NENE
International Conference
Nuclear Energy for New Europe

Challenges and Objectives in Managing Institutional Radioactive Waste in Slovenia

Simona Sučić, Janez Vodopivec, Marko Kostanjevec
ARAO
Vrbina 17
8270 Krško, Slovenia
simona.sucic@arao.si, janez.vodopivec@arao.si, marko.kostanjevec@arao.si

ABSTRACT

Managing institutional radioactive waste (IRW) poses numerous challenges, especially in countries with small nuclear programs where each waste stream tends to be unique. In such cases, providers of radioactive waste management have implemented diverse methods and developed various procedures for more common waste streams, which are now carried out routinely. The main goal of radioactive waste management is to prepare the waste in a suitable and safer form for long-term storage and eventual disposal. Another important objective is to reduce waste volume, which offers cost-effectiveness and benefits to operators with limited storage capacities and no immediate disposal options. Both aspects play a vital role in addressing IRW in Slovenia and during the past decades many measures were implemented addressing these two challenges.

The responsibility for managing IRW in Slovenia lies with the state public service. At the operational level, the main challenge for waste management operators is to identify appropriate methods for treating and conditioning radioactive waste, considering waste quantities generated in Slovenia, as well as human, economic, and infrastructure resources. This paper presents the methods, benefits, and experiences gained in the processing of radioactive waste, with a particular focus on implemented measures in waste minimisation over the past decade, given the limited storage capacity at the Central Storage Facility for Radioactive Waste (CSF).

1 INTRODUCTION

Radioactive waste originates from diverse activities involving the utilization of radioactive materials. It refers to materials containing or contaminated with radionuclides at concentrations or activities greater than clearance levels established by each country's regulatory authorities, and for which there is currently no intended use. The category of waste, known as Institutional Radioactive Waste (IRW), is generated by a wide range of activities using radioactive materials in medicine, industry and research, excluding spent fuel and radioactive waste generated by nuclear energy production facilities. IRW encompasses various forms, including liquid, solid, gaseous, and multiphase waste streams with different physical, chemical and radiological properties.

At the national level, waste management programs typically address the entire lifecycle of these waste starting from their generation and extending through collection, segregation, treatment, conditioning, storage, transportation to final disposal. Notably, Slovenia does not currently have an operable disposal facility for radioactive waste. Consequently, our focus in managing IRW primarily centres on predisposal waste management, with due consideration for planned disposal options. When selecting technologies for managing specific waste streams, we adhere to internationally recognized best practices [1–7] to ensure the safe and responsible handling of these materials.

In Slovenia, the management of IRW is carried out by ARAO as a state public service, which also includes the operation of the Central Storage Facility for Radioactive Waste (CSF). Within the framework of its mandate, the public service provider performs a comprehensive range of activities in the field of radioactive waste management generated in Slovenia. Given the relatively small size of Slovenia and the limited quantity of generated IRW, the primary challenge for the waste management provider is to identify appropriate methods for processing different waste streams while taking into account available human resources, economic factors, infrastructure and other relevant considerations.

The primary categories of IRW streams generated in Slovenia include ionization smoke detectors (ISDs), solid waste from research reactor operation and other research activities, disused sealed radioactive sources (DSRSs) categories 3 to 5 [6] mostly form industry, and a minor volume of liquid waste. The cumulative annual collection of these waste streams amounts to up to 4 cubic meters, the majority of which finds its way to storage at the CSF (refer to Figure 1).

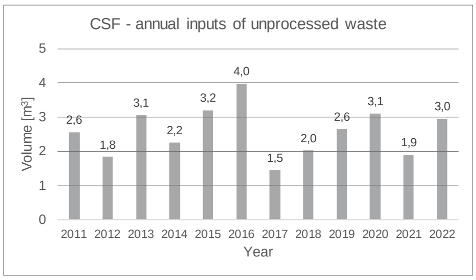

Figure 1: Annual accumulated volume of unprocessed IRW in Slovenia

After receiving waste from the waste generator, IRW is stored in the CSF. The CSF is a reinforced concrete storage facility, measuring 10.6 meters by 25.7 meters, with a height of 3.6 meters (see Figure 2). In its current configuration, the CSF has a net storage capacity of 115 cubic meters. Presently, the facility holds approximately 90 cubic meters (50 tons; approximately 3 terabecquerels) of waste, which accounts for over 80 % of its total capacity. The majority of IRW within the CSF is packed in 200-liter steel drums (see Figure 3).

Figure 2: CSF

Figure 3: Waste storage arrangement

In addition to processing of radioactive waste to ensure safe storage, a significant challenge in the long-term operation of the CSF is maintaining sufficient storage capacity while ensuring its safety and functionality. Various methods, as described in Chapter 2, are employed to reduce the volume of waste in the CSF, ensuring the necessary storage space for waste. The facility operator's plan primarily revolves around reducing waste volume until disposal becomes feasible. Furthermore, construction of a Low and Intermediate-Level Radioactive Waste Repository, where most of the waste from the CSF will eventually be disposed, is on the horizon. In an extreme scenario, with certain modifications, it may also be possible to increase the CSF storage capacity to approximately 130 cubic meters. The objective is to ensure that the CSF can meet the needs for the storage of IRW produced in Slovenia at least until disposal options are available.

2 IMPLEMENTED METHODS AND TECHNOLOGIES FOR HANDLING INSTITUTIONAL RADIOACTIVE WASTE

The activities carried out on stored IRW in the CSF include waste processing for storage. This encompasses segregation, cutting larger pieces into smaller ones, packaging, repackaging, disassembling of devices containing radiation sources into radioactive and non-radioactive components, solidification of liquids. Some of these activities result in waste taking up less space in the storage facility after processing than in its unprocessed form. In the past decade, also the exports of radioactive waste abroad for recycling or repatriation to the country of origin have been performed. Through the export of waste for recycling or repatriation to other countries, these materials were effectively removed from both the storage facility and the country. Additionally, it's important to mention the concept of 'clearance,' which involves radioactive materials being released from regulatory control when their activity decreases below clearance levels due to radioactive decay.

2.1 Methods of Processing Radioactive Waste: Selection and Considerations

Processing of radioactive waste includes its pretreatment, treatment and conditioning and is primarily intended to prepare a waste form that is compatible with the selected or anticipated disposal option. Radioactive waste also has to be in a form that is suitable for handling and storage as well as for transport. The waste management option selected may also result in a waste or material that is suitable for return to a manufacturer or supplier of radioactive material, for recycling, or for removal from regulatory control [4].

The selection of methods for processing radioactive waste is a complex task that demands careful consideration of various crucial factors. In the Slovenian context, aligning with international standards, the decision-making process is guided by the following key considerations:

a) The primary objective of processing radioactive waste is to enhance safety by creating a waste form, whether packaged or unpackaged, that meets acceptance criteria for safe processing, transport, storage and disposal. The aim is to swiftly transform waste into a safe and passive state suitable for storage or disposal [4].

b) Processing may be necessary for safety, technical or financial reasons. From a safety perspective, processing is necessary to eliminate or reduce associated hazards such as radiological, physical, chemical, and biological risks. Waste should undergo processing only after precise characterization [4].

c) Comprehensive knowledge of the waste inventory and its characteristics, including radiological, physical, chemical, and biological properties.

d) Waste minimisation is a fundamental aspect of radwaste management, aiming to reduce waste volume at every stage while minimizing secondary waste generation. If possible, waste should be stored in a way that enables further activities, should better methodologies become available [4]. The generation of secondary radioactive waste should always be a factor in processing method selection. The consequences of dealing with any secondary waste, whether radioactive or non-radioactive, created during processing, should be carefully evaluated [4].

e) Proper design and preparation of waste packages to ensure the containment of radioactive material during normal operations and potential accidents that may occur during handling, storage, transport, and disposal of waste [4].

f) When IRW is collected from generators, it undergoes segregating and temporary storage. Further activities are carried out once a sufficient amount of waste has accumulated. Due to the small quantities of IRW received at the CSF, these activities are typically conducted from once a year to once every few years, depending on the waste stream.

g) Decisions regarding waste processing methods should be based on the existing quantity of waste at the CSF and anticipated future waste receipts.

h) The exposure of workers to radiation should be considered for each processing method, both during routine operations and potential incidents.

i) Balancing occupational exposures, assessing the short-term and long-term risk implications of different waste management strategies, evaluating available technological and infrastructure options, and considering costs.

j) Adequate financial and human resources within the organization and at the national level are crucial. Capacity building is essential, and decisions should prioritize safety and economic efficiency.

k) Aligning the selection of processing methods with sustainability principles and goals.

This section provides a brief overview of the methods employed in the management of IRW in Slovenia.

2.2 Pretreatment, Treatment and Conditioning

Pretreatment activities include collection, segregation, chemical adjustment and decontamination as defined in the waste management strategy. The operator of the CSF receiving radioactive waste verify the waste characteristics by routine measurements in order to confirm the information provided by the operator of the facility where the waste was generated and to facilitate the selection of suitable treatment and conditioning techniques.

The treatment of radioactive waste includes those operations intended to allow safety, technical and financial considerations to be met by changing the characteristics of the radioactive waste. The basic treatment concepts applicable are reduction of the volume of the waste, removal of radionuclides from the waste and change of composition of the waste [4].

Conditioning of radioactive waste involves those operations that convert the treated waste into a form that is suitable for handling, transport, storage and disposal.

a) Segregation and Packing

The objective of waste segregation is to minimize the volume as well as the costs, complexity and risks associated with subsequent waste management steps. Each waste stream is kept in separate, appropriate and properly identified and labelled containers. Segregation of radioactive materials is performed according to an appropriate categorization scheme to allow for the safe and adequate accomplishment of further predisposal steps. The containers used for collection and segregation of radioactive waste are physically and chemically compatible with the waste, provide adequate confinement of the material and provide protection for workers against any chemical, biological, physical or other hazards.

Containers for solid waste are lined with a durable plastic bag. Sharp objects are collected separately and stored in rigid, puncture resistant containers (e.g., metal containers).

Liquid waste is collected in containers that are appropriate for the chemical and radiological characteristics of the waste and the volume of the waste and that meet handling, transport and storage requirements.

DSRS kept in their shielding. When the shielding is contaminated, it is decontaminated or overpackaged to avoid the further dispersal of contamination.

In certain cases, waste packages that are already stored need to be repacked and campaigns have been carried out to optimise storage space. Especially historical waste often contains significant quantities of non-radioactive material, that can be separated relatively easily saving volume.

Segregation of radioactive waste is performed primarily on the basis of the following factors: the activity of the waste and the radionuclides present, the half-lives of radionuclides present, the physical and chemical form of the waste (combustible or non-combustible solid waste, compressible or non-compressible solid waste, liquid waste or mixed waste as toxic, infectious, biological etc.), the intended processing of the waste.

b) Decontamination

Decontamination is carried out when it is confirmed that there is a removable layer of surface contamination present. Various techniques are employed to clean surfaces and remove contaminated parts.

c) Compaction of Solid Radioactive Waste

A favourable effective approach to waste minimisation involves compression. Following waste segregating, dedicated compactors (as shown in Figures 4 and 5) can substantially reduce the volume of the compacted fraction. The compactor employs a direct in-drum compaction method suitable for various solid waste types. However, it's important to note that once waste is compacted using this method, it cannot be reclaimed.

Figure 4: Radioactive waste compactor

Figure 5: Compacted radioactive waste

d) Conditioning of DSRSs Categories 3 to 5

In CSF DSRSs are included in the inventory of radioactive waste. The management of DSRSs can involve potentially serious hazards, therefore are not subjected to compaction, shredding or incineration. In the CSF, DSRSs are initially stored in their original containers. Once a sufficient quantity has been collected, a campaign is initiated to disassemble and condition them. Special attention during the storage and conditioning of DSRSs is given to monitoring for surface contamination and airborne contamination. Disused ISDs and calibration sources are dissembled and packed in steel drums. Other DSRSs are conditioned by means of encapsulation in steel capsules to facilitate their future management. A special container with adequate protection is used for storing capsules with radiation sources.

Disassembling of these devices separate the radioactive part, which ends up in the CSF, and the non-radioactive part, which can be disposed of as normal waste. These campaigns have been carried out routinely in the last decade (Figures 6 and 7) and contribute enormously to volume reduction.

Figure 6: Disassembling of ISD

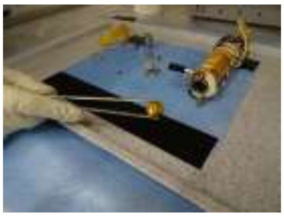

Figure 7: Disassembling of DSRS

e) Solidification of Liquid Radioactive Waste

Solidifying liquid radioactive waste prevents the dispersion of fines and liquids during handling. It also minimizes the release of radionuclides and hazardous constituents after disposal, reduces the potential for exposure of intruders, and offers a long-term solution. In the Slovenian case, it was also required that the solidified liquid radioactive waste should remain stable for storage in the CSF and be suitable for safe future transport to a final disposal facility or for potential future treatment, such as incineration, if necessary.

There is very little liquid radioactive waste generated in Slovenia, so it is necessary to employ simple methods that do not involve technological instalations to avoid the creation of secondary waste. Various methods have been employed in the management of IRW to solidify liquids, including solidification with polymers (Figures 8 and 9), draining method used for spent ion resins, destilation, evaporation and drying methods. If the generation of liquid radioactive waste were to increase, we would, of course, need to consider alternative methods.

Figure 8: Mixing liquid with polymer

Figure 9: Solidified waste package

2.3 Recycling, Repatriation and Reuse

Where appropriate, the waste material may be reused or recycled in accordance with the regulations in place.

Repatriation primarily concerns DSRSs. Some manufacturers, suppliers, or countries of origin have committed to taking them back. Typically, this service is not available free of charge and may not be accessible for all types of DSRS. Recipients can then recycle, reuse, or dispose of them.

A limited quantity of DSRSs has been permanently exported from Slovenia back to their countries of origin or elsewhere. In the past five years, a significant quantity of ionization detectors has been permanently exported abroad (see Figure 10), where they are recycled. There has also been a successful export of a smaller quantity of depleted uranium (100 kilograms), although this service is no longer available.

Figure 10: Example of shipment containing ISDs ready for dispatch abroad

In June 2023, one Category 2 DSRS was exported for recycling abroad with the assistance of the International Atomic Energy Agency. In this case, the arrangement was made directly between the DSRS holder and the recipient, and therefore, this source was not stored in the CSF.

All of these activities contribute to reducing the amount of waste that needs to be stored in the CSF. These services are typically offered for a fee, but they are valuable because their objective is to promote a more circular economy in the use of radioactive materials. This, in turn, leads to cost savings in disposal since these wastes won't need to be disposed of within Slovenia.

2.4 Clearance of Material from Regulatory Control

The clearance of radioactive waste complies with clearance levels established by the Slovenian regulatory authority [8]. Before any clearance action is initiated, a thorough evaluation of potential candidates is conducted to confirm compliance with waste activity concentration standards, and this is followed by independent measurements to ensure accuracy [4, 8].

To obtain clearance, the public service provider submits an application along with the requisite supporting documents to the regulatory authority. Only upon receiving authorization from the regulatory body can the material be considered for clearance. Information about material that has been removed from regulatory control is recorded, kept in the management system and reported to the regulatory authority.

3 BENEFITS AND LESSONS LEARNED

As previously mentioned, the public service provider employs various methods to reduce the volume of waste that needs to be stored in the CSF due to limited storage capacity. These activities have proven to be effective, as despite the continuous influx of new waste into storage, the total quantity of stored waste has remained relatively consistent over the past decade (see Figure 11).

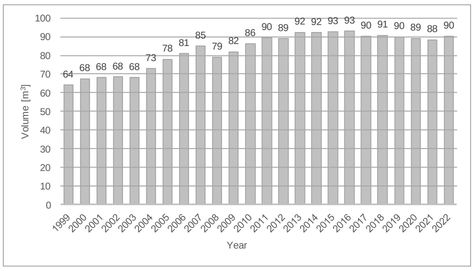

Figure 11: Annual net accumulation of IRW stored in the CSF

The efficient method for reducing the volume in the CSF is the conditioning of DSRSs. Equally important is the export of DSRSs for recycling, as it ensures that no waste returns to Slovenia. Additionally, in the context of volume reduction, compacting compressible solid waste is also highly effective.

Distillation and evaporation are effective methods for liquid waste, but it is rarely used because there is not enough waste in quantity and secondary waste would be generated. Polymerization is a simple and reliable method. However, with this method, the final volume of waste is greater than the initial volume. Thankfully, Slovenia generates only minimal quantities of liquid radioactive waste (a few litres over several years), which mitigates any significant concerns.

The activities described in Chapter 2 aren’t only beneficial for providing more storage capacity, but also enable safer handling and storage of IRW while preparing the waste for final disposal. Experience highlights the value of maintaining a diverse range of methods, given the potential unavailability of certain options in the future.

Collaboration with external organizations has demonstrated its productivity, albeit with the understanding that such partnerships may be subject to termination for various reasons. This mainly concerns recycling options. Therefore, it is crucial to maintain internal expertise and have trained and skilled personnel. In the event of a disruption in the ability to transfer ISDs abroad, the staff is trained to process these sources. Additionally, the waste acceptance criteria of foreign recycling facilities do not permit the transfer of all types of ISDs, necessitating the need to handle these sources locally.

Experience shows that it is important to have knowledge in-house and to do as much as possible with own personnel and equipment. Waste processed in this way is furthermore of comparable quality and better managed.

Another aspect is to stay well-informed about available methods and services, as well as the types of support that can be obtained from organizations like the International Atomic Energy Agency. Building a diverse network of waste management experts has proven to be highly beneficial.

4 CONCLUSION

The contribution provides insight into the complexity associated with managing IRW in Slovenia. The presented practices align with the national radioactive waste management program. The results affirm the effectiveness of implemented measures in reducing the volume of waste destined for storage in the CSF. This serves as compelling motivation for the public service provider to persist in these initiatives in the future, alongside exploring fresh prospects, particularly concerning the recycling of radioactive waste. By continuing this path, it becomes feasible to meet the IRW storage needs generated in Slovenia until the construction and operation of the Low and Intermediate-Level Radioactive Waste Repository in Vrbina, Krško. In the event that more waste is generated than anticipated in the projections, alternative solutions may be required. Options include overseas incineration of combustible waste, supercompaction of already compacted waste, or expanding storage capacities through modifications or extensions to the storage facility.

REFERENCES

[1] International Atomic Energy Agency, Techniques and Practices for Pre-treatment of Low and Intermediate Level Solid and Liquid Radioactive Wastes, Technical Reports Series No. 272, IAEA, Vienna, Austria, 1987.

[2] International Atomic Energy Agency, Treatment of Low- and Intermediate-level Liquid Radioactive Wastes, Technical Reports Series No. 236, IAEA, Vienna, Austria, 1984.

[3] International Atomic Energy Agency, Management od Disused Sealed Radioactive Sources, IAEA Nuclear Energy Series No. NW-T-1.3, IAEA, Vienna, Austria, 2014.

[4] International Atomic Energy Agency, Predisposal Management of Radioactive Waste, IAEA Safety Standards Series No. GSR Part 5, IAEA, Vienna (2009)

[5] International Atomic Energy Agency, Classification of Radioactive Waste, IAEA Safety Standards Series No. GSG-1, IAEA, Vienna, Austria, 2009.

[6] International Atomic Energy Agency, Categorization of Radioactive Sources, IAEA Safety Standards Series No. RS-G-1.9, IAEA, Vienna, Austria, 2004.

[7] International Atomic Energy Agency, Application of the Concepts of Exclusion, Exemption and Clearance, IAEA Safety Standards Series No. RS-G-1.7, IAEA, Vienna, Austria, 2004.

[8] Decree on radiation activities (Official Gazette of the Republic of Slovenia, No. 19/18).