Tritiated Waste Management Opportunities Based On The Reduction Of Tritium Activity And Out-gassing

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ABSTRACT

The so-called "Tritiated waste" contains tritium as the main radionuclide and is produced by nuclear research, fusion facilities and small producers (hospitals, research centres and industries). The management of this type of waste can be improved, using techniques in reducing tritium activity and out-gassing.

The several options are presented depending on the waste form and the amount of tritium: temporary storage for tritium decay up to 50 years, thermal treatment such as incineration and melting, and high integrity containers conditioning, considered alone or in combination.

The comparison involves the environmental impact assessed by the tritium releases, the secondary waste management, the volume reduction of the waste to be disposed and the activity of waste after treatment, as well as the safety issues, the performances of the techniques used in each option and the economical point of view.

The results obtained are shown. The advantages and drawbacks of each global chain are presented.

INTRODUCTION

Tritium requires a specific management strategy taking into account its physical and chemical properties, its capability to diffuse through metals and its half-life of 12.3 years (5.6% of the tritium decays annually).

Within the framework of French regulations, radwaste management guidelines are fixed by laws and specify that producers are responsible for their waste from generation right to disposal. Such guidelines have been widely used in the field of fission-related waste and adapted in France to cover tritiated waste produced by fusion experimental facilities operating with tritium.

The CEA is currently investigating several methods to reduce the impact of tritium out-gassing from fusion devices' tritiated waste. The relevance of using detritiation techniques is just one of these methods being assessed.

This paper presents the work carried out on the waste management opportunities offered by these techniques.

DISPOSAL ROUTES IN FRANCE

In France, the disposal routes for radwaste are developed on the basis of two main parameters: activity level and half-life of the radionuclides. Concerning tritium, the out-gassing is also to consider. Its half-life puts this radionuclide in the family of the short-lived ones, which is an advantage in terms of waste management strategy over several decades.

The National Radioactive Waste Management Agency (Andra) is a French public establishment responsible for the long-term management of radioactive waste under the authority of the Ministries for Energy, Research and the Environment.

Andra only accepts waste which complies with given acceptance criteria (e.g. packaging, radioactivity, out-gassing of radionuclide such as H-3 and C-14, chemical content and toxicity, radiolysis). These acceptance criteria are derived from the design of the facility, the safety analysis, the radiation protection measures and the environmental impact assessment of the disposal facilities in accordance with the site characteristics.

The waste produced from experimental fusion devices like ITER are expected to belong to the categories described below:

VLLW (Very Low Level Waste): from a radiological viewpoint, the acceptance of a batch depends on an index (IRAS) considering the radionuclide specific activity and the radionuclide radiotoxicity class.

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

IRAS is the French abbreviation of "Indice Radiologique d'Acceptation en Stockage", which is repository radiological acceptance index.

Am_i is the specific activity of the radionuclide i in Bq/g (waste + packaging). For example, Tritium is class 3 (IRAS = 1 →1000 Bg/g).

The "Cires" disposal facility dedicated to VLLW was commissioned in 2003 by Andra.

LILW-SL (Short-Lived Long and Intermediate Level Waste): from a radiological viewpoint, there are 143 radionuclides (period generally under 31 years) mentioned in Andra waste acceptance specifications and maximal acceptance levels are defined.

The CSA current tritium acceptance limits are as follows:

- specific activity 2E+05 Bq/g,
- out-gassing 2E+05 Bq/tonne/day,
- total activity 50GBq/package ready to be disposed.

The "CSA" disposal facility dedicated to LILW-SL was commissioned in 1992 by Andra.

ILW-LL (Long Lived Intermediate Level Waste): Disposal of this type of waste is currently under study and will be subject to government approval.

The waste expected from a fusion device might not reach the tritium acceptance criteria from the disposals, thus the next section presents the detritiation options under investigation by the CEA.

For all types of tritiated waste, reducing the tritium inventory and outgassing in the primary waste has several advantages like:

- potential downgrading of the primary waste classification,
- decreased interim storage periods,
- reduced radioprotection constraints,
- depletion of tritium out-gassing from waste,
- possible recycling of the recovered tritium.

OPTIONS TO REDUCE TRITIUM INVENTORY AND/OR OUT-GASSING

Many techniques are available, this paper will focus on the ones based on:

- an interim storage to allow tritium decay,
- a thermal treatment to reduce the two parameters,
- a high integrity container to reduce the out-gassing only.

Interim storage

As seen above, the acceptance criteria in existing Andra repositories are very strict in terms of tritium inventory and out-gassing rates. As will be the case with the waste generated by fusion facilities, most tritiated waste produced by French nuclear operators is well above these acceptance criteria and therefore cannot be routed directly to the disposal facilities. For this reason, a specific report was published by the CEA in December 2008 within the framework of the National Plan for Managing Radioactive Materials and Waste (PNGMDR, [2]). This report recommends several ways to manage tritiated waste. The recommendations that have since been endorsed by the Government are [3]:

- Setting up a temporary storage site to allow for tritium decay (for 50 years if necessary, duration based on feedback from existing storage facilities) until the waste can be accepted for disposal.
- Selecting a location for the temporary storage site which is near the producer.
- Designing future Andra repositories using tritiated radwaste characteristics as input data.
- Making sure the producer takes into account waste sorting, characterization, treatment, conditioning, final packaging, temporary storage and shipment activities.

- Paying special attention to the most out-gassing waste by considering detritiation techniques and/or high integrity containers.

Thus far, interim storage is the reference solution for the management of tritiated waste in France.

Waste treatment options based on a thermal treatment

From a technical point of view, the detritiation process should be adapted to the type of waste, the size of contaminated components, the type of contamination (superficial or in the bulk) and the activities of tritium and other radionuclides. Solid waste includes soft housekeeping waste (mainly plastics, vinyl, tissues and clothes) and metallic parts (stainless steel, etc.). For each type of waste, several detritiation processes can be envisaged.

Among these processes, those offering only superficial detritiation (leaching, abrasion, electrochemical polishing, laser treatment, etc.) have been ruled out due to the fact that contamination in the waste is mainly expected to be primarily in the bulk and beyond the range of decontamination expected from the methods mentioned above. Furthermore, some of these processes produce large amounts of tritiated water that has to be managed later on. Unless tritium from tritiated water can be recycled, this can reduce the economical attractiveness of applying a detritiation process.

The operating conditions (pressure, temperature, carrier gas, preparation of waste, etc.) were chosen to obtain optimal detritiation yields. Furthermore, treatments and purification units of the tritiated gas resulting from the process are also considered. Based on the detritiation efficiency, the secondary tritiated waste production (mostly tritiated water) and the ease of operation, a preliminary design of the processes has led to retaining the most promising processes for which conceptual designs followed by technical & economic studies.

Hence, present studies focus on:

- melting for metallic components,
- thermal treatment and incineration for soft housekeeping waste.

<u>Melting for metallic components</u>

Melting of metallic waste is considered before either surface disposal for LILW-SL without interim storage, or surface disposal for VLLW considering an interim storage of around 50 years.

In terms of detritiation factor (defined as the ratio of the initial Tritium inventory over the final Tritium inventory in the waste), it is possible to expect values nearing 1,000 for the metallic waste melting process [4].

<u>Thermal treatment for soft housekeeping waste</u>

Thermal treatment is a batch process which consists in placing waste (after sorting and preliminary cutting operations) in a rotating oven at a fixed temperature below melting temperature and under primary vacuum conditions in order to reduce tritium releases and minimise gaseous effluents. According to CEA´s experience, a temperature of 60°C for a one night treatment is sufficient to remove nearly all the tritium, mainly in the form of HTO.

In terms of detritiation factors it is possible to expect values of 8 for the soft housekeeping thermal treatment.

<u>Incineration for soft housekeeping waste</u>

Incinerator units can generally handle liquid and solid waste with limitations in terms of radionuclide activity levels and chemical species (e.g. chlorine, fluorine, sulphur, heavy metals).

The incineration system is generally composed of several combustion chambers in series operating at different temperatures and ensuring the full combustion of the waste. The resulting ash concentrates the radionuclides contained in the primary waste, except tritium and C-14 which leave the process in the gaseous stream. This ash is then conditioned and shipped for final disposal.

Fig. 1. Example of incinerator

The gaseous effluent leaving the incineration unit is composed of tritium (mainly in tritiated water form), C-14 and other chemical species resulting from the decomposition of organic species. Due to their toxicity, some of the chemical species should be removed before their release into the environment. Hence, the gaseous treatment process after an incineration unit includes a cooling unit prior to a series of high-efficiency filters and several chemical treatments (dedicated process for tritium removal, scrubber unit for chlorine/halogen/sulphur/heavy metal removal, and catalytic reactor for nitrogen oxide and dioxin conversion). The design of the whole gaseous effluent purification system depends on the way tritiated water is managed.

The volume reduction is comprised between 15 and 20. This also contributes to preserve the disposals resource.

In terms of detritiation factors, it is possible to expect values of 1000 for the soft housekeeping incineration treatment.

High integrity container

The high integrity containers considered are welded canisters. The out-gassing is depending on both the temperature of the welded stainless steel package and its thickness. Nevertheless, thickness only delays the moment when the out-gassing occurs; the result is then positive for a short term interim storage but has no or few effect for long term storage.
This type of solution presents other major disadvantages: the cost of the packages is expected to be very high and the process needed to manufacture all the packages with the same level of quality is challenging.
Thus, this option has not been assessed in details in the present paper.

RESULTS OF THE COMPARISON OF THE WASTE MANAGEMENT OPPORTUNITIES

As mentioned before, detritiation presents several advantages like:

- Inventory reduction leading to a reduced interim storage decay period or possibly direct shipping to repository,
- Reduction of tritium out-gassing leading to the same result.

However, there are also issues that have to be considered:

- Secondary waste production (HTO),
- Safety,
- Industrial maturity,
- Cost.

It is thus important to assess carefully performance (R&D), feasibility (at relatively significant scale) and cost for all radwaste categories. A global study has been launched [1].

In the present paper, we will focus on the case of combustible waste with a tritium specific activity below 2.10^4 Bq/g, which covers 100% of the VLLW expected in a fusion device. We will compare incineration or thermal treatment with interim storage.

Technical criteria used for comparison and preliminary conclusions

The technical criteria used are shown in table I. A set of independent parameters was selected, with the same weighting for each parameter. The following distribution was used: 40% to the environment, 30% to safety and 30% to technical aspects.
Each parameter was graded by a group of 5 people specialised in the following fields: radwaste, tritium management, safety, project management, and fusion energy.
A quantitative scoring was assessed whenever possible, e.g. for releases and costs. Otherwise, scores were assessed from a qualitative point of view.

TABLE I. Criteria applied in the comparative analysis.

Criteria analysed	Parameter	Justification	Scoring criteria
Environmental	Global release per year (water/gas)	The environmental impact of the released tritium has to be assessed	Tritium amount released
	Public acceptance	The awareness of the public through public enquiry for example is essential.	Possible nuisances felt by the public
	Waste volumes to be disposed of	The capacity of the repositories needs to be properly used.	Reduction factor of the waste volume
	Secondary waste management	If an option generates waste with no routes, the global chain could be questioned.	Existence of a suitable route
Safety	Public exposure	Public exposure has to be assessed	Added annual exposure
	Occupational exposure	Occupational exposure has to be assessed	Level of exposure
	Tritium incident management	Management of the tritium risk in accident conditions has to be assessed	Detritiation equipment available
Technical feasibility	Treatment availability	If the treatment is not available, this would impact the storage duration and/or the costs estimates	Time before availability
	Process complexity	It may impact the safety and the costs	Technical maturity
	Process efficiency	Each option should reach its objectives	Volume and activity reduction

The results of the analysis are shown in Figure 2. They present the scores obtained for each criteria in terms of environment, safety and technical feasibility. The maximum score is fixed to 100.

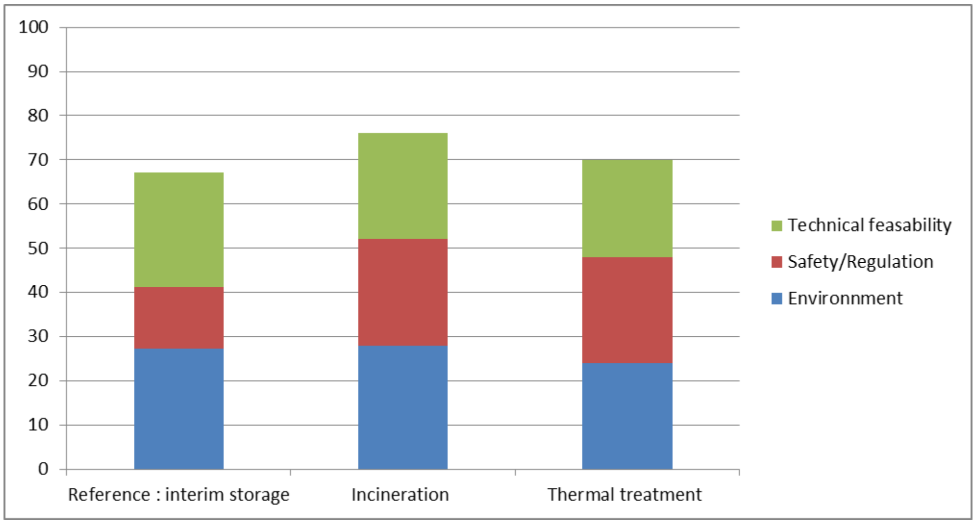

Fig. 2. Results of the comparative analysis of different combustible waste detritiation techniques

In parallel, the costs have been assessed and the most cost-effective solution is the incineration of radwaste.

CONCLUSION AND NEXT STEPS

The concerns on the tritiated waste management are linked to the fact that, as this radionuclide is very mobile and easily measured in the environment, media sensation issues can occur, even if its radiotoxicity is very low.

One of the possible solutions to reduce the ground marking with tritium around the disposals is to ensure an interim storage of the radwaste or minimise the releases from the most out-gassing waste by performing a detritiation treatment.
Detritiation treatment is based on different available techniques. Some of them have been compared in this paper taking into account safety, impact on the environment, mainly volume waste reduction, and technical feasibility and performances achieved by the process.
High integrity containers concept is based on a physical barrier associated with the management of storage temperatures and is best adapted for a short term interim storage.

The key parameters of the radwaste used as input in the comparative analysis are the type of package, the volumes concerned, the tritium amount and the radwaste flows.
The result of the analysis shows that an optimized solution is a combination of different techniques, depending on :

- the waste radiological, physical and chemical properties,
- the location of the treatment and interim storage facilities,
- the acceptance criteria of the disposals.

Interim storage for tritiated waste has a major advantage: it covers all type of waste expected from a fusion device. Nevertheless, it leads to a capital investment in a new facility and an annual operational cost during the whole period of interim storage that has to be considered to estimate the total cost.
These costs of the interim storage solution are assessed using :

- a calculation for each package of the expected duration in the storage building to assess the storage global capacity. Then, in addition, the safety options allow to define the initial capital investment and the one for the future extensions,
- the annual cost of operation can be determined taking into account the maintenance and surveillance requirements.

Incineration is competitive for the combustible tritiated waste in the study carried out by CEA. It offers interesting opportunities: an important radwaste volume reduction and an attractive cost if the incinerator benefits from adapted release permits.
For equivalent performances and final radwaste volumes, the other techniques are less interesting for soft house-keeping waste because the secondary waste amount is more elevated and the costs are higher than the incineration ones.
The work goes on based on a global optimization taking into account the required releases to ensure the good operation of the processes, the tritiated waste conditioning and the possible improvements of the disposals concept.

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