8 EXAMPLES OF EXISTING REPOSITORIES

8.1 Operating, Surface/Near Surface - The El Cabril Repository, Spain

based on input provided by ENRESA, Madrid, Spain

Intermediate and Low Level Radioactive Waste Management System (LILW)

A consolidated management system is in place for LILW. It is centred on El Cabril installations and covers all stages of LILW management [8.1]. The system was drawn up in accordance with international references and the identified needs derived from the size of the Spanish Nuclear sector. Currently there are nine Nuclear Reactors in operation, one more, Vandellós I NPP, is being dismantled. A nuclear fuel elements manufacturing plant is located in Juzbado and around 1 300 radioactive installations also generate radioactive waste.

As of 2001.12.31, the volume of the waste disposed in El Cabril cells was 40 964 m$^3$ “as disposed”, corresponding to 17 561 m$^3$ of “as delivered” waste. This means that 39% of the El Cabril capacity of 45 000 m$^3$ of conditioned wastes had been used.

According to the last operation permit issued by Ministerial Order of October 5th, 2001, ENRESA is authorized to operate El Cabril facility until the current disposal capacity is exhausted.

A History of the Development of the El Cabril Repository

El Cabril Estate was used for uranium production in the 1950’s and later it was a waste storage facility. The operations to store wastes at the Mina Beta were carried out during the 1960’s and 1970’s until was filled. In order to provide additional storage capacity, three storage modules consisting of industrial sheds with a metallic structure and concrete walls, providing a storage capacity for 15 000 drums of 220 litres each, were constructed.

Subsequently, when the National Radioactive Waste Company, ENRESA, took over the El Cabril installations in 1985, a decision was taken to move the drums from the Beta mine to modules located on the surface. The package transfer and reconditioning operations were carried out between May 1987 and January 1988, and culminated with the closure of the Beta mine. Since then, the mine has been unoccupied and clean and is no longer qualified as a storage facility.

ENRESA extended the El Cabril installations through the construction of a modern disposal facility. The project started in 1986 by extending the site characterisation work already underway and beginning the engineering, safety assessment and environmental impact assessments work in support of the licensing process to build the disposal facility. The facility construction started in January 1990 and the repository was commissioned in October 1992.

Overview of the facility

The general layout is adapted to the hilly landscape of the region. The facility is divided into two main areas: the disposal area, and the auxiliary building area. Both are separated by a
brook that surrounds the disposal area and controls the behaviour of the underground water flow. See Figure 8-1.

![Aerial View of the El Cabril Facility](image)

**Figure 8-1: Aerial View of the El Cabril Facility**

The El Cabríl facilities were designed as near surface repository for LILW. Consequently, they must meet two basic objectives: ensuring the immediate and deferred protection of people and the environment and allowing free use of the site following a surveillance period of 300 years, without radiological limitations. Furthermore, a basic objective sought in the design of El Cabríl has been the possibility of recovering the wastes if circumstances were to make this advisable.

To reach these objectives two main criteria are stressed: to isolate waste from the main vectors of radioactivity release (man and water) and to limit the activity disposed.

The disposal concept is based on a multibarrier system with the aim to isolate the metal packages containing the wastes that are stored inside concrete containers, which are allocated in the disposal vaults – see Figure 8-2. A drain control system exists in inspection galleries constructed beneath the disposal vaults. These vaults are protected from the weather during their operation and sealing by a metallic shelter, which also supports the handling crane.

After completion of a disposal area, a multi-layer-engineered cap will be constructed to divert the rainwater and to provide long term protection for the containers as well as to ensure their durability.
The El Cabril facilities includes:

- a treatment and conditioning building, which includes, institutional waste segregation, treatment (includes incineration and supercompaction) and conditioning, package transfer into disposal units, liquid waste collection, and grout preparation and injection,

- a verification laboratory supporting waste acceptance and characterization activities and for technical verification of the waste packages. This laboratory is fitted with the equipment required for sampling, mechanical testing, the extraction of dry test pieces, etc. The laboratory is completed with a waste package radiological characterization system (non-destructive characterization by gamma spectrometry), a system for the leach testing of packages (drum removed) and test pieces, a radiochemistry laboratory and a counting room,

- a shop for concrete container fabrication, and

- auxiliary systems and buildings in support of operation, maintenance and surveillance of the facility.

Primary waste packages, containing immobilized waste or pellets arising from the supercompaction process, are reconditioned in concrete overpacks thus forming the final so-called "disposal unit" to be disposed. Other types of final packages might be used upon approval of the safety authority.

Once containers are full and the lids have been placed on, they are transferred to the immobilization grout injection area. In the injection system, the dry mortar, a mix of cement and sand, is mixed with water (or liquid radioactive waste) and additives. The resulting grout
is injected, backfilling the interior of the disposal container and immobilizing the drums or pellets inside.

In order to treat and condition materials arising from events in metal scrap melting plants, in March 2002 ENRESA started the upgrading of installations currently in service as well as the construction of new buildings, which will host the additional equipment.

The main part of this waste stream, consisting of dust from fumes, dry sludges, inert wastes, slag, earth and refractory materials, will be ground and conditioned by mixing them with the waste package blocking mortar in the containers. This conditioning will allow the waste to be immobilized in a solid matrix, without them occupying any additional volume at the facility and without altering the configuration of the disposal unit of the El Cabril Disposal Facility. The rest of the waste generated: plastics, rubber, cloths and dust filters, will be conditioned either by compaction, thus producing compacted pellets that will be immobilized in containers, or incinerated, as the case may be.

These new services will allow managing any similar material to be generated in the future. It is expected that these installations will be in service at the end of 2003.

8.2 Operating, Geological - The Waste Isolation Pilot Plant Repository (WIPP) – USA

The Waste Isolation Pilot Plant [8.2], or WIPP, is the world's first and only operating deep geological repository licensed to safely dispose of transuranic (TRU, classification used in the USA, see subsection 3.2) radioactive waste derived from the research and production of nuclear weapons – see Figure 8-3. After more than 20 years of scientific study, public input, and dealing with regulatory issues, WIPP began operations on March 26, 1999.

WIPP, a cornerstone of the United States Department of Energy’s clean up effort, is designed to dispose of defence generated TRU, which consists of clothing tools, rags, debris and other items contaminated with radioactive elements, mostly plutonium (see Figure 8-4)
Located in south-eastern New Mexico, about 40 kilometres east of Carlsbad, project facilities include disposal rooms excavated in an ancient, stable salt formation about 600 metres underground in a 600 metre thick salt formation that has been stable for more than 200 million years – see Figure 8-5. Transuranic waste is currently stored at 23 locations nationwide in the USA. Over a 35 year period, WIPP is expected to receive about 37 000 shipments.

The decommissioning phase, during which the repository will be prepared for permanent closure, will follow the disposal phase. Surface facilities will be decontaminated and decommissioned, underground excavations will be prepared for closure, and shaft seals will be emplaced. This phase is currently projected to last for 10 years. The post decommissioning phase will consist of active and passive institutional controls. Active institutional controls will
include activities such as control of access to the site, implemented consistent with applicable regulations and permit conditions and will continue for at least 100 years.

For current information on WIPP, the reader is referred to “TRU Progress Online”:
http://www.wipp.carlsbad.nm.us/pr/truprog/TRU_Progress_Online.htm

8.3 Previously Operated, Geological – Morsleben Repository, Germany

In the former German Democratic Republic (East Germany) the abandoned salt mine Bartensleben was selected to serve as a repository for low and intermediate level radioactive waste [8.3]. Located near the village of Morsleben in the Federal State Saxony-Anhalt, this mine was named the “Repository for Radioactive Waste Morsleben (ERAM)”. The decision to establish the repository was based on safety and technical-economic studies performed in the 1960s. After the completion of detailed studies of its suitability, the twin-mine was chosen in 1970 for the disposal of low and intermediate level radioactive waste. It was designed, constructed and commissioned during 1972-1978. Waste emplacement started in 1978 in rock cavities at the mine’s fourth level, some 500 m below the surface. Following studies and the successful demonstration of the disposal technologies used, a first operational license was granted in 1981.

After German reunification (October 3, 1990) the Federal Government of Germany took over the responsibility for the repository. It is represented by the Federal Office for Radiation Protection (Bundesamt für Strahlenschutz, BfS) which is entrusted by the Federal Minister of Environment, Nature Conservation and Reaktor Safety (BMU). The DBE (German Company for the Construction and Operation of Repositories for Wastes) became then, on behalf of the BfS, the repository operator. The final disposal of waste was stopped on September 28, 1998. Until the end of the operational phase in 1998, about 36 800 m³ of radioactive waste was disposed.

Under contract of the BfS, the backfilling and closure of this pioneer deep geological repository is currently being planned. ERAM is now under licensing for closure. After completing the licensing procedure the repository will be sealed and backfilled. The main
The safety objective is to protect the biosphere from the harmful effects of the disposed radionuclides.

Furthermore, classical or conventional requirements call for ruling out or minimizing other unfavourable environmental effects. The ERAM is an abandoned rock salt and potash mine. As a consequence it has a void volume, which necessitates a stabilization of the cavities. In addition, groundwater protection shall be assured.

![Figure 8-7: Waste Package Emplacement at Morsleben](image)

For the sealing of the repository, a closure concept was developed to ensure compliance with the safety protection objectives. The concept anticipates the backfilling of the cavities with
two variants of hydraulically setting backfill materials (salt concretes). The reduction of the remaining void volume in the mine causes, in the case of brine intrusions, a limitation of the leaching processes of the exposed potash seams. However, during the setting process the hydration heat of the concrete leads to an increase of the temperature and, hence, to thermally induced stresses of the concrete and the surrounding rocks. Therefore, the influence of these stresses and deformations on the stability of the salt body and the integrity of the geological barrier was examined by two- and three-dimensional thermo-mechanical computations. Compliance with the safety objectives are to be proven on the basis of safety evidence criteria, which are in accordance with the German regulatory framework.

A closure concept was developed in the context of the three main characteristics of the repository mentioned previously. The goals of the concept are the long term stabilization of the cavities (the high excavation rate does not bear any risk for the geo-mechanical stability of the mine for the next decades), the limitation of leaching processes of potash seams by reducing the void volume and the sealing of the emplacement structures containing the radioactive waste by technical barriers. For stabilization of the mine, the backfilling of distinct cavities is necessary, e.g. in the highly mined central part Bartensleben. Concerning the reduction of the mine openings, generalized requirements are available with respect to different parts of mining fields. In general the backfill requirements arising from stabilization purpose are the decisive factor and the requirements arising from the limitation of leaching processes are fulfilled automatically.

To separate the emplacement structures from other parts of the mine, sealings of different cross-sections and lengths up to several hundred meters on the different mining levels are needed.

According to the main characteristics of the mine, every single cavity and mining excavation was assigned to a backfilling category:

- **Category I** Includes all cavities and mining excavations that must be sealed. For this category a high backfilling quality must be achieved. The averaged permeability of a cross section must be equal or less than $10^{-16}$ m$^2$.

- **Category II** Includes all cavities and mining excavations that must be backfilled by nearly 100% (more than 95%) by stability reasons or because they may develop an mining induced pathway for water and brine.

- **Category III** The requirement for category III is an averaged backfill standard of 65% per mining field for the reason of limiting leaching processes.

- **Category IV** Includes all excavated carnallite layers, which are mostly inaccessible. A backfill standard of more than 90% should be reached, but cannot be verified.

For this reason, only a degree of backfilling of 50% is included in the long term safety analysis. The concept relies on an almost complete backfilling of the mining excavations with solid material (salt concretes) that is placed into the underground excavations by a hydraulic transportation system.
References for Section 8

8.1 El Cabril information on the Internet (in Spanish)


9 THE MANAGEMENT OF SPENT/DISUSED SEALED RADIOACTIVE SOURCES

The purpose of this Section is to provide an overview of the status of and recent trends related to the implementation of management controls for disused and/or spent sealed radioactive sources (SRS). Included are overviews of Agency and European Union activities and national programmes in the area of SRS management.

Data collection at the international level

(1) International Catalogue of Sealed Radioactive Sources and Devices (SOURCES database) [9.1]: Collecting and entering data into the Agency’s SOURCES database continued to be an important task in 2002. The catalogue now includes technical data on nearly 4 000 SRS models but less than half (1 886, 47%) contained all the necessary “good” information. The rest of the SRS models (2 115, 53%) only contained information about the model and its corresponding reference number. Complete data will greatly facilitate the identification of SRS. In order to have a complete data on SRS worldwide, catalogues for manufacturers from various countries (e.g. Russia, China, France, Germany, etc.) have been collected and information from them is being entered in the SOURCES database. The year 2003 will see the development of software for the automatic identification of an orphaned SRS from a set of available data. International co-operation is foreseen and is required to make the catalogue a useful tool at the international, national and institutional levels.

(2) Illicit Trafficking database [9.2]: More than 70 States have joined with the Agency to collect and share information on trafficking incidents and other unauthorized movements of radioactive sources and other radioactive materials. The Agency database includes 284 confirmed incidents, since 1 January 1993, that involved radioactive material other than nuclear material [7]. In most cases, the radioactive material was in SRS but some incidents with unsealed radioactive samples or radioactively contaminated materials, such as contaminated scrap metal, also have been reported to the illicit trafficking database and are included in the statistics.

Open source information suggests that the actual number of cases is significantly larger than the number confirmed to the Agency. Not all these incidents reflect deliberate attempts to steal radioactive sources. The great majority of detected trafficking incidents appear to involve opportunists or unsophisticated criminals motivated by profit. Nevertheless, it is apparent that an important fraction of cases involved persons who expected to find buyers interested in the radioactive contents of stolen sources and their ability to cause or threaten harm.

Customs officials, border guards, and police forces have detected numerous attempts to smuggle and illegally sell stolen sources. If the perpetrator is willing to disregard his or her own personal safety, radioactive sources could be concealed in a truck or packed in a suitcase

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7 Plutonium except that with isotopic concentration exceeding 80% in plutonium-238; uranium-233; uranium enriched in the isotope 235 or 233; uranium containing the mixture of isotopes as occurring in nature other than in the form of ore or ore-residue; any material containing one or more of the foregoing.
with little effort. The danger of handling powerful radioactive sources can no longer be seen as an effective deterrent, which dramatically changes previous assumptions.

Revised action plan
A report by Director General Mohamed ElBaradei to the Agency Board of Governors meeting in September 2002 described Agency actions to implement and strengthen the Agency's Revised Action Plan (RAP) on the Safety and Security of Radiation Sources and Security of Radioactive Materials [9.3]. The plan reflects increased concerns about malicious use of sources to make so-called “dirty bombs”.

The RAP sets out actions to be taken in seven areas: regulatory infrastructure, management and control of operational and disused sources, categorization of sources, response to abnormal events, information exchange, education and training, and international undertakings.

9.1 Topical Issue: The Proposed EU Directive on Orphan SRS

On March 18, 2002, the EC proposed a new directive on the management of SRS aimed at improving harmonization among current EU countries and strengthening the EU’s legal base as it enlarges [9.4]. The EC is of the opinion that it would be appropriate to adopt specific legislation, based on the EURATOM Treaty, supplementing the BSS [4.5] with a view to strengthen control by the competent national authorities on those SRS posing the greatest risk and to emphasize the responsibilities of holders of such SRS.

The proposed directive tries to prevent SRS from being orphaned and also addresses management of those SRS for which no owner can be identified. According to a recent EC funded study, about 500 000 SRS were supplied to users in the current EU States over the past 50 years. Of these, an estimated 110 000 SRS are currently in use. The other 390 000 are disused and are stored or disposed of either in central facilities or are held on the users’ premises. The SRS that are held at user’s premises (about 30 000) are at the greatest risk of being lost from regulatory control. The cited study estimated that a maximum of 70 sources are lost from regulatory control per year in the EU. SRS carry particular risks because they are small and are often used in mobile devices. Sources are regularly found in scrap yards and metal production facilities because of they are typically enclosed in metallic capsules.

The likelihood that SRS will be lost increases when they are no longer used and controls over them are lessened. The proposed directive includes provisions for regaining control over orphan SRS; establishing controls where they are most likely to appear, like large scrap yards and material transit points; requiring EU states to share information on them; and liability for damage caused by orphan SRS, including allowing Member States to set up a fund financed by all SRS users.

Many of the provisions in the EC proposal are already in place in several Member States that have implemented the BSS. The new directive would apply to SRS sources with a dose rate of more than 1 mSv/hour at one meter. The activity levels considered are one hundredth of those that trigger requirements for specialized packaging under the Agency’s 2000 regulations on the transport of radioactive materials [9.5].

The proposed new directive would require prior authorization for any practice involving a high activity SRS, implying arrangements for the proper management of the SRS when it becomes disused, including financial provisions. The proposed directive would also impose
standard record keeping on holders of SRS. It would require holders to return or transfer SRS to a supplier or to a recognized installation for recycling, storage or disposal shortly after usage terminates. Conformance could be ensured by fees or license limitations. The directive includes provisions on SRS identification and handler training.

The proposed directive is to be implemented in EU states within two years, with national provisions expected to be applied initially to newly marketed SRS. Two further years are foreseen for application to existing SRS. According to the EU, there are four main categories of SRS:

- gamma sources, typically used in external beam radiotherapy, brachytherapy and sterilization,
- beta sources, used in thickness gauges, clinical therapy, education and training,
- alpha sources, used in smoke detectors, heat sources, and analytical practices and
- neutron sources, used in analytical practices, calibration techniques, and training.

The radionuclides involved are mainly Co-60, Cs-137, Ir-192, Am-241, Sr-90, and Ra-226.

In a July 18, 2002 opinion, the European Economic & Social Committee (ESC) said that the EC draft directive aimed at controlling or phan sources needs more work. The EU body’s opinion is not binding but the EC usually takes it into account. The opinion finds many aspects of the draft directive “a clear improvement on the rules currently in force.”

The ESC opinion notes some existing rules apply to lower activity sources and urges the EC to consider whether the directive “could be extended to cover sources involving lower levels of radioactivity.” The ESC said, “Under no circumstances should the field of application proposed by the EC be rendered less strict by confining the application of the directive to higher activity radioactive sources.” Moreover, the committee did not examine whether the proposed measures would inhibit deliberate misuse of SRS and urged that this issue be considered too. The ESC also urged clarification of the definition of “high activity source” in the proposal.

The ESC said the “financial provision” should be further specified. One possibility suggested by the ESC would be to require firms purchasing or renting SRS to pay a deposit, refundable on return of the SRS. Similarly, firms required to dispose or process used SRS could be made to establish a processing fund. The ESC faulted the lack of minimum requirements for reliability of the user in the draft directive. The ESC suggests requiring the holders of SRS to check, before a transfer is made, that the recipient holds an appropriate authorization. It also needs to be clear whether SRS must be identified and marked for every transport. “At all events the container should also carry information on the radionuclide and the initial activity,” the ESC said.

The ESC found the draft text vague about training and information requirements and on who is responsible for emergency preparedness during transports. The panel proposed mentioning in the directive’s preamble the “safety culture” required in dealing with radioactive sources.

The panel said the EC should give detailed consideration to costs of requirements, such as those for detecting radioactivity at scrap yards and smelting works. The ESC believes that the sensitivity of the tests and the measuring procedures should also be defined in detail. Finding
orphan SRS where there is efficient shielding or where no high energy gamma radiation is present is, however, “likely to be difficult.” The popular belief in the reliability of detection methods “could even under certain circumstances lead to those affected developing a false sense of security,” the ESC warned.

9.2 Topical Issue: FNCA Task Group on Spent Radiation Sources Management in the Philippines and Thailand

Based on a proposal from the Japanese Minister of Science, and Technology and upon agreement at both the first FNCA (see subsection 2.4, “Topical Issue: International Cooperation: The Forum for Nuclear Co-operation in Asia”) meeting held in Bangkok, Thailand on November 13, 2000 and the second FNCA Coordinators meeting on March 14-16, 2001, the "Task Group on Spent Radiation Sources Management in the Philippines and Thailand" was approved as a new activity for the FNCA’s Radioactive Waste Management Project [9.6]. Behind the Task Group is the fact that many problems remain to be solved on radioactive waste management and radiation protection, such as radiation exposure in Thailand (three people killed) and scrap metal contaminated with radioactive materials that was imported from the Philippines to Wakayama, Japan. It will be very significant, both academically and socially, to examine these problems within the cooperative framework of nuclear energy and radiation in Southeast Asia and to find a solution for these problems.

Meetings held to date addressed the following:

- experiences and lessons that include accident cases,
- status of spent SRS management in each country,
- international trends in the management of spent SRS, and
- possible enhancement of spent SRS management within the FNCA framework.

Through an open exchange of views and experiences among the participating countries, the management of spent SRS was recognized to be the most important factor for promoting the peaceful utilization of radiation and radioisotopes. It was agreed that exchanging information and experiences on important issues in an open way, based on mutual understanding, is most effective in improving the management of spent SRS. It was also agreed that an action plan based on the results of meetings would be offered to the other FNCA participating countries as practical information.

9.3 Examples of Member State Programmes and Experiences with SRS Management

9.3.1 Overview of SRS Management in Argentina

based on input provided by M. B. LaValle
Comisión Nacional de Energía Atómica

A large number of sources have been received at the Ezeiza Waste Management Area (WMA) within the framework of the Argentine Radioactive Waste Management Program (RWMP). Table 9-1 shows the various SRS currently handled at the Ezeiza WMA. In the table, SRS are categorized according to the scheme in IAEA-TECDOC-1191 [9.7]. Activities in Bq and have been decay corrected to 2001.08.31. For Radium, mass in grams is indicated.
### Table 9-1: SRS in the Ezeiza Waste Management Area

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Category I</th>
<th>Category II</th>
<th>Category III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number / Total Activity</td>
<td>Number / Total Activity</td>
<td>Number / Total Activity</td>
</tr>
<tr>
<td>$^{241}$Am</td>
<td>46</td>
<td>3.15E+12</td>
<td>800</td>
</tr>
<tr>
<td>$^{241}$Am/Be</td>
<td>40</td>
<td>9.74E+12</td>
<td></td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>39</td>
<td>1.57E+15</td>
<td>78</td>
</tr>
<tr>
<td>$^{252}$Cf</td>
<td>1</td>
<td>9.25E+08</td>
<td></td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>5</td>
<td>1.31E+14</td>
<td>50</td>
</tr>
<tr>
<td>$^{192}$Ir</td>
<td>1447</td>
<td>3.58E+10</td>
<td>1</td>
</tr>
<tr>
<td>$^{85}$Kr</td>
<td></td>
<td></td>
<td>68</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>3</td>
<td>3.71E+09</td>
<td>61</td>
</tr>
<tr>
<td>$^{208}$Tl</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td></td>
<td>24.03 g</td>
<td></td>
</tr>
</tbody>
</table>

SRS are under the control of the Regulatory Body. Once SRS are declared spent or disused, the Regulatory Body invites the owners/users of these SRS to transfer them to the RWMP.

The owners or users are required to contact the RWMP and provide detailed technical information about their SRS, which includes their radiological and physical characteristics as well as administrative data such as individual identification numbers and institutional permission numbers. The data are checked with the Regulatory Body and then a cost estimate is sent to the owner or user for consideration. When all arrangements, either technical or administrative, have been made, an SRS collection team consisting of operators and radiation protection personnel collects the SRS. Together with radiation protection and operational equipment, the team documents the transfer. A unique identification number is assigned to each SRS collected by the RWMP. This code provides information about the origin of the SRS and it is used for future identification.

Once SRS are in the custody of the RWMP, they can be either directly stored in their own shielding or conditioned for storage prior to disposal. Table 9-2 shows how SRS are managed, taking into account the half life of the radionuclide, its activity and the available facilities.
### Table 9-2: The Management of Spent and Disused SRS

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Typical Activity</th>
<th>Decay Energy (Kev)</th>
<th>Half-life</th>
<th>Origins</th>
<th>Applications</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{60}$Co</td>
<td>50 - 1000 Tbk</td>
<td>$\gamma$(1173;1333), $\beta$(max.: 318)</td>
<td>5.3 a</td>
<td>Medical</td>
<td>Teletherapy</td>
<td>Storage</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>500 Tbk</td>
<td>$\gamma$(662), $\beta$(max.: 512), e(624)</td>
<td>30 a</td>
<td>Medical</td>
<td>Teletherapy</td>
<td>Storage</td>
</tr>
<tr>
<td>$^{192}$Ir</td>
<td>0.1 - 5 Tbk</td>
<td>$\gamma$(317), $\beta$(max.: 675), e(303)</td>
<td>74 d</td>
<td>Industrial</td>
<td>Industrial radiography</td>
<td>Decay Storage for about two years, then disposal</td>
</tr>
<tr>
<td>$^{241}$Am/Be</td>
<td>1 - 500 GBq</td>
<td>$\gamma$(60), $\alpha$(5486), neutrons</td>
<td>433 a</td>
<td>Industrial</td>
<td>Well logging</td>
<td>Cementation in stainless steel drums followed by storage</td>
</tr>
<tr>
<td>$^{226}$Ra</td>
<td>30 - 300 MBq</td>
<td>$\gamma$(186), $\alpha$(4784)</td>
<td>1600 a</td>
<td>Medical</td>
<td>Manual brachytherapy</td>
<td>Retrievable storage</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>0.1 - 10 Gbk</td>
<td>$\gamma$(1173;1333), $\beta$(max.: 318)</td>
<td>5.3 a</td>
<td>Industrial</td>
<td>Level gauge</td>
<td>Cementation in steel drums followed by disposal at LLSWT</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>0.1 - 20 GBq</td>
<td>$\gamma$(662), $\beta$(max.: 512), e(624)</td>
<td>30 a</td>
<td>Industrial</td>
<td>Level gauge density gauge</td>
<td>Cementation in iron steel drums followed by storage</td>
</tr>
<tr>
<td>$^{85}$Kr</td>
<td>0.1 - 50 GBq</td>
<td>$\beta$(max.: 687)</td>
<td>10.8 a</td>
<td>Industrial</td>
<td>Thickness gauge</td>
<td>Cementation in iron steel drums followed by storage</td>
</tr>
</tbody>
</table>

LLSWT = Low level solid waste trenches

A computerized record-keeping system for tracking all radioactive wastes managed by the RWMP has been developed. The database contains essential information about spent and disused SRS as well.

#### 9.3.2 Management of Spent SRS in Belarus

*based on input from L. F. Rozdyalovskaya*

*Ministry of Emergency Situations*

Belarus uses a variety of SRS in various sectors of its national economy, research and medicine. National regulations prohibit the use of an SRS if its seal fails or if its service life is expired. The service life is normally specified in a “source passport” and, according to the rules, can be extended by a special commission on the basis of leak tests. The latter procedure is frequently used because many users do not have the funds to purchase new SRS.

Radioactive sources not suitable for further use are regarded as radioactive waste. Regulations require that the time of interim storage of such sources at a facility shall not be longer than six
months. During this time, the source must be decommissioned and transferred to the specialized facility Ekores for centralized storage or disposal.

The Ekores facility has a license to perform activities on collection, transport and utilization of spent SRS. Until recently there have been two options for SRS disposal. Those in protective containers with upper unloading were disposed of in the existing vaults for LILW together with their shielding containers. SRS from containers with bottom unloading were disposed of in borehole repositories known as “wells”.

Wells were constructed in accordance with the standard project TP-416-9-1 “Disposal radioactive waste facility” developed by the Moscow Project Institute (GSPI) for radon-type facilities of the former USSR in 1970. (Figure 9-1 (a)). The wells were designed for disposal of sources with the total radioactivity corresponding to a radium equivalent of 20 000 g-equiv. The maximum dose rate on the surface of the repository near the loading channel is designed to be less than 8 µSv/h The maximum allowable temperature is 230°C.

In April 2000, during an examination of the facility, Ekores staff detected a high field emanating from Rn-222 in a well. An expert mission team, under the Agency’s Technical Co-operation Project BYE/004/02, was called in to assist in the assessment of the situation, in particular to evaluate the safety of the wells containing long lived and radon-emitting sources. The investigation indicated that some of the sources in the well were partly unsealed. This was confirmed by the fact that the dust samples from the underground vessel contained Cs-137 (0.379 Bq/cm²) and Ra-226 (0.12 Bq/cm²). Trace amounts of water and elevated temperatures were observed in the problematc well. Investigations of the same type of repository in the Russian Federation showed that radiolysis of water and air may result in producing nitric acid, which accelerates corrosion of the shielding cases.

A study of geological and hydrogeological conditions at the Ekores site indicated a high water flux that could readily lead to contamination of the aquifer in the case of well failure. As a consequence, the possibility of incorporating the sources in the wells into a protective metallic matrix has been considered. The Agency mission team recommended the embedding of the SRS into a metal matrix in situ using a method developed and put into operation by the Russian Association RADON in the mid-1980’s [9.8]. A safety assessment report on the technology clearly showed a high degree of SRS isolation from the environment [9.9].

Given the situation in Belarus, the in situ metal matrix technology presents many advantages. First, it embeds SRS into a metallic matrix directly in the underground reservoir that makes the task of conditioning much more feasible. Second, the mobile unit used for conditioning in situ is in operation in the Russian Federation and may be available to Belarus without major problems. Third, according to proposed technological scheme, the metal matrix (block) can be retrieved from the underground repository. This last point is important because the disposal facility Ekores is regarded today as “interim for 20 years” according to the approved concept for its reconstruction [9.10].

There are a number of organizational and financial issues that should be settled before a final decision on the implementation of the technology in Belarus can be taken. Nevertheless, the work is expected to start no later than the summer of 2003. It is also expected that the technology should be applied to the new generation of borehole repositories, which are currently under construction at the Ekores site (described next).
Modernized borehole repositories for storage of SRS

Numerous storage procedures that had been used in the former USSR and those recommended by the Agency were considered by an expert team for the design for new facilities. The experts rejected the bulk conditioning of spent SRS into a cement matrix as recommended by Agency guidance due to many high activity SRS. The metal matrix technology was recommended.

The borehole facility design has been modernized to include retrieval of SRS. In the new design, a loading channel consists of three sections (see Figure 9-1 (b)). The bottom and top parts of the sections are designed to ensure a butt-joint connection while in operation and disconnection if retrieval is required. The weight of each section is about 3 tons and the weight of a reservoir fully filled, in the form of an entire metal block, is 2.2 tons. Therefore, a standard capacity crane could be used for reservoir retrieval.

Each section contains loading and auxiliary channels. One of the auxiliary channels ends near the bottom of the receiving reservoir, and the other – near its cover. The loading channel is used for loading SRS into the underground reservoir and for pouring molten metal. The loading channel is also used for pumping out water (if necessary) to keep the well dry. The auxiliary channels are used for making check measurements and, if necessary, for cooling of the receiving reservoir.

The modernized borehole repositories and the metal matrix technology are intended for managing SRS with less than ~30 years half lives (mainly Co-60 and Cs-137). Sources with longer half lives will be managed in another type of well (see Figure 9-2). These SRS mainly
include smoke detector sources containing Pu-239 and Am-241 that can be handled without beta/gamma shielding.

Pending construction of the new facilities, these types of SRS are temporarily stored in a simple metal vessel suitable for storage. Both types of modernized borehole facilities are under construction and are expected to be completed by July 2003. To put them into operation, the disposal facility “Ekores” should organize an expert assessment of the wells safety and obtain a license from the Regulatory Body (Promatomnadzor).

Figure 9-2: Boreholes for Long Lived SRS (> 30 year half lives)

9.3.3 Chilean Experience in the Management of SRS

*based on input by A. Sanhueza-Mir*

*Unidad Gestión Desechos Radiactivos*

*Comisión Chilena de Energía Nuclear*

Spent/disused SRS contained in measuring equipment used in industries and in radiotherapy and brachytherapy units in hospitals, represent the most common radioactive waste located throughout Chile. About 12 m³ of this kind of waste is collected annually. Activities range from several MBq (used in industry) up to several TBq (used in medicine). These SRS contain both short lived (half life less than about 30 years: I-192, Co-60, Sr-90 and Cs-137) and long lived radionuclides (Am-241 and Ra-226).

Options to manage SRS as waste are established in the country, through policies, regulations and practices. One of the options is storage for decay. This can be used for very short lived SRS, like Ir-192 sources. Users should have sufficient dedicated storage space and established procedures to control these SRS until their activity falls below the clearance level specified in regulations.
Another option is to return SRS back to the country origin. However, sometimes this option is too expensive for the user due to the high cost of transportation, exportation and the fee charged by the supplier. This last item can be so high that users may not have sufficient financial resources to cover the costs.

Disused SRS can also be transferred to another user, sometimes for a different purpose of use. However, the credentials of the receiver must be well known.

The most common way to manage spent/disused SRS in Chile is to use the services of the Unidad Gestión Desechos Radiactivos (UGDR) organized under the Comisión Chilena de Energía Nuclear (CCHEN). The UGDR has facilities for decay storage, for treatment and conditioning, and for storage prior to disposal. Methods used conform to Agency recommendations and are based on economic and safety considerations.

Industrial SRS (Co-60, Cs-137) are conditioned within their original shielding. The process involves minimizing the final package volume while maintaining fields to less than 2 mSv/h at the surface. An average of 80 SRS are processed annually using this method.

Non-gamma emitting industrial spent SRS (e.g. Sr-90, Am-241) can be taken out of their original containers and placed into smaller ones to minimize volumes for storage/disposal. Conventional risks and radiation dose levels surfaces have to be managed to levels as low as reasonably achievable, in accordance with worker exposure limits and final packaging. An average quantity of 10 SRS are managed this way annually.

Spent medical use SRS are small in size. They mainly derive from brachytherapy and skin-deep therapy. Activities range from low activity SRS (e.g. Cs-137, Ir-192) in the MBq range to high activity SRS in large shielding units, such as cobalt therapy SRS, in the TBq range. An average of 8 SRS are managed annually as waste with 0 to 1 units/year from cobalt therapy.

In accordance with Regulations for the Safe Transport of Radioactive Material [9.5], following volume optimization, an important issue is to immobilize only the activity permitted as non dispersible material. Once the parameters are determined, immobilization of SRS in a cement mortar takes place in standard 200 l drums.

Colour coded lines are placed on the containers to identify the radionuclides inside. Containers are also labelled with a number and the year processing was conducted. An average of seven 200 l drums containing spent SRS in a conditioned form, which totals about 1.4 m³, are stored annually in this way.

A recent achievement for the UGDR and the region is that the UGDR was nominated by the Agency and recognized by ARCAL (Regional Agreements of Cooperation in Latin America) as a Demonstration Centre for SRS management. Demonstration courses, provided by UGDR staff, are addressed to Group [8] A, B and C, Latin American and Caribbean countries, “which need the know-how with regard to handling and managing waste from nuclear applications, spent sealed radioactive sources being the most common in those countries”. A total of 34

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participants from 10 countries in the region have participated in the training courses offered by the UGDR and sponsored by the Agency in connection with CCHEN.

9.3.4 Management of Spent SRS in Hungary

based on input by A. Pető
Hungarian Atomic Energy Authority

Overview

There are over 15 000 SRS in use by some 500 users in Hungary. One company, the Institute of Isotopes Co. Ltd., is engaged in the manufacturing and recycling of SRS. The company is a significant exporter of SRS and is committed to accept repatriation of spent SRS originating from Hungary. The Public Agency for Radioactive Waste Management (PURAM), a state owned non-profit organization, is responsible for the management of radioactive waste, including the storage and disposal of spent SRS.

Regulatory system and management practices

The existing regulatory framework for SRS can be traced back to the 1960’s when the production and application of artificial radioactivity started in Hungary. The basic principle of regulation has always been a cradle to grave control.

All practices (production, trade, use, storage, disposal) involving radioactive materials are subject to licensing. License holders are required to maintain local registries of their inventories. There is also a central registry of all radioactive materials and users (licensees and licenses) in Hungary. Licensees must report all inventory changes to the central registry. Producers and distributors as special licensees report production and sales, therefore, SRS information enters the registry and the regulatory system at their ‘cradle’. At the ‘grave’, the waste management company is required to record and to report SRS storage or disposal. In between, it is the users’ responsibility to record all major changes in the status of their SRS (location, usage, transport etc.) and to report any change in ownership. The validity of licenses is adjusted to the recommended working life of the SRS. The competent authority inspects the licensees every 2-3 years to check the compliance with safety and security requirements, proper accounting and reporting and the inventory of SRS.

The license does not contain specific conditions for eventual SRS disposal, but in the licensing procedure the regulatory authority considers the availability of disposal options as well. The validity of the licenses corresponds to the recommended working life of the SRS. After this time, the user can apply for a prolongation of the license if the SRS passes the official leak tests. Otherwise, the SRS has to be transferred to a radioactive waste management facility.

Disused SRS are required to be held in a secure room separate from SRS in use. They are sent for disposal relatively quickly because the authority applies regulatory pressure. Licenses can be withdrawn, for example if there is no leak test or the SRS surpasses its recommended working life. The waste management organization PURAM accepts all types of spent SRS for storage or disposal. There is a charge for these services, but it is kept to a minimum so as not to prevent users from disposing of their disused SRS.
Long term storage and disposal of spent SRS

Since 1 July 1998, PURAM has been responsible for all tasks related to the collection, treatment, transportation, storage and disposal of radioactive waste of institutional (non nuclear power) producers. This responsibility includes the management of all spent SRS. At the same time, PURAM assumed responsibility for the operation of the only operational radioactive waste site in Hungary, the Radioactive Waste Treatment and Disposal Facility (RWTFD) at Püspökszilágy. The RWTFD consists of an ‘Active’ building (laboratories and waste treatment and storage area), shallow burial engineered concrete vaults (for bulk waste) and well type facilities (for spent SRS). The well type facilities have the following specifications:

Type ‘B’ - 16 wells of 40 mm diameter and 16 wells of 100 mm diameter, 6 m deep, stainless steel lined, located in a concrete monolithic structure. (Figure 9-3).

Type ‘D’ - 4 wells of 200 mm diameter, 6 m deep, stainless steel lined, located in concrete monolithic structure. (Figure 9-4).

Originally spent SRS were placed into the B and D wells and then grouted in position. This has now been reviewed and sources are now emplaced loose to allow for future retrieval. A review of the site safety case and environmental assessment is being undertaken to consider in particular the issue of special spent SRS and the presence of long lived ($t_{1/2} > 30$ years) isotopes.

The available capacity of the wells is sufficient with regards to the inventory and types of SRS and spent SRS in the country. There is no administrative limitation on the activity of sources that can be received other than the surface dose rate cannot exceed 10 mGy/h.

Management of long lived spent SRS

Currently, disused Pu sources are collected and stored at the Institute of Isotopes and Surface Chemistry. PURAM recently worked out detailed plans to construct a dedicated long term storage facility for long lived spent SRS in the ‘Active building’ at the RWTFD. Once the new facility opens, all spent SRS containing nuclear material (Pu and Pu-Be) will be transferred there.
By 1999, all Ra sources (641 pieces, circa. 4 g Ra) previously used in Hungary had been collected and stored together at the National Institute of Oncology. Subsequently these sources were repackaged into new capsules by the Institute of Isotopes Co Ltd. in line with Agency recommendations and transferred to the RWTDF for storage.

Summary

Overall, the security, safety and environmental implications of current management practices for SRS in Hungary are considered acceptable. There is effective regulatory control and tracking of SRS throughout their life cycle. The regulator holds accurate records of all SRS and it is possible to track movements of sources between different users. All sources have a maximum recommended working life after which time they either have to be submitted for formal recycling or transferred to a radioactive waste management facility. A central, safe and secure installation is available for storage and disposal of spent SRS, though this facility has to be improved to ensure that the sources are held in a more controlled and easily retrievable form.

There is always room for improvement. The most important issues to be addressed are:

1. The old bulk waste disposal vaults at the RWTDF contain some long lived spent SRS that may have to be recovered. The necessary actions will be based on the results of the currently ongoing environmental safety assessment of the site, and

2. The upgrade of the ‘Active’ building at the RWTDF to a retrievable waste store is required. Subsequently, long lived spent SRS currently stored in the existing wells and temporary storage locations in the country will have to be transferred to the new store.
9.3.5 Overview of the US DOE’s Off-Site Source Recovery (OSR) Project

based on input by J.P. Grimm
United States Department of Energy

Many long lived SRS are excess, unwanted, and orphaned in the United States industrial, medical, academic, and government sectors. This presents a growing problem because these sources are not suitable for disposal in shallow land burial facilities. Other appropriate disposal options are not yet available. The Off-Site Source Recovery (OSR) Project, managed by the US Department of Energy (DOE) at the Los Alamos National Laboratory (LANL), collects and stores these sources.

Long lived SRS consist mainly of Am neutron sources, other Am-241 sources, Pu-238 heat sources, Pu-239 neutron sources, and large Sr-90 sources. Large Cs-137 sources also typically exceed the US regulatory criteria for shallow, LLW disposal, but are largely recycled and remanufactured into new sources.

The US government recognizes that public health and safety risks are posed by unwanted long lived SRS. One of the most common isotopes used is Am-241. Many of these are used in oil and gas well-logging activities. These neutron sources are commonly owned by small firms lacking the physical capability and financial resources to provide safe storage.

Figure 9-5: An Emergency Response Team Recovers a Damaged Americium Neutron Source in Texas

Considerable numbers of heat sources containing Pu-238 once were used in manufacturing cardiac pacemakers. These pacemakers and Pu-238 batteries became obsolete in the 1970s with the onset of long life chemical battery technology. The OSR Project has recovered approximately 2 000 excess and unwanted pacemakers to date.

The most prolific use of long lived SRS in the US is in portable and fixed industrial gauges. Approximately 9 000 such sources, chiefly containing Am-241, are found in manufacturing and general commerce. Recovering these sources is particularly important because many are excess and unwanted, and commonly are lost, stolen or inadvertently discarded.
Beginning in the late 1990s, the DOE greatly expanded its SRS handling capacity at LANL to accommodate thousands of excess SRS from the commercial sector. Initially, neutron sources were chemically processed to eliminate neutron generation. However, this was determined to be unnecessary. Instead, excess and unwanted SRS are simply stored as radioactive waste at government nuclear facilities.

This strategy required developing new nuclear material containers specifically for long lived neutron sources. The first of these is a special-form overpack capsule for individual sources. The second is a multi-function container capable of providing safe storage, transportation, and ultimately disposal.

The special form overpack capsule

The special form capsule has been designed, tested, and certified in several configurations. Composed of thick walled stainless steel, it safely stores and ships damaged SRS or sources that for other reasons cannot be certified for transportation. Once closed, a special form capsule cannot be reopened. DOE and LANL continue to modify and fabricate these capsules to accommodate unique sources as they appear, especially from government nuclear research and development laboratories. These capsules are available for both government and commercial radioactive waste management activities.

The multi-function container evolved from containers used by DOE for transportation and disposal of transuranic waste. The container incorporates neutron shielding and accommodates considerable quantities of neutron sources without special handling requirements. The pipe overpack concept was modified to provide a narrow diameter (15 cm) inner payload container, within a standard 208-liter (55-gallon) drum. The annular space is filled with neutron shielding material. This multi-function container has been evaluated and approved by the government’s transuranic waste certification program, and is now acceptable for field recovery, transportation, storage, and disposal in the government’s waste repository.

Cost, Capacity, and Schedule

The OSR Project expects to store more than 14 000 long lived radioactive sources by 2010. More than 5 000 radioactive sources are already in storage at LANL. Another 4 000 radioactive sources are known to be excess and unwanted and are slated for recovery by 2005. Subsequent radioactive source recovery will occur at a pace depending upon numbers of sources declared excess and upon funding levels.
Current operating costs for SRS recovery and management average less than $USD 3 000 per source. This cost includes project management activities, recovery operations, storage facilities, and container procurements. This figure excludes the costs to site, design, and build a suitable disposal facility in the future.

![Radioactive Sources Prepared for Loading into a Multi-function Drum](image1)

**Figure 9-7: Radioactive Sources Prepared for Loading into a Multi-function Drum**

![Packaged SRS are Prepared for Shipping to Los Alamos](image2)

**Figure 9-8: Packaged SRS are Prepared for Shipping to Los Alamos**

**Ultimate Disposition**

The US has not established a disposition path for most long lived SRS. Currently, the only suitable disposal site is the Government’s Waste Isolation Pilot Project (WIPP), found in south eastern New Mexico (see subsection 8.2). WIPP is a geological repository mined in bedded salt formations. It is restricted to transuranic waste (TRU, classification used in the USA, see subsection 3.2) generated from the U.S. Government’s nuclear defence program.

A large share of waste from the OSR Project will be generated by the commercial and academic sector. These waste streams cannot be disposed with US Government waste at WIPP. Therefore, the OSR Project will develop and provide storage capacity until a disposal pathway is developed. OSR Project projections indicate less than 500 cubic meters of waste in shielded containers will require storage for an, as yet, unspecified time. The next step for the US Government is to examine disposal options.
Conclusion

The US’s OSR Project for managing large numbers of excess and unwanted long lived SRS addresses a substantial public health and safety risk, recovers SRS from the commercial and academic sector at an increased rate, and provides safe, storage pending the availability of a suitable repository.

References for Section 9

http://www.iaea.org/worldatom/Programmes/Nuclear_Energy/NEFW/wts_l8_01_SOURCE.html


9.6 Forum for Nuclear Co-Operation in Asia, Task Group on Spent Radiation Sources Management in the Philippines and Thailand”
http://www.fnca.jp/english/fnca/5_hosyasei/5/main.html


