

High-level radioactive waste management: R&D Challenges for the 21st Century

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Background: State-of-the-art at the **start of the 21st Century**

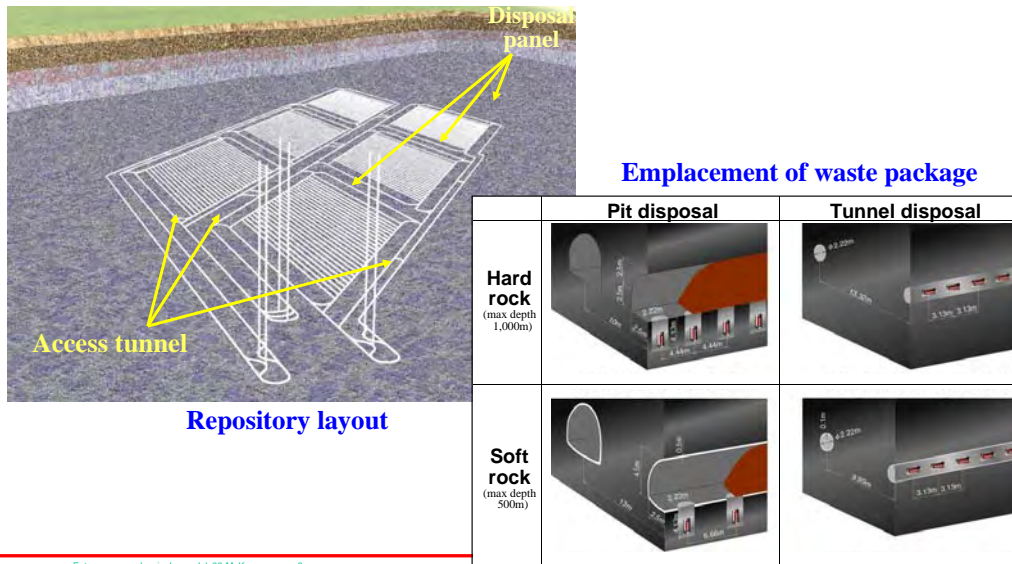
International:

- **Consensus: Geological disposal of HLW is the only practical option (“alternatives” unrealistic / unacceptable)**
- **Progress in national programmes considerably delayed by lack of acceptance / political commitment**

Japan:

- **Basic feasibility documented (H3 / H12)**
- **NUMO established and siting initiated using volunteering approach**
- **Law defines basic responsibilities, but regulations and guidelines still missing**

H12 Concept: idealised / site-generic



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The Challenge: Goals for the end of the 21st Century

International:

- Many successful ongoing or completed repository projects worldwide
 - Nuclear waste management “established” safe technology; little public concern
 - Increasingly seen as attractive local industry (high benefits to community, low environmental impact)
- ➔ Competition between communities / countries to host regional facilities

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The Challenge: Goals for the **end of the 21st Century**

Japan:

- NUMO repository #1 closed and under institutional control
 - NUMO repository #2 fully operational (50% full)
 - DIA site characterisation ongoing for repository #3
 - HLW repositories integrated within national (or regional / international) management plan for all radioactive wastes
- ➔ Within a mature industry, R&D continues to optimise the repository system in the light of developments in science & technology and to maintain the large, experienced workforce required

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5



The Challenge: Japanese goals for **mid 21st Century**

Optimisation

- NUMO repository #1 fully operational (25% full); maybe re-licensing ongoing
 - PIA site characterisation(s) ongoing for repository #2
 - HLW repositories becoming integrated within national management plan for all radioactive wastes
- ➔ R&D is strongly focused to serve the needs of the implementer (using first experience to improve designs and procedures and to develop a stronger safety case), the regulator (monitoring and inspecting operations, review of the safety case) and the local public (clear information on key scientific and technical issues)

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6



The Challenge: Japanese goals for 2025

Synthesis

- NUMO repository #1 site selected; licensing process started; DIA characterisation ongoing
 - Decision on second DIA site; continue characterisation for repository #2 or abandon?
 - 2 decades of experience at Mizunami & Horonobe; decision to continue generic work or focus on site-specific facilities?
- ➔ R&D serves the needs of the implementer (site-specific concept analysis to support selection, documentation for licensing), the regulator (review of the license application) and the local public (independent information on concerns)

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7

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The Challenge: Japanese goals for 2015

Integration

- NUMO repository #1 DIAs selected on the basis of parallel characterisation of a number of PIAs
 - Safety assessment of site specific RCs key input for selection process
 - Experience from Mizunami & Horonobe provides input for planning of site-specific URLs
- ➔ Safety case arguments developed by the implementer and reviewed by the regulator focus on integration of information from the field, URLs, specialist labs, natural analogues and fundamental, mechanistic models

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8

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Site selection and characterisation

Special challenges set by:

- **Volunteering process**; potentially
 - Several PIAs
 - Diverse host rocks and geological settings
 - Parallel characterisation
- **Very short timescale**
 - Selection of PIAs within a couple of years
 - Selection of DIA(s) within 5 years
- Requirements for **openness & transparency**

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Repository design and engineering

Special challenges set by:

- **Volunteering process**
 - RC needs to be tailored to sites
 - Potentially, range of options in each site
- Emphasis on **practicality**
 - Must be feasible using existing technology
 - Safety and QA essential
- Requirements for **openness & transparency**
- Requirements for **acceptance** (e.g. retrievability)

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Performance assessment: **codes**

Operational safety:

- Quantitative evaluation of conventional and radiological hazards
- Feedback to repository design

Post-Closure safety:

- Much greater realism (comparison of sites and concepts)
- Direct representation of time-evolution of engineered and natural barriers
- Relevant model biospheres (Japan-specific)

PA: **Data / system understanding(1)**

Operational safety

- Integration of information from underground construction and nuclear industry
- Special emphasis on detailed description of perturbation scenarios

PA: Data / system understanding(2)

Post-closure safety

- Integration of near-field analysis
 - Improved understanding of RN release & transport processes
 - Validation database for complex multi-component systems (e.g. glass-steel-bentonite)
- Site-specific far-field analysis
 - Rigorous “geosynthesis” (QA!) to derive site characteristics
 - Consistent representation of flow-paths on macro and micro scales
 - Explicit definition of time-evolution scenarios (including geosphere-biosphere interface)

R&D challenges – examples (1)

- Improved understanding of RN release & transport processes
 - Solubility, speciation, sorption & diffusion data inconsistent
 - Fundamental basis of thermodynamic approach poor
 - Need to edit databases / reactions
 - Kinetic data even more limited
 - Lack of understanding limits robustness
 - Geochemical analogues suggest approach possibly greatly over-conservative
- ➔ **A novel approach is needed**

R&D challenges – examples (2)

- **Validation database for complex multi-component systems (e.g. glass-steel-bentonite)**
 - **Multicomponent experiments**
 - **Integrated laboratory, in-situ and natural analogue programme**
 - **Large physical scale and long timescale studies essential**
 - **Development & use of state-of-the-art analytical technology**
 - **Careful synthesis of data with full analysis of uncertainties**
 - **QA!**

R&D challenges – examples (3)

- **Rigorous “geosynthesis” (QA!) to derive site characteristics**
 - **Integration throughout planning, site characterisation & data synthesis**
 - **Multi-disciplinary teams including experts in all key areas (geology, hydrogeology, geophysics, geochemistry, ...)**
 - **Close links with end-users (design engineers, PA teams)**
 - **Generalists to carry out both integration and review (esp. for regulator)**
 - **Quality management!**

R&D challenges – examples (4)

- Consistent representation of flow-paths on macro and micro scales
 - Hydrogeology evaluated on scales of 10s or 100s of km
 - Solute retardation analysis (sorption, matrix-diffusion) requires detail on cm scale (or finer)
 - PA traces solute transport paths through EBS, EDZ, host-rock, surrounding formations and into the biosphere
- To integrate these requirements, a novel approach is needed

R&D challenges – examples (5)

- Explicit definition of time-evolution scenarios (including geosphere-biosphere interface)
 - PA considers a million-year time horizon
 - The EBS, geosphere and biosphere will evolve dramatically over this period
 - Distinct events and continuous evolution should both be considered
 - The biosphere can only be evaluated with idealised representations, but major evolution (e.g. GBI in coastal sites) should be explicitly considered
- Again a novel approach is needed

The Challenge: **Infrastructure**

The next 3 decades should provide:

- Site-specific repository designs based full understanding of how characteristics of engineered and natural barriers can be combined to develop a robust safety case
 - The methodology and technology to carry out all characterisation work and resultant geosynthesis with rigorous QA and transparency
 - Well tested designs and procedures to ensure safety and quality of repository construction and operation
- ➔ Establishing required databases and practical experience requires state-of-the-art, specialist R&D facilities (allowing work with radionuclides, direct access to the deep underground environment)

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19

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The Challenge: **Human Resources!**

The next 3 decades are critical:

- NUMO's repository may be the first in the world focused on vitrified HLW and a volunteer siting approach
 - The HLW repository will develop in parallel to other projects (Rokkasho L/ILW, TRU, "RI" wastes)
 - Many licensing steps will require development and application of regulations and guidelines
- ➔ High demand for executive staff with long-term, multi-disciplinary experience supported by expert teams with state-of-the-art R&D facilities

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3 decades ago: starting a career in nuclear waste



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2 decades ago: old PNC offices - Preparation of H3



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A decade ago – Entry review



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23

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The first director of a NUMO repository



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The head of the regulatory organisation



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...and the JNC R&D support team



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Finally – to get the best people, be at the front!

In key areas, Japanese R&D groups should be world-leaders:

- Tectonics and active-fault analysis
- EBS design & optimisation
- RN chemistry / geochemistry
- Solute transport in heterogeneous rocks
- Natural analogues
- ...

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Grabbing the front page – Nuclear Engineering International



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EOS

IN THIS ISSUE: ABOUT FIVE PAGE SET OF SCIENTIFIC REPOSITORY OPERATES AT THE EQUATOR IN THE NORTHWEST PACIFIC OCEAN PAGE 417
NEW RELEASE: THE NEW GEOPHYSICAL PAGE 417

151, TRANSACTIONS, AMERICAN GEOPHYSICAL UNION

VOLUME 35 NUMBER 48 NOVEMBER 2004

Locating a Radioactive Waste Repository in the Ring of Fire

The geology, tectonics, and environmental conditions of the Ring of Fire are complex and dynamic. The high level of seismicity and volcanic activity in this region makes it a challenging environment for siting a repository. The geology is characterized by a complex pattern of faults and folds, and the tectonics are dominated by subduction. The environmental conditions are also complex, with a high level of seismicity and volcanic activity. The high level of seismicity and volcanic activity in this region makes it a challenging environment for siting a repository. The geology is characterized by a complex pattern of faults and folds, and the tectonics are dominated by subduction. The environmental conditions are also complex, with a high level of seismicity and volcanic activity.



Fig. 1. Map of the Ring of Fire region showing geological features and repository sites. The map includes labels for various geological features and repository sites. A legend indicates symbols for Quaternary sediments, volcanic basins, and faults of activity. The map shows a complex pattern of faults and folds, and the tectonics are dominated by subduction.

MODIS Detects a Devastating Algal Bloom in Paracas Bay, Peru

The Moderate Resolution Imaging Spectroradiometer (MODIS) satellite has detected a devastating algal bloom in Paracas Bay, Peru. The bloom is caused by a species of alga that produces a potent neurotoxin. The bloom is characterized by a dense layer of algal cells on the surface of the water, which can cause respiratory distress and other health problems in humans and animals. The bloom is also responsible for the death of many marine animals, including fish and birds. The MODIS satellite has provided valuable information about the extent and intensity of the bloom, which is helping scientists to better understand the underlying causes and to develop strategies for managing the bloom.

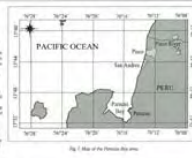


Fig. 2. Map of Paracas Bay, Peru, showing the location of the algal bloom. The map includes labels for the bay and surrounding areas. The algal bloom is shown as a dense layer of algal cells on the surface of the water.

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Repository
Has been a controversial hot issue here and there. The Commission on the Geology of the Ring of Fire in the Northwest Pacific Ocean (COGRI) has been established to study the geology and tectonics of the region. The commission is led by a group of experts in the field and is working to develop a comprehensive understanding of the region's geology and tectonics. The commission's findings will be used to inform the siting of a repository in the region.



Fig. 3. Map of the Ring of Fire region showing geological features and repository sites. The map includes labels for various geological features and repository sites. A legend indicates symbols for Quaternary sediments, volcanic basins, and faults of activity. The map shows a complex pattern of faults and folds, and the tectonics are dominated by subduction.

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NEW RELEASE
Continuum Ocean Interactions within East Asian Marginal Seas
Editor: Chuan-Chieh Wu, National Central University, Taiwan, ROC
Price: \$45.00 (US)

Chapman Conference on Radiated Energy and the Physics of Earthquake Faulting
February 1-5, 2005 - 12 June 2005

NEW RELEASE
Earth's Climate: The Ocean-Matmosphere Interaction
Editor: Wang, Song, Prog. Ser. 142
Price: \$45.00 (US)

Conference Objective
The conference, organized by the International Society of Physical and Applied Geodesy, will focus on the latest research in the field of radiated energy and the physics of earthquake faulting. The conference will provide a platform for scientists to present their research and to discuss the latest developments in the field.

Tropical-Stratospheric Climatic Teleconnections: A Long-Term Perspective
Editor: Thompson, W. W. R.
Price: \$45.00 (US)

Abstract Submission and Dead Support Deadline
15 February 2005
To be eligible for the meeting, you must submit your abstract to the conference organizers by the deadline date.