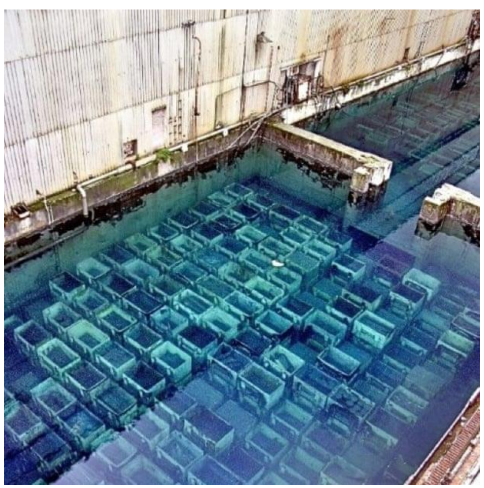
Energy
For a Low Carbon Future

About me

- BA/Meng in Civil and Structural Engineering, University of Cambridge

- Final year research on Porosity, Sorptivity, Permeability of Concrete

The PhD problem : Ponds at Sellafield



- Contain
  - $Mg(OH)_2$ rich sludge
  - Al, Mg, U
  - pH 9 - 10
- How to store/make safe
  - sludge

The Opportunity

- Magnesium – Silicate – Hydrate cement

$$MgO + SiO_2 + H_2O \rightarrow M - S - H$$

- pH 9.5 – 10.5
- Compatible with Al and Mg metal
- **Potential for waste volume reduction as sludge could be part of stabilising cement**

The approach

- Create artificial sludge like material by slow formation and sedimentation of $Mg(OH)_2$
- Investigate cementation of such sludge by condition and mixing
    - Water content and dispersant expected to be key

The approach

- Study durability of M-S-H cements
  - Little known to date
  - Important if to be stored for very long times

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

M.Baxter-Chinery19@imperial.ac.uk

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Radiation effects on nuclear waste forms: How does the degree of crystallinity in a glass-ceramic affect radiation tolerance?

Tamás Zagyva - University of Manchester, Dalton Cumbrian Facility

Themes 1&2 Integrated Waste Management, Remediation and Decommissioning

11th November 2019
Lancaster University

Energy
For a Low Carbon Future

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Tamás Zagyva

(Hungary)

Eötvös Loránd University
Faculty of Science

MFA

Earth Sciences BSc (2012 – 2016)

Submarine hydrothermal processes, mirroring the geotectonic evolution of the NE Hungarian Jurassic Szarvaskő Unit

May 2018 · International Journal of Earth Sciences

Gabriella B. Kiss · Tamás Zagyva · Domokos Pásztor · Federica Zaccarini

Materials Science MSc (2017 – 2019)

Characterization and adhesion strength of porous electrosprayed polymer–hydroxyapatite composite coatings

March 2018 · Resolution and Discovery

Tibor Sopcak · Lubomir Medvecky · Tamás Zagyva · [...] · C. Balázsi

Examination of novel electrosprayed biogenic hydroxyapatite coatings on Si3N4 and Si3N4 /MWCNT ceramic composite

June 2019 · Processing and Application of Ceramics

Tamás Zagyva · Katalin Balazsi · Csaba Balázsi

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Tamás Zagyva

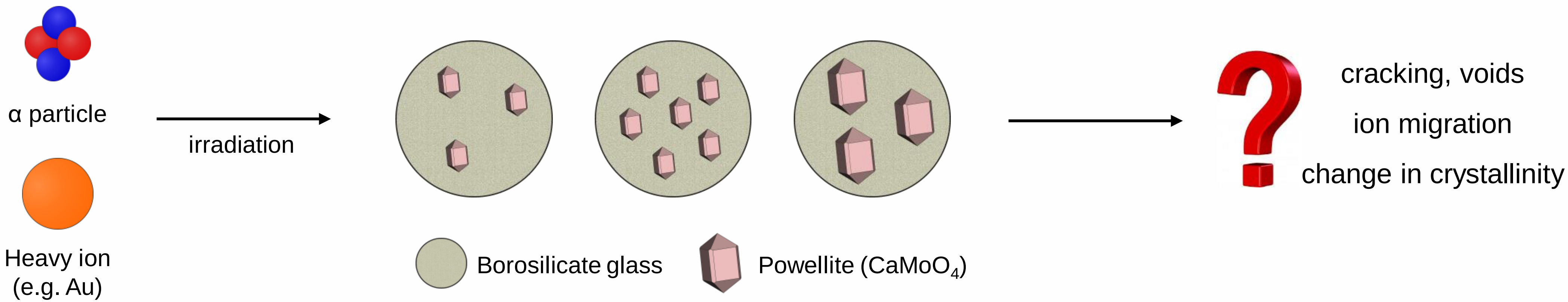
(Hungary)

MANCHESTER 1824
The University of Manchester
Dalton Nuclear Institute

PhD from the department of Chemistry (2019 – 2022)

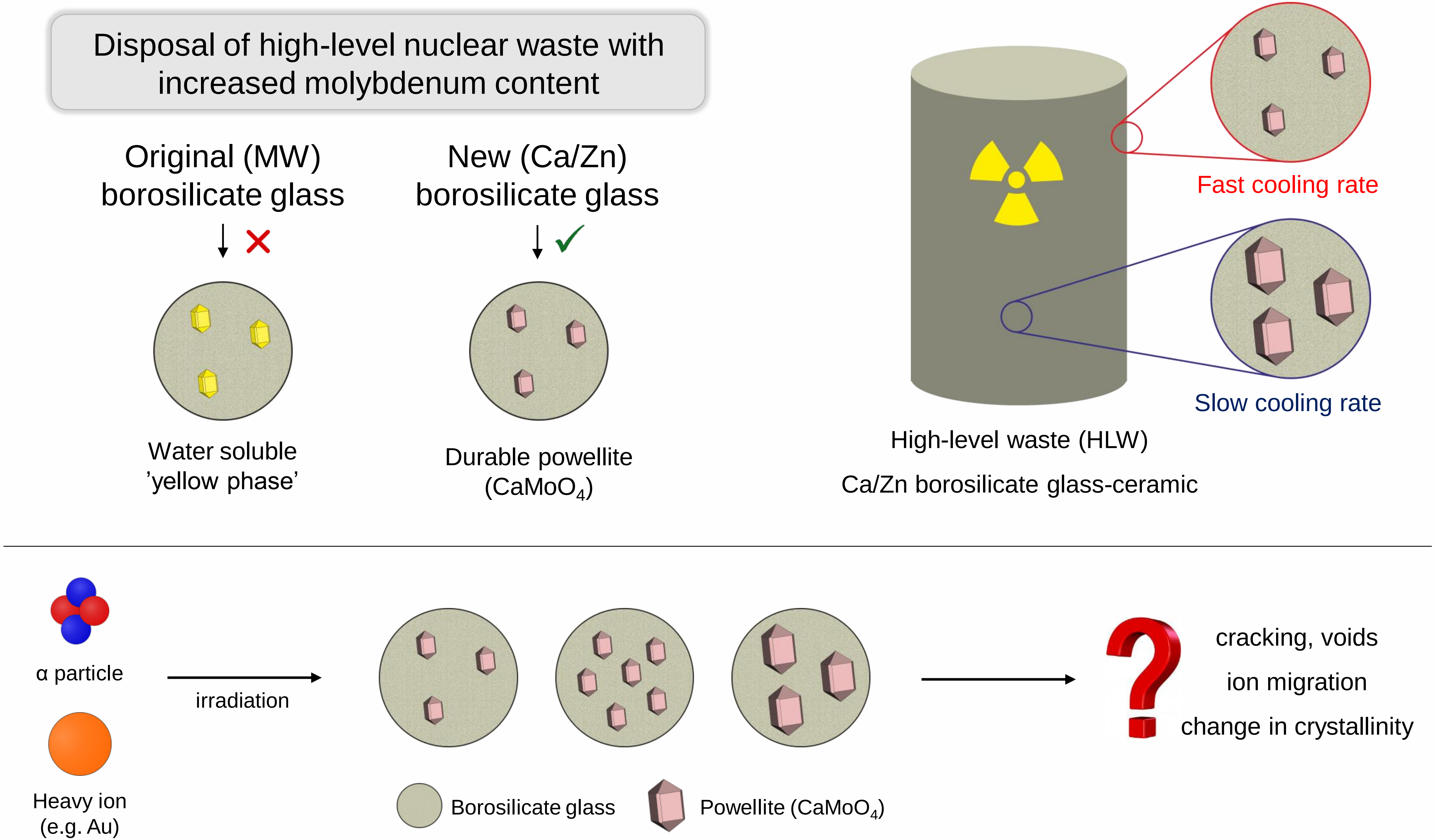
Radiation effects on nuclear waste forms: How does the degree of crystallinity in a glass-ceramic affect radiation tolerance?

Main Supervisor:	Dr Laura Leay	(The University of Manchester, Dalton Cumbrian Facility)
Co-supervisor:	Dr Brian O'Driscoll	(The University of Manchester)
Industrial supervisor:	Dr Tracey Taylor	(National Nuclear Laboratory)



TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning



Thank you!

Contact Details:
tamas.zagyva@postgrad.manchester.ac.uk

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Advanced radiation-based borehole monitoring

Soraia S. C. Elisio, Lancaster University

Integrated Waste Management, Remediation and Decommissioning

11th November 2019
Lancaster University

Energy
For a Low Carbon Future

2013-2019 5-year Integrated Masters Degree in Engineering Physics

University of Lisbon – Faculty of Science (Lisbon, Portugal)
LIP – Laboratory of Instrumentation and Experimental Particle Physics
(Radiation, health and environment research group)

Dissertation: "Development of a low-cost monitor for Radon detection in air"
Presented at 3rd International conference on Dosimetry and its Applications, May 2019, Lisbon
Submitted to Radiation Physics and Chemistry Journal

2018 2.5-month Traineeship Programme Erasmus+

CEH – Centre for Ecology & Hydrology (Lancaster, England)
Radioecology group

"The Red Forest following the July 2016 fire"
Cataloguing and analysis of photographs of vegetation recovery

Now → 3.5-year PhD Project: "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."

Supervisor: Dr. Malcolm J. Joyce (Lancaster University)

Objective of the project

Development of a resilient device which shall yield a degree of spectroscopy to identify principally **Cs-137**, and potentially **Sr-90**

LONG-TERM MONITORING IN-HOLE OF FISSION CONTAMINANTS MIGRATION IN SOIL AND GROUNDWATER

REDUCED NEED FOR HUMAN INTERVENTION

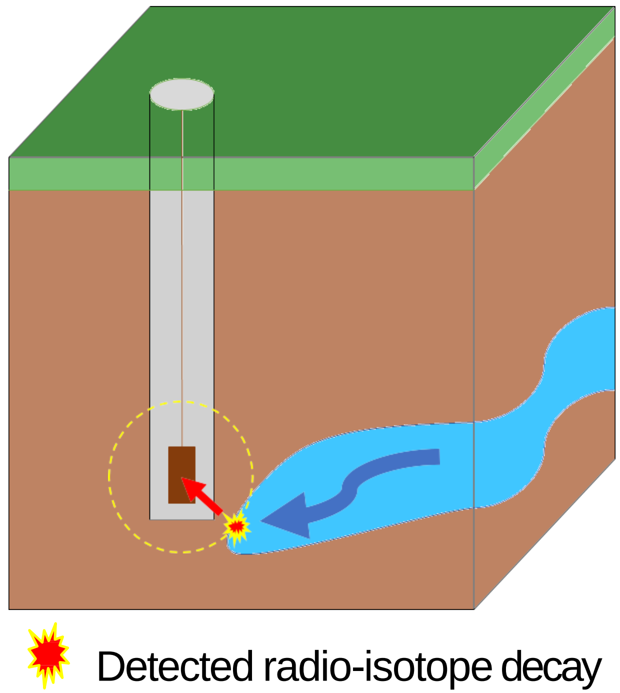


Fig. 1 - Illustration of a borehole monitoring system.

Instrument requirement specifications

Look for the ideal sensor

Laboratory-based tests

Explore its resilience

Build a prototype

Field-based tests

Fig. 2 - Soil-filled phantom.

What have been done in Lancaster University

- **Searching for zero plutonium in the far north of Scotland**, M. J. Joyce, C. Tighe, M. Christl, C. Degueldre, K. Semple and J. Andrew, in press Actinides Quarterly, 2019.
- **Remediation of 137Cs contaminated concrete using electrokinetic phenomena and ionic salt washes in nuclear energy contexts**, A. Parker, M. J. Joyce, C. Boxall, J. Haz. Mat., 340 pp. 454-462 (6th July 2017).
- **A comparison of plutonium abundance in soil from sites in the United Kingdom measured with high-efficiency, high-resolution g-ray spectroscopy, neutron assay and accelerator mass spectrometry**, M. J. Joyce, C. Tighe, C. Degueldre, M. Christl and J. Andrew, Plutonium Futures 2018, San Diego, September 2018.
- **Radiometric detection of non-radioactive caesium flux using displaced naturally abundant potassium**, A. J. Parker, M. J. Joyce and C. Boxall, J. Radioanal. Nucl. Chem. 307 (1) pp. 769-776 (2016).
- **Finding the depth of radioactivity in construction materials**, M. J. Joyce, J. C. Adams, J. A. Heathcote and M. Mellor, ICE Proc. Energy (invited) March 2013 http://dx.doi.org/10.1680/ener.12.00003 166 (2) 67-73 (2013). Winner of the ICE Proc. Energy Watt medal award, October 2014.*

TRANSCEND

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

Contact Details:
s.elisio@lancaster.ac.uk
Lancaster University

Transformative Science and Engineering for Nuclear Decommissioning

Predicting Gamma Dose Rates with Limited Information

Luke Lee-Brewin

University of Surrey

TRANSCEND Theme Meetings

11/11/2019
Lancaster

Who am I?

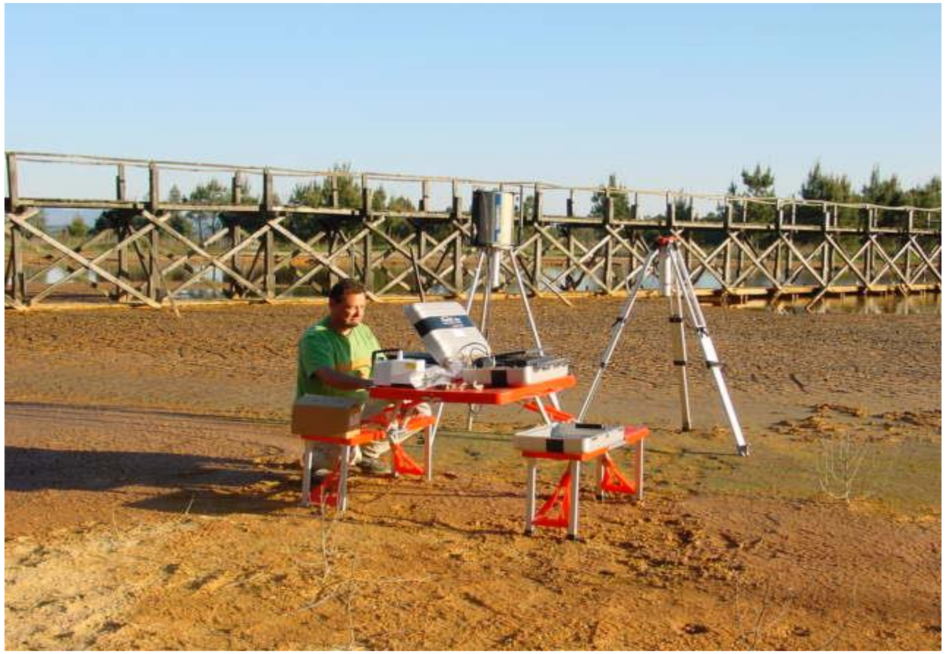
- Luke Lee-Brewin
- University of Surrey
- Mphys – Physics with Nuclear Astrophysics
- AWE research project: Developing a sensor to measure the optical emission of lightning

https://www.surrey.ac.uk/
https://www.awe.co.uk/

Transformative Science and Engineering for Nuclear Decommissioning

Predicting Gamma Dose Rates with Limited Information

- What is the project?
- Quantify the pipe contents
- Calculate dose rates as a function of depth
- TRL 6: Technology model demonstration in a relevant environment.

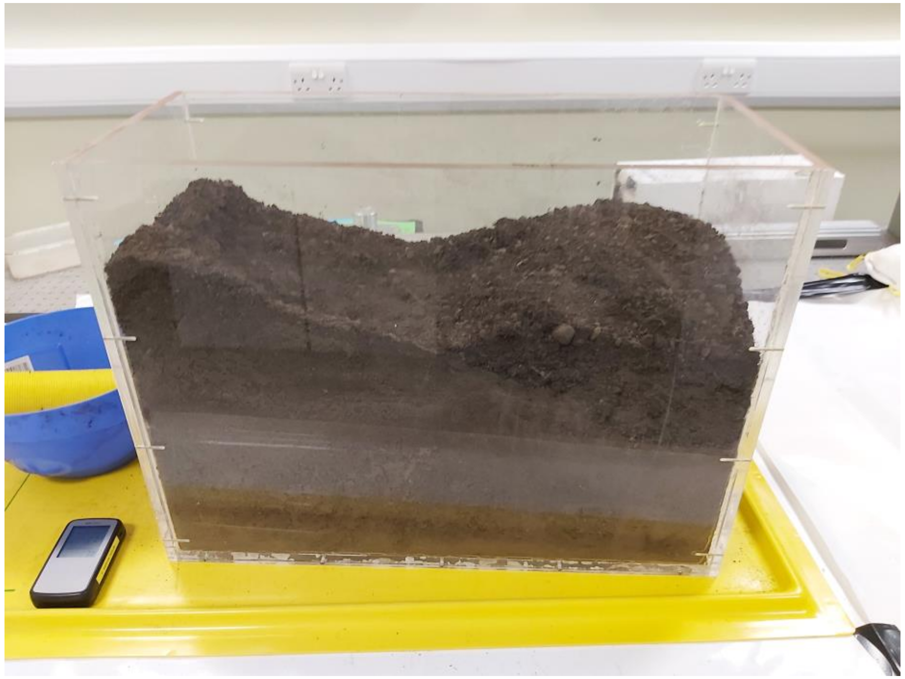


Why is this project important?

- Safety! – Dose rates might be higher than expected
- Cost effective – a non-intrusive methodology would save significant excavation work
- Efficient – Can we develop a methodology capable of being used by someone without advanced training?

Initial Challenges

- Environmental factors – Moisture Content?



Initial Challenges

- Environmental factors – Moisture Content?
- Weak Signal

➢ Wavelet Analysis

➢ Fuzzy Logic

➢ Optimised Sensor Location

Initial Challenges

- Environmental factors – Moisture Content?
- Weak Signal
- Generalisation

http://www.dorsetlife.co.uk/2009/11/how-the-mighty-atom-came-to-dorset/

Dr. Caroline Shenton-Taylor

Prof. David Read

Nuclear Decommissioning Authority

Magnox Ltd

Thank you

l.lee-brewin@surrey.ac.uk

Transformative Science and Engineering for Nuclear Decommissioning

Assessing the strength of biomineral strategies for concrete repairs

Athanasios Christos Karampourniotis, University of Strathclyde

Integrated Waste Management, Remediation and Decommissioning

11 November 2019
The Conference Centre, Lancaster University

Educational Background

Source: www.typosthess.gr

Integrated Masters in Civil Engineering

Division of Geotechnical Engineering

Aristotle University of Thessaloniki

Project Thesis:

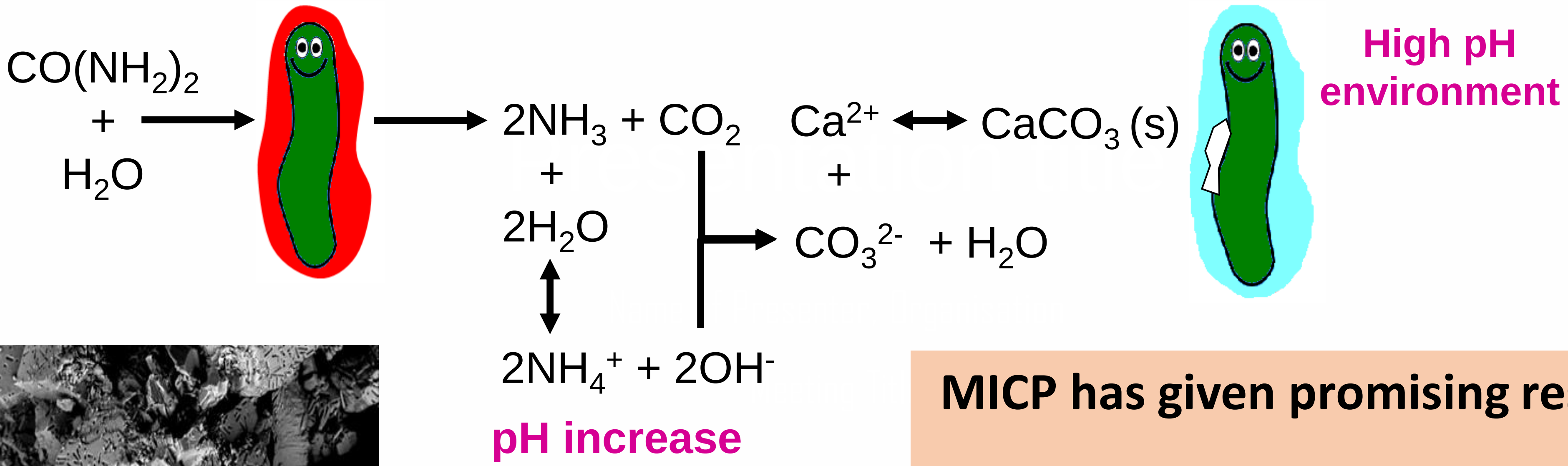
The effect of non-linear soil and the soil-structure interaction on the seismic response of a framed building structure.

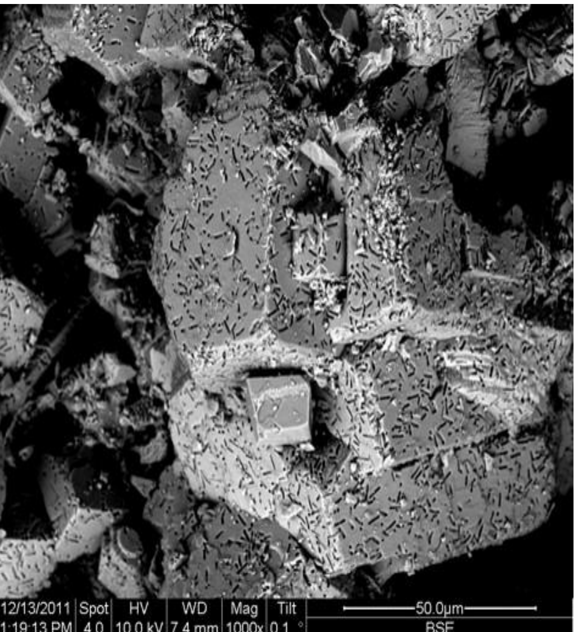
Problem

- Many concrete structures in the UK are past their design life and so there is a gradually increased risk of failure.
- Different structures are exposed to different environmental conditions, resulting in concrete degradation and cracking formation.
- The rate of concrete degradation varies highly on individual structures.

What can we do?

Microbially Induced Carbonate Precipitation





MICP has given promising results to:

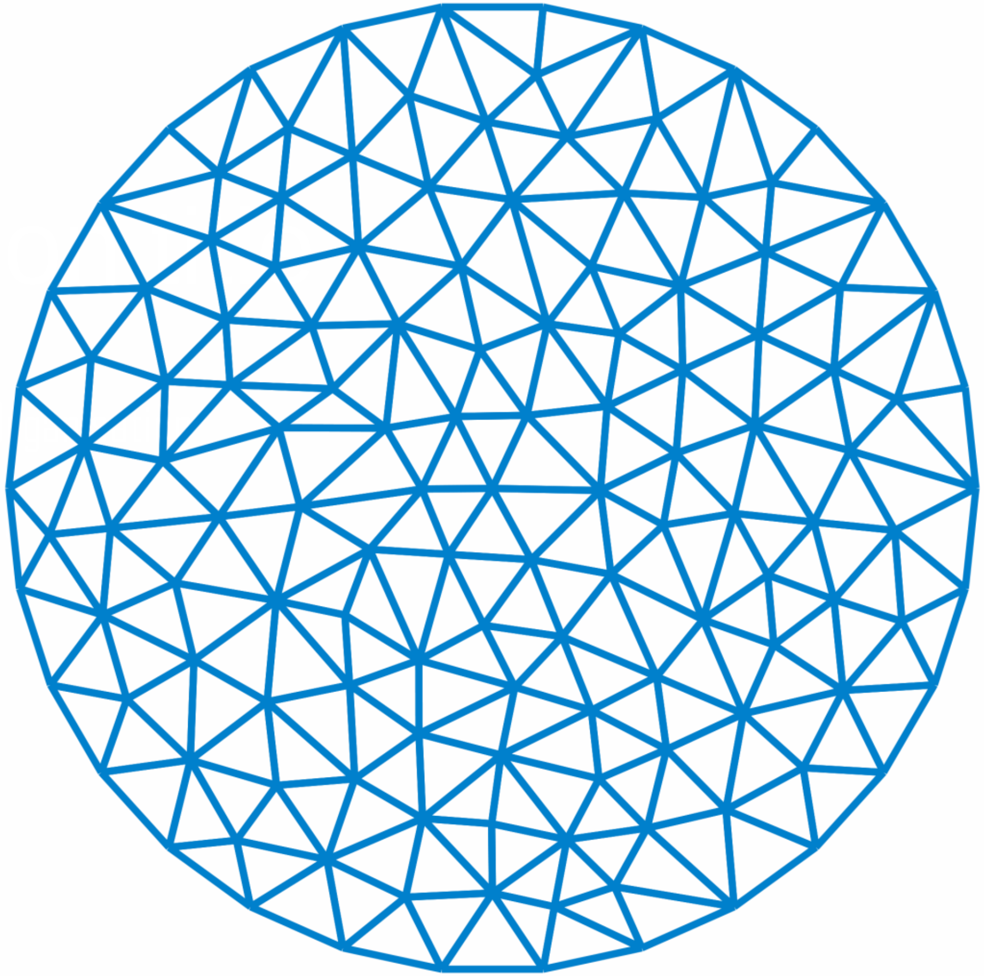
- Soil strengthening
- Permeability reduction
- Sealing fractured rock
- Increasing fractured rock's shearing resistance

Mesoscale Modelling – Finite Elements Method

- Modelling heterogeneous materials like concrete at mesoscale, can help us detail their composition.

- FEM-Mesoscale model can represent the intact concrete as it is, a non-homogeneous continuum[1]

[1]Zhou et al., 2018, Construction and Building Materials, https://doi.org/10.1016/j.conbuildmat.2018.01.040



Source: www.grasshopper3d.com

Acknowledgements

Professor Rebecca Lunn[1]

Dr. Enrico Tubaldi[2]

Dr. Grainne El Mountassir[3]

[1,2,3] Department of Civil and Environmental Engineering, Faculty of Engineering, University of Strathclyde, Glasgow, United Kingdom

University of Strathclyde Glasgow

cavendish nuclear

Transformative Science and Engineering for Nuclear Decommissioning

Thank you

athanasios.karampourniotis@strath.ac.uk