Environmental remediation and radioactivity monitoring of uranium mining legacy in Portugal

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Outline

- Uranium-radium mining
- Waste produced and radiological impact
- Radiological monitoring and surveillance
- Remediation of legacy sites
- Future of uranium mining
History of radium and uranium mining in Portugal

- 1907  Discovery of first uranium-radium deposit
- 1908  Construction of Radium Salts Factory
- 1944  Beginning of uranium production
- 1954  Foundation of Junta de Energia Nuclear (JEN)
- 1977  Extinction of JEN and creation of ENU
- 2001  Close out of facilities. End of ENU
- 2003  Approval of remediation initiative.
Geology and mine areas

- Quartz
- Impregnated schist
- Torbernite
- Sabugalite
- Gummite

Impregnated schist
Uranium extraction

- The main ore chemical treatment plant near the mine of Urgeiriça. There has been also milling in 4 other sites.
- Uranium ore from small mines was transported to Urgeiriça.
- Heap leaching with $\text{H}_2\text{SO}_4$ and *in situ* leaching in mines
Urgeiriça: ore processing

- Mine of Urgeiriça: extraction 1913 -1992
- Uranium ore processing facilities closed in 2001
  - Residues containing radioactivity ~ 13 Mton
WASTE WATERS:
Acid mine waters and Process waters

- Large volumes
- Low pH (1-3), high sulphate ion conc
- Often treated: neutralized with hydroxide, and $^{226}$Ra and U co-precipitated with BaSO$_4$
- Decantation in ponds:
  - overlaying water released into streams or pumped back into the mine
  - Decanted sludge pumped as a slurry into dewatering ponds (evaporation); mud contains high U, Ra, Po, etc.
SOLID WASTE: Mill tailings

- Fine sands, high specific activity of $^{226}\text{Ra}$, $^{230}\text{Th}$, $^{210}\text{Pb}$, $^{210}\text{Po}$, ...
- Low concentrations of uranium
- May contain stable metals, e.g., As, Y, Bi, Fe, Cu, etc
- and sludge (mud) from water treatment
Uranium mining in Europe

- France
- Germany
- Spain
- Portugal
- Others

- Discovery of Radium
- First medical applications
- Radiation protection
- Radium production
- First nuclear weapons
- Nuclear power plants
- Uranium as fissile material
- Environment rehabilitation

- 90's -End of Cold War- closure of U mines in Europe

Key Years:
- 1900
- 1925
- 1945
- 1990
- 2008

- Years

- Environment rehabilitation
Legacy of radium and uranium mining in Portugal

Mineralizations of Uranium in the centre-North of Portugal (province/region of Beiras)

- 400 uranium deposits identified
- 60 deposits exploited (open pits or underground)
- Exploitation of radioactive ores 1908-2001
Legacy of industry

- About 60 old mining sites
  - conventional safety issues
    (acid water, subsidence, ventilation wells, stability of tailings, ...)
  - radiological protection issues
  - toxicological issues (metals in water, risk to public health)

- Solid waste
  - ~ 60 Mtons total
  - ~ 15 Mtons in Urgeirica (milling tailings)

- Waste piles: uncovered, leaching, dust
- Acid water drainage
- Sludge from acid water neutralization
“MinUrar” Project

- Assessment of environmental contamination and effects on population health

Requested by the Government following protests by populations

**Recommendations**

- To undertake environmental remedial action (site dependent)
- Environmental radiological surveillance of old uranium mining and milling sites
## RADIOACTIVITY in soils and mine waste

**Bq/kg (dry weight)**

<table>
<thead>
<tr>
<th>Location</th>
<th>238U</th>
<th>235U</th>
<th>234U</th>
<th>230Th</th>
<th>226Ra</th>
<th>210Po</th>
<th>232Th</th>
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</thead>
<tbody>
<tr>
<td>Mill Tailings, Mina da Urgeiriça</td>
<td>2530</td>
<td>118</td>
<td>2880</td>
<td>10340</td>
<td>24720</td>
<td>20350</td>
<td>410</td>
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<tr>
<td>Barragem Velha</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Ore</td>
<td>38320</td>
<td>1720</td>
<td>38250</td>
<td>30115</td>
<td>15570</td>
<td>30820</td>
<td>425</td>
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<tr>
<td>M. Ureiriça. Descarga do minério-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mill Tailings, Mina da Cunha Baixa</td>
<td>2030</td>
<td>90</td>
<td>2280</td>
<td>3600</td>
<td>6700</td>
<td>4700</td>
<td>460</td>
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<tr>
<td>Baixa (Mangualde)</td>
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<td></td>
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<tr>
<td>Mill Tailings, Mina da Bica</td>
<td>10700</td>
<td>480</td>
<td>11400</td>
<td>30000</td>
<td>50000</td>
<td>29000</td>
<td>180</td>
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<tr>
<td>Sabugal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOIL</td>
<td>230</td>
<td>10</td>
<td>236</td>
<td>301</td>
<td>619</td>
<td>287</td>
<td>226</td>
</tr>
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<td>Espinho (Mangualde)</td>
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</tbody>
</table>
## Ambient dose rate

**Dose equivalent, mSv per year**

<table>
<thead>
<tr>
<th>Counties</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GE</strong></td>
<td></td>
</tr>
<tr>
<td>Canas Senhorim county (outside mining area)</td>
<td>2.4</td>
</tr>
<tr>
<td>Mill tailings Barragem Velha</td>
<td>8.8</td>
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<tr>
<td>Sludge Barragem Nova</td>
<td>3.2</td>
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<tr>
<td>Low grade ore Escomb Sta Barbara</td>
<td>16.2</td>
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<tr>
<td>Low grade ore Descarga minério</td>
<td>32.0</td>
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<tr>
<td>Shaft area Zona do Poço nº 5</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>GN 1</strong></td>
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</tr>
<tr>
<td>Old mine area Moreira de Rei</td>
<td>2.2</td>
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<tr>
<td>Old mine area Rio de Mel</td>
<td>2.3</td>
</tr>
<tr>
<td><strong>GN 2</strong></td>
<td></td>
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<tr>
<td>Reference Sátão</td>
<td>1.2</td>
</tr>
</tbody>
</table>
REMEDIATION: cover the tailings

- Prevent radon exhalation
- Prevent erosion and environmental dispersion of dust materials
- Prevent removal and use of materials (in building construction, roads, etc.)
- Reduction of external radiation dose

Tailings shall be confined and materials isolated from biosphere
Aims of radiological monitoring

- To demonstrate compliance with regulations, i.e., that environmental, radiological, or chemical contamination is not exceeding limits/standards
- To ensure that the critical groups of population are not exposed to enhanced radiation dose from this practice (1mSv/y)
- To provide information on safety to the authorities and to the public
Terrestrial ecosystems monitoring

- Ambient gamma dose rate
- *In situ* gamma spectrometry
- Sampling soils, vegetables (cabbage, potatoes, milk,…) for analysis
Aquatic ecosystems monitoring

- Water parameters measurement
- In situ filtration of water samples for radiochemical analyses
- Collection of biota samples for analysis
Atmospheric monitoring

- Measurement of atmospheric radon (outdoors and indoors)
- Sampling aerosol particulates for radioelement analysis
Radionuclide analysis

- Alpha spectrometry
- Gamma spectrometry
- Liquid scintillation
- Alpha-Beta counting
- Analytical Quality Assurance
Dose calculation

- Taking into account
  - External radiation
  - Inhalation
  - Ingestion

- Effective Dose Limit for members of the Public: 1mSv/y
Environmental Remediation

- Approved by the Government
- Implemented by Mining Company Holding - started in 2006
- Goals:
  - Confine the milling tailings
  - Concentrate mining waste in 4 disposal sites
  - treat the acid mine waters
Tailings cover

Aerial view of Urgeiriça (early 2008)

Multi layer cap
Post-remediation maintenance and stewardship

- Continuous water treatment
- Sludge-radioactive material
- Long term stewardship
Lessons from past U mining

- Post mining restoration not planned in advance
- Provision of funds not made
- Finally, environmental remediation is needed and to be performed nearly everywhere
- “Reactive” rehabilitation has been costly.
Life-cycle of an uranium mine

- **Prospection:**
  - identification of ore deposits
  - assessment of deposit value and extraction costs

- **Mining: extraction of the ore**
  - mine operation: underground/open pit
  - transport of the ore
  - ore processing

- **Close out of the mine**
  - safety requirements
  - environmental remediation
Radiological monitoring for radiation protection in uranium mining

- **Baseline survey:**
  - before the mining of radioactive ore
  - reference for post mining remediation
- **Radiological survey during mine operation:**
  - occupational exposure of miners
  - Control of external radiation (radon, etc) and environmental contamination of waters, soils, forest, etc.
- **Post mine closure:**
  - During remediation works
  - Post remediation surveillance
Future of uranium mining

- Production may increase in the future; regain of interest in nuclear energy
- Some small producers may want to come back into U production
- No future for uranium mining with traditional methods: a new paradigm is required
Environmental restoration as part of uranium production

- Public *perception of risks*: past and present
- Regulators: *Mining licenses* and permits
  - Protection of man, non-human biota, natural resources (EIA)
  - Conformity with new ICRP recommendations and dose limits
- «*Social license*»!
  - Trust, acceptable impact, post-extraction rehabilitation
- *Additional costs* that must be incorporated in uranium production costs
  - Environment protection
  - Radiological protection of workers and public (1 mSv/y dose limit)
  - Rehabilitation of sites
Thank you for your attention!

THE END