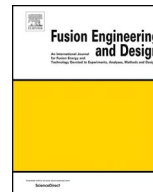




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Overview of the TRANSAT (TRANSversal Actions for Tritium) project

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ABSTRACT

In the framework of H2020 Euratom research and innovation programme, TRANSAT (TRANSversal Actions for Tritium) is a 4 years multidisciplinary project built to contribute to Research and Innovation on cross-cutting activities required to improve knowledge on tritium management in fission and fusion facilities. TRANSAT was built to answer the main following challenges: tritium release mitigation strategies, waste management improvement and refinement of the knowledge in the field of radiotoxicity, radiobiology and dosimetry. To evaluate the scientific tasks that can be covered by TRANSAT, at each step of the tritium life cycle, all the open issues that are not yet tackled by European research activities or former studies have been determined. This general landscape has been constrained to crosscutting activities on fusion and fission.

The aim of this paper is to give a general overview of the project structure and its main goals, including a detailed description of the technical topics that will be covered by the eighteen partners of the project. In particular, TRANSAT project will cover actions from tritium permeation barrier development, innovative online effluent treatments, tritium migration assessment modelling tools to tritiated waste characterization and confinement studies. In addition, part of the project will focus on radiotoxicity, radioecology, radiobiology and dosimetry on tritiated particles produced during dismantling, whose impacts have never been addressed. In order to promote TRANSAT results, a dedicated workpackage is planned to disseminate the project outcomes by means of communication actions, summer schools and development of new collaboration with external parties.

1. Introduction

Tritium (^3H) is a beta emitter (emission of electron with a range of energies up to a maximum energy of 18.6 keV and mean energy of 5.7 keV) and radioactive isotope of hydrogen with a physical half-life of 12.3 years. There exist two main sources of tritium: natural source coming from the action of cosmic rays on nitrogen, oxygen and argon in the atmosphere (stable inventory of around 3.5 kg on earth and a natural production of nearly 200 g/year [1]) and non-natural source from:

- Mainly ternary fission and reaction with ^{10}B and ^6Li in nuclear fission reactors (worldwide tritium release of nearly 35 g/year [2])
- nuclear fuel reprocessing plants (annual tritium release of 35 g/year [2])

- nuclear weapons manufacturing and former tests (nearly 30 kg in 2010 [2])
- accelerators by bombarding ^3He with neutrons
- radionuclide labelled materials for application in medicine
- fusion reactors studies

Tritium is very mobile and is released mainly as tritiated water and isotopes of hydrogen in the environment directly from any of the above mentioned sources, from tritiated waste storage or treatments. This has led to environmental and health impact issues. Recently, due to deuterium-tritium fusion reactors development studies, new fuel management (especially for GEN IV reactors) and conception choices (B_4C as structure material for fast breeder reactors), the tritium release in the environment is expected to increase. These additional releases

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combined with authority and public acceptance pressure lead to the need of new tritium release impacts mitigation strategies to be developed as well as a better understanding of tritium impacts on health and the environment [1–5].

2. Objectives of the project

Tritium is present in various amounts in all nuclear energy production systems such as former, actual and future fission nuclear power reactors, fission experimental nuclear reactor, accelerator driven systems, fusion experimental machine using tritium as fuel like JET (Joint European Torus Reactor), ITER (International Torus Experimental Reactor) and fusion nuclear power reactors like DEMO. Considering the fact that tritium is already the main radioisotope released in the environment [6], it is important for each of these systems to:

- Elaborate strategies to mitigate tritium release
- Improve waste management
- Improve the knowledge in the field of radiotoxicity, radiobiology, dosimetry

2.1. Tritium release mitigation

In general, limitation of tritium sources is taken into account during the conception phase of a reactor in which the tritium sources are limited and kept as low as reasonable. Indeed it is worth noting that the amount of boron and lithium which constitutes the source of tritium by interaction with neutrons is limited in fission reactors at the lowest possible level. Identically, the fusion community is continuously improving the fusion burn up and tritium breeding system to decrease the tritium recirculation and thus its absorption in the material of the vessel walls or of the tritium plant. But, it is not possible to go under a certain limit for operational constraints or safety reason and it is then necessary to work on tritium capture and permeation limitation between and through the circuits. Consequently, this project will focus on technologies needed to reduce this tritium permeation between and through circuits by means, for example, of the development of new materials with reduced tritium diffusion capability or in situ operational effluents treatment. Furthermore, in order to ease the tritium permeation mitigation strategy during conceptual phase of reactors or devices, modeling tools for tritium inventory and tritium permeation fluxes estimation in fusion and fission devices will be compared and benchmarked to improve the level of confidence in their estimation.

2.2. Improvement of tritiated waste management

Another important cross-cutting issue concerns tritiated waste management. Indeed, tritium, as an isotope of hydrogen, has the property to migrate and be absorbed easily in any material. For tritiated waste, this leads to tritium release which intensity and degassing rate is related to the tritium inventory, tritium profile in the material and external conditions such as temperature and humidity. As a consequence, the storage strategy of tritium contaminated waste is complex and directly related to different critical issues like tritium inventory and tritium surface contamination measurements. Non-destructive techniques like calorimetry [7] or ^3He method [8] have a too weak precision and destructive methods are based on sampling strategy that is not satisfying due to possible contamination inhomogeneity. Moreover, non-destructive and destructive methods are not related to tritium profile measurement in the material. Hence, this project will focus on innovative measurements to assess both tritium inventory and profile.

Storage facilities have also to deal with tritium release from wastes. For wastes having a tritium release rate above the acceptance criteria of the storage facility, different strategies can be considered: tritiated waste treatment (thermal treatment, incineration ...), improved confining drum, confining matrices [9,10]. These methods can be either

combined or used separately. In the framework of waste management strategy and considering the fact that detritiation processes are already covered by H2020/Power Plant Physics & Technology programme [11], this project will focus on improving new concepts for confining drums.

2.3. Refinement of the knowledge on radiotoxicity, radiobiology, dosimetry

In parallel to the previous 2 main objectives, investigations are proposed to improve knowledge in the field of radiobiology, dosimetry, radiotoxicology, genotoxicology and ecotoxicology and environmental fate in case of contamination by tritiated products. In the nuclear field, tritium can be released into the atmosphere as tritium gas or tritiated water. Some of the tritium release can be then transformed in organically bound tritium. The radiotoxicological consequences of a contamination by tritiated water or organically bound tritium in animal or cells have been identified during experiments only at high tritium concentrations [2]. Moreover, epidemiological studies conducted on workers, who may have been exposed to tritium, have included doses due to tritium exposure, but tritium-specific doses have not been the subject of a specific assessment [12]. As such, at present these studies provide only a weak indication of the risks to health posed by tritium exposure.

During the decommissioning of nuclear facilities, operations are intended to remove or eliminate any tritiated material. These operations generate fine airborne dust, namely aerosols. It is proposed here to study the consequence of a release of such tritiated particles in terms of radiotoxicology and ecotoxicology. The cross-cutting materials will be stainless steel, cement and aluminum. The outcomes foreseen in this project will help radiation protection authorities, IAEA and other nuclear safety advisory organisms to assess more precisely the radiobiology, dosimetry, genotoxicology and ecotoxicology of tritiated micron and sub-microns particles. Accordingly, new safety rules and radiation protection approaches should emerge for safe handling tritium especially during dismantling activities.

3. Overall structure of the work plan

The cross-cutting approach of the project is represented by 4 technical workpackages (called hereafter WP) that provide inputs for consolidation and driving conclusions in the WP5 (see Fig. 1). The interactions and recommendations gathered in the WP 5 aim to achieve the expected impact on paving the way for science-based policy recommendations to decision makers in the tritium area at EU level. To complete the goals of the TRANSAT project, 18 partners are involved in this programme (see Table 1) and will produce 26 technical deliverables (see Fig. 2).

3.1. WP1: developments of barriers against tritium permeation and treatment of operational tritiated gases

This WP is led by KIT and is dedicated to the development of technological solution for the tritium source limitation and tritium release mitigation. Experimental activities will cover strategies for tritium migration limitation by means of permeation barriers development (active barrier and coating technics that have potential for industrialization) or in situ operational gaseous effluent treatment. Experimental studies on tritium migration in view of refinement of knowledge on diffusion, retention and release mechanisms will be covered. In addition, the development of a viable route for the separation of lithium isotopes will be investigated as Lithium isotopes are needed for both fission and fusion reactors. In particular, availability of ^6Li for tritium production in fusion machine will help the minimization of tritium source.

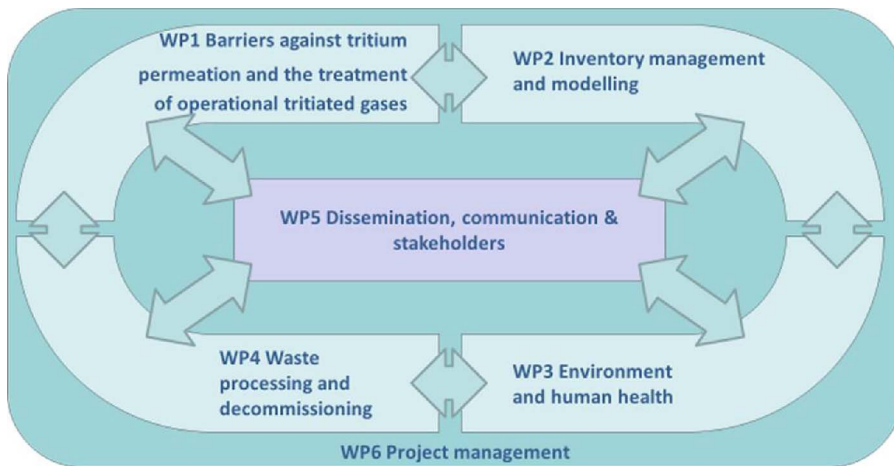


Fig. 1. Project scheme.

3.2. WP2: tritium inventory management and modelling

This work package is led by CIEMAT and will mainly focus on the development of innovative methods for tritium inventory measurements and on the improvement of modelling tools to assess the tritium inventory and tritium migration fluxes in reactors or processes.

In the field of tritium detection and inventory assessment, the coupling of the three techniques described hereafter will be investigated and applied to tritium inventory measurement in different types of materials (real waste and tritium loaded samples). The first technique is autoradiography which provides an image of the distribution of radioactivity of the surface/sub-surface of the sample owing to the measurement of the electron emitted during the decay of the tritium. The second technique is a nuclear reaction method using ³He beam which provides a tritium depth profile on the waste up to some micrometers. The last technique is Laser Induced Breakdown Spectroscopy (LIBS) which allows a tritium profile evaluation up to tens of μm. LIBS is a destructive technique that ablates very small quantity of material constituting the waste studied. Due to very high laser fluence, the ablated material is ionized to obtain a plasma which emits light that can be related to hydrogen isotopes concentration. Coupling all these three techniques is an innovative way of investigation for the assessment of tritium contamination and inventory in waste by combining information on tritium surface concentration and subsurface tritium profile (up to 10 s micrometers). Part of this activity will be devoted to integration of these couple techniques in the radioactive waste treatment in order to improve the waste management.

The second part of this WP will deal with improvement of modelling

tools to assess the tritium inventory and tritium migration fluxes in reactors or processes. Models used in KUTIM (tritium migration code developed for fission reactors [13]) and EcoSimpro (tritium migration code developed for fusion machines and processes [14]) will be compared, homogenised and their predictive capabilities compared through benchmark activities conducted on the fission GEN IV sodium fast breeder prototype ASTRID developed by CEA.

3.3. WP3: impact of tritiated products on environment and human health

During dismantling procedures, the accidental release of tritiated particles (i.e. steel, cement) into the atmosphere in case of protection containment failure will have an impact on the environment (dissemination in the atmosphere and in water). This may be also a source of contamination for living organisms, particularly the human, by inhalation at the workplace. Up to now, nothing is known on the toxicity of steel and cement tritiated particles. It is consequently difficult to anticipate the effects of an accidental release in terms of human and environmental health. Therefore, evaluation of their effect on environment and human is the goal of the WP3 led by CEA. This WP aims at covering a wide range of approaches from the development of modelling tools to assess tritiated particles transfer in atmosphere/plant transfer, up to multi-scale dosimetric approaches. As a consequence, a wide range of *in vivo*, *in vitro* and *in silico* models will be used in this work package with 4 main scientific tasks detailed below:

- A first step is dedicated to the production of relevant steel and cement particles generated during decommissioning process in both

Table 1
List of TRANSAT partners.

CEA	Commissariat à l’Energie Atomique et aux Energies Alternatives	France
AMU	Aix Marseille University	France
CIEMAT	Centro de Investigaciones Energeticas Medioambientales y Tecnologicas	Spain
CORIA	COmplexe de Recherche Interprofessionnel en Aérothermochimie	France
DH PHE	Public Health England	United Kingdom
ENEA	Italian National Agency of New Technologies, Energy and Sustainable Economic Development	Italy
IFIN HH	Horia Hulubei National Institute for Physics and Nuclear Engineering	Romania
IIT	Fondazione Istituto Italiano di Tecnologia	Italy
INFLPR	Institutul National De Cercetare Dezvoltare Pentru Fizica Laserilor Plasmei Si Radiatiei	Romania
IRSN	Institut de Radioprotection et de Sûreté Nucléaire	France
JSI	Josef Stefan Institute	Slovenia
KIT	Karlsruhe Institute of Technology	Germany
LGI	LGI consulting	France
RATEN	Regia Autonoma Tehnologii Pentru Energia Nucleara	Romania
SCK-CEN	Studiecentrum voor Kernenergie/Centre d’Etude de l’Energie Nucléaire	Belgium
UKAEA	UK Atomic Energy Authority, Culham Center for Fusion Energy	United Kingdom
UNIPV	University of Pavia	Italy
UOP	University of Plymouth	United Kingdom

	Year 1				Year 2				Year 3				Year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
WP1																
D11 Assessment of 3H source / state of the art on permeation barrier			D11													
D12 Viable route for the separation of lithium isotopes			D12													
D13 Review of gas treatment technologies				D13												
D14 Report on active barriers												D14				
D15 Assessment of transfer of technology under operating conditions of fusion/fission												D15				
D16 Experimental validation of permeation barriers based on coatings												D16				
WP2																
D21 Review of the different techniques to analyse tritium			D21													
D22 Data set on ASTRID design/operating conditions				D22												
D23 Results obtained by the LIBS technique, autoradiography and Ion Beam Analysis															D23	
D24 Comparative analysis of simulation results using KUTIM and ECOSIM PRO codes															D24	
WP3																
D31 Report on production of steel particles				D31												
D32 Report on production of cement particles					D32											
D33 Report on tritiation of particles						D33										
D34 Report on model equations and comparison with generic models																D34
D35 Development of tools to study the environment fate of particles by-products																D35
D36 Ecotoxicological/genotoxicological impact of particles on marine bivalves																D36
D37 Acute and long-term toxicities, epi/genotoxic studies and transepithelial transfer of particles on in vitro human models.																D37
D38 Report on dissolution and in vivo inhalation studies																D38
D39 Report on predicted effectiveness of tritiated products																D39
D310 Report on biokinetic parameters and organ dose calculation																D310
WP4																
D41 State of the art on tritium inventory measurement in soft waste				D41												
D42 Report on tritium measurement in soft waste												D42				
D43 State of the art on tritium confining drum.							D43									
D44 Final report on new tritiated waste packages																D44
D45 Interim report for preparation of dismantling plan				D45												
D46 Dismantling plan for a tritiated fission industrial facility with fusion relevant components					D46											

Fig. 2. Project technical deliverables and schedule.

fusion and fission. The particles produced will be tritiated and characterized in terms of their physical and chemical stability

- Second step will focus on eco-toxicological studies including assessment of the deposition velocity and metabolism of tritiated aerosols in the environment, development and validation of an associated model of deposition of tritium in particulate aerosol form on grass, environmental transformation of the released particle by-products using mesocosm scale studies as well as toxicity and genotoxicity studies of tritiated steel and cement particles studied in marine bivalve
- Third step will concern radiotoxicology studies including long-term toxicity and genotoxicity studies of these dusts on *in vitro* human lung models (cells and epithelium), evaluation of the behaviour of the tritiated dusts in lung (release of tritium from particles in lung fluids) and investigation of the inhalation biokinetics of tritiated particles on rodent models
- The last step concerns dosimetry studies with the evaluation of the dosimetry of inhaled tritiated aerosols followed by the development of biokinetics models and dose coefficients

3.4. WP4: tritium issues in waste processing and decommissioning

The work package 4 is led by UKAEA and is dedicated to experimental activities related to the improvement of waste management and tritium release mitigation during dismantling or maintenance activities. The experimental programme will cover permeation experiments to assess the permeability of disposal facility container relevant materials to tritium. The permeation experiments will be carried out at temperatures similar to those expected in a disposal facility. The objective is to propose a new concept of container for tritiated waste. In WP4, soft waste characterization will be investigated looking specifically at water leaching, off-gassing and combustion with pyrolysis. Using pre-existing soft waste present on the Culham site, advantages and disadvantages together with uncertainties present in the various techniques and sampling will be assessed. In addition, a topic is dedicated to the development of a methodology for elaboration of dismantling and disposal plan including tritium release mitigation strategies. Application of

this methodology is proposed for the dismantling of tritium getters that are present in the obsolete Variable Neutron Shields (VNS) at SCK-CEN.

3.5. WP5: dissemination, communication & stakeholders engagement

This WP is led by JSI and has the goal to assure a large dissemination of the knowledge gathered in TRANSAT project, both inside the consortium and to the relevant stakeholders in the nuclear sector. WP5 will then be in charge of:

- Spreading information on the project’s activities and results widely among stakeholders
- Ensuring the right coordination with the Scientific Advisory Committee through an integrated, targeted and participatory dissemination approach.
- Ensuring continuation and sustainability of the TRANSAT results beyond the project, thus paving the way for the continuous uptake of the results across the relevant European and international communities. This includes educational activities in form of summer schools, organization of meeting with selected stakeholders, publishing of the scientific results achieved and presenting those within appropriate fora
- Establishing synergies and boosting new collaboration with external parties, such as public authorities and international organisations, to utilise a multiplier effect, thus contributing to knowledge building and best practices diffusion in Europe and beyond, avoiding overlap of different projects
- Linking to the EC’s coordination activities on radioprotection, waste disposal management and other fission & fusion R&D initiatives

3.6. WP6: management

The overall management of the project will be carried out in the WP6, for which CEA is responsible. In terms of consortium management, WP6 objectives are to guarantee sound management of contractual and financial issues, setting-up and maintaining project management tools, good communication in the consortium, proper quality

assurance in the delivered reports, financial and contractual management, reporting to the EC. Consortium management and scientific coordination are placed under the responsibility of the coordinator.

4. Conclusion

The TRANSAT project activities will definitely reinforce the knowledge and position of the European scientists on international level in the field of tritium. In particular, the expected most relevant scientific impacts concern tritium inventory assessment, tritium release control, tritium migration modelling, tritium measurements, tritiated waste management, tritium contaminated process dismantling and tritiated particles radioecology and radiotoxicity. A number of research papers and presentations in conferences as well as recognised and open access journals are envisaged. The different outcomes of the project will represent strong progresses in the cross cutting activities of tritium for fusion and fission industrial activities.

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