# Disposal of Disused or Spent Sealed Radioactive Sources

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**Abstract.** Spent or disused sealed radiation sources are a problem for authorities and radioactive waste managers in countries where a final disposal option is unavailable and where an increasing number of sources are being kept in extended, and sometimes unsafe, storage. Annually, thousands of radium needles, teletherapy sources, oil well logging neutron sources, and miscellaneous industrial gauges are collected as waste and stored in research institutes, both in developed and developing countries, without definition of their final destination. In Brazil, about two hundred thousand sources are currently in use and about 40 thousand sources, from small smoke detectors americium sources to teletherapy sources, were already collected as waste and are stored awaiting for a decision on final disposal. In this communication, we describe the inventory of sources in Brazil and present the concept of a dedicated, deep repository where those sources could be disposed of properly.

## 1. Introduction

Disused or spent sealed radioactive sources may represent a radiation hazard. Many radiological accidents in the past two decades were the consequence of abandoned or insecurely stored disused sources [1][2][3]. After the terrorist attack of 11 September 2001, it was recognised that sealed sources with high activities are potential targets to terrorism because they could be used as raw material to assemble dirt bombs. This raised the question of the security of relevant sources, mainly in developing countries [4] and prompted efforts to secure them [5][6].

One aspect of security mentioned in the above references is the availability of proper final disposal options. Some sources can be disposed of in shallow ground disposal sites, like those in operation for low- and intermediate-level wastes in a number of countries. While almost all countries in the world make use of sealed sources, only a few of them have final disposal facilities in operation. The only option for most countries is extended storage at research institutes or at the premises of hospitals or factories where sources were once used. Many countries are facing the problem of storing a growing number of sealed sources without definition of disposal routes. However, even in some countries with operational sites, disposal of relevant sources is an unresolved issue because the higher activities, the long lived radionuclides and alpha emitters that are present preclude disposition in shallow ground facilities.

In the United States, sealed sources that fall in the category GTCC LLW (greater than class C low-level wastes) have as yet undefined disposition path and an increasing numbers are orphaned, or stored with inadequate safety and security measures [7]. In the Russian Federation, spent sources with short lived radionuclides are disposed of into shallow ground borehole "RADON" sites while long lived radionuclides are stored in shielded containers while the decision on their final disposal is pending [8]. The disposal of short- and long-lived sources in borehole of intermediate depth (45m to 100 meters) has been investigated for a relatively small inventory of sources in African countries [9].

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In Brazil, a study on the management for spent sources [10] showed that a significant fraction of the inventory of hundreds of thousands of sources is unsuitable for disposal at shallow ground facilities and therefore a deep borehole disposal concept was investigated.

## 2. Inventory of sealed sources in Brazil

About 270,000 sealed sources will be requiring disposal as radioactive waste in the near future. Table I shows the number of sources in terms of radionuclide, activity and volume, while Table II shows the number of sources per class of origin.

The figures in Table I and Table II have unavoidable inaccuracies because the inventory is dynamic and different sources of data were used in the compilations. Furthermore, sources with half-lives shorter than a few years and the $^{60}Co$ sources in large irradiators, that are usually returned to the suppliers, were excluded. On the other hand, a broader definition of sealed source was used to include the $^{241}Am$ and $^{226}Ra$ sources attached to replaced radioactive lightning rods and smoke detectors. These figures also include about two thousand sources that were collected as waste, for which there are no entries of radionuclides and/or activity. An average individual activity of 100 MBq and gross volume of 0,0074 dm$^3$ were assigned to these sources. (See Notes 'a' and 'd' in Table I).

Table I. Estimated number, activity and gross volume of sources.

| Radionuclides | Number of Sources | Total Activity (Bq) | Gross Volume (dm$^3$)[(a)] |
|---|---|---|---|
| $^{60}Co$ | 2,611 | $2.60 \times 10^{16}$ | 3.0 |
| $^{85}Kr$ | 440 | $4.93 \times 10^{12}$ | 42. |
| $^{90}Sr$ | 846 | $1.82 \times 10^{12}$ | 4.0 |
| $^{137}Cs$ | 6,153 | $3.27 \times 10^{14}$ | 13. |
| $^{226}Ra$ | 4,535 | $1.29 \times 10^{12}$ | 0.92 |
| $^{241}Am$ | 255,548 | $1.35 \times 10^{13}$ | 130. |
| $^{241}Am$-Be | 319 | $4.16 \times 10^{13}$ | 35. |
| Other SL[(b)] | 419 | $1.03 \times 10^{13}$ | 10. |
| Other LL[(c)] | 311 | $2.45 \times 10^{12}$ | 3.5 |
| Unknown[(d)] | 2,331 | $2.33 \times 10^{10}$ | 17. |
| Total | 273,513 | $2.64 \times 10^{16}$ | 257. |

[(a)] Volume of sources randomly packed. [(b)] Short-lived ($T_{1/2} \leq 30$ y), mainly $^{55}Fe$, $^{244}Cm$, $^{252}Cf$. [(c)] Long-lived, mainly $^{63}Ni$, $^{226}Ra$-Be, $^{238}Pu$, $^{238}Pu$-Be. [(d)] Assumed individual source activity 0,1 GBq, and volume 7,4 cm$^3$.

Table II. Number of sealed sources in Brazil by origin.

| Class of the source | Number |
|---|---|
| Miscellaneous sources held by licensees | 9,182 |
| Industrial gauge sources collected as waste | 5,808 |
| $^{226}Ra$ sources in lightning rods collected as radioactive waste | 440 |
| $^{226}Ra$ needles collected as waste | 2,535 |
| $^{241}Am$ sources in smoke detectors collected as radioactive waste. | 13,548 |
| $^{241}Am$ sources in lightning rods collected as radioactive waste | 39,478 |
| $^{241}Am$ sources at the premises of smoke detector manufacturers. | 86,000 |
| $^{241}Am$ sources in lighting rods awaiting replacement | 116,522 |
| Total | 273,513 |

## 3. Concept of the repository

The proposed repository is a single deep borehole penetrating a stable geological formation. The depth will depend on the geological characteristics of the selected site, but will be deep enough to accommodate completely the wastes inside a granite batholith, yet provide enough isolation space above the wastes and below the weathered strata of the geological setting. Fig. 1 shows the proposed configuration of the repository. The height of the zone of the well where the wastes will be stored is the 'emplacement zone'; the rest of the well toward the surface is the 'isolation zone'. The actual profile of the geological setting will be known after completion of the site selection process, an endeavor that is yet to be undertaken. General characteristics of the site include: reasonable distance from populated areas but with good access to transportation; distance from areas subject to flooding, erosion, or subsidence. The subsurface emplacement zone must have a long history of tectonic stability, limited open fractures or void spaces, little free water, lack of evident recoverable mineral resources, and adequate thickness to accommodate the repository.

Rotary drilling is a viable method of borehole construction. The well is clad with a flush joint steel pipe and the annulus between the pipe and the geological formation is filled with cement paste. Sources will be removed from their original shielding in a hot cell and put inside about 300 lead containers. Each container will be lowered to the bottom of the borehole and stacked in a single column, filling the well to about 100 meters from the bottom. The containers can be raised back to the surface during the operational phase of the repository, making the facility a retrievable storage. After the decision to close and to decommission the site, the space above the containers will be filled with concrete up to the top and the well definitely sealed.

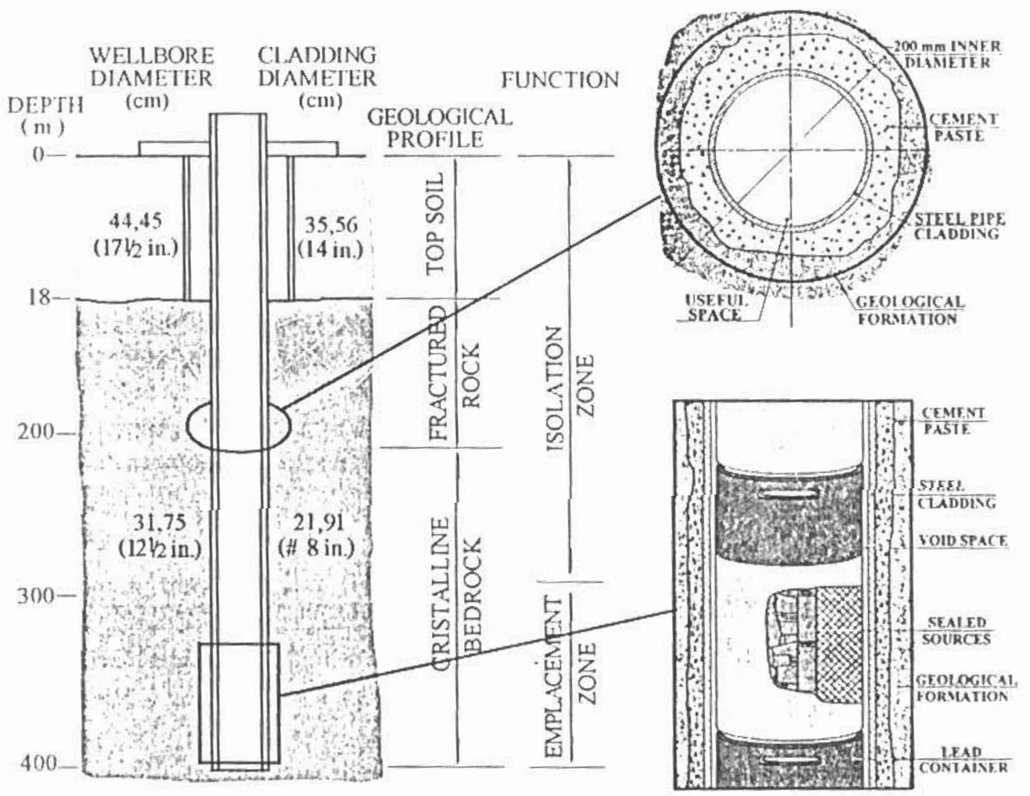


*FIG. 1 Concept of the repository and view of the well cross section and emplacement method. Dimensions in inches that are still used in the drilling industry were also included.*

Isolation against water intrusion is achieved by the multi barrier concept of the repository. The barriers are: the geological medium, a dry granite batholith; the cemented annulus that restricts water flow between the different strata crossed by the well; the borehole steel cladding that also functions as a smooth casement wall; the lead container; and the steel capsules of the sources themselves. The barriers as a whole will postpone the contact of groundwater with the wastes and delay the transport and migration of the radioactive material back to the surface, allowing radionuclides to decay before dispersion into the biosphere. The depth of the emplacement will function as an isolation barrier against human intrusion.

Suitability of the concept to a developing country as an alternative technology to disposal of spent sources is evaluated under three main aspects: availability of construction technology, costs, and safety. The construction technology is the same used in oil or deep water exploitation projects and many companies have the equipment and expertise to do the job. The cost of drilling, encasing, and cementing the well is only a small fraction of the costs of a radioactive waste disposal facility. Finally, as a preliminary safety assessment of the concept, compliance with a checklist of requirements from relevant IAEA and ICRP publications demonstrate that the proposed facility is feasible and acceptable.

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