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Overview on the Brazilian scenario and the first efforts towards the development of a borehole repository

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1. Introduction

The use of nuclear technologies has increased considerably and, consequently, each year, the volume of radioactive waste grows. In the next years, the Brazilian National Nuclear Energy Commission (CNEN) will face a great challenge in managing and disposing the disused sealed radioactive sources (DSRS) and the spent nuclear fuel from the research nuclear reactors (SFRR). Since the radioactivity of these waste materials can remain at dangerous levels for thousands of years, their final disposal is a challenge. The design of a disposal facility for these propose is currently object of research worldwide. Deep borehole to disposal facilities has been reported as the device which offers the best levels of isolation and security to dispose, for instance, DSRS. Currently, the Brazilian inventory has approximately a hundred of thousand DSRS pending of a final disposal, and their characteristics, as size and shape, are not suitable to be disposed in the borehole design proposed by the International Atomic Energy Agency (IAEA). Based on the requirements to recommend a design for the Brazilian repository, an overview on the country scenario and the first efforts towards the development of a borehole repository project is presented.

2. Brazilian scenario and the first efforts towards the development of a borehole repository

The National Nuclear Energy Commission (CNEN) acting as the regulator agency in Brazil authorized the installation of more than two thousand radioactive facilities where radioisotopes, radioactive sources and radiation emitting equipment are manufactured which are used in medicine, industry, research and other activities. Most of these services generate radioactive waste for which is necessary long-term storage and disposal [1]

The wastes managed by CNEN institutions are characterized by a wide diversity, in nature, shape, radionuclide contents and activities. The materials for disposal are mainly lightning rods, smoke detectors, medical and industrial wastes containing DSRS and nuclear gauges. The main disused sealed radioactive sources (DSRS) contain 241Am, 60Co, 137Cs, 226Ra, 241Am-Be, 85Kr and 90Sr sources [2,3].

In the DSRS, the radioactive material remains encapsulated and shielded. When out of use, both sealed and unsealed sources (open sources) are problems regarding health and public safety, as they are still active. Boreholes are deep and narrow underground facilities that provide the level of isolation and containment, low volume radioactive wastes. Their diameters are about dozens of centimeters and are directly connected to the surface, during the period of operation. The depth range is from few dozen until few thousand of meters. They have been reported as ideal concepts for the disposal of lower volumes of DSRS [4,5]. The borehole is lined and the waste would normally be contained in a package with the void spaces filled with cement. Despite the proposed International Atomic Energy Agency (IAEA) borehole concept, the design of the device can change worldwide. For instance, Brazilian DSRS inventory can comprise sources of dimensions varying from few to hundreds of centimeters, as well as, different types of radionuclides. These differences can be a limitation to the application of the IAEA proposed borehole concept.

The first Brazilian proposal of radioactive waste repository has been described by Vicente et al. [6]. The structure consists of a single deep borehole penetrating about 400 m, in a stable geological formation, with at least 4 engineering barriers: cement, steel cladding, the metallic container and the radionuclide metallic shield (generally stainless steel) and; to complete isolation, the host rock will act as the natural fifth barrier.

Besides the waste dimensions, corrosion issues must be considered during the project of boreholes. For instance, the local geology can affect the borehole design, besides the choices of number of barriers and candidate materials. Few studies have been performed with candidate materials for the different barrier layers, in order to understand their behavior under Brazilian service conditions/environments. Despite the good corrosion properties of the steel and their good shield properties against radiation, the first Brazilian container design proposed the used steel and lead. However, the use of this material can be a concern, when corrosion is considered. Lead is toxic and in contact with groundwater it can results in risk for human health and environmental contamination. Besides, points of contact between steel parts and lead can favor galvanic coupling in corrosive environments.

Stainless steels are suitable reference materials for DSRS borehole facilities if the passive environment is guaranteed. The most used grades are the 304 and 316, and the low carbon equivalent grades, 304L and 316L. Whereas the 304 grade has good corrosion resistance it is susceptible to crevice corrosion the 316 grade, of improved corrosion resistance, is the main reference material for DSRS disposal containers [4].

Currently Brazil has a capability to produce 51 Mt y^{-1} of steel. It is in the 9th ranking position among the steel manufacturers in the world. The consumption of stainless steels in the country is increasing each year. For instance, in 2019 the stainless steel production was about 300 thousand tons. Duplex and super duplex stainless steels are versatile alloys that combine corrosion resistance and mechanical strength, and can also be applied in aggressive environments, such as the oil and gas industry and applications in pressure vessels. The 2304 and 2205 grades are produced in the country, thus, they are ease to obtain and have been studied as possible candidates to be used om containers for the deposition of radioactive waste [7–13].

Figure 1 shows preliminary results comparing the corrosion resistance of the 2205 duplex stainless steel to the 316L stainless steel, this last the reference material for the IAEA borehole design.

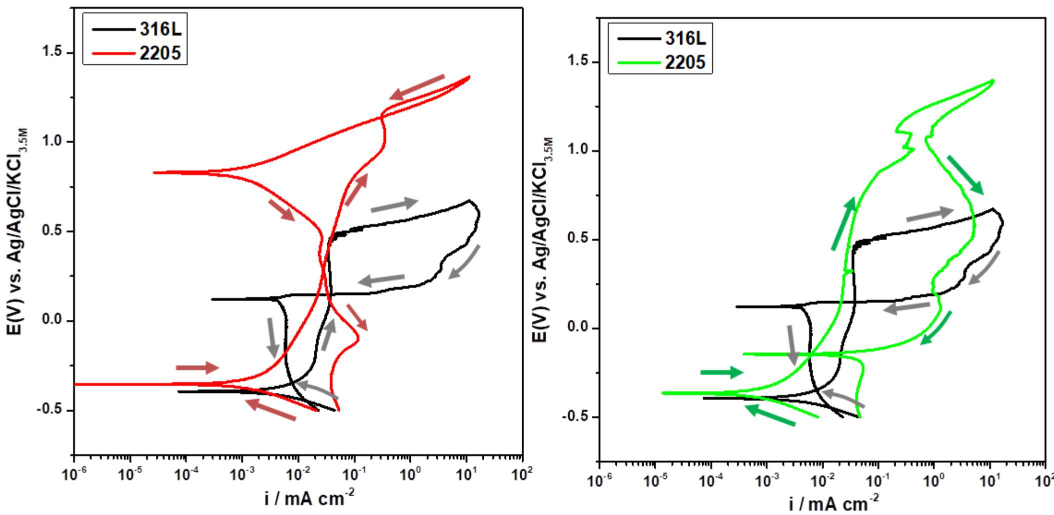

Figure 1 – Cyclic polarization curves obtained after 15 min of immersion in 3.5% NaCl for the 316L. stainless steel and the 2304 and 2205 duplex stainless steels.

The polarization curves in Figure 1 show higher pitting potentials and shorter hysteresis area for the 2205 comparatively to the 316L showing higher pitting resistance and repassivation tendency for the duplex SS (2205) compared to the austenitic one (316L). The results showed that the 2205 DSS presented superior corrosion resistance in relation to the steel used as reference material and can be considered a potential candidate for use in containers of the Brazilian deep borehole DRSS repository.

4. Summary

This overview is based on the necessity to select candidate materials for use in the Brazilian waste disposal repository. The Brazilian scenario on the waste disposal management and the factors which affect corrosion was introduced. The Brazilian repository facility design is a great challenge and the studies on this field are scarce. Despite some previous studies, the selection of materials for the container of the borehole Brazilian concepts are still pending of decision. Future works must be focused on material's selection for container and their corrosion resistance considering the Brazilian waste scenario and environmental conditions.

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