Uranium mining and NORM legacy sites in Brazil
Remediation, modeling and decisions

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National Nuclear Energy Commission (CNEN)
Outline

• The Brazilian Nuclear Industry
• The Brazilian Regulatory Framework
• The Licensing Process
• Uranium production in Brazil
• The Caldas former U mining and processing facility
• Caetité uranium mining and milling facility
• The Remediation of NORM sites
• Work developed within MODARIA II WG-1
The Brazilian Nuclear Industry
The Brazilian Nuclear Industry

A synergic mix of:

- Large uranium reserves
- Fuel cycle technology
- PWR technology
- Non-proliferation
First Brazilian Uranium mine;
Operated from 1982 to 1995;
Finished operation and considering process of remediation and closure.
U Mining and Milling Facilities in Brazil

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- The only active U mine in Brazil;
- In operation since 2000.
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- In process of commissioning;
- The largest discovered U reserve in Brazil. U is associated with phosphates.
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Mining and Milling of ores containing U and/or Th
The Brazilian Regulatory Framework
The Brazilian Nuclear Policy

• Nuclear energy shall only be used for peaceful purposes (Fed. Constitution)
• Nuclear material production: federal government monopoly
• Radioactive waste disposal: federal government responsibility (CNEN – R&D)
• Nuclear Licensing: CNEN
• Mineral-industrial (NORM) facilities – authorization: CNEN
• Environmental Licensing (NFCF): IBAMA
The Licensing Process
The Nuclear Licensing Process

- The operating organization is the prime legal responsible for the safety of a nuclear or radioactive installation
- No nuclear installation shall operate without a license
- To obtain and maintain the licenses, the operating organization must fulfill all the requirements established in the legislation and in the ensuing regulations
- Licensing regulation establishes the steps of the review and assessment process & the documentation to be presented to CNEN at each phase of the licensing process
- The system of inspections and enforcement mechanisms is established in the regulation, and includes the authority of CNEN to modify, suspend or revoke the license
- All nuclear and radioactive installations shall have a Radiation Protection Supervisor certified by CNEN
Public Hearings (Environmental Licensing – IBAMA)

• Aim to expose stakeholders to the Environmental Impact Study / Environmental Impact Report, to answer questions and to collect critiques and suggestions

• Public hearings may be requested by civil societies, Public Attorney or 50+ citizens – More than one public hearing may be conducted

• Hearings are used to support the regulatory assessment that supports the license
  – All requested hearings must be conducted for the license to be issued
  – All received documents shall compose the environmental licensing documentation and shall be cited during the Public Hearing
  – Minutes signed by the relevant stakeholders (later)
  – Public hearings recordings are added to the licensing documentation
  – Written comments: 10 days to be sent to IBAMA
The NORM (mineral-industrial) facilities

- CNEN regulates activities related to prospecting, exploration, mining, industrialization and commerce of nuclear materials and minerals that bear U / Th
- Regulatory oversight and surveillance of NORM facilities aim to warrant the application of safety and radiation protection measures
- Standard CNEN-NN-4.01: safety and radiation protection requirements for NORM facilities
  - Authorization for ownership, use, storage of ores, raw materials and other NORM-bearing materials, slags and radioactive waste storage
  - Classification of facilities: according to $[A_{\text{total}}]$ for natural radionuclides from the U and Th series (Bq.g$^{-1}$) – criteria for documentation requirements for authorization
Joint IBAMA-CNEN licensing
Uranium Production in Brazil
Lessons learned and Legacy prevention
The Caldas uranium mining and processing facility
Caldas – Former U mining and milling
Lessons learned (Legacy)
Caldas: History and Characteristics

- Installation operated from 1982-95 by state company
- 1995 onwards: Decommissioning phase
- Open pit mining / sulfuric acid leaching
- Located close to important tourist cities; within two major watershed (Antas & Verde rivers)
- Water is used for irrigation and cattle drinking
- Licensing :1970/80’s → no decommissioning plan
- Operation before new environmental legislations
- At that time, the operator was not legally required to present an Environmental Impact Statement (EIS) prior to the operation of the mining and processing facilities
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Caldas – current technical challenges

- The mining site → high precipitation rates
- Acid Mine Drainage + High precipitation rates:
  ➔ Large volumes of water to treat (heavy metals & radionuclides)
  ➔ Liquid effluent treatment plant is still in operation
  ➔ Large amounts of sludge need to be disposed off (mine pit)
- Radiological control of the site is maintained by the Operator, especially at effluent discharge points (from waste dam, water treatment plant and other drainage points)
- Main sources of contamination:
  - Mine pit
  - Waste rock piles
  - Tailings dam
  - Ore processing and storage facilities
Caldas – current technical challenges

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Caldas – other challenges

- Acid Drainage treatment: large amount of resources spent per year
- Relevant information about the site is dispersed
- The Plan for Recovery of Degraded Areas (PRAD) submitted to IBAMA
  - Additional resources will be needed to implement adequate solutions
- Decisions needed on dismantling the industrial area and site remediation
- Funding for decommissioning and remediation needs to be well defined
- Compliance endpoints are established on a case by case basis
- Political and psychosocial aspects involved
  - Operation ceased in 1995, but population is still concerned
  - AMD and presumed watershed contamination are always on the local news
  - Population believes in unconfirmed high levels of cancer occurrence
  - Need to establish a structured, systematic, long term communication and a stakeholder involvement programme
  - Multidisciplinary group created the municipality to assess local water bodies (radiological, chemical and biological contamination) - includes the regulators
Publications about the water quality studies

Studies on cancer epidemiology in Poços de Caldas
The Caetité uranium mining and milling facility

Efforts to prevent Legacy
Caetité – Operating U mining and milling (Prevention)
Caetité – uranium mining and milling facility

The site → low precipitation rates: ~ 650 mm/year
The facility has been in operation in Caetité since 2000.
Operated by state-owned company INB.
Reserves of 100,000 t of $\text{U}_3\text{O}_8$.
Capacity of 400 t/year of yellow cake.
Open pit mining / heap leaching.
A Remediation and Decommissioning Plan is required by the Environmental Legislation, containing:
- Remediation goals and criteria and methods for dose assessment.
- Description and assessment of the remediation strategy for all areas: mine pit, industrial area, tailing ponds and waste rock piles.
Remediation activities and operation of the facility are performed simultaneously, in order to prevent future legacy.

Focus: Waste Rock Pile and Tailing Ponds
Caetité – mining/milling waste management

Open pit mine

Waste Rock Pile

Photo source: INB
Caetité – remediation of waste rock pile

- Measures to ensure long term stability:
  - The waste rock pile is being built on a natural slope of a dry valley in order to ensure the geological and geotechnical stability
  - The rain water infiltration is directed to a sump by an underlying drainage system. After monitoring, the collected effluents can either be treated or directly discharged to the environment
  - The leached ore is emplaced into specific sectors of the waste rock piles so that such material remains encapsulated, in order to reduce the transport of fine material due to infiltration
Caetité – remediation of waste rock pile

• The main steps of remediation of Waste Rock Pile are:
  – After waste rock and leached ore piles reach the final elevation, they are covered with a semi-compacted layer of soil (clay)
  – After sealing with the clay layer, the topsoil cover is emplaced and revegetation is carried out. This procedure aims to prevent erosion of the surface layer
Caetité – remediation of waste rock pile

• Safety analysis of waste rock pile:
  – Radiological Environmental Impact Assessment (Source term characterization, Radionuclide migration studies etc.)

• Environmental Monitoring Programme (EMP):
  - Surface water and groundwater are monitored in several points around the waste rock pile
  - EMP is dynamic (periodically reassessed)
  - Intervention measures are established, if necessary
Caetité – remediation of the tailing ponds

- Tailing ponds characteristics:
  - HDPE-lined ponds with a drainage system which retains the solid phase and allows the recycling of the liquid
  - When the ponds are full, they will be closed with compacted clay and topsoil covers, and revegetated
Caetité – remediation of the tailing ponds

• Remediation of the pond slopes:
  – During the operation of the facility the slopes of the ponds are covered with topsoil and revegetated (simultaneous decommissioning and remediation)
Caetité – Remediation of the tailing ponds

- Safety Analysis of Tailing Ponds:
  - Radiological Environment Impact Assessment (Source term characterization, Radionuclide migration studies etc.)

- Environmental Monitoring Programme (EMP):
  - Surface water and groundwater are monitored in several points around the tailing ponds
  - EMP is dynamic (periodically reassessed)
  - Intervention measures are established, if necessary
Caetité – Remediation: Arboretum

- Most plants and seeds used in vegetation cover are grown at the facility’s arboretum.
Contamination prevention of Nuclear Fuel Production facilities
Nuclear Fuel Production
The remediation of NORM sites
The remediation of the Santo Amaro site (USAM)

Former monazite sand processing facility
The Remediation of the USAM site
The Remediation of the USAM site
The Remediation of the USAM site
The remediation of the Interlagos site (USIN)

Former monazite sand processing facility
Remediation of a former NORM facility in São Paulo

Current work being developed to collaborate with MODARIA II – WG-1
Site background information

• NORM (mineral-industrial) facility was formerly located at the site – tin metallurgy (*Tin Company*)
• Site formerly used for disposal of waste and residues from physical processing of the ore (cassiterite – SbO₂, tin oxide mineral)
• Currently the site harbors a conventional industry (*Conventional Company*)
• May 1990 – CETESB (state regulator) charged the *Tin Company* for disposing of wastes without design approval
• August 1990 – *Tin Company* requests CNEN registration
  – Lack of clear regulatory framework and overlap of competences hindered the possibility for a regulatory solution at the time
• Remediation of the area was conducted in the meantime, and effectiveness of which is being assessed
Site background information
Timeline

- **Irregular disposal of residues by the Tin Company**
- **1990 – 1995**
  - **2000**
    - **In 2000**, the *Mining Company* sells the land property to two gentlemen.
    - **In 2003**, owners rent the land to a *Conventional Company*.
- **2004 – 2006**
  - **Denouncement of contamination and start of Civil Prosecution**
  - **In 2004**, the *Mining Group* buys the *Tin Company*
- **2004 – 2006**
  - **Denouncement of contamination and start of Civil Prosecution**
  - **In 2008**, *Mining Group* buys the *Mining Company*
Storage facility
Storage facility
Characterization

- Demolition rubble (asphalt-like material; glassware etc.)
- Background radiation level, indicating that other materials were used to fill the area
- Gray powder material
- Indicated that the drills were done inside the structure
- Found the continuation of the disposal cell structure, but not possible to find the end. Estimated lengths of cells are around 30 m
- Found the disposal cells structure
- Indicated possible L construction (from 20 to 30 m wide)
- Material similar to the slag found outside the structure
- Material similar to the slag, in bags
- Demolition rubble only
- Background radiation level (indicated that disposal cells do not reach out to the area of the trenches that hold the slags)
## Characterization

<table>
<thead>
<tr>
<th>Place</th>
<th>Material</th>
<th>Appearance</th>
<th>Composition</th>
<th>Dose Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Surface</td>
<td>-</td>
<td>-</td>
<td>0,3 μSv/h</td>
</tr>
</tbody>
</table>
|       | Slag         | ![Image](image1.png) | **SnO₂** 0,005%  
**Nb₂O₅** 0,166%  
**ZrO₂** 1,060%  
**ZnO₂** 0,005%  
**ThO₂** 1,061%  
**U₃O₈** 0,120% | 140 μSv/h |
|       | Gray material | ![Image](image2.png) | **SnO₂** 0,384%  
**Nb₂O₅** 3,741%  
**ZrO₂** 0,385%  
**ZnO₂** 0,075%  
**ThO₂** 1,026%  
**U₃O₈** 0,096%  
**Ta₂O₅** 0,428%  
**PbO** 1,516% | 30 μSv/h |
|       | Black material| ![Image](image3.png) | **SnO₂** 1,193%  
**Nb₂O₅** 8,877%  
**ZrO₂** 1,211%  
**ZnO₂** 0,049%  
**ThO₂** 0,777%  
**U₃O₈** 0,116%  
**PbO** 0,178% | 3,5 μSv/h |
Work developed within MODARIA II WG-1

• Apply the MODARIA II methodologies to the NORM site, including with regards to site modeling and decision-making. Recent progress:
  – Initiated a cooperation network between different divisions within CNEN/regulator, CNEN research institute, and operator
  – Started the development of a conceptual model for site remediation
  – Collected additional site data in the installation documentation and next to online sources
  – Additional data had to be collected on site during recent inspection to the site – critical assessment underway

• Comparison and benchmarking of the models (RESRAD, NORMALYSA, …). Recent progress:
  – Elaborated template for NORM site data collection, determining the additional data to be collected
Work developed within MODARIA II WG-1

- Comparison with other NORM sites
- Implementation in Brazil of a common framework for tackling the remediation of NORM sites
- Capacity building for national regulators and TSO, including support from TC and from other MS
Lessons learned

- The decommissioning plan / remediation project should demonstrate safety
  - Including: site characterization; dose assessment; future land use restrictions; long-term maintenance and monitoring; required administrative controls; and specified institutional control period
  - Compliance endpoints for remediation need to be established and coordinated among multiple regulators
  - A radioactive waste disposal strategy should be defined at the early phases of (or prior to) the operation, including for the decommissioning wastes
  - A regulatory framework on radiation protection has recently been developed for the NORM industry
  - Standard practices need to be developed for NORM waste disposal
  - Financial provisions for decommissioning and remediation need to be well defined and established
  - Coordination among regulators is paramount to avoid duplication of efforts, omission, and gaps or overlaps of competences

- Remediation activities and operation of the facility should be performed simultaneously, in order to prevent future legacy situations (Caetité example)
Lessons learned

• Definition of responsibilities with regards to liabilities in legacy sites is complex and involves multiple stakeholders with conflicting interests
  – Public perception of radiation risks has shown that scientific arguments are not enough to address social and political concerns
  – Stakeholder engagement provides a valuable focus on aspects that need to be addressed by operator and regulators

• Partnerships with the Technical Support Organizations (TSO) need to be targeted towards enhancing their technical assistance for the regulatory body, to be achieved through capacity building of the TSO in regulatory issues
  – The IAEA has provided valuable cooperation with this respect

• Further cooperation activities within MODARIA II are opening new avenues for collaboration for institutions within Brazil, as well as establishing new paths for best practices and understanding among Member States
Thank you

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