SESSION 2b

Predisposal

—

Storage
### ORAL PRESENTATIONS

<table>
<thead>
<tr>
<th>No.</th>
<th>ID</th>
<th>Presenter</th>
<th>Title of Paper</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>02b</td>
<td>00</td>
<td>INV 02b</td>
<td>Storage: a Necessary Step towards the Endpoints</td>
<td>4</td>
</tr>
<tr>
<td>02b</td>
<td>01</td>
<td>159</td>
<td>E. Maset</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A. Smetnik</td>
<td>Application of SAFRAN Tool for the Knowledge Management at the Stage of Radioactive Waste Retrieval from Historical Radon-type Storage Facility</td>
<td></td>
</tr>
<tr>
<td>02b</td>
<td>02</td>
<td>202</td>
<td>M. Braeckevedt</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Russia Federation</td>
<td>40 Years of Experience of NIRAS / Belgoprocess on the Interim Storage of Low, Intermediate and High Level Waste</td>
<td></td>
</tr>
<tr>
<td>02b</td>
<td>03</td>
<td>214</td>
<td>S. Wisbey</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>United Kingdom</td>
<td>Protecting the Investment – Guidance on the Storage of Packaged Wastes in the UK</td>
<td></td>
</tr>
<tr>
<td>02b</td>
<td>04</td>
<td>216</td>
<td>J. Boelen (E. Verhoef)</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Netherlands</td>
<td>The Essence of Time in Policy and Design Radioactive Waste Management Strategy in the Netherlands</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>ID</td>
<td>Presenter</td>
<td>Title of Paper</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>----</td>
<td>------------------</td>
<td>--------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>02b – 05</td>
<td>29</td>
<td>D. Prifti Albania</td>
<td>Radioactive Waste Management and Centralized Interim Storage Facility in Albania</td>
<td>25</td>
</tr>
<tr>
<td>02b – 06</td>
<td>63</td>
<td>M.C. Bossio Argentina</td>
<td>Long Term Storage of Radioactive Waste in Argentina – Regulatory Framework</td>
<td>29</td>
</tr>
<tr>
<td>02b – 07</td>
<td>129</td>
<td>J. Mueth Switzerland</td>
<td>Waste Management in a National Institute</td>
<td>34</td>
</tr>
<tr>
<td>02b – 08</td>
<td>134</td>
<td>N. González Rodriguez Cuba</td>
<td>Safety Assessment for the Management of Disused Radioactive Sources from the Irradiation Facility Product I in Cuba</td>
<td>39</td>
</tr>
</tbody>
</table>
STORAGE: A NECESSARY STEP TOWARDS THE END POINT

E. Maset

National Atomic Energy Commission, Buenos Aires, Argentina

E-mail contact of corresponding author: maset@cnea.gov.ar

Nowadays the most accepted solution for high level waste and spent fuel is disposal in deep geological repositories. But, for many reasons, most of the countries have failed to advance towards the construction of a repository. Hence, these wastes will have to be stored, in processed and unprocessed forms, for varying periods of time, perhaps for long term.

Also, there are many other reasons why radioactive waste may be stored, for instance:

a) To allow for the decay of short lived radionuclides to a level that permit its release from regulatory control (clearance) or authorization for discharge, or recycle and reuse;

b) To collect and accumulate a sufficient amount prior to its transfer to another facility for treatment and conditioning;

c) To collect and accumulate a sufficient amount prior to its disposal;

d) To reduce the heat generation rate of high level radioactive waste prior to its disposal and, in some cases, prior to steps in its predisposal management;

Examples a), b) and c) are usually encountered at small storage facilities for radioactive waste, where storage is incidental to the primary purpose of the facility. Example d) is usually associated with larger facilities such as those of the nuclear fuel cycle.

The period of storage may be highly variable and may be only a few days, weeks or months in the case of storage for decay or storage prior to the transfer of waste to another facility. The storage facility may be located at the generation place, such as a nuclear power plant, hospital or laboratory, or it may comprise a separate entity such as a centralized or a national treatment and storage facility. Storage facilities can range from cabinets and closets at laboratories up to large facilities built for serving a nuclear power plant.

Long term storage may be necessary in the case of high level waste for cooling or for radioactive waste for which there is no disposal option yet available. For example some countries have historical disposal facilities, like trenches, which do not comply with current safety standards and waste have to be stored since the decision of reassessment or closing. Besides, nowadays is much more difficult to succeed in the siting of a repository than it was in the past, even for a near surface type.

A wide variety of waste types and storage needs may be encountered in practice, for example, in terms of the storage duration, radioactive inventory, radionuclide half-lives and associated radiological hazards. A special case is the wet or dry storage of spent fuel. Some countries are
evaluating the technological and safety aspects of multi-purpose casks for their storage, transport and disposal.

It must be considered the risks associated to the storage, both radiological and non-radiological, such as corrosiveness, flammability, explosiveness, toxicity and pathogenicity.

A storage facility should be designed and operated to ensure that the radiation protection of workers and the public is optimized as required and to ensure the containment and facilitate the retrieval of the waste. The design will depend largely upon the properties, the total inventory and the potential hazard of the stored material. Design features should last for the expected lifetime of the facility. When storage time is extended for longer periods than planned, some challenges must be faced like waste form evolution/degradation, relicensing, ageing management, regulatory considerations for storage time extensions.

In the generation and storage of waste, as well as subsequent management steps, a safety culture should be applied. Also, storage should be undertaken within an appropriate national legal framework that provides for a clear allocation of responsibilities and ensures the effective regulatory control of facilities and activities.

Some additional factors relevant to the safety and sustainability of storage facilities must be considered, such as:

Storage of radioactive waste has been demonstrated to be safe over some decades and can be relied upon to provide safety as long as active surveillance and maintenance is ensured. In contrast, geological disposal promises long term safety without surveillance and maintenance.

Maintenance is easier on the surface than underground, but institutional controls cannot be maintained for the period that the wastes remain hazardous.

Retrieval of material is easier from surface facilities than from underground facilities, but geological disposal can be developed in stages so that the possibility of retrieval is retained for a long time.

a) Putting hazardous materials underground increases their safety and security.
b) Disposal has a large capital cost; storage has a significant operating cost.
c) Storage facilities tend to excite less public opposition than disposal facilities.
d) Long term storage of radioactive waste requires transfer of information to future generations.

The safety of long term storage requires the maintenance of the industrial, regulatory and security infrastructure. Long term safety also requires that future societies will be in a position to exercise active control over the waste and maintain effective transfer of responsibility, knowledge and information from generation to generation. Long term storage is only sustainable if future societies can maintain these responsibilities.

Active controls cannot be guaranteed in perpetuity because there is no guarantee that the necessary societal infrastructure can be maintained in perpetuity. Therefore, for radioactive
wastes that remain hazardous for thousands of years, perpetual storage is not considered to be either feasible or acceptable.

The safety of geological disposal is widely accepted amongst the technical community and a number of countries have now decided to move forward this option. Storage and disposal are complementary rather than competing activities and both are needed. However, the timing and duration of the process of moving from storage to disposal is not only influenced for the sustainability of long term storage. Strategies for storage and disposal of waste involve, among others, transport from storage to disposal sites, security, safe packaging and conditioning, availability of suitable disposal sites, confidence that adequate levels of safety can be achieved, public acceptance and availability of finances.

In conclusion, storage must be as long as necessary but as short as possible.
APPLICATION OF SAFRAN TOOL FOR THE KNOWLEDGE MANAGEMENT AT THE STAGE OF RADIOACTIVE WASTE RETRIEVAL FROM HISTORICAL RADON-TYPE STORAGE FACILITY

A. Smetnik, D. Murlis

FSUE VO "Safety", Moscow, Russian Federation

E-mail contact of corresponding author: smetnik2000@yahoo.com

Abstract. Within the framework of the IAEA project “CRAFT” (2011-2014), specialists of FSUE VO “Safety” participated in working group “Safety assessment of the Radon-type facilities”. The IAEA GSG-3 methodology was used in order to address the issue of safety assessment of radioactive waste removal from historical near-surface storage facility of the Radon type. SAFRAN tool (Facilia AB (Sweden)) was used for qualitative safety assessment of a historical Radon type storage facility. Practical experience of SAFRAN application has shown that it can play a significant role in managing records and knowledge on radioactive waste, nuclear facility site, characteristics of geological environment and safety barriers. It can provide reliable long-term storage and effective management of safety related records for the purposes of safety reassessments, review and supervision.

Key Words: SAFRAN tool, knowledge management, radioactive waste retrieval, Radon-type storage facility.

1. Introduction

Safe radioactive waste retrieval becomes even more difficult due to absence of complete and reliable information about quantitative and qualitative inventory of radioactive waste, conditions of natural and engineering barriers, etc. at historical radioactive waste storage facilities which were constructed in 1950s and early 1960s of the 20th century.

Such issues as preservation of knowledge about facilities, of history records, knowledge transfer to future generations and assurance of competences of personnel involved into decommissioning and remediation activities, may raise difficulties, especially in case of historical facilities.

2. Results and discussion

Within the framework of the IAEA project “CRAFT” (2011-2014), specialists of FSUE VO “Safety” participated in working group “Safety assessment of the Radon-type facilities”. The IAEA GSG-3 methodology [1] was used in order to address the issue of safety assessment of radioactive waste removal from historical near-surface storage facility of the Radon type.

2.1. Safety Case

This work was important not only from the methodological point of view, but also from the practical one, since there are many similar storage facilities in the former USSR countries and countries of the Eastern Europe.
SAFRAN tool (Facilia AB (Sweden)) [2] was used for qualitative safety assessment of a historical Radon type storage facility.

The Radon-type facilities took their name from the RADON system that was established in the former Soviet Union for collecting, transportation, processing and near surface disposal of low and intermediate level institutional radioactive waste including disused sealed radioactive sources. Typical initial design of a Radon-type facility includes three or four disposal vaults of 200 m$^3$ each.

In the majority of Radon-type facilities, there are a few common problems relating to waste inventory records. One specific problem relates to the uncertainty associated with insufficient information on waste inventory, e.g. the waste is commonly labeled as ‘mixed fission products’ or simply ‘radioactive waste’.

Prior to waste retrieval from the Radon-type facility in Russia the radiation survey and visual examination of the facility and waste forms were performed. The results of radiation survey (dose rates on surfaces of waste forms and radionuclide activities) were included in SAFRAN tool. List of operations to be performed during retrieval of radioactive waste was also included in SAFRAN tool.

The full scope of the Safety Case includes the retrieval of solid RW from the RADON-type historical facility as a precursor to its decommissioning, historical waste packaging and preparation of waste packages for further transportation to existing authorized waste storage site.

The process of waste retrieval from each Vault is divided into the following phases:
- Phase I. Unloading of large-sized RW packages available for gripping and retrieval;
- Phase II. Unloading of small-sized RW packages;
- Phase III. Accomplishment of unloading of large-sized RW packages released from under the debris;
- Phase IV. Collection and packaging of spillages.

For illustrative purposes only the waste retrieval from Vault 1 is considered in this Safety Case.

Exposure dose rates calculated for normal operation in Phase I are presented in Table 1.

**TABLE 1. RESULTS OF EXPOSURE DOSE RATES CALCULATION FOR PHASE I**

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Doses to personnel at different sub-phases of phase I, mSv/y</th>
<th>Total dose (Phase I), mSv/y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area A, B</td>
<td>Area D, E*, F</td>
</tr>
<tr>
<td>I1</td>
<td>I2</td>
<td>I3</td>
</tr>
<tr>
<td>Slinger</td>
<td>3.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Hoist man</td>
<td>0.45</td>
<td>0.53</td>
</tr>
</tbody>
</table>
Area E is the area for primary attendance of Supervisor. He uses industrial television for the observations in other areas.

Table 2 presents values of cumulative doses calculated for the full duration of waste retrieval operations.

After comparison of the columns in the tables 1-2, we can give a note regarding the worker with the highest dose (the slinger) – 6.2 mSv/y for normal operation. He will receive the major dose during Phase I: Unloading of large-sized RW packages available for gripping and retrieval – 5.8 mSv/y. This operation is the most critical from the radiation safety point of view, and important for further considerations. The other three phases are less dangerous. During these three phases slinger will receive the total dose - only 0.4 mSv/y.

The results of the quantitative safety assessment for the retrieval of the waste from the Vault 1 as reflected above are well within the national and international safety criteria for workers and the public.

**TABLE 2. DOSES TO PERSONNEL AT DIFFERENT PHASES OF WASTE RETRIEVAL**

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Doses to personnel at different phases of waste retrieval, mSv/y</th>
<th>Total dose, mSv/y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Phase I</td>
<td>Phase II</td>
</tr>
<tr>
<td>Slinger</td>
<td>5.8</td>
<td>0.19</td>
</tr>
<tr>
<td>Hoist man</td>
<td>2.1</td>
<td>7.4E-2</td>
</tr>
<tr>
<td>Health Physicist</td>
<td>0.83</td>
<td>5.7E-2</td>
</tr>
<tr>
<td>Supervisor</td>
<td>1.3</td>
<td>8.9E-2</td>
</tr>
<tr>
<td>Check man (RW Accounting Person)</td>
<td>0.56</td>
<td>5.2E-2</td>
</tr>
<tr>
<td>Decontaminator</td>
<td>0.39</td>
<td>3.3E-2</td>
</tr>
</tbody>
</table>

Results of SAFRAN calculations indicated a maximum dose rate to a worker of 6.2 mSv/a under normal conditions and 7.0 mSv under accident conditions during radioactive waste
retrieval. The maximum public dose under accident conditions is 0.8 µSv, with negligible public dose under normal conditions. The safety case demonstrates full compliance with national and international dose limits and dose constraints.

2.2. Conclusions

Practical experience of SAFRAN application has shown that it can play a significant role in managing records and knowledge on radioactive waste, nuclear facility site, characteristics of geological environment and safety barriers. It can provide reliable long-term storage and effective management of safety related records for the purposes of safety reassessments, review and supervision.

Main advantages of SAFRAN:
• It uses methodologies agreed upon at the international level, namely, by IAEA standards;
• Several experts can work more effectively when performing the same safety assessment. SAFRAN makes it easier to exchange experience through sharing projects and data bases;
• It is helpful for systematic and structured safety assessment as per safety standards;
• It manages information and data in the same software environment.

REFERENCES


40 YEARS OF EXPERIENCE OF NIRAS/BELGOPROCESS ON THE INTERIM STORAGE OF LOW-INTERMEDIATE AND HIGH LEVEL WASTE

N. Huys, M. Braeckeveldt, B. Ghys

Belgoprocess, Mol, Dessel
NIRAS, Brussels, Belgium

E-mail contact of main author: niels.huys@belgoprocess.be; bart.ghys@belgoprocess.be; m.braeckeveldt@nirond.be

1. Introduction

ONDRAF/NIRAS is responsible for the management of all radioactive waste in Belgium. ONDRAF/NIRAS has a policy of centralised waste management, making use of processing and interim storage facilities centralised in Dessel (site BP1) and Mol (site BP2). These facilities are operated by BELGOPROCESS, the industrial subsidiary of ONDRAF/NIRAS.

2. History

Nuclear activities in Belgium strongly developed from 1955 (nuclear research centre SCK•CEN, Eurochemic reprocessing facility, …) and so the production and interim storage of radioactive waste. Upon 1982 sea dumping at high depths of low level radioactive waste, based on a dilute and disperse model was the selected waste disposal flow. Quality requirements of the waste drums made of carbon steel were aligned with the relative short cycle time between production of the waste and the interim storage on site. The waste was conditioned in a standard cement mortar or a bitumen matrix.

With the moratorium on sea dumping, a re-orientation on the waste management program was set up with the focus on the realization of a surface disposal solution for low level waste (LLW) in the mid 90’s. Interim storage solutions were developed and the quality of the waste drums was improved. For interim storage a new storage building for LLW waste (building 150) was constructed and became operational in 1986. The storage of the drums had to be done with forklifts. The waste drum was galvanized so that there was a guaranteed life cycle of 10 years.

As of 1989, further quality enhancing steps were introduced. A new, improved and enlarged interim storage building for LLW with a capacity of 40,000 400 liter drums was put into service (building 151).

In 1995 the surface disposal decision for LLW waste was further delayed. New quality improvements on the waste drums had to be made. A new waste processing and cementation installation CILVA was installed at Belgoprocess. The galvanized drum received an epoxy coating to extend life expectation to a minimum of 75 years. The bottom plated was reinforced to prevent deformations during conditioning.

ONDRAF/NIRAS has introduced a license request in 2013 for a disposal site for so called cat A-waste (short-lived low and intermediate level radioactive waste) in Dessel. In line with the disposal facility, a new waste post-conditioning facility will be operated. Following the current planning, the disposal and post-conditioning facility will be operational from 2022.
Beside the interim storage of LLW, several other interim storage facilities for ILW, HLW and spent fuel from the research reactor BR3 have been put into service on the BP1 site. For the ILW and HLW waste, ONDRAF/NIRAS has been studying geological disposal in a clay layer as the reference option since more than 30 years. There is still no institutional policy in Belgium for the long-term management of this waste (including spent fuel if declared as waste).

3. Storage facilities

The conditioned waste is stored in different appropriate buildings on the site BP1.

- **Building 150** (storage of LLW) is now completely filled with cemented packages of different volumes (400, 500, 1000, 1200, 1500, 1600, and 2200 liter).
- **Building 151** (storage of LLW) is now almost complete filled with cemented 400 liter packages.
- **Building 127**, for the storage of bituminised and cemented ILM waste in 220 and 400 liter packages. **Building 129** for the storage of HLW in canisters mainly arising from the vitrification of liquid waste from the Eurochemic reprocessing facility.
- **Building 136**, modularly designed, for the storage of HLW and ILW waste coming from the reprocessing in France of spent fuel from Belgian NPP. It can store canisters with vitrified waste, canisters with compacted hulls and end pieces and other types of ILW packages.
- **Buildings 155**, for the storage of mainly 400 liter drums with cemented ILW alpha- and radium-bearing waste.
- **Building 156 for the storage of** irradiated fuel from the BR3 reactor.


<table>
<thead>
<tr>
<th>Buildings</th>
<th>Number packages (#) / volume (m³)</th>
<th>Capacity (m³)/filling rate (%)</th>
<th>Activity (Bq)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alpha</td>
</tr>
<tr>
<td>127</td>
<td>15910 / 3885</td>
<td>4650 / 83.5%</td>
<td>3.3 $10^{24}$</td>
</tr>
<tr>
<td>129</td>
<td>2335 / 215</td>
<td>250 / 86.1%</td>
<td>1.7 $10^{15}$</td>
</tr>
<tr>
<td>136-Zone C</td>
<td>390 / 70</td>
<td>106 / 66.2%</td>
<td>8.1 $10^{16}$</td>
</tr>
<tr>
<td>136-Zone D</td>
<td>556 / 147</td>
<td>600 / 24.5%</td>
<td>1.8 $10^{14}$</td>
</tr>
<tr>
<td>150</td>
<td>3330 / 1922</td>
<td>1929 / 99.6%</td>
<td>1.9 $10^{12}$</td>
</tr>
<tr>
<td>151</td>
<td>34446 / 13985</td>
<td>14707 / 95.1%</td>
<td>5.6 $10^{13}$</td>
</tr>
<tr>
<td>155</td>
<td>6603 / 2694</td>
<td>4221 / 63.8%</td>
<td>1.8 $10^{13}$</td>
</tr>
<tr>
<td>156</td>
<td>7 castors</td>
<td>8 castors / 88.0%</td>
<td>2.0 $10^{15}$</td>
</tr>
</tbody>
</table>

4. Inspection of the waste packages during interim storage

ONDRAF/NIRAS and Belgoprocess decided to use a 400 liter drum as a standard package for the interim storage of LLW. New waste processing and storage facilities were adopted to this standard package.

The quality of the 400 liter drum was improved over the time (from a carbon steel drum over a galvanized version up to an extra epoxy protection layer. The design of the drums was also improved over the years in order to improve the mechanical integrity. During the years in
some cases a deformation of the bottom plate was observed due to the filling of the drum from an elevated height. This impact caused in some cases a deformation and reinforcement in the design was made. The waste was centralized in the center of the drum and a filling space was maintained between the waste and the drum to avoid contact between the waste and the drum after pouring of the cement matrix.

Quality control and requirements drastically improved over the years going from corrosion studies in the design, quality plan, quality follow up during construction and factory acceptance test of the 400 liter drums.

In 2003 ONDRAF/NIRAS and Belgoprocess decided to start an inspection program for all the stored conditioned waste drums. The objective was to classify the stored waste packages, after a visual inspection. In case of observations of non-conformities with the waste acceptance criteria (e.g. degradation of waste packages due to corrosion phenomena) specific measures were taken.

This inspection program took several years and ended around 2012. Beside this overall inspection program, specific systematic inspection campaigns were defined for the newly stored waste packages. Before storage, full recording of all visual aspects of the waste package takes place and for a number of waste packages (so called witness packages), a full visual inspection takes place the first time three years after storage and then every ten years.

5. Observations of the inspection program on the conditioned waste

In the following, the main observations of the inspection program performed between 2003 and 2012 are described.

In the conditioning processes there are 2 main conditioning methods. One being a homogeneous conditioning method where the waste is homogeneously mixed in a matrix and poured into a drum. A second method is heterogeneous condition where the waste (eg pellets of compressed drums) are put into a drum and a conditioning matrix is poured around the waste. As a matrix typically cement is used. In the past also a bitumen matrix was used.

5.1. Low level waste

5.1.1. Expanding bitumen - Reterogeneous solid bitumen waste

For this type of waste, a swelling phenomena of the bitumen was observed.

![FIG. 1.](image)

Cause:
Due to radiolysis, hydrogen production takes place. Because of the solid waste structures inside the bitumen, a preferential path was created accumulating the gas in certain spots and pushing out the bitumen.
RX pictures were taken and demonstrated that these bells were present.

Interim storage:
The affected drums were placed in an over pack after puncturing the original drum in a protected environment.

5.1.2. Corrosion of drums

For a number of waste packages produced in the period 1983-1990 a corrosion phenomena was observed.

![FIG. 2.](image)

*Cause:*
Analysis showed that despite the high quality of the drum, the corrosion was initiated due to a contact of the waste with the metal surface of the drum. Due to this observation placeholder and baskets were developed to prevent direct contact.

*Interim storage:*
The affected drums were placed in an overpack.

5.1.3. Homogeneous conditioned concentrate waste

A yellow gel-like material was found on the outer surface of the lid of a LLW-package. This waste package, a 400-liter drum with borated evaporator concentrate immobilized in concrete and produced in 1995 by the nuclear power plant of Doel was taken out of interim storage and opened by way of removing the lid. The gel-like substance was found on the whole of the surface of the concrete matrix.

After similar observations on waste packages containing the same type of waste, ONDRAF/NIRAS and Belgoprocess broadened the scope of its inspections to waste packages from a wide range of production periods and loaded not only with concentrates, but also with ion exchange resins and filters discharged from the primary circuit of the nuclear power plant Doel.

During these inspections, several packages were opened and some of them showing the presence, to some degree, of the gel-like substance. An alkali-silica reaction (ASR) has been identified as the most likely root cause for this phenomenon.

![FIG. 3.](image)

**FIG. 3. Opened drums with evaporator concentrates conditioned by the nuclear power plant of Doel**

ONDRAF/NIRAS and Belgoprocess developed a roadmap in order to deal with this situation, covering amongst others a major inspection programme on some 9000 potentially affected waste packages that will take place between 2002 and 2018, a research and development programme to better understand the ASR- phenomenon and avoiding this event in the future, the construction of a new interim storage building for the potentially affected waste packages. From an operational point of view, the nuclear power plant Doel halted the conditioning of evaporator concentrates and ion exchange resins on its Doel site.
5.2 Intermediate level waste:

5.2.1. Expanding homogeneous conditioned sludge of salts in bitumen

This type of waste was produced from 1976 till 1999 in the Eurobitumen installation. The salts were the remaining product out of a liquid treatment and concentration step. The end product was poured into a stainless steel drum.

**FIG. 4.**

**Cause:**
Due to a phenomena a radiolysis there was a formation of hydrogen, expanding the bitumen and pushing out the matrix.

**Mitigation:**
A safety study was performed if hydrogen formation could be a problem on the safety of the storage by creating a dangerous atmosphere. The concentrations are so low that there is not a problem. Measurement of the exhaust air confirm the study.

5.2.2. Discoloration

The first like 5874 drums of 200L from the Eurobitumen conditioning of sludge of salts with bitumen - were poured into chromated drums. Only on these type of drums, a coloration of the welds was noticed.

**FIG. 5.**

**Cause:** Corrosion investigation demonstrated that the phenomena was caused by the construction method. The chromated surface was cut and welded into the cylindrical form. By cutting and welding after chromation impurities were included into the weld and causing the discoloration.

**Mitigation:**
A drying system on the ventilation was installed.

6. Conclusion

ONDRAF/NIRAS and Belgoprocess have gained over time an extended experience on the interim storage of Low-Intermediate and High level waste. An systematic inspection strategy was developed in order the verify the conformity of the different waste-packages and corrective measures were taken to guarantee safe storage conditions.
PROTECTING THE INVESTMENT – GUIDANCE ON THE STORAGE OF PACKAGED WASTES IN THE UK

C. Naish, P. Skelton, S. Wisbey

RWM Harwell, Oxfordshire, OX11 0RH, UK

E-mail contact of main author: simon.wisbey@nda.gov.uk

Abstract. Radioactive Waste Management Limited (RWM), a wholly owned subsidiary of the Nuclear Decommissioning Authority, has a mission to deliver a geological disposal facility (GDF), and to provide radioactive waste management solutions for all Higher Activity Wastes in the UK. The planned opening of a GDF is still decades away, and in the interim period the waste packages must be stored safely, securely and under conditions that maintain their disposability. Guidance on an integrated approach to the interim storage of waste packages is maintained through the pan-industry Store Operations Forum, led by RWM. This paper summarises the key elements of the Industry Guidance, focusing on waste package performance and system assurance, via package baselining and planned inspection regimes, and indicates how it is being used to meet the needs of waste packagers and regulators in the UK.

Key Words: radioactive waste management, storage, guidance, monitoring and inspection

1. Introduction

Decommissioning of the legacy nuclear infra-structure in the UK represents a significant investment. Large quantities of radioactive waste are being prepared for disposal, so that by 2015 more than 50,000 conditioned waste packages were in storage at sites across the UK. Waste storage is an essential component of the higher activity waste (HAW) management lifecycle and provides a safe, secure environment for waste packages awaiting final disposal. A system of robust storage arrangements provides high confidence that packages will be disposable at the end of the storage period.

The waste packages, and the stores that protect them, are key assets that require active management. The UK Industry Guidance, first published in 2012, is maintained and updated through the Store Operations Forum (SOF). The SOF drives strategy development through shared learning concerning the storage of containerized HAW across the UK prior to disposal, and ensures that this HAW Industry Guidance document represents good practice.

2. Overview of the Guidance on Storage

The UK Industry Guidance was developed through an Integrated Project Team, which met between 2009 and 2011, engaging with the industry and UK nuclear regulators through workshops and commissioned development work. The current version, published in 2016, covers a broad range of waste package types, including stainless steel, mild steel and concrete containers [1]. It also includes guidance on decay storage management, along with sections on the approach to setting environmental controls. To accommodate the diversity of UK HAW, the Guidance describes six common principles, which are summarised below:
- Packages should be managed to protect their overall longevity, from manufacture of the container through retrieval and export to closure of a disposal facility.
- Good package design should be matched by appropriate store design, taking due account of the hazards presented by the waste packages.
- The waste hierarchy should be deployed across the system’s lifecycle, from design through to decommissioning of the store, to avoid unnecessary generation of waste.
- The storage system should be managed to minimise the risk that intervention will be required to maintain safety functions.
- The storage system design should be flexible to meet likely future needs that take account of uncertainties and incorporate proportionate contingencies.
- The experiences and lessons learned from existing store operations should be shared between Store Operators to inform the development of standards and designs.

The Guidance covers design and performance relating to: waste packages, store structure, store operations and system assurance. It identifies a number of specific ‘approaches’ that can be applied by waste managers, covering the lifecycle of interim storage and variations in HAW properties. Foremost among these is guidance on Operating Limits and Conditions for the temperature and relative humidity of the store atmosphere, and for the chloride concentration on package surfaces. The Guidance lists examples of good practice, supported by toolkits. When implemented together, the Guidance forms an ‘integrated approach’ to interim storage, from the design of new stores to the eventual export of waste packages.

3. Waste Package Performance

Waste packages provide a number of safety functions, in particular:

- **Containment** during normal operating conditions, and under accident conditions arising from impact events and thermal excursions
- **Identification** by unique markings, linked to accessible package records
- **Handling**, for emplacement and retrievability
- **Stacking**, to maintain emplaced position and withstand stacking stresses
- **Venting** of gases, to avoid over-pressurisation
- **Shielding**, to protect workers at a GDF and members of the public during transport
- **Criticality prevention**, by preservation of a safe distribution of fissile material.

For each safety function the performance defined by relevant measurable indicators can be assigned to one of three performance zones (Ideal, Tolerable and Failing), as shown in FIG. 1.
These performance zones are defined as follows:

- **Ideal**, where evolution has no negative bearing on safety performance – this is bounded by ‘Optimum performance’, which defines the target specification and a ‘1st trigger level’, which defines the transition from ideal to tolerable performance.

- **Tolerable**, where evolution has led to detectable change, while retaining acceptable performance – this is bounded by a ‘1st trigger level’, which defines the transition from ideal to tolerable performance, and a ‘2nd trigger level’, which defines the transition from tolerable to failing performance.

- **Failing**, where evolution has led to a significant loss in performance, but a ‘margin of safety’ is retained – this is bounded by a ‘2nd trigger level’, which defines the transition from tolerable to failing performance, and ‘Minimum performance’, which defines the lowest performance at which the safety function is still provided.

The measured package performance metrics can be plotted on the chart shown in FIG. 1 as a function of waste management phase. This approach is being utilised by Store Operators to provide transparent and consistent indicators for long-term package safety, with full visibility to key stakeholders. The information can also be used to define when intervention may be required to maintain safety functions. Although the approach is focused on the waste package, it may be adapted to include aspects of the storage environment, and life-limiting components of the store structure.

4. **System Assurance**

The Industry Guidance encourages all storage systems to implement a well underpinned monitoring and inspection regime. This should be proportionate to the ‘risk’ from the waste packages and the operational experience of the storage system type.
4.1. Baselining

The baseline condition relates to each of the storage system components. Once established, departures from these initial conditions can be detected through regular monitoring and inspection, and any necessary intervention can then be planned. The baseline condition for each waste package would ideally be fully established prior to import to the interim store, whereas the baseline for store environmental conditions needs to be established over an extended period (at least one calendar year).

4.2. Monitoring and Inspection

A robust system of inspection and monitoring of waste packages should be established. This may include environmental monitoring and inspection of life-limiting components. The frequency of inspections should be based on ALARP considerations, noting the positive safety benefits realised by monitoring and inspection. There are opportunities to reduce the number of active package movements for inspection, including: use of dummy packages; exploitation of small-scale samples, and; sharing monitoring and inspection results from similar stores.

On the basis that packages are subject to a monitoring and inspection regime focused on the appropriate indicators, information will be obtained to allow evolutionary traces to be plotted on the package performance figure, as shown in FIG. 2 (example cases ‘a’ to ‘d’).

4.3. Intervention

Intervention should be used to prevent the unacceptable deterioration of waste packages, and maintain or restore the safety function. Any intervention needs to be planned with care, as poorly planned or implemented actions may have unanticipated consequences.

FIG. 2. Hypothetical Patterns of Package Evolution
Five approaches to intervention have been defined to address potential evolution, as follows:

- ‘Zero implication’, which is restricted to expert assessment desk studies (e.g. may be an appropriate response to case ‘a’ in FIG. 2)
- ‘Low implication’, in which additional physical information about package performance would be collated (e.g. may be an appropriate response to case ‘b’)
- ‘Active intervention’, which may require changes to the operation of the storage system (e.g. may be an appropriate response to case ‘c’)
- ‘Non-invasive physical reworking’, which would seek to restore the safety function by direct contact with the container but without direct contact with the wasteform (e.g. response to case ‘c’, if the active intervention above does not arrest the change)
- ‘Invasive physical reworking’, which would restore the safety function by direct contact with the wasteform (e.g. may be an appropriate response to case ‘d’).

5. **Summary**

The UK nuclear industry has developed a system of Integrated Guidance for stores and store operations. This integrated system is now being applied by waste owners, and is providing a significantly improved measure of assurance that waste packages will be maintained in a state suitable for ultimate disposal.

**REFERENCES**

Abstract. The Dutch national framework for management of radioactive waste and spent nuclear fuel has been revisited in 2015. The Netherlands have a relatively small but broad nuclear programme. It has always prided itself to have a unique, safe solution in place attuned to its needs and possibilities.

Policy
The Dutch policy accepts that the nuclear operations are not able to support an immediate solution for disposal of long-lived high-level waste. It therefore adapted an approach to isolate, control and monitor the radioactive waste with an unique emphasis on a long-term, but well-defined pre-disposal phase accompanied by a financing scheme. The distinctive elements are a managed pre-disposal period of 100 – 150 years and transfer of ownership with full and final payment at acceptance of the waste at COVRA. Critics have sometimes described this approach as "bury your head in the sand" and of course care should be taken in developing the necessary policy and technical infrastructure comprises. However when well managed and structured this approach offers a practical and affordable solution for smaller countries without putting an undue burden on future generations.

Design
Because of the long-term storage, considering time in the design of waste packages, buildings and the site itself is essential. This paper addresses the challenges of designing for a long-term storage time. Specifically, how in the Netherlands COVRA has designed its facilities for the long-term from the outset. How a balance has been found between safety, security and safeguards, but also transparency and openness in the relation to the local community and the public at large. Awareness of the importance of all these factors in facility and site design helped to establish a good relation with the public and are key to communicate aspects as stability, carefulness, good quality, reliability over a long time. The paper concludes with showing how these aspects are applied in design and construction of the new building for depleted uranium and the extension of the building for high-level waste.

1. Introduction
The Netherlands literally means low lands; large parts of the country are indeed below the sea level. In their century-long struggle with water, the Dutch have relied on an approach of long-term, inclusive and pragmatic solutions. This approach is also reflected in the practical radioactive waste management policy.

In the Netherlands there are some 200 producers of radioactive waste, varying from nuclear power plants, research establishments, all sorts of industries and hospitals and (TE)NORM producing industries. Most of them generate only small volumes of low- and medium-level waste. These small volumes however cover a wide range of waste forms: solids, liquids of all natures, slurries, animal carcasses, machines, equipment, sealed sources etc. Some (TE)NORM processing industries generate larger volumes of solid low-level radioactive material. This includes also the depleted uranium resulting from the uranium enrichment plant in the Netherlands. Smaller volumes of high-level waste are produced by the nuclear power plants and by the research reactors.
2. **Legal framework**

The legal foundation of the policy governing nuclear activities, including all activities with radioactive materials, is contained in the Nuclear Energy Act (NEA) and the legislation based on it, together with the licences and relevant licence conditions.

This institutional arrangement for radioactive waste management follows the IAEA ‘classical triangle’ model. The model separates the three roles of the regulator, the waste producer and the waste manager/disposer. Each has separate responsibilities and must exhibit independence from the other. The nuclear sector in the Netherlands is regulated by the Authority for Nuclear Safety and Radiation Protection (ANVS), which began operating on 1 January 2015.

The NEA stipulates that a licensee can dispose of its waste only by handing it over to an authorised waste management organisation. As such the Central Organisation for Radioactive Waste (COVRA) is the only organisation authorised by the government of The Netherlands.

3. **Isolate, control and monitor**

Radioactive materials for which no use, reuse or recycling is foreseen, are isolated from our living environment. The radioactive materials are contained in such way that the risk of the ionizing radiation are controlled. Finally, the waste is monitored until a passively safe situation has been achieved.

Geological disposal is passively safe situation and currently regarded as the only safe option for the management of radioactive waste over the very long term. Any kind of storage (including long-term storage) of radioactive waste will always be a temporary solution and is not considered as an alternative to disposal. Long-term storage is essential because direct disposal is not yet feasible in the Netherlands.

Over thirty years already, the government of the Netherlands follows a straightforward policy based on the above-mentioned philosophy. All kinds and categories of radioactive waste are stored for at least 100 years above ground, in engineered structures, which allow retrieval at all times. This long-term storage, together with a central treatment facility is considered as a normal industrial activity and is located on a single industrial site. COVRA has been established to manage all Dutch radioactive waste. In principle, all the costs for radioactive waste management are borne by the waste producers. This includes all costs incurred by COVRA for collection, conditioning, storage and disposal. These costs are charged to the waste generators through COVRA’s fees.

The choice to store for a long time was well considered and was not taken as a ‘wait and see’ option. This is clearly demonstrated by the fact that integral parts of the policy are: the establishment of the capital growth fund, a clear choice for the ownership of the waste and a secured knowledge and know-how management at a common single place. This policy does not leave the burden of waste generated today to future generations. Only the execution of the disposal action is left as a task for the future.

4. **COVRA**

COVRA, founded in 1982, is the only organisation in the Netherlands that is authorized as a radioactive waste management company. Since 2002 all shares in Covra N.V. are held by the Dutch government. As COVRA takes over ownership of the waste, its fees must at a minimum cover costs, now and in the future, hence also including future disposal costs. The Dutch government does not provide structural financial support.

COVRA:
• Accepts ownership and full liability for the radioactive waste transferred.
• Collects and transports the waste to be treated.
• Treats low- and medium-level radioactive waste, creating an encapsulated stable product.
• Stores low-, medium- and high-level radioactive waste in purpose-designed buildings.
• Monitors and controls all stored waste and accurately registers all waste.
• Ensures that the radiation emitted during processing and storage is kept within the legal limits.
• Coordinates research on geological disposal.
• Communicates actively the population about these tasks and about the work done

5. Long-term, inclusive and pragmatic solutions

For centuries the Netherlands have been shaped by water: its history, landscape and infrastructure. A large part of the country is situated below sea level and would be flooded without the manmade dikes and natural dunes that hold back the waters of the rivers and the sea. The ever-present risk of flooding required the looking for long-term, inclusive and pragmatic solutions. Actually, early forms of democracy in the Netherlands were related to dike and sluice maintenance and management. From the thirteenth century onward, specialized water boards have assumed responsibility for local dikes and sluices. These boards still function today and have maintained and developed the system for flood protection and water management over centuries.

The lessons from the century-long struggle with water are reflected in the radioactive waste management strategy: a long-term, inclusive and pragmatic solution. Assuming this long-term responsibility has been taken into account from the earliest start of COVRA and is reflected in the organisational structure, the place of residence, the integral waste acceptance criteria and the design of equipment, buildings and infrastructure. In all aspects of the company the future requirements for disposal, long-term storage and financing needs are reflected in how it operates today.

Transparency and communication are an integrated part of the operations of COVRA. COVRA can only deliver its long-term objectives effectively when it fosters already today a good, open and transparent relationship with the public and particularly with the local population. When COVRA in 1992 constructed its facilities at the present site, from the beginning attention was paid to psychological and emotional factors in the design of the technical facilities. All the installations have been designed so that visitors can have a look at the work as it is done. Creating a good working atmosphere open to visitors was aimed at. The idea was not to create just a visitors centre at the site, but to make the site and all of its facilities the visitors centre. The storage building for high-level waste (HABOG) is more than an interim storage, it is a work of art. As a work of art it is a communication tool. Currently, the construction of a new building for the storage of depleted uranium is nearing its completion. Again a new spectacular work of art is created. The building will become the largest sun dial of Europe, indicating the phenomenon of time as important factor to render radioactivity harmless.

To ensure long term accessibility and access to support services and a skilled workforce, it was decided to set up COVRA at a conventional industrial estate. This also emphasises the fact that radioactive waste management in The Netherlands is considered a safe 'normal' industrial activity. The industrial site acquired is large enough to accommodate future growth.

In the design of the buildings and equipment for straightforward, robust basic equipment and constructions are preferred. Even the buildings themselves are designed for easy
maintenance. For instance by applying additional plating to shield the structural elements periodic maintenance is easy and cheap. No internal contamination is allowed. Hence at the end of the storage period there is no nuclear dismantling necessary it can be done by simple conventional means and even the re-use of the infrastructure for conventional activities is possible.

To ensure this approach is viable over the long term, it essential to have an integral requirements management system (RMS) in place. An RMS links in a logical and structured manner the (inter) national safety requirements, with permits and policies, with safety functions of components installations and buildings, with safety specifications down to acceptance and design criteria.

6. Conclusion

The solution chosen for the Netherlands creates at least six positive effects:

- Public acceptance is quite high for long term storage. The general public has more confidence in physical control by today’s society than in long-term risk calculations for repositories even when the outcome of the latter is a negligible risk.
- There is a period of 100 years available to allow the money in the capital growth fund to grow to the desired level. This brings the financial burden for today’s waste to an acceptable level without transferring it to future generations.
- During the next 100 years an international or regional solution may become available. For many countries the total volume of radioactive waste is small. Co-operation creates financial benefits, could result in a higher safety standard and a more reliable control.
- In the period of 100 years the heat generating waste will cool down to a situation where cooling is no longer required.
- A substantial volume of the waste will decay to a non-radioactive level in 100 years.
- A little bit more than 100 years ago, mankind was not even aware of the existence of radioactivity. In 100 years from now new techniques or management options can become available.

But this approach requires accepting a long-term responsibility from the outset.

The Netherlands followed a straightforward and clear line to implement the governmental policy to manage the small volume of radioactive waste. COVRA executes this policy: facilities are in operation to store low-, medium- and high-level waste for a period of at least 100 years. COVRA takes over full title of the waste and prepares financially, technically and socially the steps to be taken after this period of storage. This is a dedicated management solution for the Netherlands that works!
RADIOACTIVE WASTE MANAGEMENT AND CENTRALIZED INTERIM STORAGE FACILITY IN ALBANIA

D.Prifti, B.Daci, E.Bylyku

Institute of Applied Nuclear Physics, (IANP), Tirana, Albania

E-mail contact of corresponding author: berati77@yahoo.com

Abstract. In 1999 a new radioactive waste storage facility was constructed within territory of Institute of Applied Nuclear Physics (IANP) in Tirana, Albania for processing and storage of radioactive sources/wastes in accordance with National / International waste acceptance criteria. The safety assessment of this facility is performed considering its impact to workers, public and environment. The process of decommissioning of old interim storage facility in IANP began as result of its surrounding from the private houses at a 10-meter distance. In Albania, radioactive sources are used in medicine, industry, agriculture, research and teaching process. The new building is considered suitable for the radioactive waste processing and storage. The building structures are stable and endurable to withstand degradation processes over the operation period envisaged. The layout of the building is in accordance with generic IAEA design. The storage capacity will be sufficient for the needs of Albania over the anticipated operation period of 30 years. Radiation protection of public and workers can be ensured using this building for waste processing and storage. The building is equipped with entrance and exit for emergency situations. Visible signs of radioactivity are located, inside and outside this building. The building is equipped with elements of high security system. Inactive area is separated from the operational areas with a high security door. Entry and exit in the premises of the operational area and in other areas is done by inserting the input code. Management and treatment of radioactive waste is not a static process. Review of programs that deal with the problems for radioactive waste storage facilities is a permanent task of the staff working in this field. Rhythms of activities with radioactive sources in a near future in our country will be added and our study for them provides filling and closing of the works in the premises of this storage at IANP planned for 2030. For this reason is needed to undertake a study on the location and construction of a permanent storage of radioactive waste in our country. This study should be undertaken taking into account the guidelines and recommendations of the IAEA.

Keywords: Radioactive Sources / Waste, Storage, Waste Processing, Disposal.

1. Introduction

Since 1999 a new centralized Radioactive Waste Management Storage Facility (RWMSF) is constructed within territory of IANP for processing and temporary storage of radioactive wastes and disused sealed radioactive sources in accordance with National / International waste acceptance criteria (WAC) [2], [3]. The safety assessment of this facility is performed considering its impact to workers, public and environment [1], [4], [6]. The site receiving LLW/ILW of non-nuclear power plant origin (health care, industry, agriculture, education, research) has been operating since 1971 with a capacity of 60 m$^3$, reinforced by concrete / bricks vaults accommodating solid spent sources into drums. The process of decommissioning of old interim storage facility in IANP began as result of its surrounding from the private houses at a 10-meter distance. For that reason the staff of IANP had transferred all plastic bags, lead containers and 200-liter drums conditioned with $^{226}$Ra, $^{137}$Cs, $^{60}$Co into the new Radioactive Waste Management Storage Facility [7]. The temporary storage facility of LLW / ILW is operated based in the IAEA Recommendations, as well in the daily practice considering the country specific features. Institute of Applied Nuclear Physics (IANP) is the only institution in the country in charge for collection, import - export, transport, pre-treatment, treatment, conditioning and temporary interim storage of radioactive sources and radioactive wastes licensed by the RPC as the National Authority. IANP
collaborates with National Radiation Protection Commission (NRPC) for all radioactive sources entering Albania and carries out contracts with users for the conditioning of DSRS. The facility is designed based in the IAEA documents and consultancy [5]. There are two principal areas inside facility, Operational area and Temporary Interim Storage area. The centralized storage facility for waste management was designed, constructed and supported financially by Albanian government and equipped by IAEA Project. The license issued from RPC is renovated every five years.

![FIG.1 Operational area](image)

![FIG.2 Temporary Interim Storage area](image)

2. **Storage / Disposal Options in Albania**

The Albania schema of National Strategy for Radioactive Waste Management is shown below:

<table>
<thead>
<tr>
<th>Half life</th>
<th>Activity</th>
<th>Preferred</th>
<th>Options</th>
<th>Alternative</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{1/2}$ (Bq)</td>
<td>Processing</td>
<td>Final step</td>
<td>Conditioning Standard waste package</td>
<td>Disposal Near Surface Repository</td>
<td></td>
</tr>
<tr>
<td>&lt;100 days</td>
<td>All</td>
<td>Decay</td>
<td>Clearance</td>
<td>Processing</td>
<td>Final step</td>
</tr>
<tr>
<td>&gt;100 days</td>
<td>&lt; $10^6$</td>
<td>Conditioning Standard waste package</td>
<td>Disposal Near Surface Repository</td>
<td>Packaging for transport</td>
<td>Return at supplier or (other export)</td>
</tr>
<tr>
<td>&lt; 30 years</td>
<td>&gt; $10^6$</td>
<td>Packaging for transport</td>
<td>Return at supplier or other - export</td>
<td>Conditioning special waste package</td>
<td>Disposal Deep Repository</td>
</tr>
<tr>
<td>&gt;100 days</td>
<td>&lt; $10^3$</td>
<td>Conditioning Standard waste package</td>
<td>Disposal Near Surface Repository</td>
<td>Packaging for transport</td>
<td>Return at supplier or other - export</td>
</tr>
<tr>
<td>&lt; 30 years</td>
<td>&gt; $10^3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3. Safety Assessment of Radioactive Waste Management Storage Facility

The building of the waste storage facility is considered suitable for the waste processing and storage. The site of the building is considered suitable in terms of possible external effects; the close vicinity of population to the site is not considered to represent a problem for safety. Building structures are stable and endurable to withstand degradation processes over the operation period envisaged and also disruptive events (earthquakes) that may occur during the operational period. There are passive safety features:

- protecting against floods by passive drainage systems and concrete barriers
- the building and in particular the roof will prevent water entering into the storage facility
- safety inside the storage facility does not rely on active systems like ventilation (which is only needed in the waste processing section of the building during the work)
- wastes are protected by several physical (embedding in concrete, building structure, fences around the institute) and organisational (access control) barriers

The layout of the building is in accordance with generic IAEA design and suitable for the planned operations [5]. The storage capacity will be sufficient for the needs of Albania over the anticipated operation period of 30 years. Radiation protection of public and workers is ensured using this building for waste processing and storage [1,2,6]. The building is equipped with entrance and exit for emergency situations. Visible signs of radioactivity are located, inside and outside this building. Lighting system inside the building and outside is very efficient. The building is equipped with elements of high security system. Inactive area is separated from the operational areas with a high security door. Entry and exit in the premises of the operational area and in other areas is done by inserting the input code (PIN). Movement of staff inside the premises is under continuous monitoring of the cameras, which are connected to the central system for monitoring the movements in the main entrance. Acoustic signal and data on the light is strong and immediate functional if any foreign person touches or violates these environments [8]. Retention rate and readiness in an emergency is carried out by high security system that is already in this building.


The facility represents a solid concrete construction with outside walls of a thickness between 20 and 40 cm. All main entrances to the facility are protected with double security locks. There exists an alarm system, which is monitored by cameras at the main entrance by policeman. Behind the fences of the IANP begins a residential area. The closest buildings are at a distance of 60-80 m. The fence separating these building from the site has a height of 2 m. The waste management facility has been designed for VII\textsuperscript{th} degree of seismicity MSK-64; therefore no detrimental impacts from earthquakes are to be expected. There are no faults close to the site and geo-technical conditions are appropriate. In the site vicinity has no major industries with risk of explosion. There is a sufficient distance from railway lines and the airport (over 10 and 20 km, respectively). Exposures from incidents and accidents will be addressed in the emergency response planning, ensuring that adequate responses are taken. The dimensions of this building are 16 x 17 x 3.20 m.
5. Prospects of Radioactive Waste Treatment in Albania

Management and treatment of radioactive waste is not a static process. Review of programs that deal with the problems for radioactive waste storage facilities is a permanent task of the staff working in this field. Rhythms of activities with radioactive sources in a near future in our country will be added, and, our study for them provides filling and closing of the works in the premises of temporary storage in IANP planned for the year 2030. For this reason is needed to undertake a study on the location and construction of a permanent storage of radioactive waste in our country. This study should be undertaken taking into account the guidelines and recommendations of the IAEA for the design and construction of such buildings or special places for storage of radioactive waste with low and intermediate activity near the soil surface. For the DSRS should be provided for their return to the manufacturer after the end of working hours (consumption). In cases where return is not provided or is not feasible, and in other cases of unknown origin, the treatment of these radioactive waste or DSRS will be performed by IANP. Acceptance of these DSRS will be made on the basis of a draft agreement between IANP and interested companies. The experience of countries such as Turkey, Hungary, Czech Republic, Spain, France, and England, which have consolidated such activities, must be in consideration of specialists working in this field in our country for years to come.

REFERENCES


[6] Regulation Nr.313 dated 9.05.2012 "On protection of the public from environmental emissions, the definition of sampling, regions and frequency of measurement


LONG TERM STORAGE OF RADIOACTIVE WASTE IN ARGENTINA - REGULATORY FRAMEWORK

M.C. Bossio

Nuclear Regulatory Authority - Argentina

E-mail contact of corresponding author: mbossio@arn.gob.ar

Abstract. During the late 90’s facilities for the storage of radioactive waste in Argentina were constructed as short time storage. The delay in the availability of a final disposal site has led to interim storage for periods beyond design bases. The Department of Management and Control of Radioactive Waste of the Nuclear Regulatory Authority, has carried out specific inspections to verify the radiological safety of the actual facilities and established regulatory requirements in order to improve or modify their safety conditions. In addition, it has developed together with the Regulatory Standard Department guidelines for safe storage waste in accordance to the IAEA Safety Standards. The results of the inspections and the main requirements of the guidelines are addressed in the paper.

Key Words: Long term Storage

1. Introduction

Pacific uses and applications of nuclear energy in Argentina began in 1950, year in which the National Atomic Energy Commission (CNEA) was created. From the year 1970 until the late 90’s, the low level radioactive waste generated from the nuclear activities was disposed by the CNEA at the Waste management Area (AGE).

This site consisted on the following facilities:

- Two final disposal trenches for solid radioactive waste
- Two underground silos for the disposal of structural solid waste and disused sealed sources.
- Three trenches for very low level radioactive liquid waste disposal

In 1994, the article 28 of the Buenos Aires Constitution prohibited the entrance to the province of the radioactive waste that was generated outside Buenos Aires. In addition, by the year 1999, CNEA decided to suspend the operation of these final disposal systems due to changes in factors related to hydrology, meteorology and demography that might affect operativeness[1].

As consequence, the NPP’s operators of Embalse and Atucha I had to store on site the radioactive waste while waiting for another final disposal site. The storage facilities that were constructed were designed for short time storage. However, the delay in the availability of a final disposal site has led to interim storage of radioactive waste for periods beyond design bases. It is expected that these radioactive waste facilities should last at least 50 more years

Due to the fact that the AGE is located in the Ezeiza’s Atomic Centre, it only continued receiving the radioactive waste arising from the Nuclear Fuel Fabrication Plant (CONUAR), Mo-99 Production Plant, Research Centers, Research Reactor RA-3, and spent sources from Nuclear Medicine Centers.
In this context, the Department of Management and Control of Radioactive Waste of the Nuclear Regulatory Authority (ARN) carried out specific inspections to verify their radiological safety. In order to carry out the inspections, an exhaustive check list for design, operation, infrastructure issues and record keeping was prepared.

The check list took into account the following aspects:

- **For the design:** approval of safety assessments, lay outs, maximum inventory allowed, definition of zones for different kind or radioactive waste, maintenance, prevision for dismantling, i.e. preliminary dismantling plan.
- **For the operational stage:** contamination control, control of dose rate, airborne and gas measurements, dose rates inside the deposit, dose rates in contact with external walls, physical security and conventional security measures, correct radioactive waste characterization, especial arrangements and conditioning for radioactive liquid waste, retrievability for clearance and existence of treatment facilities.
- **For infrastructure and physical security:** existence of physical security such as fences, locks, humidity protection measures, ventilation systems, control of volatiles from drums containing oils, conventional security such as fire extinguisher and illumination
- **For the inspection itself:** possibility of visual inspection, arrangements for minimization for contamination, prevision for spillage, robustness of radioactive waste drums (contention resistant to deterioration), existence of radiation monitoring systems, epoxy coating in the floor and walls, existence and state of the ID of the drums, height of vertical storage of drum stacks.
- **For record keeping:** existence of procedures, updates of records, accidents or incidents records, perdurability of records.

2. **Results of the inspections**

The results of the inspections determined that many safety requirements had to be updated. For example, it was found that some deposits did not have epoxy coating, that visual or remote inspection of drums was not possible, high dose rates in contact with walls were measured and no illumination system inside the deposits was found.

As consequence, it was necessary to establish regulatory requirements to the nuclear power plants in order to improve or modify the safety conditions of the storage facilities. The requirements only apply to the already existing storage facilities at the NPP’s sites. As a result, the operator presented a schedule, for Atucha I and Embalse’s storage facilities, where it was established how the improvements were going to be fulfilled. During inspections carried out along the year 2015 and 2016, it could be observed that the stacking of drums was improved, floors and walls were covered with epoxy coating, deteriorated drums were repackaged, fire detectors were installed and zones for possible clearance of drums were defined.

Regarding the AGE, the ARN did not make a regulatory requirement due to the fact that the safety issues that need to be improved were established in an inspection act and began to be solved by this way.

In addition to the inspections, the Department of Management and Control of Radioactive Waste of the Nuclear Regulatory Authority has developed together with the Regulatory Standard Department specific guidelines for the safety criteria associated with the storage of radioactive waste in accordance to the IAEA Safety Standards [2]. The main safety requirements taken in to account are listed below [3]:

- Radioactive waste storage facilities should be designed and operated in such way that the radiological safety requirements for workers, public and the environment are guaranteed according to the ARN’s Safety Standards (AR.10.1.1. Basic Safety Standard and AR 10.12.1Radioactive Waste Management)[4].
- The responsible entity of a radioactive waste storage facility should develop safety assessments, taking into account the maximum radioactive inventory, for the design, construction, operation and decommissioning stages.
- The design and operation of the radioactive waste storage facility should guarantee the containment of the radioactive waste and allow their retrievability.
- The radioactive waste storage facilities should be designed and operated in such way that the probability of contamination is kept to the minimum as reasonable achievable, using for example, impermeable coatings, containments, etc.
- The radioactive waste stored should be characterized, including activity content of alpha, beta, gamma emitters and neutrons.
- The radioactive waste should be immobilized and the containment should be stable and resistant to deterioration. If it were necessary, shielding should be applied.
- The radioactive waste should be stored in such way that visual inspection can be performed.
- The design and operation of the storage facilities should take into account previsions for safety during normal operation as well as for low probability situations such as flooding, earthquakes, fires or other events. Radioactive waste storage facilities should count with security systems, such as, fences, video cameras, locks, as established in the ARN’s standards
- The design and operation of the storage facilities should be such that the maximum dose rate in contact with the external walls remains lower or equal to 10 μSv/h. In accesses, ventilation and cooling systems extra shielding may have to be considered in order to fulfill the dose criteria mentioned above.
- The surface contamination level at a radioactive waste storage facility should be kept as low as reasonably achievable.
- If radioactive liquid waste were to be stored, the facility should count with drainage systems and equipment to detect possible leakages until their immobilization is fulfill.
- The radioactive waste that in addition to radioactivity possess other hazards such as toxicity, inflammability, should be identified and stored in a different place than the rest of the radioactive wastes.
The radioactive waste that could be cleared from regulatory control after a certain decay period should be stored at a recognizable sector from the rest of the radioactive waste.

The responsible of the radioactive waste storage facility should count with the actualized mandatory documentation including the decommissioning plan.

Records associated to the operation of the radioactive waste storage facility should be kept according to the implemented quality system. The perdurability of the records should be guarantee.

Emergency procedures should be kept actualized and at reach of the personnel in charge of emergency situations. Storage Facilities should have appropriate technological devices of radiological protection according with the ARN requirements as ventilation, shielding, control leakages and control of temperature and humidity.

In addition, emphasis in the following requirements should be made for long term storage.

- Radioactive waste storage facilities should count with an identification system for the radioactive waste drums.
- Radioactive waste storage facilities should count with a record keeping system that guarantees the perdurability through time.
- Radioactive waste storage facilities should guarantee radiological safety and security during the storage period previous disposal.
- The responsible for the radioactive waste storage facility should demonstrate to the ARN that the integrity of the radioactive waste drums is kept during all the storage period.
- The licensee of the radioactive waste storage facility should present periodic radiological safety assessments to the ARN.

Storage facilities should implement the criteria established in the guidance using a graded approach depending of the type of radioactive waste, volume and radiological inventory.

Due to the fact that guidance are not mandatory, the criteria listed above is nowadays being included in the revision 3 of AR 10.12.1 Standard “Radioactive Waste Management”, in order to make it mandatory at national level. This revision is in the final process of approval.

4. Conclusion

Radiological safety of nuclear facilities is one of the main concerns of the Regulatory Nuclear Authority. Inspections, audits and new guidance are the result of the continued control to the operators. It is expected that all new storage facilities will adjust their design and construction to the safety requirements established in the new standard, that are in line with International references. In particular it’s important to mention that from now on, all facilities that will be constructed are required to present a safety assessment. In addition, existing facilities will be gradually updating those aspects regarding safety in order to comply with the new guidance.

REFERENCES


WASTE MANAGEMENT IN A NATIONAL INSTITUTE

J. Mueth
Paul Scherrer Institute (PSI), Villigen-PSI, Switzerland

E-mail contact of main author: Joachim.mueth@psi.ch

1. Introduction

The Paul Scherrer Institute (PSI) is the largest research institute for natural and engineering sciences within Switzerland. Its multidisciplinary research is dedicated to a wide field in natural sciences, medicine and technology as well as particle physics.

In this context since more than 30 years, PSI is operating:
- a large proton accelerator facility for medical and research purpose
- a hot laboratory
- the Federal Interim Storage for waste originating from Medicine Industry and Research (not from Nuclear Power Plants) and the facility for conditioning the waste (mainly with cement)
- old nuclear research facilities in decommissioning, that are (or still have to be) dismantled

This inevitably generates radioactive waste we are taking care of. At PSI the Dismantling and Waste Management Section is responsible for this task.

To achieve an optimal waste management strategy for interim storage or final disposal, radioactive waste has to be characterized, sorted and treated. This strategy is based on radiation protection demands, raw waste properties (size, material, etc.), and requirements to reduce the volume of waste; mainly for safety, legal and economic reasons. In addition, the radiological limitations for shipping of the waste packages to a future disposal site (planned in Switzerland to be in operation in approximately 40 years) have to be taken into account, as well as the ever-increasing regulatory and safety demands. All these activities are subject to changes kept up with the time. The main resulting challenges are listed below.

2. The Task

According to the law, the PSI operates the National Collection Center for all resulting radioactive waste from Medicine, Industry and Research (MIR) in Switzerland. Waste originating from nuclear power plants is not stored at PSI. The conditioned waste is stored in the Federal Interim Storage for radioactive waste, operated by the Institute.

Since the beginning of nuclear research in Switzerland, radioactive material is handled at PSI. The PSI was formed in 1988 through the merger of EIR (Eidgenössisches Institut für Reaktorforschung, Federal Institute for Reactor Research, established in 1960) and SIN (Schweizerisches Institut für Nuklearforschung, Swiss Institute for Nuclear Research, established in 1968). Further, the major part of nuclear research in Switzerland is performed at PSI.
3. Waste Management over the time at a research center

Radioactive waste arises by using radionuclides in medicine, industry and research (MIR), as well as by decommissioning of research facilities at the end of their life time. These are almost exclusively low and intermediate level waste (SMA), but some alpha-toxic waste is generated from industry, too (e.g. smoke detectors, investigations on spent fuel).

For archiving a good practice in waste management, you should know the requirements to the resulting waste packages. In Switzerland, two repositories are foreseen, one for low and intermediate level waste (SMA) and the other for high level waste (including spent fuel, which is not reprocessed and declared as waste) and long-lived intermediate level waste. All activities in waste management are influenced by the demands of a future geological repository as well as by the demands concerning transportation and interim storage, indicated by regulations and technical possibilities. Every change of those requirements and new developments influences the waste management processes and has to be qualified to remain for the next several years.

In the first twenty years of nuclear research, the waste was collected and stored in an elementary hall (1965 – 85). Radioactive material for commercial use, like radium or later tritium used for illumination paintings in e.g. the watchmaking industry, was once stored or disposed like conventional waste, before it was separated and collected. Nowadays, a large campaign is running in Switzerland to locate these former deposits for remediation.

As well as waste from the chemical industry, from 1969 to 1982 radioactive waste was dumped in the North Atlantic within the framework of campaigns organized by the OECD Nuclear Energy Agency (NEA).

Burnable low level waste was incinerated at PSI until 2002. Today, the Central Storage Facility (ZWILAG) is in operation for incinerating or melting the low level waste in a plasma incinerator.

In Switzerland the safe inclusion of waste in a stable matrix is standard and state of the art. Commonly, cement based mortar, in special formulas designed for this purpose, is used in Switzerland.

The conditioning of any radioactive waste, including spent fuel if declared as waste, requires an approval from the Swiss Federal Nuclear Safety Inspectorate ENSI. First regulations were done within the Atomic Energy Act in 1959 but radioactive waste was not mentioned. First precise regulations were done in 1980 by the HSK-Guideline R14, now edited as B05 by the ENSI. The nuclear energy legislation and the corresponding regulations require that the raw waste has to be minimized and conditioned as soon as possible. Approximately at the time when the regulations were established, it was decided that the Swiss radioactive waste has to be dumped in a deep geological disposal. The first estimation to provide a deep geological disposal for SMA has been achieved in the beginning of the 20th century. Waste, embedded in a stable matrix, was planned to be stored in waste packages approximately for two decades.

The first Federal Interim Storage was planned for this time-frame. It was finished and started to operate in 1992.

Today it is estimated, that a geological repository for SMA will not be ready for operation before 2050. With this prospect, the capacity of the Interim Storage is more and more dominating the management of waste.
An easy summary: First the waste was collected and stored. Different solutions of waste disposal were tested. Nowadays the radioactive waste in Switzerland has to be embedded into a solid matrix and will be kept in an interim storage until it will be transferred into a deep geological disposal. The time for the waste to stay in an interim storage is extending and as a result, the requirements and demands (technically and administratively, e.g. management of aging) are changing with the time and with stricter regulations.

Examples

In case of operational and dismantling radioactive waste, the existing conditioning methods (waste package in general, graphite, aluminum, bulk waste, burnable etc.) are in the process of a continuous enhancement – technically and administratively.

Drums are made of steel. They are part of the waste package. They have to shelter the conditioned and in mortar embedded waste. Further they have to fulfill transportation/handling purpose and shipment. Now, they must be made of stainless steel. Thus, to minimize corrosion during the time of interim storage and to reduce the corrosion rate in the repository.

Graphite is an example for the enhanced activities to minimize the volume of the conditioned waste packages under strong Swiss conditions (limited capacity for interim storage), suitable for “only” 40 t graphite to be conditioned) /1/, /2/.

Aluminium is an example for material with a highly gas production, if humidity would be present in a deep geological repository. In Switzerland, geological formations of Opalinus Clay are regarded as best choice to locate a deep repository. Among other positive aspects, this material is supposed to prevent circulation of water. Nevertheless, aluminium (if there is no possibility for decontamination or decay storage) has to be conditioned with a minimized surface to reduce the corrosion rate in a repository. The process used for conditioning aluminium originated from the research reactor DIORIT is described in /1/.

For burnable waste, which could generate gas from the decay of organic substances, the standard method in Switzerland is the incineration, melting and vitrification at the Plasma Facility at ZWILAG.

With the focus on volume minimization of very low radioactive organics, the advanced method done by ZWILAG is not the only possibility. Combined with economically aspects, other solutions could be taken into account.

Potentially, new solutions should be found. This requires time. To open a new and proofed safe waste stream will take several years, regarding the evaluation of an appropriate treatment facility and place. Administrative processes, storage of raw waste, transportation, interim storage, predictable demands of the future repository have to be also adjusted.

As shown before, we have to handle technical, administrative and legislative requirements:

- The time extension for operating the interim storage demands measures like aging management for waste packages and higher security levels.
- The existing authorized specifications for conditioning processes (ENSI-Guideline B05) have to be extended to optimize and fully describe the progresses in treatment of radioactive waste, including inevitably occurring changes in the waste streams. Changes in waste material mixtures and involved nuclides have to be described in advance, predicting the future as far as possible.
The expected demands of a future final deposit, enhanced safety criteria and additional requirements have to be fulfilled. Existing safety reports are newly interpreted or are completely rewritten.

Changes in regulatory demands with respect to safety and security of waste handling and storage cause completely new and expensive investigations. It has to be proven that our safety standards still match the increasing requirements of technical and scientific standards. In case of the Swiss Federal Interim Storage an example is the implementation of the safeguards also for waste never used in nuclear facilities, e.g. thorium-oxide mantles for gas lighting or welding rods.

Additional challenges are resulting from changes in legal and regulatory requirements to the waste packages. An example is the definition and declaration of exempted fissile material for shipment and the difficult worldwide research for finding appropriate certified containers.

4. Development of waste management of the Swiss Federal Interim Storage

In the beginning from 1969 to 1980, waste originating from nuclear research facilities and historic waste, e.g. radium, was more or less only collected and stored or dumped in the Atlantic Sea until 1982. With upcoming regulations and safety demands (storage, transport), embedding the waste into a safe matrix became the standard method, accompanied by scientific research and development.

Further demands under the aspects of safe transportation, interim storage and behavior in a final repository had to be taken into account and were embedded into the workflow of the PSI facility. All processes of waste handling, treatment and storage are now documented in the framework of a certified quality management.

Safety demands with respect to a future deep geological disposal were also added as the fulfilment of standard safety investigations: Measures are taken against material corrosion and other chemical reactions, material and nuclide inventory are not only documented for each waste package, but also standardized by specifications, which also describe the technical properties that collectives of conditioned waste packages have to fulfil.

The waste streams from MIF are changing over the time and are different in their composition: Nowadays and in future, the main waste stream from MIF in Switzerland will increasingly result from accelerator facilities at PSI and e.g. international research facility.

On the other hand, research in the field of nuclear technology is decreasing as well as the research of burn up.

An increasing time span for interim storage has to be taken into account, too. The resulting administrative and technical consequences have to be considered, e.g. aging, higher amount of waste packages to be stored (volume) or inspections of the stored waste packages. Most of these consequences were not planned in the beginning and have to be considered today.

Nowadays we focus on

- All done changes over time must be documented in complete detail in a traceable manner
- Exact documentation of the waste packages to be able to give accurate answers in case of changes in requirements and
- Optimization of the waste volume and generating waste packages. Mainly to minimize the waste, because of the rising time until the deep geological disposal gets into operation.
To minimize waste, a very good characterization of the waste has to be performed. This includes the history, the exact material analysis (technically and chemically) and the radiology.

For sure, the next change, verification of process or improved safety procedure will arise and has to be adequately implemented (transportation, storage, conditioning, documentation). This could be done only with a good documentation of the more or less inhomogeneous waste streams from medicine, industry and research.

This short overview shows the different influences (administratively and technically) affecting the main focus in waste management and resulting in continuous changes in it. These challenges we have to meet today.

5. Figures

The Paul Scherrer Institute (PSI) operates the National Collection Centre for all non-nuclear radioactive waste (e.g. from medicine, industry and research), where the waste is sorted and conditioned. In this context, PSI also operates the Federal Interim Storage (BZL/ORIAA) for this waste (see Figure). Further are shown the early storages as well as the planned new additional interim Storage (OSPA/ORAB).

REFERENCES

SAFETY ASSESSMENT FOR THE MANAGEMENT OF DISUSED RADIOACTIVE SOURCES FROM THE IRRADIATION FACILITY PRODUCT I IN CUBA

N. González Rodríguez, M. Salgado Mojena

Center of Radiation Protection and Hygiene (CPHR), La Habana, Cuba

E-mail contact of main author: niurka@cphr.edu.cu

Abstract. The Food Irradiation Plant, type Product I from the former Soviet Union, was put into operation in Cuba in 1987, in the Research Institute for Food Industry. It was used for irradiation of foodstuffs and other types of products. The facility was initially charged in 1987 with 52 Co-60 radioactive sources, with total activity of 2.50E+15 Bq (67.6 kCi). It was necessary to remove the disused radioactive sources from the irradiator in order to allow the recharge of the facility with new radioactive sources. The disused sources were temporary transferred to the reserve pit, located in the same facility. The safety assessment carried out for this operation is presented in this paper. It included the dose estimations for normal operations and potential doses in accidental situations. Several postulated events were considered. The initiating events were identified, as well as the associated risks and safety barriers. The safety assessment was presented to the Regulatory Body as part of the documentation for license application.

Key Words: safety assessment, industrial irradiation, disused sources, management of disused sources.

1. Introduction

The Food Irradiation Plant (PIA), type Product I from the former Soviet Union, was put into operation in Cuba in 1987, in the Research Institute for Food Industry (IIIA). It was designated mainly for irradiation of foodstuffs for preservation, later it was used to irradiate other types of products. According to the IAEA classification, this is a category II irradiator, panoramic irradiator with dry storage of the radioactive sources. The facility was charged with 52 Co-60 radioactive sources, with an initial total activity of 2.50E+15 Bq (67.6 kCi), reference date May 1986. The total activity in 2015 was 53 TBq (1.4 kCi).

There exists the intention to recover the irradiation capacities at PIA and install new radioactive sources. Consequently, it was necessary to unload the 52 disused radioactive sources (DSRS) from the irradiator and temporarily transfer to a reserve pit located in the same facility, until adequate containers are available to transport and store them at the Radioactive Waste Management Facility. The reserve pit, by design, is the same as the irradiator and it was used to temporary store the radioactive sources during maintenance operations in the irradiator. A container for transferring the DSRS from the irradiator to the reserve pit was available in the facility. Other auxiliary tools for handling the sources were produced, specifically for these operations.

The transfer of DSRS, as any activity involving ionizing radiations, required the authorization of the Cuban Regulatory Body, the National Centre for Nuclear Safety (CNSN). The operations were carried out with the assistance of an IAEA expert.

The paper shows the safety analysis (SA) carried out to support the license application for source transfer operations. The SA used the methodology of risk matrixes. It included the estimation of expected doses during normal operations and in radiological emergency situations; the identification of possible initiating events of accidental sequences; the
description of radiological consequences and the safety barriers to prevent accidents or to mitigate their consequences.

2. **Authorization of source transfer operations**

The documents presented to the Regulatory Body, CNSN, to support the License application for source transfer operations included:

- Operational and safety procedures
- Safety assessment
- Emergency response plan

2.3. **Operational and safety procedures**

Operational and safety procedures were developed to describe:

- The transfer container (Fig. 1) and the auxiliary tools
- The cold test to be carried out in the reserve pit, using the dummy sources, the transfer container and auxiliary tools
- The real operations for transferring the sources, from the irradiator to the reserve pit
- Radiological controls during the operations: dose rates measurements and contamination controls
- Record keeping, including the distribution of the radioactive sources in the reserve pit

Transfer operations were planned in stages. The sources contained in a selected channel of the irradiator were transferred to a predefined channel of the reserve pit.

![FIG. 1 View of transfer container](image)

2.4. **Safety assessment and Emergency plan**

The safety assessment carried out to support the license application for source transfer operations included the dose estimation due to external radiation during normal operation and potential doses for foreseeable incidents. A series of events were postulated, related with the failure of equipment, leakage of radioactive sources and human errors. The safety barriers to prevent or mitigate accidental situations were identified and radiological consequences were evaluated.

The expected doses for occupational exposed workers during normal operations were estimated according to the working procedures, taking into account the foreseeable workload.
and using conservative scenarios. As a result, it was obtained that the total effective doses will not exceed 125\(\mu\text{Sv}\).

Potential doses for foreseeable accidental situations were also estimated. The respective scenarios, described in the IAEA document “Dangerous quantities of radioactive material (D-values)” were evaluated for each case. The initiating events were identified (Table I) following a methodology analogue to the HAZOP method (HAZard and Operability study).

The methodology of risk matrices was used to evaluate the postulated initiating events. According to this method, the risks were classified by levels. The results obtained were used for decision making regarding the operational safety.

**TABLE I: IDENTIFIED INITIATING EVENTS.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Initiating event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Breakage of the metallic rod (tool used to remove the sources)</td>
</tr>
<tr>
<td>2.</td>
<td>Inadvertent access of non-authorized person (public) to the facility during transfer operations</td>
</tr>
<tr>
<td>3.</td>
<td>Leakage or breakage of the radioactive source(s)</td>
</tr>
<tr>
<td>4.</td>
<td>Different distribution of the radioactive sources in the irradiator channels as it was registered</td>
</tr>
<tr>
<td>5.</td>
<td>A radioactive source is removed from the shielding (from the transfer container) during operations</td>
</tr>
<tr>
<td>6.</td>
<td>Source or dummy stuck inside the channel of the irradiator</td>
</tr>
<tr>
<td>7.</td>
<td>Source or dummy stuck inside the channel of the transfer container</td>
</tr>
<tr>
<td>8.</td>
<td>Radioactive source(s) remain in the transfer container by the end of operations</td>
</tr>
<tr>
<td>9.</td>
<td>Power blackout</td>
</tr>
<tr>
<td>10.</td>
<td>Transfer container falling down during the movement from the irradiator to the reserve pit</td>
</tr>
</tbody>
</table>

The persons affected (operator or public), the frequency of occurrence of the event (\(f\)), the safety barrier for each one and the probability of fault (\(p\)) were identified and the radiological consequences (\(C\)) were evaluated. This analysis allowed evaluating the risk of each event. The results of this analysis are summarized in Table II.

**TABLE II: VALUES ASSIGNED TO INDEPENDENT VARIABLES F, P AND C AND RESULT OF APPLICATION OF RISK MATRIX TO EACH IDENTIFIED INITIATING EVENT.**

<table>
<thead>
<tr>
<th>Initiating event</th>
<th>Persons affected</th>
<th>Frequency</th>
<th>Probability of fault of barrier(s)</th>
<th>Consequence</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Operator</td>
<td>(f_L)</td>
<td>(P_{VL})</td>
<td>(C_L)</td>
<td>(R_L)</td>
</tr>
<tr>
<td>2.</td>
<td>Public</td>
<td>(f_{VL})</td>
<td>(P_{VL})</td>
<td>(C_L)</td>
<td>(R_L)</td>
</tr>
<tr>
<td>3.</td>
<td>Operator</td>
<td>(f_L)</td>
<td>(P_{VL})</td>
<td>(C_M)</td>
<td>(R_L)</td>
</tr>
<tr>
<td>4.</td>
<td>Operator</td>
<td>(f_{VL})</td>
<td>(P_{VL})</td>
<td>(C_L)</td>
<td>(R_L)</td>
</tr>
<tr>
<td>5.</td>
<td>Operator</td>
<td>(f_L)</td>
<td>(P_{VL})</td>
<td>(C_M)</td>
<td>(R_L)</td>
</tr>
<tr>
<td>6.</td>
<td>Operator</td>
<td>(f_L)</td>
<td>(P_L)</td>
<td>(C_L)</td>
<td>(R_L)</td>
</tr>
</tbody>
</table>
As a result, it was obtained that none of identified accidental sequences had neither high nor very high risk. Nevertheless, two of identified initiating events could cause accidental sequences of medium risks and one of them affecting the public and the consequences could be very high. So it was very important to strictly follow operational procedures and operational radiological controls.

As no accidental sequences with high risks were obtained, a second analysis was not considered necessary.

The results of the safety assessment were used as reference to develop an emergency response plan, where the all initiating events of accidental sequences previously identified were included.

3. Conclusions

The result of the safety analysis demonstrated that none of identified accidental sequences had neither high nor very high risks, for any group of exposed persons. Two initiating events could result in accidental sequences of medium risks. For one of them, the group of exposed persons was the public and the radiological consequences could be very high.

Special attention was given to strictly compliance with operational procedures and radiological controls during operations.

An emergency plan was developed to mitigate the consequences of radiological accidents that may occur. All identified initiating events were included.

No radiological incidents occurred during real operations.

The results of individual radiological monitoring during real operations demonstrated that the doses received by the operators were below 100µSv.

REFERENCES


