Tritiated Waste Management Opportunities Based On The Reduction Of Tritium Activity And Outgassing – 15607

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ABSTRACT

Tritiated waste is called as such because tritium is the main radionuclide contained in this waste which is generally produced by nuclear research, fusion facilities and small producers, e.g. hospitals, research centers and industries. The management of this type of waste can be improved by using techniques that reduce the tritium activity and outgassing levels.

Several options are possible 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 for conditioning, either considered alone or in combination with one of the other options.

This paper compares a number of waste management parameters with respect to tritiated waste: the environmental impact of tritium releases, secondary waste management, volume reduction of the waste for final disposal, and the waste activity after treatment, not to mention the related safety issues, the performance of the techniques used in each option, and economic aspects.

The results of this comparative work are given in this paper, with the advantages and drawbacks of each option discussed in detail.

INTRODUCTION

Tritium requires a specific management strategy that takes 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 through to disposal. Such guidelines have been widely used in the field of fission-related waste and since 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 outgassing from fusion-related 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

The disposal routes for radwaste in France are developed on the basis of two main parameters: activity level and half-life of the radionuclides. Outgassing also needs to be considered in the case of tritium. Its half-life means that this radionuclide is classified as short-lived. This is an advantage in terms of waste management strategies spanning several decades.

The French National Radioactive Waste Management Agency (Andra) is a public-sector organization 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 that complies with the given acceptance criteria, e.g. packaging, radioactivity, outgassing of radionuclides such as H-3 and C-14, chemical content and toxicity, and radiolysis. These acceptance criteria are derived from the facility design, 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 is expected to belong to the categories described below:

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

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

IRAS is the French abbreviation of *Indice Radiologique d'Acceptation en Stockage*, which is a radiological acceptance index for repositories.

Am_i is the specific activity of 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.

SL-LILW (Short-Lived Low- and Intermediate-Level Waste): from a radiological viewpoint, there are 143 radionuclides (period generally under 31 years) mentioned in Andra's waste acceptance specifications, which also define their maximal acceptance levels.

The current tritium acceptance limits for Andra's CSA disposal facility are as follows:

- Specific activity: 2E+05 Bq/g,
- Outgassing: 2E+05 Bq/ metric ton/ day,
- Total activity: 50 GBq/ package ready to be disposed.

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

LL-ILW (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 meet the tritium acceptance criteria applicable in the disposal facilities, which is why the next section describes the detritiation options under investigation by the CEA.

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

- Potential downgrading of the primary waste classification
- Decreased interim storage periods
- Reduced radiation protection constraints
- Reduction of tritium outgassing from waste
- Possible recycling of the recovered tritium.

OPTIONS TO REDUCE TRITIUM INVENTORIES AND/OR OUTGASSING

Many techniques are available for reducing tritium inventories and outgassing levels, though this paper chooses to focus on those involving:

- Interim storage to allow tritium decay
- Thermal treatment to reduce the two above parameters
- High-integrity container to reduce outgassing only.

Interim storage

As seen above, the acceptance criteria applicable in existing Andra repositories are very strict in terms of tritium inventories and outgassing 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 French 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 (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 outgassing 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 viewpoint, the detritiation process should be adapted to the type of waste, the size of the contaminated components, the type of contamination (superficial or in the bulk) and the activity levels of tritium and other radionuclides. Solid waste includes soft housekeeping waste (mainly plastics, vinyl, tissues and clothes) and metallic parts (stainless steel, etc.). Several detritiation processes can be envisaged for each type of waste.

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 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 also has to be managed. Unless tritium from tritiated water can be recycled, this can reduce the economic 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 for tritiated gas resulting from the process are also considered. Preliminary designs of the most promising processes were developed based on 1) the detritiation efficiency, 2) secondary tritiated waste production (mostly tritiated water) and 3) the ease of operation. The conceptual design phase together with supporting technical & economic studies will now be necessary for these processes.

Hence, studies in France are currently focusing 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 surface disposal for SL-LILW without interim storage, or before surface disposal for VLLW considering an interim storage of around 50 years.

In terms of detritiation factors[1], 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 minimize gaseous effluents. According to the CEA´s experience, a temperature of 60°C for an 12-hour treatment is sufficient to remove nearly all the tritium, mainly in the form of HTO.

It is possible to expect a detritiation factor of around 8 for the thermal treatment of soft housekeeping waste

[1] Defined as the ratio of the initial tritium inventory over the final tritium inventory in the waste

Incineration for soft housekeeping waste

Incinerator units can generally handle liquid and solid waste with limitations in terms of radionuclide activity levels and chemical species, e.g. chlorine, fluorine, sulfur and 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 an 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/sulfur/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.

Volume reduction ranges between 15 and 20. This also helps to preserve disposal resources.

It is possible to expect detritiation factors of around 1000 for the incineration treatment on soft housekeeping waste.

High-integrity container

The high integrity containers considered in this paper are welded canisters. Outgassing depends on both the temperature of the welded stainless steel package and its thickness. Nevertheless, the canister thickness only delays the moment when outgassing occurs; the result is then positive for short-term interim storage, but has no or little 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 complex.
Thus, this option has not been assessed in detail in the present paper.

RESULTS OF THE COMPARISON OF WASTE MANAGEMENT OPPORTUNITIES

As mentioned before, detritiation presents several advantages, such as:

- Inventory reduction leading to a reduced interim storage decay period or possibly direct shipping to repository
- Reduction of tritium outgassing 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 carefully assess performance (R&D), feasibility (at relatively significant scales) and cost for all radwaste categories. A global study has been launched [1].

In this 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 and 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 specialized in the following fields: radwaste, tritium management, safety, project management, and fusion energy.
A quantitative scoring method was used 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

Criterion analyzed	**Parameter**	**Justification**	**Scoring criteria**
Environmental	Global release per year (water/gas)	The environmental impact of the released tritium has to be assessed	Amount of tritium released
	Public acceptance	Public awareness through public enquiries, for example, is essential	Possible nuisances felt by the public
	Waste volumes for disposal	Repositories capacities need to be used properly	Waste volume reduction factor
	Secondary waste management	If an option generates waste with no routes, the global process 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 treatment is unavailable, this would impact the storage duration and/or the cost estimates	Time before availability
	Process complexity	It may impact safety and 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 the environment, safety and technical feasibility. The maximum score is fixed at 100.

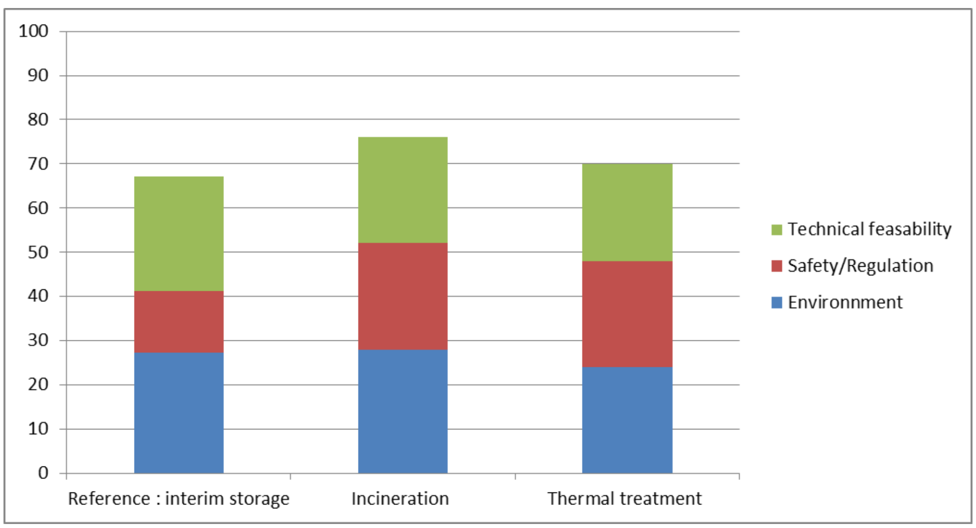

Fig. 2: Results of the comparative analysis for different combustible waste detritiation techniques

In parallel, the costs were assessed and the most cost-effective solution proved to be the incineration of radwaste.

CONCLUSION AND NEXT STEPS

Tritiated waste management concerns are linked to the fact that this radionuclide is very mobile and easily measured in the environment, even if its radiotoxicity is very low. This makes tritium an easy target for the media.
One of the possible solutions to reduce tritium ground marking around disposals is to ensure the interim storage of radwaste or to minimize releases from the most outgassing waste by performing detritiation.
Detritiation can be carried out using various techniques. Some of them have been compared in this paper taking into account safety, environmental impact, volume waste reduction, technical feasibility and performance achieved by the process.
The high-integrity container concept is based on a physical barrier associated with the management of storage temperatures and is best adapted to short-term interim storage.

The key radwaste parameters used as input data in the comparative analysis were: type of package, waste volumes, quantity of tritium and radwaste flows.
The results of the analysis show that an optimized solution can be reached by combining different techniques, depending on:

- Radiological, physical and chemical properties of the waste
- Location of the treatment and interim storage facilities
- Acceptance criteria of the disposal facilities.

Interim storage for tritiated waste has a major advantage: it covers all type of waste expected to be produced by a fusion device. Nevertheless, it requires capital investment in a new facility and generates annual operational costs during the whole interim storage period that have to be considered when estimating the total cost.
The costs of the interim storage solution were assessed on the basis of:

- Calculation of the expected storage times for each package so as to assess the storage facility's global capacity. Additionally, the safety options were used as a basis to define the initial capital investment and the cost of any future extensions
- Annual cost of operation, which can be determined taking into account the maintenance and surveillance requirements.

Incineration is a competitive solution for combustible tritiated waste in the study carried out by the CEA. It offers interesting opportunities: a significant radwaste volume reduction and lower costs if the incinerator benefits from adapted release permits.
For equivalent performance levels and final radwaste volumes, the other techniques are less interesting for soft house-keeping waste because more secondary waste is produced and the costs are higher than those for incineration.
Research is continuing based on a global optimization approach that takes into account the release requirements to ensure the correct operation of the processes and of tritiated waste conditioning, while investigating any possible improvements for the disposal concepts.

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