theramin

thermal treatment for radioactive waste minimisation and hazard reduction


University of Sheffield

Andra's underground research laboratory, Bure

INTRODUCTION

Safe management of radioactive waste is challenging to waste producers and waste management organisations. Thermal pre-treatment or immobilisation processes result in significant volume reduction, waste passivation and destruction of organic materials, which reduces risks during waste storage and supports development of safety cases for geological disposal.

Some thermal processes, such as induction melting, plasma melting or hot isostatic pressing, immobilise the waste into a disposable product, such as a glass, ceramic or metal. Other thermal processes, such as incineration, pyrolysis, calcination and gasification, are pre-treatment steps and the product may need further processing prior to disposal.

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For further information:
please see our website at http://www.theramin-h2020.eu or contact the project coordinator Matti Nieminen, VTT at Matti.Nieminen@vtt.fi

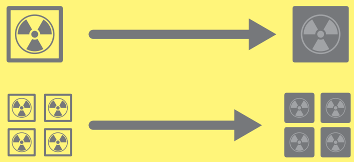
Example pilot plant.

PROJECT SUMMARY

theramin aims to identify which wastes could benefit from thermal treatment, which processes are under development in participating countries, and how these can be combined to deliver a range of benefits across Europe.

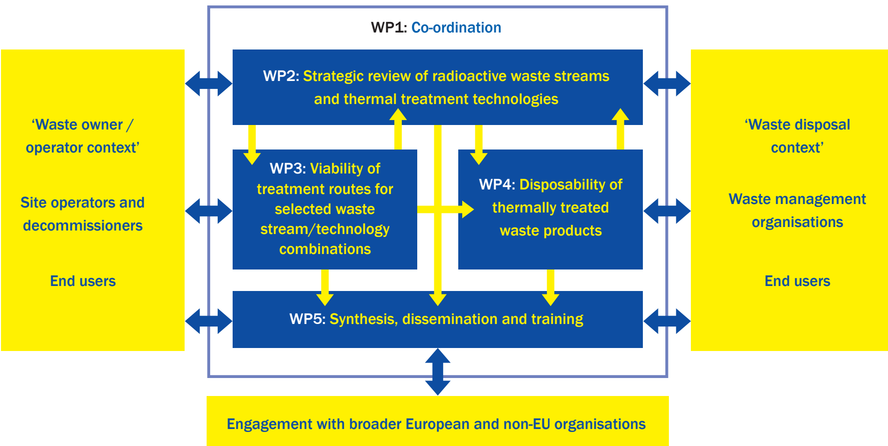
theramin is being carried out by a consortium of 12 partners representing a European-wide community of experts on thermal treatment technologies and radioactive waste management and disposal. The project includes an advisory group of waste producers and management organisations to provide an end user view.

the theramin PROJECT IS:



- Providing an EU-wide strategic review and assessment of the value of thermal treatment technologies applicable to a broad range of waste streams (e.g. ion exchange media, soft operational wastes, sludge, organics and liquids).
- Compiling a database of thermally treatable wastes in participant countries, documenting the strategic benefits of thermal treatment, and identifying the opportunities, synergies, challenges, timescales and cost implications to improve radioactive waste management.
- Evaluating the applicability and achievable volume reduction of the technologies through active and non-active pilot-scale and full-scale demonstration tests, and assessing the disposability of residues.

theramin is divided into five work packages. The aim of each work package (WP) is summarised in the diagram below, which also shows how information flows between WPs.

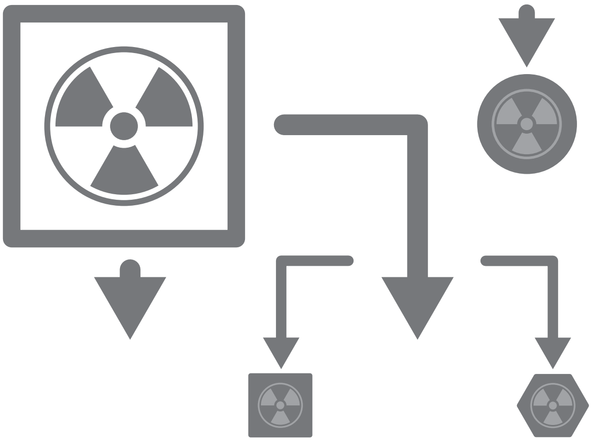


DATES FOR YOUR DIARY

- Value Assessment Workshop
  3-4 December 2019, Stamford, UK
- **theramin** 2020 Project Conference
  4-5 February 2020, Manchester, UK

WP2:
STRATEGIC REVIEW OF RADIOACTIVE WASTE STREAMS AND THERMAL TREATMENT TECHNOLOGIES

WP2 has identified a wide range of wastes that could benefit from thermal treatment and documented thermal treatment technologies available in Europe (summarised in the first theramin Newsletter).



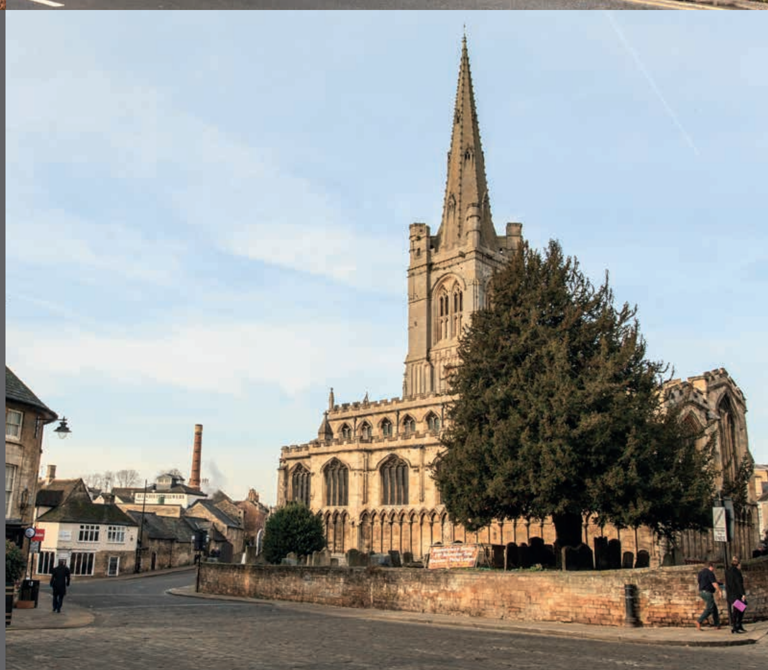
Ongoing work in WP2 has focused on the development and testing of a Value Assessment methodology for use by decision-makers seeking to select a thermal technology to treat radioactive waste.

A trial Value Assessment methodology developed in year 1 will be refined at the Value Assessment Workshop (see below).

The River Welland, Stamford

UPCOMING EVENT:
VALUE ASSESSMENT WORKSHOP

The Value Assessment Workshop will be held on 3-4 December 2019 in Stamford, UK. The workshop will review the outputs from WP3 and WP4 and use them to build upon the trial Value Assessment to develop a final version. The methodology will be tested using **theramin** examples.



The Church of All Saints, Stamford

WP3:

VIABILITY OF TREATMENT ROUTES FOR SELECTED WASTE STREAM/ TECHNOLOGY COMBINATIONS

This work package involves demonstrations by partners of thermal treatments for specific waste streams of interest across the EU which were selected for this experimental programme based on the output from WP2.

The work of all WP3 partners has been summarised in deliverables, available from the **theramin** website http://www.theramin-h2020.eu/downloads.htm .
Two examples are summarised here.

In-Can melting Trial

The CEA performed a full-scale trial consisting of the vitrification of inactive ash using the In-Can Melter technology. The trial aimed to demonstrate the feasibility of confining by-products of existing incineration processes in a vitreous matrix. The In-Can Melter is a metallic crucible heated in a refractory furnace using electrical resistors, allowing in-container vitrification.

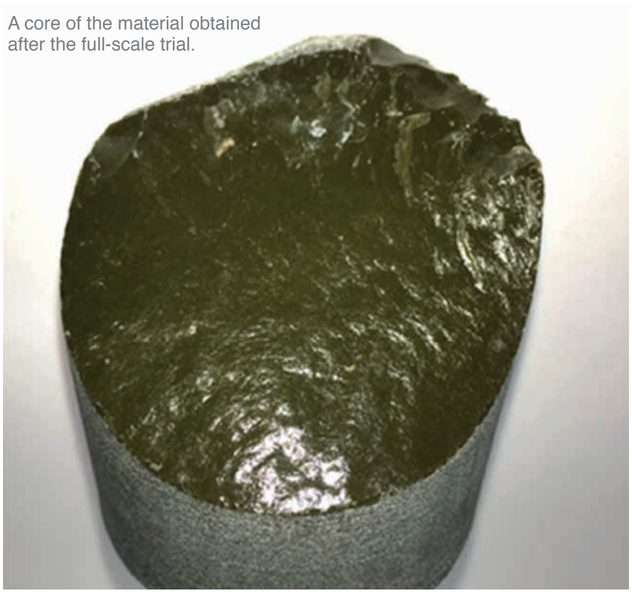
The ashes – mainly composed of Al, Ca, Si, Zn, Bi, K, Mg – were the product of incineration of wastes such as cotton, latex, neoprene or polyethylene. The glass feasibility was first evaluated at a laboratory-scale (10-100 g of glass). The volatile behaviour of fly ash was controlled by pelletizing to avoid pipes clogging when performing the full-scale trial. A 10 wt.% bentonite binder was added to obtain cohesive pellets.

Ash pellets
(5 mm x 5 mm scale)

A borosilicate glass frit was selected and a waste loading of 50 wt.% was achieved. After this step, a bench test (1 kg of glass) was done to verify the absence of corrosion of the metallic can. Finally, this was followed by a full-scale trial (50 kg of glass) with 75,000 ash pellets used.

The trial demonstrated the success of the In-Can process for the vitrification of ash resulting from the incineration of organic nuclear waste. A waste loading rate of 50 wt.% was achieved in this first approach, and the resulting wasteform from the process was a crystallized glass. The trial also made it possible to begin the technical investigation required for the processing of powdery solids into the can while avoiding the emission of dust.

Introduction of the can in the furnace.



A core of the material obtained after the full-scale trial.

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Vitrification of Chrompik III

Vitrification technology has been chosen for the treatment and conditioning of a inorganic liquid radioactive waste (Chrompik), main contaminant ^{137}Cs. The owner and operator of the vitrification facility is JAVYS, Inc. Jaslovske Bohunice, Slovakia.

During the period 1996 to 2001, an initial batch of Chrompik (18.5 m^3) was vitrified producing a total volume of 1.53 m^3. Due to the higher ^{137}Cs contamination levels associated with Chrompik III, the vitrification line required several modifications to improve the process.


Model of the vitrification facility


Sample of inactive Chrompik III glass block

Sample of active Chrompik III glass product prepared using vitrification facility.


The vitrification line is a discontinuous batch process. One batch of 50 dm^3 of Chrompik is initially concentrated before being added to glass frit and additives in an inductively heated melting crucible. Water is evaporated at ~130°C before being heated to a temperature of 960-990°C over a period of approximately 6 hours. The resultant vitrified product is poured into a storage container, which has the capacity to accommodate two batches. Off-gas from the vitrification process is drawn into an off-gas treatment system producing a condensate which is decontaminated via a sorption column prior to further treatment.
As part of WP3, the use of chemical additives to absorb Cs and thereby minimise Cs losses from the melter crucible during drying and melting was successfully tested. The vitrified product is stored in fully sealed hermetic casks. The treatment of the Chrompik recommenced in the modified facility after trials in 2016.

WP4:
CHARACTERISATION AND DISPOSABILITY OF THERMALLY TREATED WASTE PRODUCTS

Characterisation of thermally treated waste products

In order to be disposed of, radioactive waste must comply with the Waste Acceptance Criteria (WAC) for a disposal facility – this identifies the characteristics required in a waste product in order to ensure that the waste cannot have a significant detrimental impact on the long-term safety provided by the disposal facility. This compliance can be checked by characterisation of the thermally treated products.

Since the previous newsletter was published (February 2019), WP4 partners have completed the characterisation of samples resulting from the work in WP3, and also of some additional samples from thermal treatment processes not tested in the project. The output from each partner has been compiled in deliverable D4.2, which is available from the **theramin** website www.theramin-h2020.eu/downloads.htm . Two examples are presented here.

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List of thermal process/waste stream combinations characterised in WP4

Thermal treatment process	Waste stream/simulant	Final wasteform	theramin partner
Shiva	Mixture of zeolites, diatoms and ion exchange resins	Glass	CEA
In-Can Melter	Ashes from technological waste incineration		
GeoMelt	Simulated cemented package representing conditioned waste	Glass	NNL
	NNL		
	Heterogenous sludge		
	Plutonium Contaminated Material/Magnox sludge simulants		USFD
	Pile fuel cladding/clinoptilolite		
HIP	Uranium	HIP matrix	NNL
	Magnox sludge simulants		USFD
Vitrification	Chrompik liquors	Glass	VUJE
Thermal Gasification	Organic IER	Ashes	VTT
JÜV 50/2 incinerator	Mixed radioactive waste	Ashes	FZJ
Plasma vitrification	PCM	Glass	USFD
Plasma incineration	Cemented concentrates	Glass	SCK.CEN
	Cemented anionic resins		

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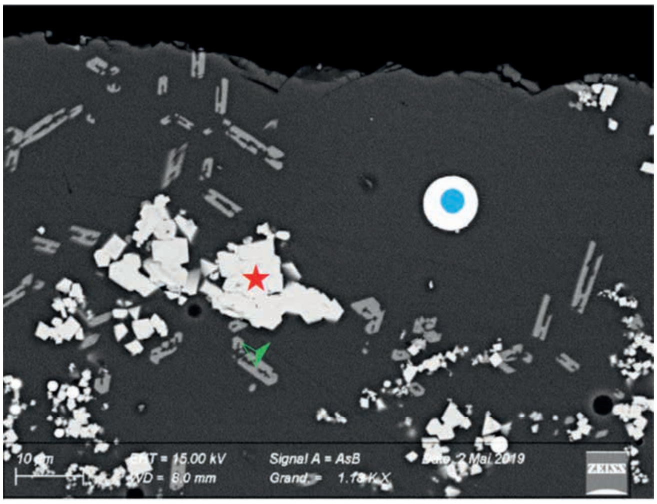
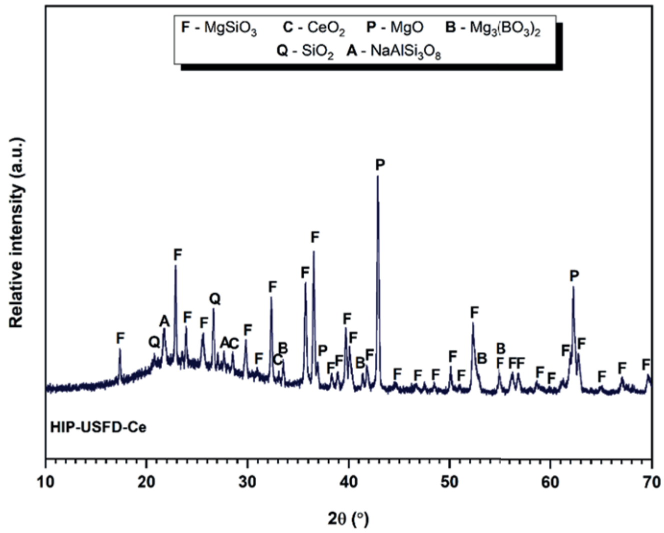


Scanning electron microscopy image of the wasteform produced using the In-Can Melter (CEA), showing crystals of hydroxyapatites (★) and zincochromites (▽), and bismuth alloys (●) embedded in a borosilicate glass matrix.



XRD spectra of a wasteform produced by the thermal treatment of Magnox sludge simulant with HIP process (USFD). It shows multiple crystalline phases such as forsterite (MgSiO3), ceria (CeO_2), periclase (MgO), quartz (SiO_2), kotoite ($Mg_3(BO_3)_2$ and albite ($NaAlSi_3O_8$).

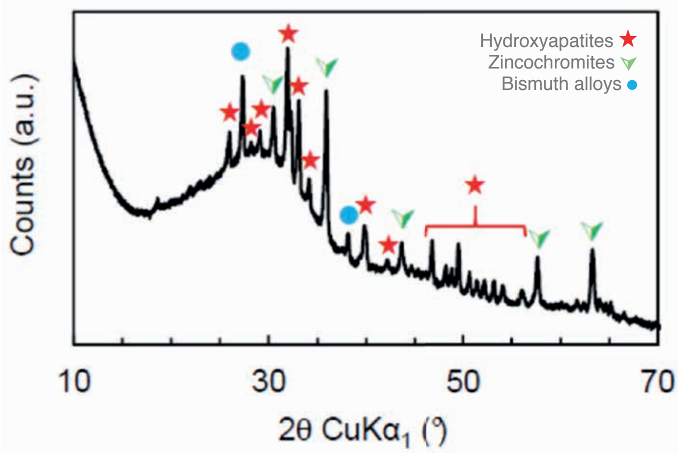
Characterisation of the wasteform produced using the SHIVA process

The wasteform produced by the SHIVA process consisted of an amorphous glass mainly composed of SiO_2, B_2O_3, and Al_2O_3. Leaching tests showed that the hydrolysis rate of the glass is significantly lower than that of the International Simple Glass reference. Complete understanding of the long-term behaviour of the wasteform would require further investigation, but these initial results are encouraging.

Characterisation of the wasteform produced using the In-Can Melter process

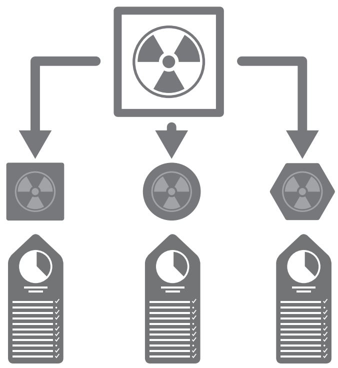
The wasteform produced by the In-Can Melter process consisted of a crystallised glass mainly composed of SiO_2, Na_2O, B_2O_3, Al_2O_3, and CaO. The term "crystallised glass" refers to a vitreous matrix including crystals of hydroxyapatite, zincochromite and bismuth alloy. The crystals were distributed homogeneously in the characterised sample. Since the crystalline phases are durable, the durability of the wasteform is controlled by that of the vitreous matrix. The hydrolysis rate of the vitreous component was relatively high because of its high content of B_2O_3 and Na_2O. However, the trends observed suggest that, in the long term, an alteration layer will form, leading to a significant decrease in the alteration rate.

X-ray diffraction of the wasteform produced using the In-Can Melter.



Disposability and safety case implications

Based on the WAC identified during the project for thermal treatment products and the characterisation results, an evaluation of the impact of thermal treatment on the disposability of the waste is currently ongoing. A safety case implication study is being completed for each waste stream/treatment process combination studied in the project and for selected disposal concepts in participating countries. Partners are investigating the ways in which thermal treatment can provide benefits/ disadvantages in terms of WAC, subsystem performance, long-term behaviour or overall disposal system safety.



WP5:
SYNTHESIS, DISSEMINATION AND TRAINING

theramin WP5 aims to disseminate knowledge and the outcomes of the project within the technical community and more widely. This includes:

- Training placements linked to experimental trials or sampling and analysis that were conducted in WP3 and WP4 (summarised in the **theramin** Newsletter 2).
- A technical training school.
- An open project conference.

theramin Technical Training School

The **theramin** Technical Training School was hosted by the CEA at Marcoule in June 2019. The training school was attended by 22 participants (largely early career researchers and PhD students from the project Partners and End Users). Oral and poster presentations were given on the toolbox of treatment and characterisation approaches demonstrated in the project, and these are available on the **theramin** website: www.theramin-h2020.eu/trainingschool2019.htm

Participants also had the opportunity to visit industrial and prototype thermal treatment facilities operated by the CEA and Cyclife-EDF.

theramin Project Conference

The **theramin** Project Conference will be held on 4-5 February 2020 in Manchester. Oral and poster presentations will be given on the topics of

- Strategic impact of thermal treatment
- Demonstration of thermal treatment technologies
- Disposability of thermal products and characterisation techniques

There will also be a visit to the Immobilisation Science Laboratory at the University of Sheffield on 6 February (limited spaces – to be booked on registration).

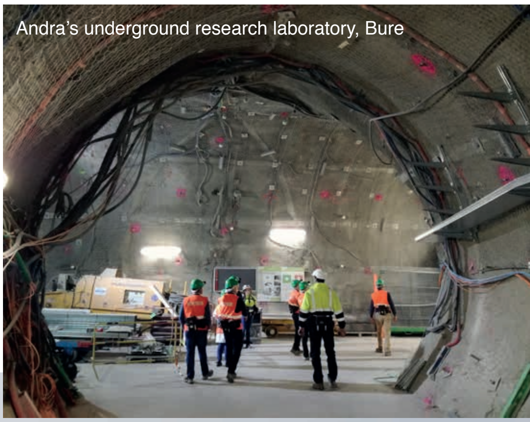
To register, please visit the **theramin** website (www.theramin-h2020.eu/conference.htm) before 20 December. Registration costs £150, with fees waived for Project participants. A limited number of free places are available for students and some EC funding is available to help cover travel expenses for students, early career researchers or others unable to access alternative sources of funding. Please contact Neil Hyatt (n.c.hyatt@sheffield.ac.uk) for details.

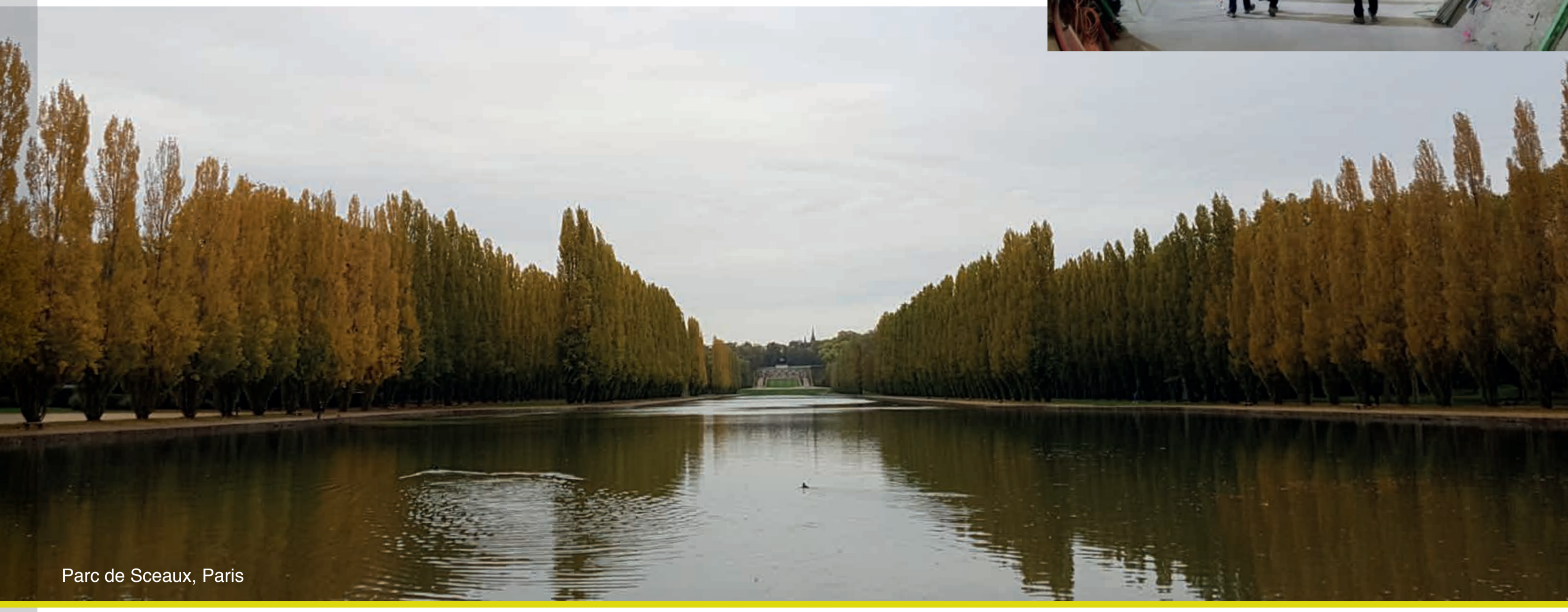
RECENT
EVENTS

General Assembly Meetings in Brussels and Paris

NIRAS/ONDRAF hosted the fourth **theramin** General Assembly meeting in Brussels on 14/15 May 2019 at the Hotél Congrés, Brussels. A new member of the **theramin** End User Group, Idaho National Laboratory (INL), gave a presentation on their previous and ongoing environmental activities.

Andra hosted the fifth **theramin** General Assembly meeting in Paris on 29/30 October 2019 at their offices in Châtenay-Malabry, following an excellent visit to the underground research laboratory in Bure on 28 October 2019.


Andra's underground research laboratory, Bure


Parc de Sceaux, Paris

Project participants:
The theramin project benefits from participation from waste management organisations, waste producers, and research organisations, with input from technology specialists. It therefore offers a "joined-up" perspective of the advantages and disadvantages of using thermal treatment within the waste management lifecycle.

theramin partners:
- VTT Technical Research Centre of Finland (VTT), Finland
- Agence Nationale pour la Gestion des Déchets Radioactifs (Andra), France
- Orano, France
- Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA), France
- Galson Sciences Limited (GSL), United Kingdom
- Forschungszentrum Jülich GmbH (FZJ), Germany
- Lithuanian Energy Institute (LEI), Lithuania
- National Nuclear Laboratory Limited (NNL), United Kingdom
- Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), Belgium
- Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire (SCK•CEN), Belgium
- University of Sheffield (USFD), United Kingdom
- VUJE a.s. (VUJ), Slovakia

End users:
- National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland
- Radioactive Waste Management (RWM), UK
- Sellafield Limited, UK
- Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP)
- Électricité de France (EDF), France
- Fortum, Finland
- Teollisuuden Voima Oy (TVO), Finland
- Agence Nationale pour la Gestion des Déchets Radioactifs (Andra), France - Project Partner as well
- Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA), France - Project Partner as well
- Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), Belgium - Project Partner as well
- AWE, UK
- Idaho National Laboratory (INL), USA

European Commission

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