Methodology to prepare the tritiated waste management : Defining WAC for an interim storage facility

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Considering the high mobility of tritium through the package in which it is contained, the new 50-year storage concepts proposed by the CEA currently provide a solution adapted to the management of waste with tritium concentrations higher than the accepted limits in the disposals. The 50-year intermediate storage corresponds to 4 tritium radioactive periods i.e. a tritium reduction by a factor 16.

This paper details the approach implemented to define the waste acceptance criteria (WAC) for an interim storage facility that not only takes into account the specificity of tritium provided by the reference scheme for the management of tritiated waste in France, but also the producers' needs, the safety analysis of the facility and Andra's disposal requirements. This will lead to define a set of waste specifications that describe the generic criteria such as acceptable waste forms, general principles and specific issues, e.g. conditioning, radioactive content, tritium content, waste tracking system, and quality control. This approach is also a way to check in advance, during the design phase of the waste treatment chain, how the future waste could be integrated into the overall waste management routes and identify possible key points that need further investigations (design changes, selection of materials, etc.): the results obtained are shown. It supports the nuclear operator to ensure the compliance of the future waste packages with the disposal acceptance criteria.

Keywords: tritium, tritiated waste, fusion, interim storage, route, disposal.

1. Introduction

Fusion facilities like ITER will produce radioactive waste during operation and decommissioning [1][5]. This waste results from the activation of materials by 14 MeV neutrons and from contamination by tritium, which is used as fuel in the fusion reaction. Most of the waste will be tritiated, which requires a specific management strategy taking into account the physical and chemical properties of tritium, its capability to diffuse through metals and its half-life of 12.3 years. In the nuclear field, as well as in other industrial sectors, interim storage can be a necessary buffer function in process management. A program for the creation of interim storage facilities for tritiated waste was defined in France, within the framework of the National Radioactive Materials and Waste Management Plan [PNGMDR, Réf. 2]. After a period of tritium decay, the waste packages will be shipped to the surface disposal facilities.

Waste acceptance criteria have to be established to specify the radiological, mechanical, physical and chemical characteristics of waste packages to be stored: for example, their radionuclide content or activity limits, the properties of the waste form and packaging. This paper presents the studies carried out on one of these interim storage facilities in order to establish the Waste Acceptance Criteria (WAC) taking into account all of the requirements. The implementation of this approach has provided relevant results by the identification of studies and actions required to improve the detailed design of the whole radwaste chain, early in the development.

2. Tritiated waste management in France

2.1 General principles

Waste management can be optimized as a whole system - from production to disposal – and comprises the following steps [6]:

- Waste production and primary waste sorting, treatment and characterization,
- Waste packaging compliant with storage, transportation and disposal requirements,
- Transportation and storage with an optimization of the storage periods,
- Waste package disposal.

This requires a great deal of interfacing between radwaste management, engineering, regulation and safety players to find the optimum solutions in terms of cost efficiency.

At each stage of the waste management process, producers are involved and responsible for maintaining a high level of quality to prevent the occurrence of any problem.

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2.2 Legal framework of radwaste management

Waste management is governed by law which complies with the international requirements: each government shall provide for an appropriate national legal and regulatory framework within which radioactive waste management activities can be planned and safely carried out.

Decommissioning must be considered at an early stage, an initial version of the decommissioning plan must be submitted to the regulatory body to support the license application. This document includes consideration of the major safety issues, generic study showing the feasibility of decommissioning, consideration of the quantity of waste to manage (large volumes expected) and demonstration that dismantling is taken into account during the design phase.

In France, the PNGMDR is a key tool in ensuring the long-term implementation of the principles laid down in the Program Act of June 28, 2006 concerning the sustainable management of radioactive materials and waste to protect individual health, security and the environment.

It aims primarily at producing a regular overview of radioactive substance management policy, to evaluate new requirements and to determine the objectives to be met in the future, particularly with regard to studies and research. Its validity was confirmed on a European level when the directive establishing a community framework for the responsible and safe management of spent fuel substances was adopted on July 19, 2011.

The PNGMDR also organizes the implementation of research and studies on the management of materials and waste according to three aspects [6]:

- Reducing the quantity and harmfulness of the waste, in particular by reprocessing spent fuels and processing and packaging radioactive waste
- Using interim storage as a preliminary step, in particular with a view to carrying out fuel and waste reprocessing, or to dispose of the waste;
- Using deep geological disposal after interim storage as a permanent solution for ultimate waste that cannot be disposed of on the surface or at a shallow depth for nuclear safety or radiation reasons.

2.3 Strategy proposed for tritiated waste management

For the case of waste which can contain tritium in excess of the specific thresholds at the entrance of the disposals, a strategy has been established within the framework of the PNGMDR program [5]:

- Setting up a temporary storage site to allow for tritium decay if necessary for about 50 years, based on feedback from existing storage facilities, until the waste can be accepted for disposal
- Selecting a temporary storage site that is located as close as possible to the producer
- Designing the future disposal sites considering the tritiated radwaste characteristics after an interim storage period
- Making sure the producer takes into account waste sorting, consistency of the conditioning, characterization and treatment
- Paying special attention to the most out-gassing waste, considering for example detritiation techniques or high integrity containers.

The creation of new storage facilities by the CEA offers a satisfactory solution in terms of short- to medium-term safety, pending its future transfer to disposal facilities.

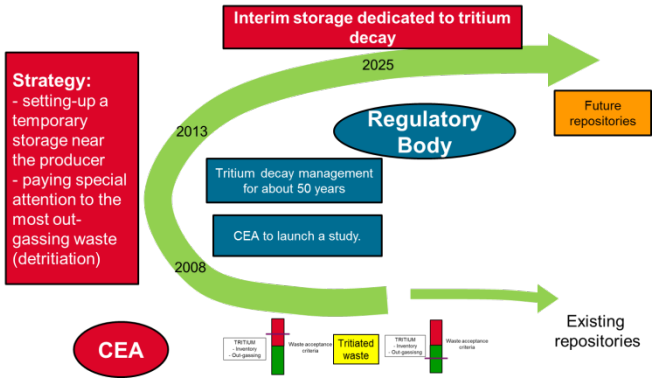

Fig. 1: French strategy for tritiated waste management.

Interim storage is well-adapted while waiting for availability of the permanent disposal facility or taking advantage of the activity and/or heat decay, which provides a solution in an industrial optimized chain. Nevertheless, an optimized solution is often reached by combining different techniques such as incineration or thermal treatment in addition or not to the interim storage [4].

3. Input data for the Interim Storage facility design

The data required to launch the process to establish the Waste Acceptance Criteria (WAC) of the interim storage are detailed in the following paragraphs.

3.1 Producers' data and solutions for radwaste transportation

The data required from the producers is the characteristics of the primary radwaste and of the packages: inventory and associated uncertainties,

physical and chemical characteristics, radiological spectrum, dynamic calculation of the activities, conditioning and packaging, dose rate, assessment of the removable surface contamination. In parallel, the production and shipping records, the identification of the waste packages and means of transportation are required.

This list is consistent with the international recommendations [3].

Keeping records is a key point. For this reason, all the data, for each package, is archived in digital form at each step of the waste management process. This guarantees that the data is conserved throughout the entire interim storage period right up to shipment of the packages to the disposal facility.

Waste traceability in the interim storage facility is ensured by dedicated software. The producer uses this software to declare the waste characteristics at production (ID card) prior to interim storage, which must comply with waste requirements. This software is also used to declare these characteristics prior to disposal.

3.2 Interim storage functions

The technical interim storage functions are divided into several steps corresponding to the arrival of the packages, the interim storage period and associated monitoring actions, the shipment of the packages and in parallel a repackaging step is possible.

Arrival of the packages

- Collection of the packages provided by the producers
- Loading / unloading of the transport casks and packages
- Radiological control of the packages when received (contamination, dose rate, etc.)
- Packages control and characterization (tritium activity, outgassing measurements, etc.)
- Buffer storage of the packages

Interim storage period

- Intermediate storage
- Packaging retrieval when needed
- Facility operation and maintenance
- Monitoring of the packages
- Environment monitoring (releases)

Shipment of the packages to the disposals sites

Repackaging.

3.3 Safety options and impact on the design

The safety case has to be prepared by the operator early in the development as a basis for the regulatory decision-making process and approval with the main objective to protect the workers, the public and environment against the hazards associated with radioactive waste in normal and accident conditions.

Depending on the source term, the facility will be licensed under the French "Licensed Nuclear Facility" ministerial order (called in France Installation Nucléaire de Base – INB).

To comply with this regulation, design is driven by the safety options chosen to demonstrate that the environmental impact is acceptable and the exposure of workers and the public in normal and accident conditions is also acceptable taking into account: earthquake hazard, extreme weather conditions, external flooding, internal fire, and load drop, etc.

The safety options in terms of confinement are based on static barriers (the radwaste package itself and the building) and on a dynamic confinement ensured by a specific air renewal system.

Due to the high amount of tritium in the radwaste, the packages are expected to be stored for about 50 years; therefore, specific measures are required to take into account aging, the monitoring process and the maintenance strategy.

3.4 Specifications of the disposal facilities [6]

The packages after storage shall comply with the acceptance criteria of the disposals. In France, there are 2 surface disposals available: the Cires dedicated to the VLLW and the CSA for SL-LILW. Andra is the French national agency for radioactive waste management and it is in charge of disposal.

Very Low Level Waste (called "déchets TFA" in French):

From a radiological viewpoint, the acceptance of a waste batch depends on the IRAS (French radiological acceptance index for repositories), which takes into account the specific activity and the radiotoxicity class of the radionuclide:

$$IRAS = \sum \frac{A_{mi}}{10^{class_i}}$$

where A_{mi} is the specific activity of the radionuclide i expressed in Bq/g (waste + packaging).

To be considered as VLLW, the IRAS of a batch must be lower than or equal to 1 and the IRAS of each package in the batch must be lower than or equal to 10.

As an example, the radiotoxicity class of tritium is 3. This means that for purely tritiated waste, an IRAS of 1 is obtained with a tritium activity in the waste equal to 1000 Bq/g. The lower the toxicity class of a radionuclide, the smaller the amount accepted in the waste package.

The Cires disposal facility dedicated to VLLW was commissioned in 2003 by Andra and has a licensed storage capacity of 650,000 m^3.

Short-lived Low and Intermediate Level Waste (called "Déchets FMA-VC" in French):

In its waste acceptance specifications, Andra has defined maximal activity levels for a list of 143 nuclides (half-life generally lower than 31 years). Out-gassing of gaseous radionuclides is also an important criterion.

For safety reasons, Andra has set rather stringent acceptance criteria in terms of tritium contents and out-gassing for its present disposal facilities. The waste acceptance criteria in terms of tritium for SL-LILW are as follows (current specifications):

- Specific activity acceptance limit $< 2.10^5$ Bq/g
- Total activity < 1 GBq for a 200L drum compactable and 50 GBq for the other packages
- Out-gassing acceptance limit < 0.2 MBq/metric ton/day.

Located in the Aube Department, the CSA disposal facility for SL-LILW was commissioned in 1992 by Andra and offers a licensed waste storage capacity of 1,000,000 m^3. It took over from the CSM facility (Manche Department) which is currently being monitored as part of its post-closure phase.

Based on the safety options, Andra's disposal specifications and taking into account the requirements defined in the reference strategy for tritiated waste management, the WAC of a dedicated interim storage have been established.

4. Establishment of the WAC of an Interim Storage for tritiated waste [6]

4.1 Approach

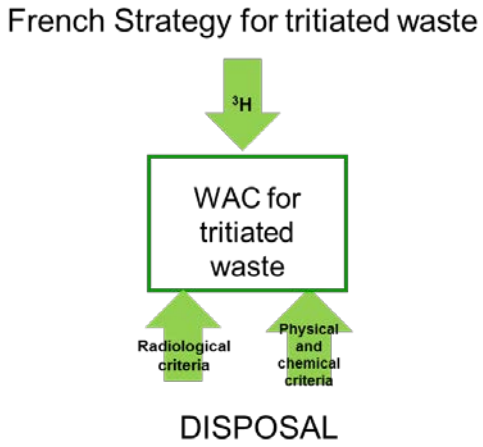

Fig.2: Approach to define WAC for tritiated waste interim storage

The results of implementing this approach are detailed in the next sections.

4.2 General WAC for an interim storage

The interim storage will be designed taking into account the requirements defined by Andra which will be used as input data and the WAC are defined so as to avoid including any additional requirements than the one defined by Andra in its specifications. The CEA will be elaborating the interim storage specifications in line with Andra requirements.

The waste producer must sign an agreement with Andra for its packages and only pre-accepted waste packages that comply with the disposal requirements will be stored.

The process for accepting waste packages in disposals is under construction with Andra and expected to be as follows:

- The producer must declare the characteristics of these packages to Andra to check the possibility of their transfer to the final disposal site on the basis of:
  - The radiological and physicochemical criteria defined in the acceptance specifications of the disposal facilities at the time the waste packages are produced
  - Tritium activity and off-gassing rate at the time the waste packages are produced.
- Only those packages declared by Andra to comply with these criteria can be directly shipped to Andra
- Those complying with the first criterion and expected to comply with the second after a decay period up to 50 years will be deemed pre-accepted by Andra and shipped to the interim storage facility.

As an example, the waste producer must comply with the following main provisions to ensure its waste packages will be pre-accepted by Andra and therefore accepted by the interim storage facility:

- All waste packages accepted into the interim storage facility will have an outlet in the long run,
- Most accurate knowledge possible of the type of waste and its non-hazardous nature. In particular, waste exhibiting flammability, reactivity or pyrophoricity should be specifically treated or packaged
- Assessment of the waste activity levels and related decay dynamic calculations covering a period of 50 years (βγ total, α, tritium, 14C)
- Assessment of tritium packages off-gassing rates and related decay dynamic calculations covering a period of 50 years
- Conditioning adapted to the type of waste and to the transport

- Issuing of a tracking sheet and a waste package ID card which implies the producer's responsibility
- Compliance with irradiation levels and external labile contamination thresholds,
- Compliance with mechanical resistance properties that are compatible with the waste handling, stacking and recovery operations.

Quality system:

The producer must provide a file ahead the storage of the packages. The important points from the quality point of view are the following:

- Radwaste management organization consistency
- Radwaste traceability
- Processing of non-conformities and possible refusal of the faulty packages
- Devices and equipment for measurement, inspection and periodic tests
- Checks performed by the producer (formalisation, traceability)
- Consideration of monitoring performed by the interim storage operator and the disposal facility.

The producer is responsible for making sure their packages comply with the requirements stipulated in both the Andra reference documents and in the specifications for the interim storage facility.

4.3 Specific WAC for an interim storage for VLLW and SL-LILW tritiated waste

Tritiated Very Low Level Waste (VLLW):

The acceptance criteria are mainly the following ones:

- the authorized physical natures are defined in the Andra's specifications,
- Conditioning and packaging adapted to a 50-year interim storage are required,
- the IRAS repository radiological acceptance index shall be less than 1 for waste batches or less than 10 for waste packages, calculated on the basis of the tritium activity after a 50-year decay period and the activity levels of other radionuclides on the waste production date.

Short-Lived Tritiated Low and Intermediate-Level Waste (SL-LILW):

The acceptance criteria are mainly:

- Authorized physical natures are defined in the Andra's specifications
- Conditioning and packaging adapted to a 50-year interim storage are required,
- Radwaste radiological activities comply with maximum acceptance limits after a 50-year cooling period for tritium and at the waste production date for other radionuclides.

4.4 WAC revision

The WAC may need to be revised in the following cases in the event of:

- Lessons learned from the analysis of an unexpected event
- Regulatory body (ASN) demand asking for a modification of the authorised range
- Change in the producer's needs if the impact is accepted by Andra and the interim storage operator
- Extension or reduction of the disposal WAC, in particular in the allowed physical and chemical forms and the RN amounts after review and approval by the interim storage operator.

5. Tritiated waste management preparation: first results

The main results obtained when applying the approach presented in the previous section are the following:

Materials:

The establishment of the WAC, dealing with the physical and chemical forms of the radwaste, has helped to identify the specific materials for which further investigation is required to demonstrate the acceptability in the disposals such as reactivity of the materials in presence of water. An example of specific materials for which studies have been launched is given in [7].

Treatment:

Specific treatment could be necessary to meet the WAC. Therefore, an analysis from the producer needs to be carried out and could impact the design of the radwaste package production chain.

Interfaces management:

The methodology takes into account the waste packaging required for interim storage and several options therefore helping to determine the dimensions of the producer building openings hosting the radwaste package production process.

Modelling:

The approach allows to identify the models needed to assess the tritium behavior through the packages from a radwaste point of view. It is common that the models

used to build the general safety analysis of the waste producer chain could be penalising.

Monitoring:

As the interim storage can last up to 50 years and that the WAC take into account the disposal requirements, the key parameters to be monitored are determined and used as input data for safety analysis.

The design of interim storage facility for tritiated waste is in progress at CEA based on the principles detailed in the present article.

6. Conclusion and Next Steps

6.1 Conclusion

The interim storage concept has shown its robustness, its technical maturity and is well-tried and tested. It also offers an answer to all types of tritiated radwaste as compared with other solutions and is often combined with other techniques aiming at reducing tritium inventory or out-gassing

Defining WAC is a relevant way to identify ahead of time the studies to be launched and the required actions to converge on a detailed design for example material specific studies, required treatment, interfaces management, modelling and monitoring studies.

6.2 Next steps

In parallel to the interim storage preliminary design ensured by an engineering contractor, several potential improvements will be examined such as incineration or thermal treatment with R&D ongoing to assess carefully the process performance. These opportunities to reduce tritium contents in order to optimize the dimensions of the interim storage facility are currently under investigation.

A review involving radwaste experts, who will present the operational feedback of other facilities of the same type, will take place at the end of the preliminary design stage of the interim storage facility. The main objective of this review is to select the technique or combination of techniques to reduce tritium contents and freeze the capacity of the interim storage facility.

The results of this review will provide the input package for the detailed design stage of the facility.

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