Disposal of Disused Sealed Radiation Sources in Boreholes

R. Vicente
Institute of Energy and Nuclear Research
Av. Prof. Lineu Prestes, 2242 – C. Universitaria – Sao Paulo – 05408-900
Brazil

ABSTRACT

This paper gives a description of the concept of a geological repository for disposal of disused sealed radiation sources (DSRS) under development in the Institute of Energy and Nuclear Research (IPEN), in Brazil. DSRS represent a significant fraction of total activity of radioactive wastes to be managed. Most DSRS are collected and temporarily stored at IPEN. As of 2006, the total collected activity is 800 TBq in 7,508 industrial gauge or radiotherapy sources, 7.2 TBq in about 72,000 Americium-241 sources detached from lightning rods, and about 0,5 GBq in 20,857 sources from smoke detectors. The estimated inventory of sealed sources in the country is 2.7 hundred thousand sources with 26 PBq. The proposed repository is designed to receive the total inventory of sealed sources. A description of the pre-disposal facilities at IPEN is also presented.

INTRODUCTION

The first use of sealed radiation sources in Brazil is dated September 7, 1922, when 0.25 g of radium encapsulated in platinum needles were brought from France to the Faculty of Medicine of Belo Horizonte for cancer treatment [1]. However, it was in the seventies, when applications of nuclear technology became more accessible, that sealed radiation sources started being widely used in many applications in medicine, industry and research. Since then, many thousands of nationally produced or imported sources entered the market. One recent estimate of the inventory of sealed sources in Brazil [2] accounted 273.000 sealed sources, including sources attached to radioactive lightning rods and smoke detectors.

The first those sources to get in the radioactive waste management system arrived at the Institute of Energy and Nuclear Research (IPEN) in the end of the eighties, becoming a class of radioactive waste we call Disused Sealed Radiation Sources (DSRS). Up to now, 7,508 sources, mainly Sr-90, Cs-137, Ra-226, and Am-24, formerly used in industrial gauges or radiotherapy, were received for treatment as radioactive waste. To this figure, it should be added 72,000 Americium-241 sources detached from lightning rods and 20,857 sources from smoke detectors. DSRS at IPEN are stored waiting for a decision on the final disposal.

Concerns about the safety of DSRS emerged in the late eighties when it became clear that some inadequately secured disused sources were causing accidents. The radiological accident in Goiânia, Brazil, in 1987, left four dead and contaminated large areas of the city; in many countries, incidents in which sources were melted in steel mills costed tens of millions of dollars. These occurrences motivated the International Atomic Energy Agency (IAEA) to take steps to lower the risks of accidents with sources in developing countries [3]. IAEA started developing guidance documents for the proper management of DSRS and various actions were implemented to improve the management of DSRS and, specially, to provide options for their safe disposal.

Most radioactive waste disposal technologies are not acceptable for DSRS in general. The reason is that sealed sources contain radioisotopes with have half lives varying from less than one year to many thousands years and activities ranging from less than one megabecquerel to more than one terabecquerel. Sources with low activity and short half lives could be accepted in shallow ground disposal sites while higher activities and longer half lives requires greater containment than that provided by surface repositories. Examples of traditional methods of disposal found in the literature are that of Russia, Czech Republic and India though not for all kinds of sources or for all activities. In Russia, DSRS have been disposed of in shallow boreholes in RADON sites since the early sixties [4]. In Czech Republic they were disposed in abandoned deep mines [5], while in India, sealed sources has been disposed of in tile boreholes [6].

In most countries with advanced nuclear programs, disposal of DSRS is a small problem as compared with other large volume and high activity wastes. Decisions on the disposal of the sealed sources can be postponed because of the certainty that disposal options will be available as spent nuclear fuel disposal projects evolve.

IAEA recommends intermediate depth boreholes as the type of repositories for sealed sources in developing countries [7]. Apart from satisfying safety requirements and being attractive from an economic viewpoint, is considerably more flexible and modular, has no large initial investment demands and is less intrusive on the landscape than conventional disposal facilities. The Agency developed the BOSS concept (Borehole Disposal of Sealed Sources) under the AFRA Project, an IAEA program to strengthen waste management infrastructure in African countries, undertaken during the last ten years [7].

Conceptually, the BOSS disposal concept comprises a standard borehole 165 mm in diameter drilled down to a depth of 100 m and encased with a 150 mm casing. Temporary site office can be erected at the site and the disposal area can be fenced off to limit access. The reference design includes a container of stainless steel, a cement based waste form and encapsulated sources. The waste package is placed into wet concrete in the borehole. A specially formulated concrete would then be poured on and around the container. The next package is then lowered into the hole and the process repeated until the Waste Acceptance Criteria for that hole is met or until the cut-off depth is reached. The rest of the hole is sealed off with concrete. [8]

In parallel, we independently have studied a concept of repository that is convergent in some aspects, but differs from the BOSS concept in two points: the deeper emplacement zone and the absence of immobilization matrix. A description of the proposed concept of repository for DSRS follows.

REPOSITORY CONCEPT

The concept of repository under development is a deep borehole drilled in a crystalline rock formation, for instance a granite batholith. The emplacement zone is below the groundwater table, inside an expanse of the lower stratum of the geological unit, below the upper weathered-, and the medium fractured-layers of the geological setting, deep enough to accommodate all

DSRS, yet providing an isolation space above the wastes and below the fractured stratum of the rock.

Available technologies for drilling the hole are air percussion rotary hammer or rotary drilling with mud pump, which are used by drilling companies exploiting ground water in Brazil. The concept of the repository, with a stylized geological profile, is shown in Fig. 1.

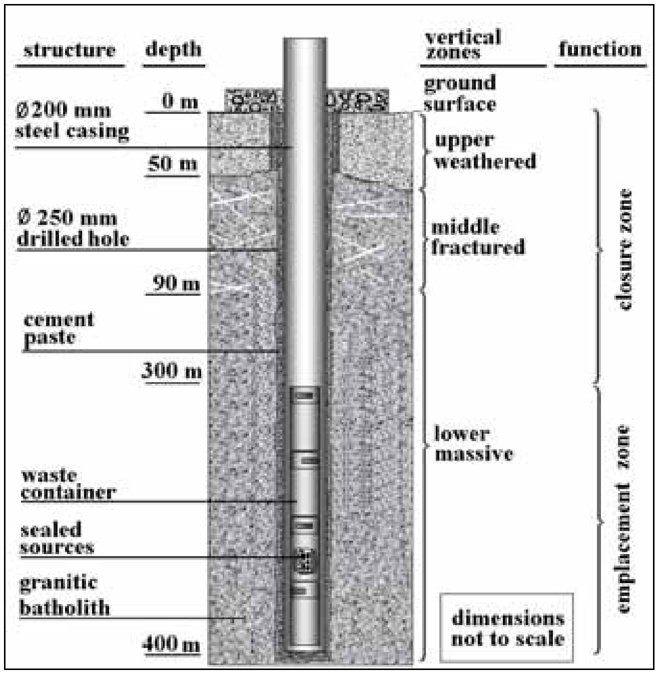

Fig. 1. Concept of the repository for disused sealed radiation sources

The hole is encased with a flush joint steel pipe, and the annulus between the pipe and the geological formation is filled with cement paste. Plastic casings, PVC for instance, are not deemed acceptable because of the higher temperatures found in the deeper part of the structure, the high radiation field around the high activity gamma and neutron sources, and the long term service required, of the order of thousands of years.

The hardened cement paste around the casing is an additional barrier against the migration of radionuclides from the repository and, mainly, is an obstacle to the flow of water between the different layers cut across by the borehole.

The sources are disposed of within lead containers, which functions as a shielded package and as a long standing barrier against the release of the radionuclides present in the sources. The use of the lead container shown here, under development at IPEN, presents advantages over other concepts of disposal packages: a) it can be closed and sealed with a cheap, remotely operated hydraulic press. Sealing steel packages by welding requires either an expensive welding station inside a hot cell or contact handling the packages what results in high doses to the operators. b) the shielding provided by lead is much better than that provided by cement paste and steel containers of the same size; c) lead is more resistant to corrosion in the long-range.

Figure 2 shows a drawing of the package and the stopper being inserted during a test of the package.

Fig. 2. Disposal package: a) cut view with dimensions; b) top view without the stopper; c) just before being sealed in a hydraulic press; d) a smooth top surface is left after stopper is inserted.

The space between the casing and the containers is left void, without grouting, first because lead would be corroded by the calcium hydroxide present in Portland cement materials and, on the other hand, the repository can function as a retrievable storage until it is sealed off. Retrievability is a controversial question but the concept is flexible allowing both conditions: in the form it is presented here, it is a retrievable storage; small changes in the design of the disposal package can render the wastes almost irretrievable.

After the capacity of the repository is reached, the space above the packages is sealed off with concrete and the site can be immediately decommissioned and released from institutional control. It is estimated that the whole inventory of sources can be disposed of inside 300 lead containers, stacked in a single column, filling the emplacement zone to about 100 m from the bottom of the repository.

Estimated costs of drilling, encasing and cementing the borehole to the depth of 400 meters are in the range of US$100.000 to US$200.000 depending on the site, with Brazilian prices and middle 2006 exchange rates. However, a program to dispose of the sealed sources shall make provisions for the costs of the lead packages, surface facilities, transportation, and, most of all, licensing the facility. This last item of cost is very important because, although there is not yet an assessment of the costs of characterizing a site for the safety assessment, it is perceived as being much higher than the construction costs. This is a point for future investigations.

The long term safety of the facility will be achieved by the multi barrier concept of the repository. The first barrier is the geological medium which must be a continuous and dry expanse of a granite batholith, with no open fractures. The second is the cemented annulus that will restrict water flow between the different strata crossed by the hole. The third is a steel casing that also functions as a smooth casement wall. The fourth is the lead container and the fifth is the steel capsules of the sealed sources themselves. The barriers as a whole will postpone the contact of groundwater with the wastes and retard the transport and migration of the radioactive materials back to the surface, allowing radionuclides to decay much before dispersion into the biosphere occurs. The safety aspects of this concept are discussed in another paper in this conference. [9]

PRE-DISPOSAL FACILITIES

Formerly, DSRS were treated by encapsulation in concrete inside 200 L drums at IPEN. This method was used for all kind of sources including radium needles; unless acceptance criteria in the future shallow ground disposal site for low-level wastes, allows the disposal of this 'historical' wastes as they are, these packages shall be opened, the concrete block penetrated, and the sources removed. Seventeen drums with various industrial gauge sources, sixteen drums with radium needles and one drum with a neutron emitting Ra-Be source were produced until 1993.
Presently, all DSRS are managed at IPEN according to the general flow diagram presented in figure 3, which is consistent with the intent of disposing the sources in a repository of the kind proposed here, although Brazilian authorities did not decide on the disposal method yet. Nevertheless, this management does not forbid future decisions in other directions, for instance, encapsulation of low activity and short lived DSRS in 200 L drums and disposal in a surface repository.

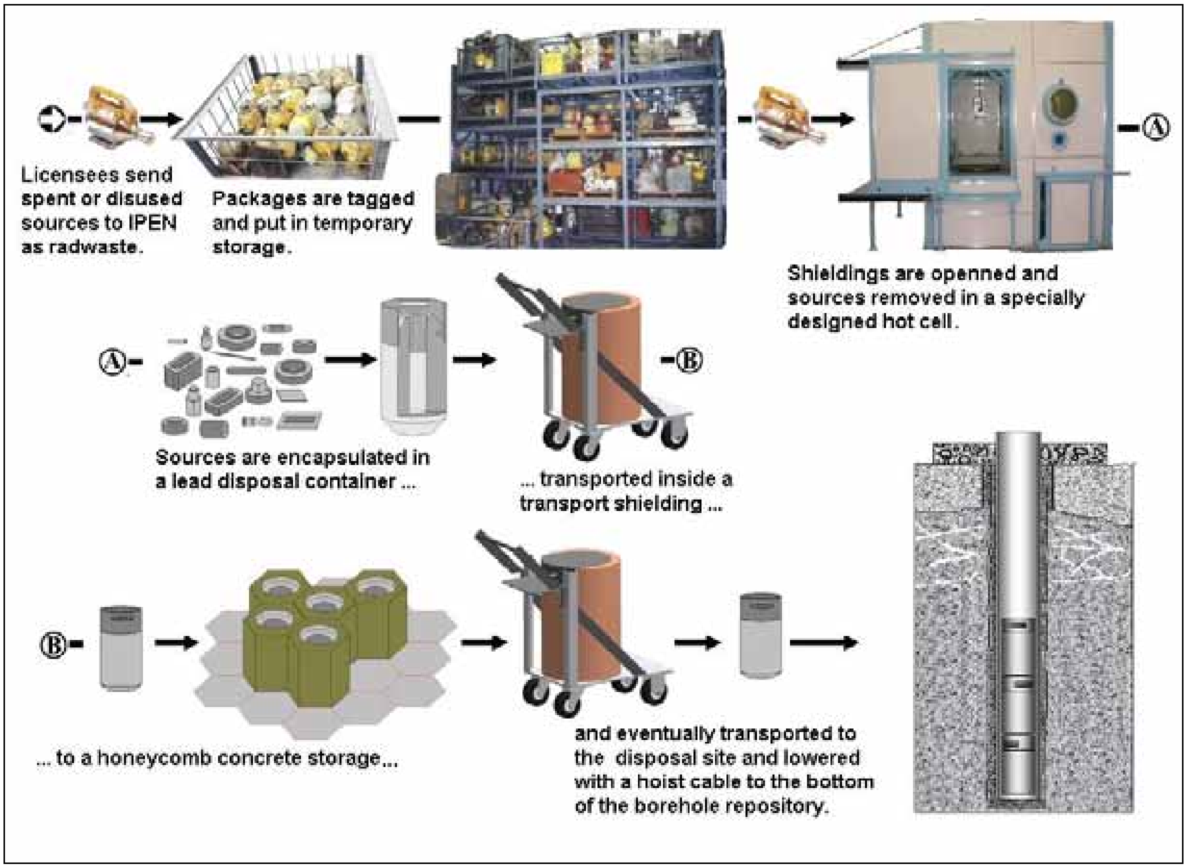

Fig. 3. Flow diagram of the pre-disposal management of the DSRS.

CONCLUSION

A deep borehole drilled in a crystalline rock with enough extension and depth, encased and cemented in all its height, is the concept of repository that allows the disposal of the entire inventory of DSRS of Brazil, including the long lived brachytherapy Ra-226 needles, the disused neutron emitting well logging Be-Am-241 sources used in the petroleum industry, and the high activity teletherapy Cs-137 sources.

On going research to further develop this concept focus on requirements for the geological setting, quality assurance for the construction of the facility (for instance the verticality and linearity of the borehole, and the continuity and homogeneity of the cement paste during the cementing job), conditions for retrievability of the sources, accident mitigation, optimization of radiation protection in the context of the long term disposal, performance and safety assessment, etc.

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