Russian – German R&D Cooperation regarding HLW Disposal in the Krasnoyarsk Region

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### Russian – German Research Cooperation

**June 2001:** Agreement between MINATOM and Federal Ministry of Economy to enter into a R&D-Cooperation regarding radwaste disposal

**Project B.2** Investigations regarding HLW disposal in granite formations

<table>
<thead>
<tr>
<th>Russia</th>
<th>Germany</th>
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</thead>
<tbody>
<tr>
<td><strong>Coordinators</strong></td>
<td><strong>Participants</strong></td>
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<tr>
<td>VNIPI Promtechnologii</td>
<td>Radium Institute</td>
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<td></td>
<td>Mining-Chemical Combine</td>
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<td>IGEM</td>
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<td>VNIPIET</td>
<td>Federal Institute for Geosciences and Natural Resources (BGR)</td>
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<td></td>
<td>Gesellschaft für Reaktor- und Anlagensicherheit (GRS) mbH</td>
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</tbody>
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[www.dbe-technology.de](http://www.dbe-technology.de)
Russian – German R&D Cooperation

1st Phase: Requirements for Site Investigation for a HLW Repository in Hardrock Formations
2002 - 05

Objective: To develop a well-justified methodological approach for site investigation and selection for disposal of

- conditioned HWL sludge from former weapon plutonium production and
- vitrified reprocessing HLW in the Nizhnekansk granite formation near Krasnoyarsk

Funded by: Federal Ministry of Economy
Overall Methodological Approach

Site Exploration and Selection Programme

Site Suitability Criteria and Needs in Site Data

Sensitivity Analysis of Site Factors:
  • Technical Feasibility
  • Environmental Safety

Geo-Scientific Prognose

Analytical Safety Model

Technical Repository Concept

Compilation and Analysis of Available Data

Waste Inventory  Design Requirements  Site Geology

Geological Site Model
Nizhnekansk Granite Formation

1 Archaic gneisses
2 Proterozoic gneisses with amphibolites
3 Archaic orthoclase granites
4 Granitoids of the Nizhnekansk complex
5 Devonian sediments
6 Jurassic sediments
7 Quarternary sediments
8 Tectonic disturbances

9 Prospective sites:
   1 – Verchneitatsky
   2 – Yeniseysky
   3 – Nizhneitatsky
   4 – Telsky
   5 – South
   6 – Kamenny
   7 – Itatsky

10 Sites of geophysical investigations by AMTS
11 Archaic mafites
3D-Geological Model of Kamenny Site

Permeability levels
Green and pink = high
Blue and red = low
Conceptual Design for HLW Borehole Disposal

Temperature gradient (diagrammatic)

Cask
Isolator
Bentonite + graphite

Host rock

0.15
2.9
2.9 - 2.2
W / (m K)
Selected Reference Site

River
- Tectonic disturbances
- Fractures
- Surface inclination
- Itatski
- Modelling area (~11 km²)
- Supposed repository site (~1.5 km²)
3D-Permeability Model of the Reference Site

Area: ~ 11.5 km²
Elements per slice: 54,000
Total Elements: ~ 700,000
Total knots: 400,000
Dependence of Calculated Exposure Dose from Rock Properties

Reference cases:
fe - Recent site (host rock)
crush - highly crashed host rocks
frac - host rocks with fractures of small width
Main Conclusions of Phase 1

- Impressive volume of geological and geophysical investigations – although, sites aren't characterised sufficiently

- Very limited data on the deep geological structure and hydrogeology from deep boreholes

- Lack of a complex evaluation of all investigation results

- Recommendations for a more systematic application of selected investigation techniques and for improving their efficiency, in particular seismic and borehole investigations

- Proposal for cooperating in site characterisation – rejected due to security constraints
2nd Phase: Concept development, financial and implementation planning for a pilot storage / disposal facility
2003 – 04

Objective: To develop a preliminary concept and to prepare a preliminary cost estimate and implementation plan for storage / disposal of

a) conditioned HWL sludge from former weapon plutonium production and non-reprocessible SNF
b) MOX SNF from weapon plutonium disposition

Funded by: a) Federal Ministry of Economy
b) Nuclear Disarmament Forum
Considered Repository Layout

1. Technologischer Schacht
2. Bergbau-technischer Schacht
3. Bewetterungsschacht
4. Hauptgrubenlüfter
5. Transportstrecke
6. Umladekammer für Abfallcontainer
7. Endlagerstrecke für HLW/ILW
8. Endlagerstrecke für BE
9. Endlager-Bohrlöcher für BE
10. Untertage labor
11. Auffahrstrecken
12. Drainage- und Bewetterungsstrecken
13. Bewetterungsstrecke
14. Notausgangsstrecke
15. Werkstatt
16. Brandschutzlager
17. Depot
18. Zentrale Elektroversorgung
19. Umgehungsstrecke der Einlagerungsstufe
20. Umgehungsstrecke der Bewetterungsstufe
21. Pumpstation
22. Wassersammel
23. Sonderbewetterungslüfter
24. Bewetterungsdurchschlag

Richtung der Bewetterung
## Preliminary Cost and Implementation Plan

<table>
<thead>
<tr>
<th>No.</th>
<th>Task</th>
<th>Costs [Mio $]</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site investigation and selection</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Investment justification</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Repository design</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Detailed repository design</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>R&amp;D work</td>
<td>34</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Licensing</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Construction of surface facilities</td>
<td>45</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>Construction of underground fac.</td>
<td>116</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Commissioning</td>
<td>13</td>
<td>9</td>
</tr>
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3rd Phase: Performance investigation of engineered and geologic barriers of a HLW repository in magmatic host rock

Motivation: Dispute between Russian experts on the “importance” of geologic vs. engineered barriers

Objective: Safety function based performance analysis of the system of geologic and engineered barriers for the proposed HLW disposal facility at the Yeniseyskiy site

Funded by: Federal Ministry of Economy
### Considered Barrier Functions

<table>
<thead>
<tr>
<th>Technical Barriers</th>
<th>Geotechnical Barriers</th>
<th>Geological Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waste matrix</strong></td>
<td><strong>Mineral mixture</strong></td>
<td><strong>Near field</strong></td>
</tr>
<tr>
<td>Mechanical fixing</td>
<td></td>
<td>Limiting the hydraulic flow</td>
</tr>
<tr>
<td>Chemical fixing</td>
<td>Heat protection of bentonite</td>
<td>Radionuclide retention</td>
</tr>
<tr>
<td><strong>Container</strong></td>
<td><strong>Bentonite buffer</strong></td>
<td>Ensuring preferable groundwater chemistry</td>
</tr>
<tr>
<td>Encapsulation of radionuclides</td>
<td>Separation and fixing of containers</td>
<td>Far field</td>
</tr>
<tr>
<td>Chemical fixing</td>
<td>Contact with host rock for heat conduction</td>
<td>Slowing radionuclide transport</td>
</tr>
<tr>
<td></td>
<td>Exclusion of advective water transport</td>
<td>Radionuclide retention</td>
</tr>
<tr>
<td></td>
<td>Prevent radionuclide transport</td>
<td>Overburden</td>
</tr>
<tr>
<td></td>
<td>Radionuclide retention</td>
<td>Radionuclide retention</td>
</tr>
<tr>
<td></td>
<td>Compensate rock movements</td>
<td>Slowing radionuclide transport</td>
</tr>
<tr>
<td><strong>Backfill / lining</strong></td>
<td>Minimise advective water flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Prevent radionuclide transport</td>
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</table>

**Near field**
- Limiting the hydraulic flow
- Radionuclide retention
- Ensuring preferable groundwater chemistry

**Far field**
- Slowing radionuclide transport
- Radionuclide retention

**Overburden**
- Radionuclide retention
- Slowing radionuclide transport

- Minimise advective water flow
- Prevent radionuclide transport
Yeniseyskiy Site: Top View
Yeniseyskiy Site: 3D Model
Yeniseyskiy Site: 1 kΩ m surface
Yeniseyskiy Site: 3 kΩ m surface
Yeniseyskiy Site: 5 kΩ m surface
Main uncertainties and weaknesses

- Tectonic structure, existence and linkage of disturbed zones
- Composition and heterogeneity of the metamorphologic complex
- Existence of dikes and intrusions
- Site hydrogeology
- Vertical and horizontal movements of geological blocks
- Local stress conditions (likely strongly non-isotropic)
Earthquake Magnitudes (1806-2000)

Krasnoyarsk

- $M_L < 2$
- $2 < M_L < 3$
- $3 < M_L < 4$
- $4 < M_L < 5$
- $5 < M_L < 6$
- $6 < M_L$

Size: 1 : 2600000

Longitude

Latitude
Deformation Impact on Engineered Barriers
Modelling Results

Horizontal Slip

Contour of Shear Strain Increment

Magnitude $M\text{agfac} = 1.000e+000$

Gradient Calculation

-1.333e-002 to -1.000e-002
-1.000e-002 to 0.000e+000
0.000e+000 to 1.000e-002
1.000e-002 to 2.000e-002
2.000e-002 to 3.000e-002
3.000e-002 to 4.000e-002
4.000e-002 to 4.225e-002

Interval $= 1.0e-002$
Coppersmith & Youngs 2000
Wells & Coppersmith 1994:

Resulting from regression analysis:
Slip at the primary fault \( M \) \( \sim \) induced slip at the secondary fault as \( f(d) \)

If a fault with a length \( L > 40 \) km at a distance \( d < 20 \) km can be excluded, then any secondary slip \( < 16 \) cm \( (M = 7) \)
Impact of Far Field Geology Models

Gneiss
Sim 405

Radiation exposure [Sv/yr]

Time [y]

Basalt
Sim 821

Radiation Exposure [Sv/yr]

Time [y]
Main Conclusions

- Conclusions from Phase 1 remain
- In order to reduce the impact of uncertainties and weaknesses regarding the performance of the geological barriers a well developed system of engineered barriers is recommended
- Based on a systematic site investigation the assumptions made for the performance model have to be confirmed and/or corrected
- Further stepwise optimisation of the concept based on total performance assessment should be performed in close link with future site investigation work and results
Lessons Learned

- For implementing HLW disposal projects well developed technical and scientific capabilities and well educated experts in nuclear, geology and mining are available in Russia.
- So far unclear responsibility for implementing and operating repositories – capabilities and activities are spread over several (competing) institutions.
- Limited specific experience in developing waste disposal projects – mainly handled as usual nuclear or mining once.
- Weak perception of the advanced international “safety discussion” (safety case, stepwise approach, optimisation …)
- Better integration into the international community and closer international cooperation are highly desirable.
Thank you for your attention!