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URANIUM MILLS AND MINES ENVIRONMENTAL RESTORATION IN SPAIN

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Abstract

ENRESA and ENUSA have dismantled and restored a uranium mill in Andújar (Andalucía), a uranium facility based on open pit mining and plant in La Haba (Extremadura) and 19 old uranium mines in Andalucía and Extremadura. The Andújar Uranium Mill was operated from 1959 to 1981 and has been restorated between 1991 and 1994. The site included the tailings pile and the processing plant. The Haba Uranium Site included the Plant (operating from 1976 to 199), four open-pit mines (operating from 1966 to 1990), the heaps leaching and the tailings dam and has been restorated between 1992 and 1997. The 19 abandoned uranium mines were developed by underground mining with the exception of two sites, which were operated by open pit mining. Mining operations started around 1959 and were shutdown in 1981. There was a great diversity among the mines, in terms of site conditions. Whereas in some sites there was little trace of the mining works, in other sites large excavations, mining debris piles, abandoned shafs and galeries and remaining surface structures and equipment were encountered.

1. DESIGN OBJECTIVES

1.1 Uranium Mills

Primary objectives for the Andújar and La Haba sites were the following:

- Dispersion and stabilization control, to ensure confinement and long-term stability of tailings and contaminated materials.
- Erosion control to prevent surface water contamination and ensure long-term integrity of the closed-out facilities.
- Radon control to reduce radon emissions.
- Groundwater protection to prevent groundwater contamination by rainfall water infiltration into the tailings.

1.2 Uranium Mines

Primary objectives for mines remediation were the following:

- Minimize risks to the public health and the environment.
- Prevent inadvertent intrusion into mines and waste rock piles.
- Restore the mining sites to simulate initial conditions as closely as possible.

2. DESIGN CRITERIA

2.1 Uranium Mills

Design criteria used for the remediation activities were as follows:

- *Dispersion Control*: prevent inadvertent human intrusion and dispersion of contaminated materials by wind and water erosion.
- *Long-Term Radiation Protection*: achieve an effective equivalent dose to the individual in the critical group below 0.1 mSv/year for Andújar and the radiation background of the zone for La Haba.
- *Design Life*: remain stable for 1000 years to the extent reasonably achievable and in any case for at least 200 years.
- *Soil Cleanup*: reduce the residual concentration of radium-226 in land, averaged over and area of 100 m^2, so that the background level is not exceeded by more than 195 mBq/g (5pCi/g) (averaged over the first 15 cm soil) and is less than 555 Bq/g (15 pCi/g) (averaged over 15 cm thick layers of soil more than 15 cm below the surface).
- *Radon Control*: reduce radon flux over the surface of the final pile to an average release rate of less than 740 $mBq/m^2.s$ (20 pCi $m^2.s$) in Andújar and 1000 $mBq/m^2.s$ (27 mCi/ $m^2.s$) in La Haba.
- *Groundwater Quality Protection*: control groundwater contamination so that background water quality or maximum concentration levels (in accordance with Spanish regulations and CSN guidelines for radioactive constituents) are achieved in the long-term.
- *Long-term Maintenance*: minimize the need for long-term maintenance.
- *Construction Works*: minimize hazards to the workers and the environment.
- *Regulations*: comply with other applicable and relevant Spanish regulations governing air and water quality in non radiological aspects.

In addition to the above design standards, a performance standard has been established: groundwater quality must be monitored during the compliance period (10 years for Andújar and 5 years for La Haba) to confirm adequate performance of the cover and compliance with the maximum concentration limits.

2.2 Uranium Mines

Standards of design criteria to be achieved in the remediation were less prescriptive than for the mill sites, reflecting the lower level of radiological risks associated with the mines. These criteria may be summarized as follows:

- *Dispersion and intrusion control*: prevent inadvertent human intrusion into mines and dispersion of mining debris.
- *Radon control*: reduce radon flux and radon concentration over the site to background levels.
- *Radiation control*: reduce gamma radiation to background levels.
- *Stabilization control*: ensure long-term stability of waste and rock piles, open-pits and mine workings.
- *Water Quality Protection*: minimize contact between water and waste rock piles and prevent access to mine waters.
- *Restoration*: restore disturbed areas, mitigate environmental impacts and integrate the remediated site into de landscape.
- *Construction works*: minimize hazards to the workers and the environment.

A compliance period of one year has been established to confirm adequate performance of the adopted solutions.

3. ENGINEERING FEATURES

3.1 Andújar Site

The final pile configuration has been designed to minimize the movement of tailings and the size of the restricted disposal area. The pile was constructed with 4% top slopes and 20% side slopes, providing sufficient static and dynamic slope stability without requiring excessively large orcks to resist erosion. Protection against upland watershed runoff was provided by channelling runoff and away from the pile via drainage diversions walles along the perimeter of the pile. Protection against floods associated with the Guadalquivir river was provided by a rock apron around the perimeter of the pile and riprap layers on the sideslopes. The pile was covered with a multilayer system to meet the three simultaneous demands of erosion control, infiltration and radon control. The top slope cover consists of, from top down, a 500 mm vegetation growth and desiccation protection zone of random soil; a 250 mm filters of clean sand; a 300 mm biointrusion barrier of coarse rock; a 250 mm drawn of clean sand; and a 600 mm radon an infiltration barrier of silty clay. The most significant benefits of this cover are its ability to deal effectively with vegetation and to reduce infiltration to the cell because of effective evapotranspiration. From top down, the sideslope covers consist of 30 mm of sol to migrate into the rock and help support vegetation; a 300 mm erosion barrier of coarse rock.soil matrix; a 500 mm vegetation growth and desiccation protection zone of random soil; a 250 mm filter of clean sand; a 300 mm biointrusion barrier of large rocks; a 250mm rain of clean sand; and a 600 mm radon and infiltration barrier of silty clay. The advantages of this cover include protection of the radon infiltration barrier from desiccation and the existence of a controlled zone (the random soil) for vegetation that might establish through the riprap and help reduce the visual impact of the remediated pile.

Decommissioning of mill facilities and buildings involved the dismantling of the equipment and process facilities, the demolition of the buildings, the reduction of metal waste and demolition debris to manageable pieces, the cementation of the metal wastes and the disposal of dismantling and demolition wastes in the tailings pile. The major activities involved were decontamination/cleanup, dismounting and cutting of the equipment, demolition of structures, transportation of debris to the tailings pile and confinement in a cement matrix. Special containers were used to facilitate handling, transportation and cementation of the metal wastes. Cementation proved to be a cost-effective operation and provided a more stable structure to the wastes than the conventional alternative of mixing and compacting with the tailings.

3.2 La Haba Site

A part of the Waste Rock Disposal (5 x 10^6 t) has been stabilized in situ, the other part (4 x 10^6 t) has been transported and used for backfilling of the open pit mine. The heaps with low ore grade (less than 300 p.p.m. of U_3O_8) have been taken to the open pit mines and the others have been carried to the tailing dam. All the scrap components coming from both, the equipment disassembling and the soil clean up of the plant have been taken to the tailings dam. The wastes stored in the tailings dam have been the following:

100.000 tons of tailing,
150.000 tons from the heaps leaching depleted,
20.000 m^3 scrap material from the plant disassembling.

The multi-component cover incorporates the following components:

A layer of 3,00 m thickness including depleted ore from the heaps leaching.
And infiltration and radon barrier 1,50 m thickness consisting in waste rock from the mine. This material contains about 30% of clay.
A layer of about 0,50 m thickness with gravel to drain water
The top soil cover with vegetation of 0.30 m thickness.