Defining WAC for interim storage dedicated to tritium decay

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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 high tritium concentrations, associated with adapted disposal sites. The 50-year intermediate storage corresponds to 4 tritium radioactive periods i.e. a tritium reduction by a factor 1/16.

The waste acceptance criteria (WAC) for this interim storage concept will take into account the safety of the facility, the reference scheme for the management of tritiated waste in France, and the criteria applicable at Andra[1] disposal centres. 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 paper details how the work by the CEA has led to a storage facility project that not only takes into account the specificity of tritium, but also the producers' needs and Andra's disposal requirements.

Keywords: tritium, tritiated waste, incineration, thermal treatment, fusion, interim storage.

1. Introduction

As described in [1], fusion facilities like ITER will produce radioactive waste during operation and decommissioning. 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 (5.6% of the tritium decays annually).

In the nuclear field as well as in other industrial sectors, interim storage is a necessary buffer function in the 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 the 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 that are 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 taking into account all of the requirements.

2. Tritiated waste management in France

2.1 Legal framework of radwaste management

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

- Waste production (waste volume, material used in processes, possibilities of sorting/recycling/treatment),

- Packaging design in relation with storage, transportation and disposal,

- Storage duration and waste package flow in relation with transportation and disposal.

This requires strong interactions between waste management actors within a structured framework to find the optimum solutions in term of costs efficiency of the radwaste management.

Producers are involved and responsible at each stage of the waste management process and must ensure a high level of quality to prevent the occurrence of any problem.

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.

In France, the National Radioactive Materials and Waste Management Plan is a key tool in ensuring the long-term implementation of the principles laid down in the Programme Act of 28 th June 2006 concerning the sustainable management of radioactive materials and waste to protect individual health, security and the environment.

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

The PNGMDR also organizes the implementation of research and studies into the management of materials and waste, in accordance with the three directions [2]:

- Reducing the quantity and harmfulness of the waste, in particular by reprocessing spent fuels and processing and packaging radioactive waste;

- Storage as a preliminary step, in particular with a view to fuel and waste reprocessing, or to disposal of the waste;

- After storage, deep geological disposal as a permanent solution for ultimate waste that cannot be disposed of on the surface or at shallow depth, for nuclear safety or radiation reasons.

2.2 Interim storage for tritiated waste management

Because of their properties, certain categories of radioactive waste require special management routes. This is, for example, the case with waste containing tritium (tritiated waste). The key points of the strategy established within the framework of the PNGMDR for tritiated waste management are :

- setting-up a temporary storage site to allow for tritium decay if necessary for about 50 years, based on feed-back from existing storage facilities, until the waste can be accepted for disposal

-selecting a location of the temporary storage site near the producer

- designing the future repositories considering the tritiated radwaste characteristics as input data

- making sure the producer takes into account waste sorting, consistency of the conditioning, characterisation and treatment

- paying special attention to the most out-gassing waste considering detritiation techniques or high integrity containers.

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

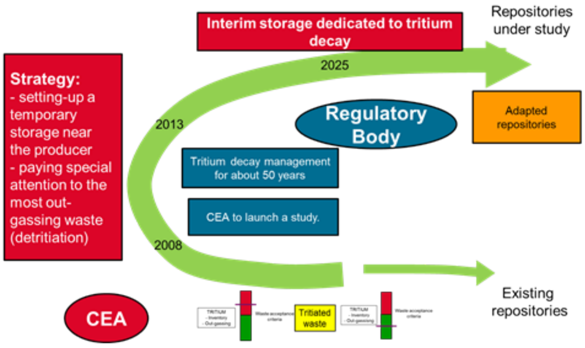

Fig.1 French strategy for tritiated waste management

Interim storage requires:

- Pending availability of the repository,

- To benefit from activity and/or heat decay providing a solution in an industrial optimized chain.

The next section presents the input data required to design an interim storage.

3. Interim storage facility design

The design requires:

- The producers' data and the solutions for the radwaste transportation,

- The interim storage facility functions,

- The safety options of the facility and associated design,

- The specifications of the disposals' facilities.

Based on these data, the process to create the Waste Acceptance Criteria (WAC) of the interim storage can be launched (see section 4).

3.1 Producers' data

The data required on the packages are the following:

- Data required on the primary radwaste:
  - Radwaste inventory during the whole life of the interim storage, with amounts uncertainties estimation,
  - Physical and chemical characteristics of the radwaste,
  - Radiological spectrum used with tritium content and associated uncertainties,
  - Packaging envisaged for the radwaste and durability during the whole life of the interim storage.
- Production and shipping chronicles,
- Required documentation and records including the history of the waste,
- Identification of the waste packages,
- Identification of the means of transportation.

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

3.2 Interim storage functions and main components

<u>Technical interim storage functions:</u>

- Collection of the packages provided by the producers,

- Loading / unloading of the transport casks and packages,

- Packages radiological control at reception (contamination, dose rate,..),

- Packages control and characterization (tritium activity, outgassing measurements,..)

- Buffer storage of the packages,

- Intermediate storage,

- Packaging retrieval when needed,

- Facility operation and maintenance,

- Monitoring of the packages,

- Environment monitoring (releases),

- Shipment of the packages to the disposals,

- Treatment (study as an option),

- Repackaging.

From the safety point of view:

The safety case has to be prepared by the operator early in the development as a basis for the process of regulatory decision making and approval with the following objectives:

- Protect the packages from the external and internal hazards in order to maintain the packages integrity (see section 3.2),

- Protection of the workers, the public and environment against the hazards associated with radioactive waste in normal and accidental conditions.

Main equipment of the facility

- Concrete buildings including truck bay, measurement/characterization rooms, storage rooms, maintenance/repair cell, control room, ancillary buildings,...

- Ventilation devices,

- Power supply components,

- Power supply emergency unit,

- Handling equipment: cranes, forklifts,...

- Discharges/releases monitoring,

- Radioprotection monitoring components.

3.3 Safety options and impact on the design

The design of storage facility mainly depends on the type of radioactive waste, its characteristics and associated hazards, the constraints linked to the handling equipment, the radioactive inventory and the anticipated period of storage.

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

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

The safety options in terms of confinement are based on the static barriers (the radwaste package itself and the building) and on a dynamic confinement.

The tritium out-gassing resulting from the large volumes of radwaste implies a specific air renewal system in the areas where the dynamic confinement is not required.

The earthquake hazard recommends the building to be constructed on rock.

The high amount of tritium included in the radwaste can lead, for the packages, to a 50-year interim storage before shipment to the disposals; therefore, the lifetime expected for the interim storage facility (including the loading and unloading periods) is about 70 years, requiring specific measures to cope with aging, the monitoring process and the maintenance strategy.

As a licensed facility, the nuclear facility will be subject to decennal inspections by the safety authority, usually leading to refurbishments or upgradings.

3.4 Specifications of the disposal facilities

The packages after storage shall comply with the acceptance criteria of the repositories. In France, there are 2 surface repositories available : the Cires dedicated to the VLLW and the CSA for the LILW-SL.

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

From a radiological viewpoint, the acceptance of a waste batch depends on the IRAS (French abbreviation of Indice Radiologique d'Acceptation en Stockage, which is repository radiological acceptance index) which takes into account the specific activity and the radiotoxicity class of the radionuclide:

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

where Ami is the specific activity of the radionuclide i expressed in Bq/g (waste + packaging).

As an example, the radiotoxicity class of tritium (T) 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.

To be considered as VLLW, the IRAS of a batch must be lower or equal to 1 and the IRAS of each package in the batch must be lower or equal to 10. The Cires disposal facility dedicated to VLLW was commissioned in 2003 by Andra and has a storage capacity of 650,000 m3.

Hence, only purely tritiated waste with an initial tritium activity below 15 kBq/g (VLLW, IRAS = 1) will comply with the present disposal acceptance criteria based on a 50-year decay period (interim storage).

Low and Intermediate Level Waste-Short Lived (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). Outgassing of gaseous radionuclides is also an important criteria, ie for tritium (HT and HTO).

These limits are defined to protect people and the environment (dose limit for members of the public) against the hazards associated with waste management activities relating to waste disposal, including hazards that could arise in the operational period and following closure (including inadvertent human intrusion).

Located in the Aube Department, the CSA disposal facility for LILW-SL was commissioned in 1992 by Andra and offers a waste storage capacity of 1,000,000 m3. It took over from the CSM facility (Manche Department) which is currently being monitored as part of its post-closure phase.

Andra has set, in its present repositories, for safety purposes, rather stringent acceptance criteria in terms of tritium content and out-gassing. The Waste Acceptance Criteria in terms of tritium for LILW-SL are the following (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/tonne/day.

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

4. Establishment of the WAC of an interim storage for tritiated waste

4.1 Methodology

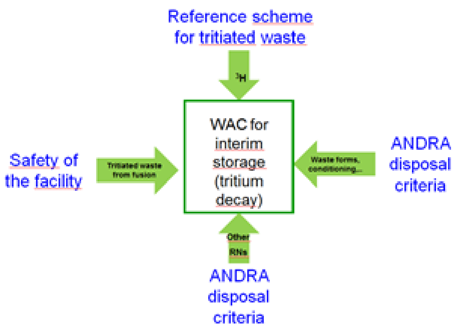

Fig.2 Methodology to define WAC for tritiated waste interim storage

The results of the application of the methodology are detailed in the next sections.

4.2 General WAC for an interim storage

The waste producer must launch an agreement with Andra for its packages and only the ones accepted for disposal after tritium decay are stored.

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

- most accurate knowledge possible of the type of waste and its non-hazardous nature (see section 3.1). In particular, waste exhibiting flammability, reactivity or pyrophoricity should be specifically treated or packaged,

- assessment of the waste activity level (βγ total, alpha, tritium, 14C),

- assessment of tritium packages off-gassing,

- 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 will provide upon request the documents related to the measurement methods or the assessment methods of the radiological activity contained in the radioactive waste especially tritium assessment methods.

The application of the quality system will be reviewed regularly. In particular, the operational measures put in place by the producers to ensure the conformity of the packages to the WAC of the interim storage and to the WAC of the disposal facilities will be checked.

The other points important from the quality point of view are the following:

- Radwaste management organization consistency,

- Radwaste traceability,

- Treatment of the non-compliances and possible shipment back of the incriminated packages,

- Approval of the activity declaration methods by the interim storage nuclear operator.

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

Very Low Level Waste (VLLW) :

The acceptance criteria are detailed below.

- the authorised physical natures of this waste are defined in the ANDRA specifications.
- the boxes or other containers for the conditioning are adapted to a 50-year interim storage are required.
- Radiological requirements for VLLW:
  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 cooling period and the activity levels of other radionuclides on the waste production date,
  Specific case of tritium:
  - Specific activity level for waste batches < 15,000 Bq/g
  - Specific activity level for waste packages < 150,000 Bq/g
  - Maximum off-gassing:1 GBq/year/package

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

The acceptance criteria are detailed below.

- the homogeneous and heterogeneous waste are authorized in terms of physical nature,
- Packages classified IP2 according to the ADR Order of 5 December 1996 concerning the carriage of hazardous goods by road
- Radiological requirements for LILW-SL
  The IRAS of the packages is required to be greater than 1 (segregation criterion for VLLW and LILW-SL) calculated on the basis of the tritium activity level after a 50-year storage period and the activity of other radionuclides on the waste production date.
  The radwaste characteristics are compliant with maximum acceptance limits.
  Specific case of tritium:
    - Specific activity for waste packages < 1 MBq/g (of package)
    - The measurement methodology must be accepted by the interim facility manager.

4.4 WAC revision

The current WAC may need to be revised in the following cases upon :
- regulatory modification related to the overall tritiated waste management facilities managed by the producer or the interim storage licensee or the disposal operator,
- a regulatory body (ASN) demand,
- a change in the producer’s needs if accepted by the operator of the interim storage,
- if an extension of the disposals WAC in particular in the allowed physical and chemical forms and the RN amounts can be applied to the interim storage,
- lessons learned from the analysis of an unexpected event.

5. Conclusion and next steps

Conclusion :

Interim storage is a buffer function in the process management and the Waste Acceptance Criteria definition is a key milestone in the facility development cycle.
The interim storage concept has shown its robustness, its technical maturity and is well-tried. It also offers an answer for all types of tritiated radwaste as compared to other solutions.
The validation of the Waste Acceptance Criteria validation by the producer and the waste disposal manager is ongoing.

Next steps :

In parallel of the facility detailed design, several potential improvements will be examined:
- Define mechanisms securing the acceptance of the packages after the interim storage phase,
- Prepare a dynamic management of the interim storage which is a provisional solution :
    - Adaptability to the possible modifications in the producer’s process, in the interim storage safety analysis or in the disposal facility,
    - Flexibility of the facility and of its future upgrades. For example, a staged construction for is foreseen,
    - Taking into account the operational feedback of other facilities of the same type,
    - Launch at a national and international level an active technology watch on alternatives solutions to the interim storage such as new radwaste treatment allowing tritium content reduction.

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