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Development and Identification of Detritiation Techniques for DEMO Radioactive Waste Management

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In the context of the Eurofusion project, WP SAE (safety and environment) WBS-3 (Radioactive Waste Management) existing detritiation technique were reviewed for different material types, and techniques for further development were identified. Moreover criteria for assessment were proposed and techniques were described. The most efficient treatment techniques for different groups of material types proposed for DEMO were established. The basis is a broad knowledge of the materials being considering for the EU DEMO design concept.

Keywords: DEMO, safety, environment, detritiation, Molten Salt Oxidation, Cold Crucible.

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1. Introduction

Operation of fusion facilities using deuterium and tritium to fuel the fusion reaction will lead to the generation of radioactive waste during operating and decommissioning phases. Most of these wastes are expected to be contaminated with tritium and will require a specific management strategy taking into account the physical and chemical properties of tritium.

The basis of the work are the conceptual design studies for a European DEMO. Some procedures and monitoring of the criteria are mentioned here.

2. Basic information about the methods and techniques

The contamination of radioactive waste with tritium may lead to difficulties in disposal or recycling. A comprehensive review has been completed of potential detritiation techniques to minimize this problem for waste from DEMO.

The procedure for processing information on the candidate procedures and methods and their general applicability is briefly described below.

The methods are divided into

- non-destructive
- destructive

Methods are divided according the degree of knowledge on

- described
- common - uncommon
- verified - unverified
- under development

After the first basic division of detritiation methods, specific existing methods are sought. After identifying these methods, they are broken down in terms of the degree of knowledge and the usability for the intended materials. The choice of materials is based on the present knowledge of the design of the equipment of DEMO.

The development needs for methods and techniques are listed as:

- None
- For further development work, it is necessary to carry out laboratory research
- The technique exists, but requires further work for specific materials
- Generally known for water, requires further work for specific materials and tritiated water
- Research only done to a lab scale
- The technique exists, but may not scale up well to industrial process.

Table 1. Important properties and behaviour of materials for the components of a device designed to be detritiated [2]

Property	Range of possibilities		
Toxicity	none	small and defined	high
Impurity	suitable for the method	unsuitable for the method	
Temperature	transform ation	melting	boiling
Porosity	closed	apparent	open
Resistance to environment	resistance to acids	resistance to alkalis	resistance to other solvents
Evaluation of the adsorption and desorption	isotopes of hydrogen	various liquids	various gases
Variability of properties	properties of the surface	properties just below the surface	parameters in the main body material
Material characterization	characteristics		
	electrical	magnetic	optical properties
	mechanic resistance		
	hardness and rigidity/ softness	strength of materials	toughness /fragility
	wettability to various fluids	passivity and reactivity to various chemical agents	evaluation of the adsorption and desorption

Table 1 presents a selection of some important material properties, but the list is not necessarily comprehensive. Many of these parameters and properties will be taken into account when designing suitable procedures for the treatment of materials originating from DEMO.

Table 2. General evaluation criteria of detritiation methods

Criteria methods	Criteria specification			
Evaluated method and technology	description of methods and technology	aspects and conditions when operating	dimensional characteristics of materials	size and degree of a detritiation factor
	degree of advanced technology	common or recommended applications	limitation and barriers	destructive or non-destructive with respect to treated materials

Requirements for development	method commonly used	method in the state tested	method need to be developed	references on the method exist
Process outputs	repeated use	recycling	elimination	deposition
Impacts in the wider perspective	environmental impacts	security impacts	economics and cost of operation	acquisition and disposal costs
General evaluation	acceptability to the regulator	public acceptance	technological viability	

3. Non-destructive and destructive methods

The basic steps for how to find the best method among non-destructive and recycling methods is illustrated in Table 3. Destructive recycling methods can be divided into several groups which are shown in Table 4. It is important to know whether only the surface of the material can be treated or if the transformation goes through its entire volume.

3.1 Non-destructive methods

Table 3. Non-destructive recycling technology

Step 1	A selection of detritiation techniques already processed in the detritiation matrix [3]
Step 2	For already used, it is necessary to add new classification
	Multi-stage evaluation
	Influences
	Options and survey
	Cost assessment
	Feasibility with regard to construction
	Other selection criteria
Step 3	Creating a new database for description of techniques

3.2 Destructive recycling technology

Table 4. Evaluation of the degree of destruction

Recycling after treatment	Surface modified removing only a surface layer - e.g. after buffing turn may be functional even if the cut portion is thinner
	Volume preparation (thermal, pressure, penetration etc.)
Re-use with a new layer	Surface modified
	Volume preparation
Obtaining materials for reuse	Rare materials
	Re-usable materials in the same method – reprocessing

It is necessary to monitor the relevant limit values for materials according to the type of radiation and a reference entirety in units of volume or surface. Now, some used methods of recycling have set general limits for radiation. Some ones are unsuitable for adaptation to the specific tritiated material from the DEMO. It will be necessary to revise not only the method and apparatus as well as radiation limits. There must be systematic way toward a redefinition of the limit 20mSv/h for potential recycling as a priority.

Table 5. Structure, hierarchy of procedures and the evaluation of identified suitable detritiation technologies [3].

Order of severity for procedures	Type of procedures and methods	Possibly suitable	Strong suitability
1	Short-term repeated use	1	2
2	Long-term repeated use		1
3	Recycling	4	9
4	Clearance and storage	12	12

In group WBS 3 (Radioactive Waste Management) a total of 59 detritiation techniques were proposed. 41 appropriate techniques for DEMO appear as candidates, bearing in mind that the design of DEMO is currently at the pre-conceptual stage.

3.3 Some technologies for the future

The Research Centre ŘEŽ proposes to begin testing two destructive technologies [1]. There will be removal of tritium from materials by the Molten Salt Oxidation (MSO) and the Induction Melting in Cold Crucible (IMCC).

3.3.1 Cold Crucible

The experiments are carried out on a device specifically designed for melting in a cold crucible in a defined atmosphere.

Advantages of IMCC

- Melting of low electrical-conductive materials (refractory compositions, oxides, glasses)
- Temperature melt up to 3000°C (overheating of the melt point till 1000°C)
- High specific power in the melt (surface specific power up to $200W/cm^2$)
- High temperature liquid phase synthesis of materials, no interaction with crucible material

- Long term retention of the melt at fixed temperature of air and inert atmospheres (robustness and controllability)
- Automation and remote control (future development)

3.3.2 Molten Salt Oxidation

Molten Salt Oxidation is a flameless method, which is well suited for the destruction of hazardous and radioactive organic waste streams. MSO has several advantages over traditional incineration, including lower emissions of specific gases and particulates.

Benefits of MSO

- The proposed application is for a carbonaceous material
- Solids and ash are removed in the salt. Tritiated water is collected in condenser liquids.
- Carbonaceous substances burn to carbon dioxide gas
- The possibilities of recycling rare materials from salts

4. Conclusions

The goal of the waste management study was to minimize radioactive waste quantities and hazard levels connected mainly with tritium in a DEMO plant. The procedure of finding the most suitable methods was described. Due to the expected development of the design of the device, currently at the pre-conceptual stage, it was necessary to prepare a basic plan ready for the disposal or recycling of tritiated components. The candidate detritiation techniques were prepared by a general procedure that was based on a specific matrix. Using the procedures indicated, it is possible generally regardless of the specific chemical composition, physical chemistry and mechanical characteristics of materials and the exact dimensions of the individual parts. The work has resulted in the launch of ongoing research and development. Future techniques and discoveries in relation to new techniques cannot be excluded..

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