Closure of Uranium Mine Waste Facilities Using Multilayer Granular-Bentonite Cover Systems

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Introduction

- Nuclear fuel cycle → U mining cycle
- By-products
  - Incomplete ore recovery
  - Other minerals containing radionuclides
  
  **Tailings contain residual uranium and progeny**

- Low-level radioactive wastes
- Special closure considerations
Uranium Tailings Radiological Risks

Direct
- Residence time

Dust
- Transport to offsite receptors

Leaching of Radionuclides
- Oxidation of uranium-bearing minerals (e.g., uraninite)
- Dissolution of secondary minerals

Radon
- Readily migrates through unsaturated porous media
- Grain size, porosity, saturation, pore pressures
Uranium Tailings Cover Options

- Single layer soil covers
- Multi-layer soil covers
- Water covers
- Geosynthetics

Post rehab tailings will remain at 100% saturation, and therefore radon dissolved in water must travel to surface through diffusion or slow convection.

Relative radon flux (post-rehab)
Granular-Bentonite Cover Systems

- Thick protective layer for gamma and erosion/dust
- Bentonite has high swell capacity – liquid and gas barrier
- Bonus: Less susceptible to freeze-thaw effects
Granular-bentonite cover systems decrease surface water influx

Low-permeability nature of granular-bentonite

Reduces water-tailings interaction and mobilization of radionuclides

Characteristics need to consider design objective
Radon Mitigation

- Granular-bentonite cover systems perform well as gas barrier
- Utilize radon $t_{1/2} - 3.8$ days
- Increased residence time
  1. Increases length of gas transport pathway
  2. Decreases radon diffusion rate through high saturation
## Granular-Bentonite Hydraulic Conductivity

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Description</th>
<th>Hydraulic Conductivity (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA02b</td>
<td>Untreated granular</td>
<td>1.1 x 10^{-4}</td>
</tr>
<tr>
<td>5% GB [SA02b]</td>
<td>Granular treated with 5% bentonite</td>
<td>2.1 x 10^{-6}</td>
</tr>
<tr>
<td>10% GB [SA02b]</td>
<td>Granular treated with 10% bentonite</td>
<td>2.0 x 10^{-10}</td>
</tr>
<tr>
<td>SA35b</td>
<td>Untreated granular</td>
<td>3.0 x 10^{-4}</td>
</tr>
<tr>
<td>5% GB [SA35b]</td>
<td>Granular treated with 5% bentonite</td>
<td>4.0 x 10^{-6}</td>
</tr>
<tr>
<td>10% GB [SA35b]</td>
<td>Granular treated with 10% bentonite</td>
<td>3.0 x 10^{-11}</td>
</tr>
</tbody>
</table>
Field Trials

Test pad construction

Moisture and suction sensors
Final test pad

Radon flux monitors
Radon Flux

Average Radon Flux (Bq/m²/s)

- Background Stations: 0.04
- Existing Cover - Avg: 4.26
- Local Cover - Avg: 0.92
- TP1 (Granular): 0.08
- 7% SGB: 0.05
- 10% SGB: 0.03
- Silt: 0.04
- LLDPE + 10% SBG: 0.04
Granular-Bentonite Cover Construction

- Feedstock Material Preparation
- Mechanical Mixing
- Transport & Placement
- Spreading & Compaction
- Protective layer
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Granular-Bentonite Cover Construction
Radiation Hazard Mitigation

Stations on granular-bentonite cover placed over uranium tailings
Summary

- Uranium tailings are low-level radioactive wastes requiring special closure considerations
  - Ionizing radiation
  - Long-lived radioactive dust
  - Radon gas
  - Radionuclide leaching
- Closure strategies include cover systems
  - Granular-bentonite cover systems can be designed to mitigate multiple radiological risks
  - Project example demonstrates real application and success story
THANK YOU!

LET’S CONTINUE THE DISCUSSION:

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