Geological Disposal of Radioactive Waste: UK position on role of Underground Research Laboratory-based Research & Development

US NWTRB Workshop on Recent Advances in Repository Science and Operations from International Underground Research Laboratory Collaborations

Dr Simon Norris, Radioactive Waste Management, UK

April 24-25, 2019, Embassy Suites by Hilton San Francisco Airport Waterfront, California, USA

Radioactive Waste Management - A UK governmental organisation whose mission is to deliver a geological disposal facility (GDF) and provide radioactive waste management solutions.
Wastes (& potential wastes) for disposal

Low heat generating waste (LHGW)
- Intermediate Level Waste (ILW)
- Being produced and packaged now
- Interim storage then disposal

High heat generating waste (HHGW)
- High Level Waste (HLW)
- Spent Fuel (SF)
- Uranium & Plutonium

<table>
<thead>
<tr>
<th>Material</th>
<th>Packaged volume (m$^3$) (2013 baseline inventory)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HLW</td>
<td>9,290</td>
</tr>
<tr>
<td>ILW</td>
<td>456,000</td>
</tr>
<tr>
<td>LLW</td>
<td>11,800</td>
</tr>
<tr>
<td>Plutonium</td>
<td>7,820</td>
</tr>
<tr>
<td>Uranium</td>
<td>112,000</td>
</tr>
<tr>
<td>Spent Fuel</td>
<td>66,100</td>
</tr>
</tbody>
</table>
Long-term Management of Higher Activity Radioactive Waste

- UK Government committed to geological disposal and Geological Disposal Facility (GDF), otherwise referred to as a repository – 2014 ‘White Paper’
What is Geological Disposal?

Key principles:

ISOLATE radioactivity from the surface

CONTAIN until most of the hazard has decayed

PASSIVE safety, not requiring human action

A suitable site with a willing host community
Long-term Management of Higher Activity Radioactive Waste

• UK Government committed to geological disposal and Geological Disposal Facility (GDF), otherwise referred to as a repository – 2014 ‘White Paper’

• Work started on three “Initial Actions”:
  – National Geological Screening
  – Land-use planning – GDF becomes a Nationally Significant Infrastructure Project (NSIP)
  – “Working With Communities”

• Commitment to early Community Investment funding of £1m/£2.5m per year

• Policy based on community consent
Since 2014 - Learning Lessons and New White Paper

- 2015 legislation makes GDF a Nationally Significant Infrastructure Project (NSIP)
- 2018 consultations on Working With Communities and National Policy Statement (part of NSIP planning process)
- Updated GDF siting policy framework published December 2018
  - replaces 2014 White Paper in England
Process for Implementing Geological Disposal
Process for Working with Communities

1. Interested party
2. Working group
3. Community Partnership
4. Test of Public Support

Investment:
- Up to £1M per year per community
- Up to £2.5M per year per community

1 - 5 Years
- Talking
- Forming Groups

10 - 15 Years
- Local Studies
- Drilling Boreholes
- Test of Public Support
- Right of Withdrawal

Radioactive Waste Management
The Science: A Multi-barrier System

An Example Multi-barrier System for Low Heat Generating Waste

- Cemented Wasteform
- Stainless Steel Waste Container
- Cement Buffer
- Rock

An Example Multi-barrier System for High Heat Generating Waste

- Solid Glass Wasteform
- Durable Metal Waste Container
- Clay Buffer
- Rock
Far Distant Future

And so on into the far distant future...

What are we considering the performance of?

- How harmful is the dose?
- Radiotoxicity & chemotoxicity
- What routes give a dose?
- Human uptake
- Environmental behaviour, including non-human biota

How does rock affect radionuclide movement?
- Groundwater movement
- Rock matrix diffusion
- Sorption
- Diffusion and dispersion

Can isolation & containment function of rock be ‘short circuited’?
- Waste-derived gas
- Resources / Future human intervention
- Natural processes (tectonic and climatic)

NOT TO SCALE

Radioactive Waste Management
Generic Geological Disposal Facility

• In the absence of a site, assume generic GDFs

• Range of host rock geologies
  – Higher strength rock (e.g. granite)
  – Lower strength sedimentary rock (e.g. clay)
  – Evaporite (e.g. salt)

• Develop illustrative disposal concepts, cognisant of international precedents, UK waste characteristics and UK geological options

• Develop Generic Safety Cases
Safety Cases, Knowledge Base, Needs-based Research and Role of URLs

<table>
<thead>
<tr>
<th>Transport Safety Case</th>
<th>Operational Safety Case</th>
<th>Environmental Safety Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geosphere Status Report</td>
<td></td>
<td></td>
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<tr>
<td>Biosphere Status Report</td>
<td></td>
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<tr>
<td>Gas Status Report</td>
<td></td>
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<tr>
<td>Criticality Safety Status Report</td>
<td></td>
<td></td>
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<tr>
<td>Waste Package Accident Performance Status Report</td>
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</tbody>
</table>
# Relationship between Laboratory Studies, In-situ Experiments in URLs and Natural Analogues
(modified after Kickmaier 2002)

<table>
<thead>
<tr>
<th>Approach</th>
<th>Characteristics</th>
<th>Duration of the experiments (observation period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiments in conventional laboratory settings</td>
<td>Well defined boundary conditions, artificial environment</td>
<td>Weeks to years</td>
</tr>
<tr>
<td>In-situ experiments in URLs</td>
<td>Defined but complex boundary conditions, realistic / GDF-relevant environment</td>
<td>Several years to decades</td>
</tr>
<tr>
<td>Study of natural analogues</td>
<td>Boundary conditions less well defined, realistic environment</td>
<td>Up to millions of years</td>
</tr>
</tbody>
</table>
Schematic Illustrations of Six URLs

(a) Äspö Hard Rock Laboratory (Sweden)
(b) Meuse/Haute-Marne URL at Bure (France)
(c) ONKALO Underground Rock Characterization Facility (Finland)
(d) Mont Terri rock laboratory (Switzerland)
(e) Grimsel Test Site (Switzerland)
(f) KURT-KAERI underground research tunnel (South Korea)
Grimsel Test Site, Switzerland (higher strength rock)

http://www.grimsel.com/
Long-term Cement Studies Project (LCS)
Long-term Cement Studies Project (LCS)
Äspö Hard Rock Laboratory Prototype Repository, Sweden (higher strength rock)

- SKB Engineered Barrier System Task Force
- Alternative Buffer Materials

[Link to SKB publication](http://www.skb.com/publication/2492513/TR-18-10.pdf), February 2019
Mont Terri project, Switzerland (lower strength sedimentary rock) – RWM recently joined

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-A</td>
<td>Well leakage simulation &amp; remediation</td>
<td>HC</td>
<td>Hydrogeological characterization of the transition Opalinus Clay – Passwang Formation</td>
</tr>
<tr>
<td>DF</td>
<td>Drilling fluids for Opalinus Clay</td>
<td>HS</td>
<td>Hydrogeological survey of aquifers around the Opalinus clay</td>
</tr>
<tr>
<td>DR-B</td>
<td>Long-term diffusion</td>
<td>HT</td>
<td>Hydrogen transfer</td>
</tr>
<tr>
<td>FE-G</td>
<td>Monitoring the gas composition within the full-scale emplacement experiment</td>
<td>IC-A</td>
<td>Corrosion of iron in bentonite</td>
</tr>
<tr>
<td>FE-M</td>
<td>Long-term monitoring of the full-scale emplacement experiment</td>
<td>MA</td>
<td>Microbial activity</td>
</tr>
<tr>
<td>FI</td>
<td>Fluid-mineral interactions in OPA during natural faulting</td>
<td>SB-A</td>
<td>Borehole sealing experiment</td>
</tr>
<tr>
<td>GD</td>
<td>Analysis of geochemical data</td>
<td>SE-P</td>
<td>Self-sealing processes in old EDZs and breakout zones</td>
</tr>
<tr>
<td>GT</td>
<td>Evaluation of gas transport models and of the behaviour of clay rocks under gas pressure</td>
<td>SW-A</td>
<td>Planning and technical preparatory work for a large-scale Sandwich seal experiment</td>
</tr>
<tr>
<td>HA-A</td>
<td>Analysis and synthesis of the variability of hydrogeological and geophysical parameters of OPA</td>
<td>TS</td>
<td>Testing different tunnelling support in sandy facies</td>
</tr>
</tbody>
</table>

https://www.mont-terri.ch/
Preparation of a large-scale Sandwich seal experiment

DEvelopment of COupled models and their VALidation against EXperiments

DECOVALEX-2019 is the current and 7th project phase and runs from 2016 through 2019. Modeling teams from 12 international partner organizations participate in the comparative evaluation of seven modeling tasks involving complex field and/or laboratory experiments in the UK, Switzerland, Japan, France and Sweden. Together, these tasks address a wide range of relevant issues related to engineered and natural system behavior in argillaceous and crystalline host rocks. More »

The primary purpose of Task A is to better understand the processes governing the advective movement of gas in two low permeability materials. The first material being considered is a compacted bentonite, which is frequently considered as a buffer and seal material. The second is the Callovo Oxfordian Claystone, a potential natural repository host rock. The task will focus on a series of laboratory experiments, initially considering the compacted bentonite and then moving on to the natural clay. More »

The primary purpose of Task E is to investigate upscaling of THM modeling from small size experiments (some cubic meters) to real scale cells (some ten cubic meters) and to the scale of the waste repository (cubic kilometers). The task uses two field-scale experiments at the Meuse-Haute-Marne underground research laboratory, France, the smaller scale TED experiment and the 1:1 scale ALC heating experiment. The results of this work will then be applied to predictive modelling of the behaviour of a single disposal cell at the repository scale, hence investigating the thermal-hydraulic-mechanical (THM) coupling across a range of spatial scales. More »

https://decovallex.org/
RWM Position – UK Underground Investigations

- When programme is site-specific, integrate underground investigation activities and disposal facility construction activities.
- Knowledge gained from surface-based investigations to inform requirements for underground works.
- **Now** - RWM will maintain our links and co-operation with a network of underground research facilities located in rock-types of relevance. This will provide access to the techniques and results of research relevant to features and processes in underground openings and can inform a judgement on the need to conduct equivalent research under the specific conditions of a preferred site.