European Commission

EURADWASTE '19

9th European Commission Conference on EURATOM Research and Training in Radioactive Waste Management

Co-organised by the European Commission and the Romanian Presidency of the Council of the EU in 2019

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INSTITUTUL DE CERCETĂRI NUCLEARE

in cooperation with

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4-7 June 2019
Pitesti, Romania

PROGRAMME & ABSTRACTS

Research and Innovation

EURADWASTE'19 Programme and Abstracts

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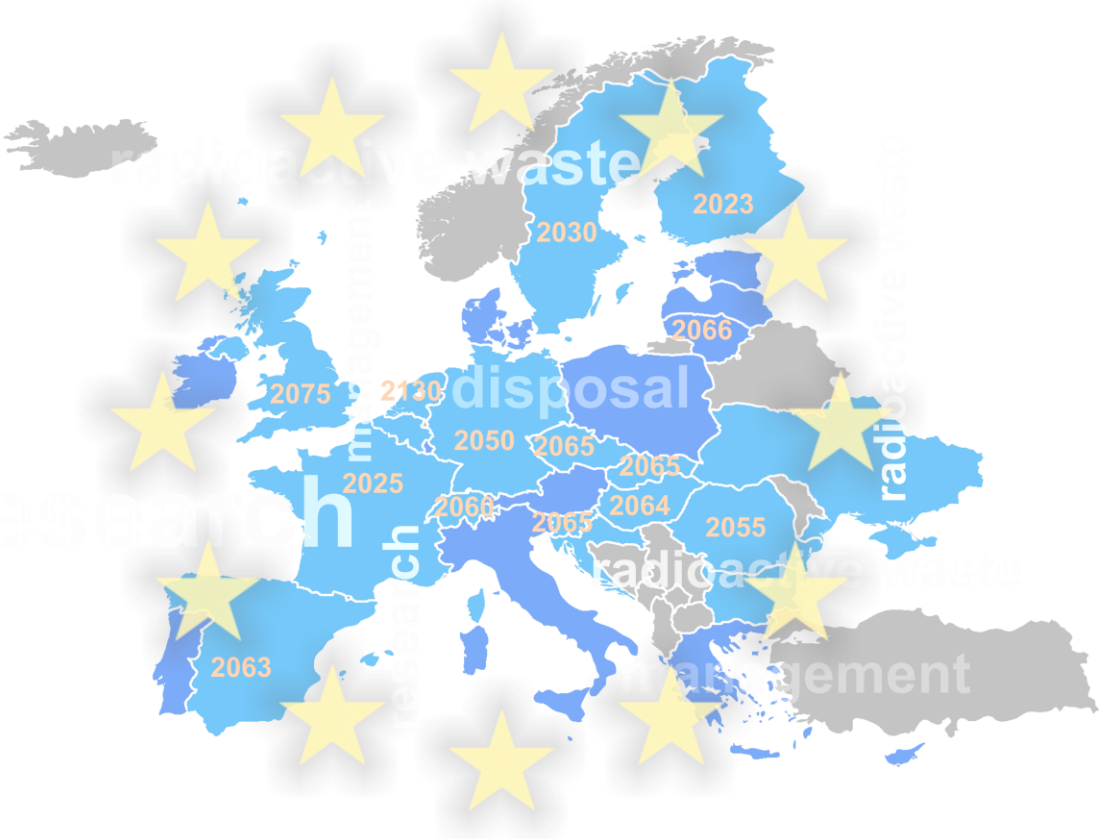
EUROPEAN COMMISSION

EURADWASTE ’19
Programme and Abstracts

edited by Daniela Diaconu and Cristina-Alice Mărgeanu

2020 Directorate-General for Research and Innovation
Euratom Research and Training Framework Programme EN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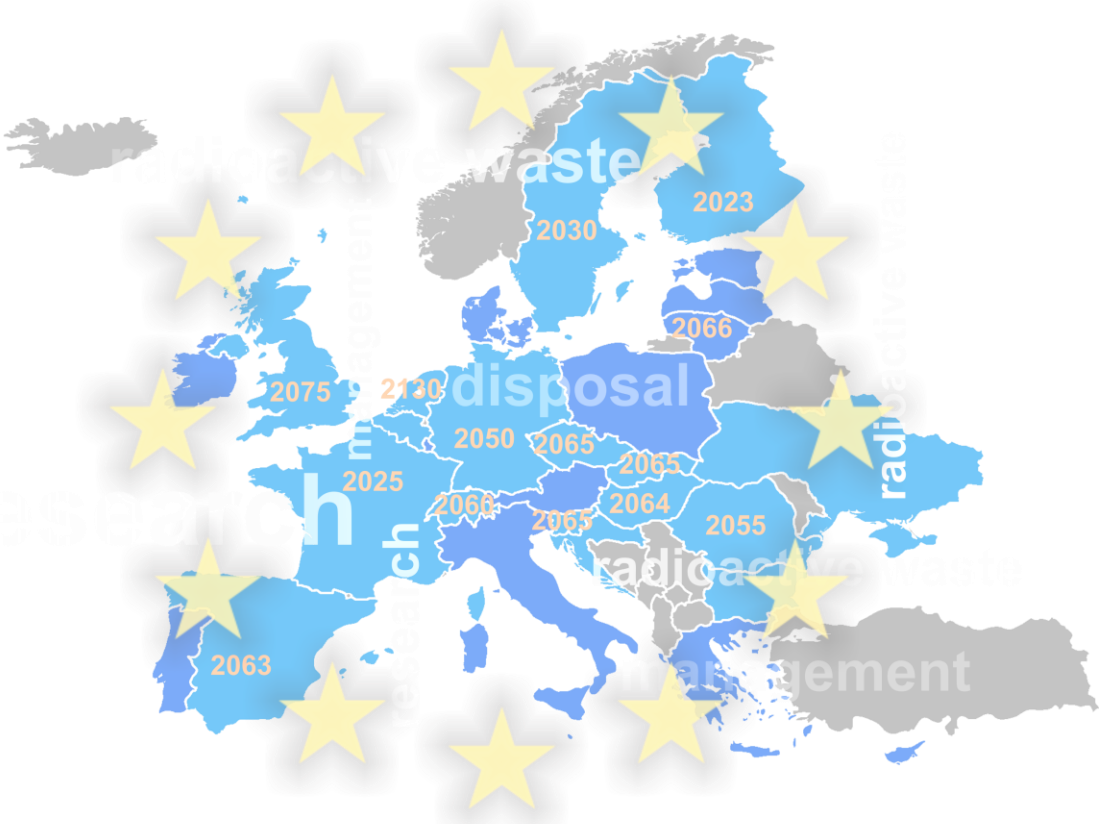
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INTRODUCTION

The structure of the conference programme and the objective of the sessions aim at taking stock of what kind of research the Commission has funded during Horizon 2020, why and how the topics of successive calls for proposals were shaped, and open-up exchange and discussions on future collaborative research of EU added-value.

The list of activities, which the European Commission can support are defined in the Euratom research and training programme complementing the Framework Programme (FP) Horizon 2020 (2014-2018/2020).

The objectives are:

"Contributing to the development of safe, longer-term solutions for the management of ultimate nuclear waste, including final geological disposal as well as partitioning and transmutation".

These objectives are met through:

- Joint and/or coordinated research activities on remaining key aspects of geological disposal (GD) of spent fuel (SF) and long- lived radioactive waste with, as appropriate, demonstration of technologies and safety. Those activities are to promote the development of a common Union view on the main issues related to waste management from discharge of fuel to disposal.
- Research activities related to management of other radioactive waste streams for which industrially mature processes currently do not exist.

The FP has been implemented through 4 work programmes (WP 2014-15, 2016-17, 2018 and 2019-2020)

In 2014, at the beginning of the FP, the main aim of the EC was to prepare for integration of the research communities on disposal, including Waste Management Organisations (WMOs), Technical Support Organisations (TSOs) and other Research Organisations (Entities) in Joint Programming at European level. To fulfil this aim the expectation was for these communities to develop and implement a joint Strategic Research Agenda (SRA), which would integrate the needs from all communities and from all MSs, in particular those either with small programmes or with less-developed knowledge or less-advanced in geological disposal.

Another aim of the FP was to enable the TSOs to continue to structure between themselves and exchange knowledge and competence for their reviews of license applications for repositories.

The third aim of the FP was to support implementation-oriented research and science underpinning the safety case (SC) of GD for SF and long-lived radioactive waste, which had been the core of the Euratom Research and Training programme for many years. This aim was in line with the SRA of IGD-TP (Implementing Geological Disposal – Technology Platform) and the activities of the FP and was to focus on 'remaining key aspects of geological disposal'.

In the first call, Work Programme (WP) 2014-2015, three topics were opened for proposals and five projects were selected:

JOPRAD - EU concerted development of Member State research on radioactive waste management, to prepare for a Joint Programme co-fund,

SITEX II - EU regulatory requirements for licensing geological repositories, to network/coordinate the TSOs and

CEBAMA (Cements barrier interactions), *MIND* (Microbiology in repositories), and *Modern 2020* (repository monitoring strategies & technologies) to support implementation-oriented research and 'remaining key aspects of geological disposal'.

In 2016, WP 2016-2017 took stock of the outcome of the last Euratom projects of FP7 (2007-2013), of the evolution of the research programmes in the MSs and of disposal programmes and the analysis and perception of the needs for R&D on pre-disposal for other categories of waste than HL&LL W and SF. The context at the time was that knowledge on science supporting the SC for GD was advanced in many countries and license applications were about to be submitted or authorisations were expected shortly, giving perception that the Euratom scope of activities was focussing more and more on 'remaining key aspects of geological disposal'. The question was and still is, is such a concentrated scope of research activities sufficient to justify the long-term role and sustainability of the Euratom programme to support the wider needs of MSs.

These situations and observations triggered some kind of turning point for the Euratom programme in considering the kind of topics it would open for proposals in WPs from then on. In order to cover other needs of national programmes, in particular those with longer time schedules for GD implementation (beyond 2050) and also attract gradually larger participation from these countries, WP 2016-2017 opened a new topic on Characterisation, quality control / checking and treatment of unconventional or legacy waste, operational wastes, waste arising from repair or maintenance and decommissioning/dismantling waste.

In the second call, WP 2016-2017, three topics were proposed, and five projects were selected:

DISCO - Modern/doped SF dissolution & characterisation, and *Beacon* - Bentonite engineered barrier mechanical evolution, both to support key priority R&Innovation (R&I) issues for the first-of-the-kind geological repositories and

CHANCE - Characterisation of conditioned waste, and *THERAMIN* - Thermal treatment for waste minimisation and

INSIDER - Characterisation for waste minimization in decommissioning and dismantling, to support R&I on the overall management of radioactive waste other than geological disposal

In 2017, during progress of work of the JOPRAD project towards a Joint Programme,

analysis was conducted by the Commission on the long-term role of a public institutional programme such as the Euratom research and training programme. Management of knowledge and the need for each national programme to perform its own research were two activity domains were Euratom should play a role. This later point was one of the key messages delivered at the previous EURADWASTE conference in 2013, stating that each underground repository is the first of the kind. The key question for those less-advanced programmes is to know what research is needed while trying to avoid duplication of state-of-the-art knowledge. On knowledge management, generations of scientists are retiring and given also the long lead time (several decades) needed to reach readiness to start operating an underground repository, there is a critical role for institutional programmes to help maintaining, developing and exchanging knowledge and competence between generations and national programmes. This was emphasised by the Euratom coordination project to IGD-TP, SecIGD 2 (FP7) completed at the end of 2015, which produced the first guidance document called PLANDIS on research needed by less-advanced programmes.

At the same time, SecIGD 2 also issued a report on the IGD-TP SRA acknowledging that it was of limited use for small and less-advanced national programmes. The focus of the Euratom projects on very specific scientific/technical issues could not be of interest to these less-advanced programmes and their participation in projects was marginal.

The Commission expressed its vision to the JOPRAD consortium of the needs to develop extensive knowledge management activities. Among others, the concept advocated is to further develop/deepen the PLANDIS guide of SecIGD 2 and make KM a priority core activity of the future Joint Programme (JP). Also, in order to establish its central role in helping all MSs and defining future R&D needs in common the JP was prompted to include specific activities aimed at producing strategic studies.

In 2018, the Commission issued the third Euratom call, WP2018. A single topic was published calling for a 'European Joint Research Programme (EJP) in the management and disposal of radioactive waste'.

The concept of the EJP is to integrate the needs of national programmes across EU MSs via all mandated research organisations by their official National programme for R&D i.e. (i) WMOs whose mission covers the management and disposal of radioactive waste, (ii) TSOs carrying out activities aimed at providing the technical and scientific basis for notably supporting the decisions made by a national regulatory body and (iii) nationally funded Research Entities (REs) which are involved in the R&D of radioactive waste management, under the responsibility of Member States, as well as radioactive waste producers/owners.

The EJP based on the JOPRAD SRA is expected to cover joint research activities on the domains of management (pre-disposal) and disposal of radioactive waste (RW) defined in Directive 2011/70/Euratom.

EURAD - European Joint Research Programme (EJP) in the management and disposal of radioactive waste, is the EJP proposal submitted in response to the call. It includes participation from 21 MSs plus the two associated countries to the Euratom programme: Switzerland and Ukraine, for a total of 53 mandated organisations (Beneficiaries) and 59 organisations linked to a mandated organisation.

EURAD includes twelve work packages (seven technical, two strategic and three horizontal KM), which result from joint decision of the governing committee representing the three mandated communities. The budget put forward by the Commission is €32.5m

at a co-fund rate of 55%, allowing a total budget of €59.09m. The plan is to launch 'EURAD' at the EURADWASTE conference.

Providing that the EURAD performs adequately, the EJP instrument could be continued in the next Euratom FP (Horizon Europe) and would be the main instrument for Euratom support to research and training on RWM.

In the meantime, in order to reinforce R&D on pre-disposal and to gradually include the waste producers in the EJP concept, the Commission has opened a topic on pre-disposal as part of WP2019-2020 on:

Developing pre-disposal activities identified in the scope of the European Joint Programme in Radioactive Waste Management.

The aim is to develop methods, processes, technologies and demonstrators for the treatment and conditioning of wastes for which no or inadequate solutions are currently available (except spent nuclear fuel and high-level radioactive waste to which means have been allocated as part of previous Euratom Work Programmes).

This action is defined as complementary to the EJP co-fund action mentioned above, and consequently the reference founding documents of the EJP (vision, SRA, roadmap and governance and implementation mechanisms) are expected to be updated and adapted jointly with the programme executive body of the EJP to align and share the approaches between the different communities.

The successive Euratom calls and the selected projects and up-coming new ones are the results of EC strategy for its Euratom programme and future developments. The three proposed sessions reflect the evolution of this strategy during the Horizon 2020 FP and summarise the approach described above.

The Commission and the Programme Committee wish you a pleasant and productive EURADWASTE '19 conference with many fruitful discussions.

On behalf of the Organising and Programme Committee

Christophe Davies (EC DG RTD, EURADWASTE'19 Chair)

Daniela Diaconu (RATEN-ICN and Romanian Presidency, Co-chair)

EURADWASTE'19 Conference PROGRAMME

EURADWASTE'19 PROGRAMME

Tuesday, 4th June

Joint Introduction FISA2019 and EURADWASTE'19

Joint session - International / EU / EURATOM Status in Radiation Protection, Safety of Reactor Systems and Radioactive Waste Management

PhD/MSc Poster Session

Poster Session: Euratom Projects and Euratom Topics

Wednesday, 5th June

Session 1 - Predisposal and disposal technology developments

Session 2 - Radioactive waste source term and science for disposal safety

PhD/MSc Poster Session

Poster Session: Euratom Projects and Euratom Topics

Thursday, 6th June

Session 3 - Networking of research communities, Joint Programming of national programmes and Integration of radioactive waste producers infrastructures and international cooperation

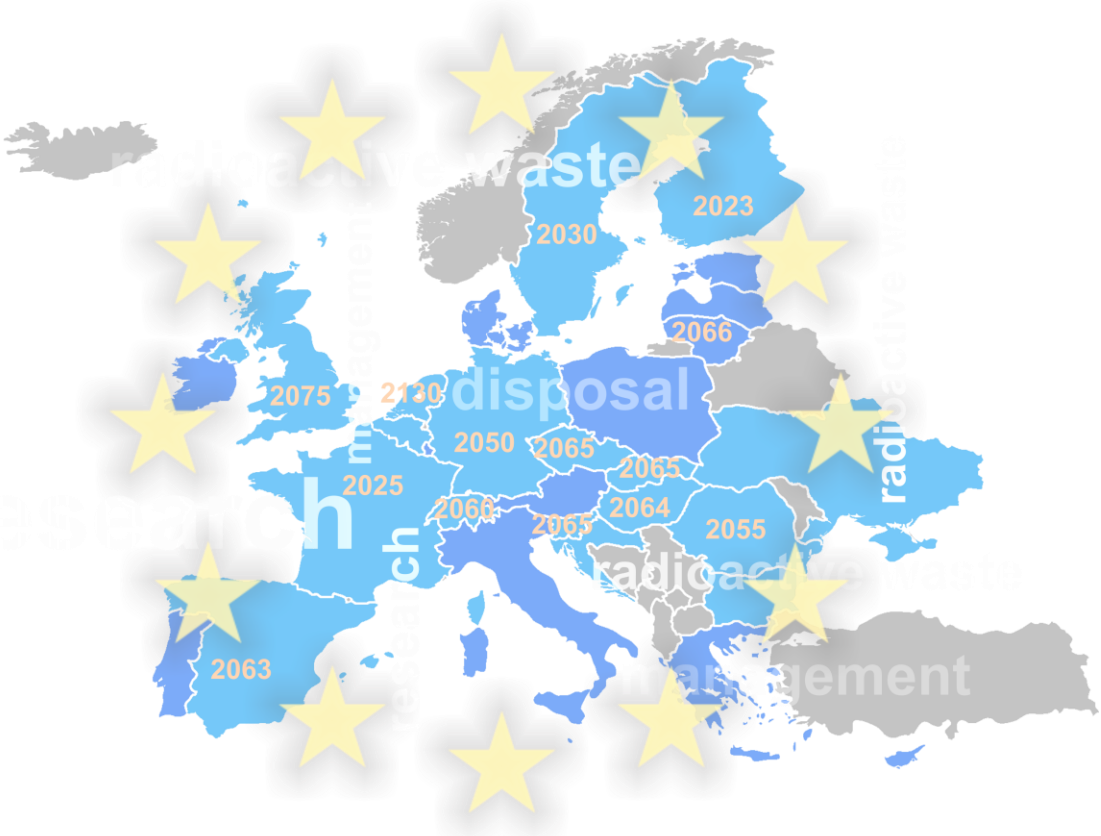
PhD/MSc Poster Session

Poster Session: Euratom Projects and Euratom Topics

Joint conclusions FISA2019 and EURADWASTE'19

Friday, 7th June

Technical tours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Tuesday, June 4th AM

JOINT INTRODUCTION FISA 2019/EURADWASTE '19

Ramada Hotel, Diamond Room

Chair: Serban Constantin VALECA (RATEN ICN, RO)
Co-chair: Domenico ROSSETTI DI VALDALBERO (EC, DG RTD)
Rapporteur: Stefano MONTI (IAEA), Expert

09:00	**Patrick CHILD** (EC, DG RTD), Deputy Director General, Research and Innovation, European Commission Keynote: Euratom Research and Training and Horizon Europe framework programmes
09:15	**Charlina VITCHEVA** (EC, DG JRC), Deputy Director-General of the Joint Research Centre, European Commission Keynote: JRC role in Euratom Research and Training and Horizon Europe
09:30	**Nicolae HURDUC** (Minister, RO), Ministry of Research and Innovation, Romania Keynote
09:50	**Stefano MONTI** (IAEA), Section Head, Nuclear Power Technology Development section, Division of Nuclear Power, Department of Nuclear Energy Keynote: Research and Innovation for a safe, secure and safeguarded nuclear power in support of the UN Sustainable Development Goals
10:10	**Daniela LULACHE** (OECD/NEA, FR), Head of Office of Policy and Coordination, OECD Nuclear Energy Agency Keynote: Nuclear Research and Innovation successes and accomplishments looking to the future
10:30	*Coffee Break*
11:00	**Teodor CHIRICA** (FORATOM, BE), President of the European Nuclear Industry Association Keynote: Research and Innovation benefits for a low-carbon economy, Industrial Competitiveness and sustainable development
11:20	**Pierre Jean COULON** (EESC, EU), President of the Transport Energy and Networks section, European Economic and Social Committee Keynote: Research and Innovation missions and benefits to Civil Society to tackle today's Societal Challenges
11:40	**Nathan PATERSON** (ENS YGN, BE), Chair European Nuclear Society Young Nuclear Generation and **Joerg STARFLINGER** (ENEN, BE), Vice-President of ENEN, University of Stuttgart, Germany Keynote: The future of Nuclear: Collaboration, Vision and Innovation – perspectives from the YGN
12:00	**Lunch and MSc/PhD Poster Session**

Joint Session

International / EU / EURATOM Status in Radiation Protection, Safety of Reactor Systems and Radioactive Waste Management

Al. Davila Theatre

Chair: Horia Grama (ANDR, RO)

Co-chair: Massimo Garribba (EC, DG ENER)

Rapporteur: Hans Forsström (SE), Expert

The Euratom Treaty provides the legal Framework to ensure a safe and sustainable use of peaceful nuclear energy across Europe and helps non-EU countries meet equally high standards of safety and radiation protection, safeguards and security. With legally binding Nuclear Safety Directive (2009/71/Euratom) and its latest amendment (2014/87/Euratom), EU nuclear stress tests, complemented with common safety approaches of the Western European Nuclear Regulators Association (WENRA) and the International Atomic Energy Agency (IAEA), the EU became the first major regional nuclear actor with a legally binding regulatory framework as regards to nuclear safety. Furthermore, this legal framework has been recently complemented by the Directive (2011/70/Euratom) that establishes a Community framework for the responsible and safe management of spent fuel and radioactive waste (both from fission and fusion systems), and the Directive (2013/59/Euratom) laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation.

Directives on Nuclear Installations' Safety (Art.7), Nuclear Waste Management (Art.8), Basic Safety Standards (Ch.4) and IAEA Convention on Nuclear Safety, all emphasize that each MS shall take the appropriate steps to ensure that sufficient numbers of qualified staff with appropriate education, training and re-training are available for all safety-related activities in - or for each - nuclear installation throughout its life. 'Conclusions' were issued at: a) 'EU Competitiveness Council in November 2008 encouraging Member States and the EC to establish a 'review of EU professional qualifications and skills' in the nuclear field; and b) a 'Second Situation Report on EU E&T in the Nuclear Energy Field' was published in 2014 by the European Human Resources Observatory in the Nuclear Energy Sector (EHRO-N, the latest created in 2009 by the European Nuclear Energy Forum (ENEF)).

International / EU/ Euratom latest state of implementation of the main directives in radiation protection, safety of reactor systems and radioactive waste management, and role of the projects co-funded in the framework of EU/Euratom research and training programmes, challenges and research expectations will be presented during this FISA2019 EURADWASTE'19 plenary session.

	STATUS OF EU/EURATOM DIRECTIVES
14:00	**Michael Huebel** (EC, DG ENER), Head of Unit, Radiation Protection and Nuclear Safety EU/Euratom Directives, 2013/59/Euratom on Basic Safety Standards, 2009/71/Euratom and 2014/87/Euratom update on nuclear safety of nuclear installations: status, challenges and future perspectives
14:20	**Massimo Garribba** (EC, DG ENER), Director Nuclear Energy, Safety and ITER EU/EURATOM R&D supporting Directive 2011/70/Euratom on the responsible and safe management of spent fuel and radioactive waste: status, challenges and future perspectives

RADIOACTIVE WASTE MANAGEMENT

14:40 **Pierre-Marie Abadie** (ANDRA, FR), CEO
Keynote: European & International status on the management and disposal of radioactive waste, developments and challenges ahead

15:10 **Andrew Orrell** (IAEA, Section Head for Waste and Environmental Safety)
ARTEMIS in Europe, the Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation

15:40 **Christophe Davies** (EC, DG RTD), Euratom Fission, Project & Policy officer
Euratom research and training programme in radioactive waste management: Overview status, vision and future perspectives

16:00 *Coffee Break*

SAFETY OF REACTOR SYSTEMS

16:30 **Martin Murray** (Environment Agency, UK)
EURATOM STC Opinion (Scientific and Technical Advisory Committee): Key recommendations from the Opinion published early 2017 and future perspectives

16:50 **Roger Garbil** (EC, DG RTD), Euratom Fission, Project & Policy Officer
Euratom research and training programme in safety of the reactor systems: Overview status, vision and future perspectives

17:10 Panel and General discussion on the **Role of the Euratom R&T programme and Directive: Challenges and Research expectations (50')**

Chair: Horia Grama (ANDR, RO)

Rapporteur: Hans Forsström (SE)

Panellists : Pierre-Marie Abadie (ANDRA, FR), Massimo Garribba (EC, DG ENER), Martin Murray, Hamid Ait Abderrahim (SCK.CEN)

Objectives :

- Discuss MSs' challenges and needs.
- Discuss the role of the Euratom programme and Directive.
- Ask MSs expectations from Euratom and how to address them

Questions :

1. What is or should be the added-value of the Euratom programme, in which domains (decommissioning, waste management, waste disposal, strategies including long-term energy strategy,…) and how Euratom should provide its support (via Joint Programming of MSs' programme or competitive project proposals)?
2. What should be the criteria for EU support to R&D?
3. Should Euratom support R&D up to industrial scale?
4. R&D for joint solutions, is there a role for Euratom?
5. What is the value of participating in Euratom projects?
6. How shall decisions on projects be made between partners?
7. How can countries with small programmes or longer implementation timescales influence and learn?

18:30 MSc/PhD Poster introduction and Conference cocktail

Wednesday, June 5th AM

SESSION 1 - Predisposal and disposal technology developments

Al. Davila Theatre

Chair: Jon Martin (RWM, UK)
Rapporteur: Wilhelm Bollingerfehr (BGE, DE), Expert

Pre-disposal is becoming a pillar domain of Euratom. It will require involvement of waste producers, technology developers and Research Entities in general. The RE also play a role in the development of technologies for GD. The keynote should illustrate the role and contribution of REs in developing treatment processes and solutions for legacy and problematic waste, in particular from the perspective of smaller nuclear countries. The idea with the panel is seek a wider view from the different categories of organisations from different countries on the issues they have to solve or contribute to in term of pre-disposal and disposal technologies.

09:00	**Radek Trtílek** (ÚJV Řež, CZ) Keynote: Role, contributions, challenges and perspectives from Research Entities in advancing knowledge, solutions and technologies for the management and disposal of radioactive waste
09:25	**Danièle Roudil** (CEA, FR) Nuclear site integrated characterisation for radioactive waste minimisation (INSIDER)
09:50	**Denise Ricard** (ANDRA, FR) Characterization of conditioned nuclear waste for its safe disposal in Europe (CHANCE)
10:15	*Coffee break*
10:45	**Matti Nieminen** (VTT, FI) Thermal treatment for radioactive waste minimisation (THERAMIN)
11:10	**Johanna Hansen** (POSIVA, FI) Tunnel plugs and shaft seals demonstrations (DOPAS)
11:35	**Johan Bertrand** (ANDRA, FR) Development and Demonstration of Monitoring Strategies and Technologies (Modern2020)

12:00

Panel and General discussion on Predisposal and disposal technology developments (30')

Chair: Jon Martin (RWM, UK)

Rapporteur: Wilhelm Bollingerfehr (BGE, DE)

Panellists: Irina Gauss (NAGRA, CH), Veronica Andrei (SNN, RO) and Christine Georges (CEA, FR)

Objectives :

- To get on the one hand a clearer view on the relationship between waste characterization methodologies/ -techniques and Waste Acceptance Criteria for a repository; and on the other hand to better understand the dependencies between repository design (in particular the most important technical barriers) and adequate monitoring systems/programmes.
- To discuss the challenges on pre-disposal R&D and disposal technology development in national programmes.
- To discuss the commonalities between MSs for future activities at EU level.
- To find out whether Euratom Horizon 2020 projects have delivered the expected results and demonstrated EU added-value.

Questions :

1. What are the most challenging requirements from the waste management organisations towards a perfect description of the radioactive waste to be disposed in a repository?
2. What are the advantages and disadvantages to incorporate a monitoring system from the very beginning of the repository design in particular for the safety case relevant engineered barriers?
3. What technical challenges remains for implementing geological disposal?
4. Are there waste streams and across EU MSs, which remain without efficient solutions?
5. What are the priorities and / or the challenges to address for legacy / past activity wastes, small waste inventories and waste streams for which there is currently no predisposal (Characterisation, treatment, conditioning) and disposal solutions and for which there would be added-value of engaging joint research and development at EU level?
6. What is the "prize" (economical and environmental) for waste treatment (compaction, thermal treatment, others)?
7. Is there scope for optimization in waste treatment?

12:30 Lunch and Poster Session

SESSION 2 - Radioactive waste source term and science for disposal safety

Al. Davila Theatre

Chair: Antonio Gens (UPC, ES)
Co-chair: Jean-Paul Glatz (DG JRC, EC)
Rapporteur: Piet Zuidema (Zuidema Consult GmbH, CH), Expert

'Science for safety of geological disposal' remains the key challenge facing national programmes for HLW and SF disposal. But it is acknowledged that science and knowledge is very mature. So what role and support can Euratom provide in the future? The keynote should highlight the forward-looking view from a country with an advanced GD programme, compared to many other EU MSs. The panel should discuss the challenges in science for the SC and how to handle them for the benefit and synergies between different national programmes and categories of organisations.

14:00	**Johan Andersson** (SKB, SE) Keynote: From past to future science underpinning the Safety Case of deep geological repositories – Challenges until licensing and how maintain knowledge and competence on cutting edge science afterwards during operation
14:25	**Lena Zetterstrom Evins** (SKB, SE) Spent fuel dissolution (REDUPP and DISCO)
14:50	**Simon Norris** (RWM, UK) Overview of Carbon-14 Source Term generation and release from irradiated metals, ion-exchange resin and graphite (CAST)
15:15	**Marcus Altmaier** (KIT/INE, DE) Research and innovation action on cement-based materials, properties, evolution and barrier functions (CEBAMA)
15:40	*Coffee break*
16:10	**Patrick Sellin** (SKB, SE) Bentonite Erosion: Effects on the Long-term Performance of the Engineered Barrier and Radionuclide Transport (BELBAR), and Bentonite Mechanical Evolution (BEACON)
16:50	**Birgitta Kalinowski** (SKB, SE) Microbiology in nuclear waste disposal (MIND)
17:15	**Panel and General discussion on Radioactive waste source term and science for disposal safety (30')**

Chair: Antonio Gens (UPC, ES)
Rapporteur: Piet Zuidema (CH)
Panellists: Frédéric Bernier (FANC, BE), Lucy Bailey (RWM, UK), and Johan Andersson (SKB, SE)

Objectives :

- To discuss the ''remaining'' challenges in science for the safety case of geological disposal. Do the nature of these challenges and their relevance across MSs justify future Euratom involvement?
- To seek the view of the informed communities (regulator, implementer, science) about the stage of knowledge for the topic of the session, taking into account that licensing has started or will start soon in some member states.
- To obtain some feedback for which areas it would be useful to continue with coordinated research (of general value to many member states), in which areas the main emphasis will be on site/system-specific issues and in which areas the level of knowledge is 'fit for purpose'.
- Find out whether Euratom Horizon 2020 projects have delivered the expected results and demonstrated EU added-value

Questions :

1. How comfortable are you with the state of knowledge in the areas discussed (address all or a selection of areas)?
2. Where do you see most benefit from future coordinated activities and why?
3. Do you see the need to take action to ensure that the knowledge also needed in future will be maintained? If yes, in which areas and how?
4. Is the state of knowledge sufficient for your current status of the programme and the safety case you have to produce in the near future?
5. What kind / level of knowledge should countries with small programmes or longer implementation timescales acquire?
6. From what we heard (the topics addressed in the session), do you see a strong need to make significant progress (a big step forward); if yes: which topics? If yes, is the 'open' question generic (suitable for cooperation) or is it site-/system-specific and needs to be addressed by individual programmes?

19:00 ENEN PhD Prize and Conference Dinner at Ramada Event

SESSION 3 - Networking of research communities, Joint Programming of national programmes and Integration of radioactive waste producers

Al. Davila Theatre

Chair: Piet Zuidema (Zuidema Consult GmbH, CH)
Co-chair: Ian Gordon (IAEA, AT)
Rapporteur: Jacques Delay (ANDRA, FR), Expert

Networking and support to collaborative research across different countries can be considered as the 'raison d'être' of the Euratom programme. The first part of the session is dedicated to seeking the views of the three communities in the EJP (WMOs, TSOs and REs) and from Central and Eastern Country smaller and less-advanced programmes on the benefits they see both for their own community or countries but between them in working together in the EJP in a structured way and their forward looking. The result of this integration process is the EURAD EJP, which will be announced during the session. KM in the form of 'State of knowledge, Guidance on R&D and Training and mobility' activities within the Joint Programme is considered as the domain where the Euratom role and support can bring most European added-value. Coordination with IAEA and NEA, who also carry out KM activities, should be ensured. So, a clear, structured and coordinated interaction of the EJP in this field with both IAEA and OECD NEA is expected. Intervention from these two international organisations should highlight ways and means to implement this interaction. Finally, the panel and its introductory keynote aim at discussing/preparing both communities of Waste management and Waste producers, and technology developers, to work together as part of research activities at European level in future joint activities.

08:30	**Christophe Davies** (DG RTD, EC) Session Introduction Networking of the research communities with a national mandate for RD&D in RW disposal – view from WMOs, TSOs, REs and less developed or advanced programmes on their R&D needs, contribution to the European Joint Programme development, expected impacts and future perspectives
08:40	**Robert Winsley** (RWM, UK) The Implementing Geological Disposal of radioactive waste Technology Platform (IGD-TP) – evolving into our second decade
08:55	**Delphine Pellegrini** (IRSN, FR) The SITEX initiative
09:20	**Christophe Bruggeman** (SCK-CEN, BE) "EURADSCIENCE", a research organisations network for radioactive waste management science within Europe
09:35	**Bálint Nos** (PURAM, HU) Needs of countries with longer timescale for deep geological repository implementation
09:50	**Frédéric Plas** and **Marie Garcia** (ANDRA, FR) European Joint Programme on radioactive waste management (EURAD) Joint Programming of national research and development programmes in the management and disposal of radioactive waste – The European Joint Programme in Radioactive waste management (EJP)

10:20 *Coffee Break*

10:50 **Stefan Mayer** (IAEA, AT)

Radioactive waste management: a national responsibility, at a global scale, requiring local solutions – and things the IAEA can do to help

11:05 **Rebecca Tadesse** (OECD/NEA, FR)

Perspective from the OECD Nuclear Energy Agency radioactive waste management programme

Synergies between the Euratom European Joint Programme on radioactive waste management and the IAEA and OECD NEA programmes on the State of knowledge, Guidance on R&D and Training and mobility – Way forward

11:20 **Michel Pieraccini** (EDF, FR)

Keynote: EDF suggestions and strategy on ways and means, including R&D on pre-disposal and radioactive waste management for enlarging the European Joint Programme on waste disposal for joint implementation of joint programming

Keynote scope: RD&D programmes and activities of waste producers on pre-disposal (Chraracterisation, treatment and conditioning) of radioactive waste in Europe, and Vision, Strategy and suggestion for enlarging the EJP on waste disposal for joint implementation of joint programming.

11:45 Panel and General discussion on **Joint Programming of national programmes and integration of waste producers**

Chair: Piet Zuidema (CH)

Rapporteur: Jacques Delay (ANDRA, FR)

Panelists : Frédéric Plas (ANDRA, FR), Michel Pieraccini (EDF, FR), Ian Gordon (IAEA), Radek Trtílek (ÚJV Řež, CZ)

Objectives :

- To get some input in how far there is a recognised need to enhance the interaction and cooperation between waste producers and waste management organisations at the international level.
- Clarify which topics would benefit most from such a cooperation. Discuss the different options to organise such a cooperation.
- Discuss the benefits of Joint research Programming (JP) within the disposal communities at EU level and the benefits and any limitation for the waste producers to join to enhance efficiency and effectiveness of joint work.
- Discuss the potential, feasibility and interest of development of pre-disposal technologies for specific waste types and forms between waste producers at EU level for potential shared exploitation.

Questions :

1. Where do you see benefits from cooperation between waste producers and those in charge of waste disposal at international level compared to the interaction at national level? and what are the potential hurdles to make it happen?
2. If we want to have a closer cooperation at the international level, how could that be organised within the EJP framework?
3. Is research on pre-disposal of waste (characterisation, treatment and conditioning) leading to potential commercial activities compatible with the open science approach of the European Joint

Programme? Or what are the boundary conditions for their inclusion?

4. Which topics are most important / urgent for your country?
5. What role can IAEA play in fostering cooperation between waste producers and the disposal communities within the EJP?
6. To what extent is knowledge transfer considered important?

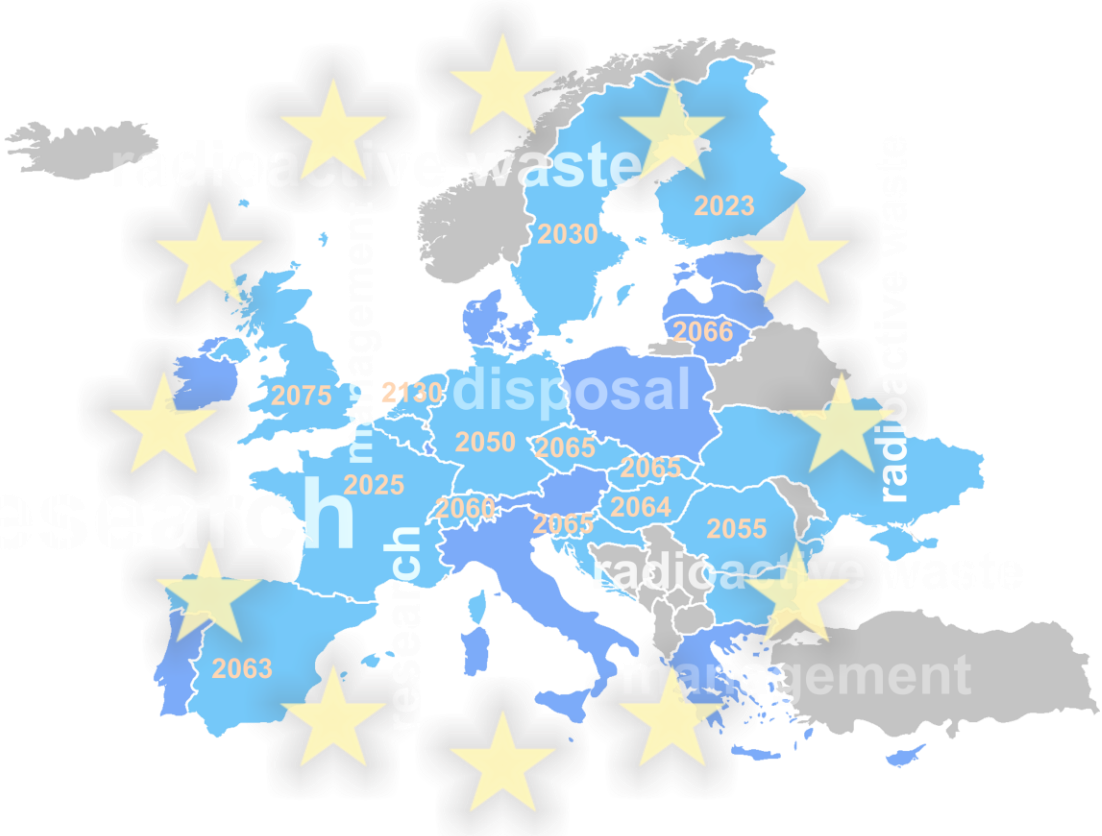
12:30 Lunch

JOINT CONCLUSIONS

Hotel Ramada, Diamond Room

Chair: Said ABOUSAHL (EC, DG JRC),
Co-chair: Domenico ROSSETTI DI VALDALBERO (EC, DG RTD)
Rapporteur: Stefano MONTI (IAEA), Expert

14:00	**Nicolae Hurduc** (Minister, RO), Ministry of Research and Innovation, Romania Keynote
14:15	Poster and PhD Awards FISA 2019 and EURADWASTE '19 Poster and PhD Awards
15:00	**Hans Forsström** (SE), Expert rapporteur EURADWASTE '19 - Key messages and future perspectives
15:20	**Stefano Monti** (IAEA), Expert rapporteur FISA 2019 - Key messages and future perspectives
15:40	Closing remarks from the Romanian Presidency and the European Commission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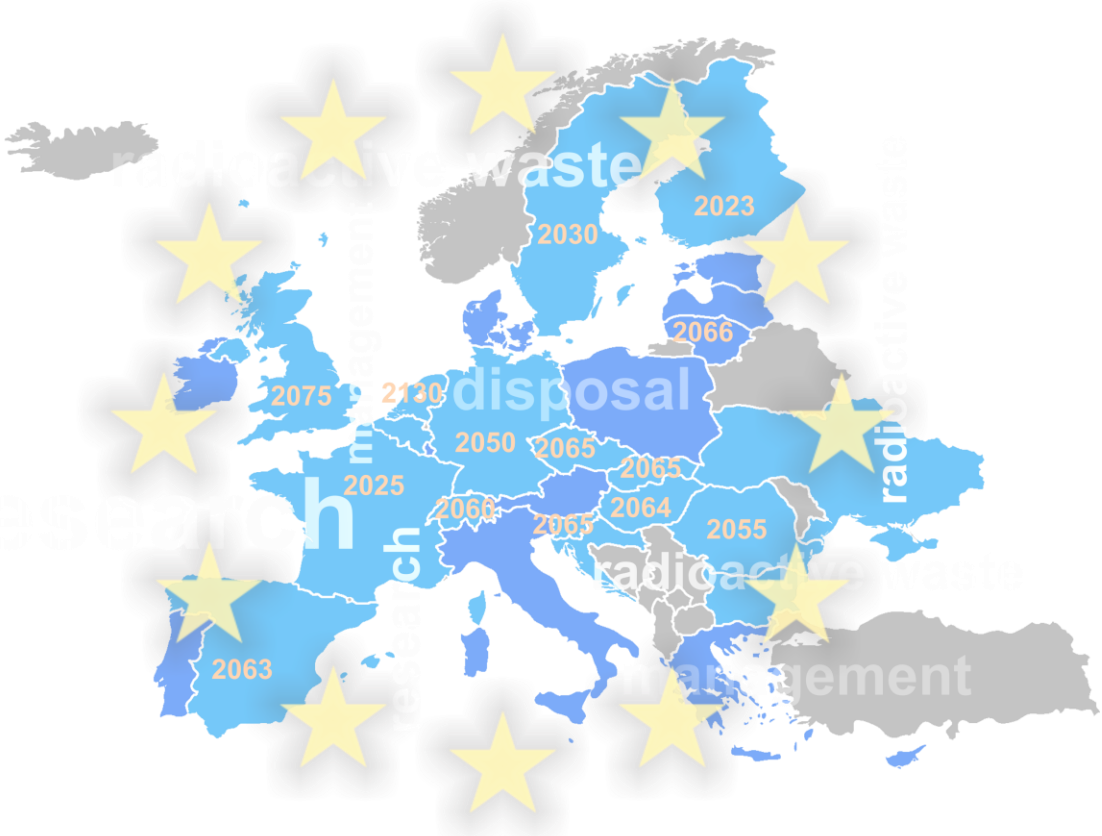
ABSTRACTS
Invited papers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Joint Introduction - International R&D and Euratom Directives

EU/EURATOM DIRECTIVES-2013/59/EURATOM ON BASIC SAFETY STANDARDS AND AMENDED NUCLEAR SAFETY DIRECTIVE 2014/87/EURATOM: STATUS, CHALLENGES AND FUTURE PERSPECTIVES

Dr. Michael HUEBEL

European Commission, Luxembourg

The presentation will be focused on the Euratom legal framework for nuclear safety and radiation protection as set out in Directives 2014/87/Euratom and 2013/59/Euratom, respectively.

Taken together with the Radioactive Waste Directive, the Directives provide a comprehensive framework to ensure a high level of radiation protection and nuclear safety across the European Union.

The Nuclear Safety and Basic Safety Standards Directives have undergone significant changes in their latest iterations, and the Commission is currently assessing their transposition into national legal systems.

The presentation will set out the main new features of the amended Nuclear Safety Directive such as the enhanced safety objective. On the Basic Safety Standards Directive it will focus on key areas of application such as emergency preparedness and response, the medical field and naturally occurring radiation and radon. The presentation will also cover non power uses of radiation and nuclear technologies. It will look into the way the legal framework has built upon lessons learnt from research, and emerging needs for new research to be launched in the future.

DIRECTIVE 2011/70/EURATOM ON THE SAFE AND RESPONSIBLE MANAGEMENT OF SPENT FUEL AND RADIOACTIVE WASTE AND ITS CURRENT IMPLEMENTATION STATUS

Dr. Massimo GARRIBBA

European Commission, Luxembourg

Radioactive waste is generated in all EU Member States by a large variety of activities ranging from medical applications to electricity power generation. Owing to its radiological properties and the potential hazard it poses to workers and the public, it is important to ensure the safe management of such material from generation to disposal. This requires containment and isolation from humans and the living environment over a long period.

The EU nuclear legal framework has undergone significant changes in the last decade with the adoption of legislation on nuclear safety, radioactive waste and spent fuel management and in depth revision of the radiation protection acquis.

The adoption in 2011 of the Directive on the safe and responsible management of spent fuel and radioactive waste was a major step towards achieving a comprehensive and legally binding framework at EU level. Through the implementation of this Directive, Member States are required to demonstrate that they have taken reasonable steps to ensure that radioactive waste and spent fuel is managed safely and that no undue burden is passed to future generations.

The safe and responsible management of these materials is of particular importance. This is especially the case now as many existing nuclear power reactors are reaching the end of their operational lives and will need to be decommissioned. The radioactive waste generated in this process will need to be stored and/or disposed.

In 2017 the Commission was in a position to provide for the first time a comprehensive overview to the Council, European Parliament and EU citizens on this important issue. Such a report will be submitted every three years, on the basis of Member States' reports to the Commission on the status of their implementation of the Directive.

The presentation will relate the latest update of implementation of the Directive by EU Member States and challenges for the future.

EUROPEAN & INTERNATIONAL STATUS ON THE MANAGEMENT AND DISPOSAL OF RADIOACTIVE WASTE, DEVELOPMENT AND CHALLENGES AHEAD

Pierre-Marie ABADIE

ANDRA, France

In nuclear energy producing countries, the 2019 international panorama concerning the management of spent fuel or radioactive waste arising from the production of electricity now includes three categories of countries:

- countries such as Sweden, Finland or France, where Deep Geological Repository projects are well advanced;
- countries such as Russia and China, where Underground Research laboratories are being constructed; and
- countries such as UK, Germany and Japan that each now have a structured siting strategy.

Due to the timeframes of these projects, and their needed safety, all actors have now realized that they require adequate Human Capacity Building and in depth Knowledge Management. The International agencies (IAEA and NEA) support these projects completely, as does the EC, and one must note the recent set up of the European Joint Programing EURAD that brings together Research entities, TSO s and WMOs to deal with Waste Management. Of course, the pros and cons of such organizations must be kept in mind.

The situation regarding the waste arising from the dismantling of nuclear Power Plants raises different challenges compared to the previous ones in view of the volumes of radioactive waste generated (with or without exemption levels). The subject is key and dealt with in ad hoc recently organized structures such as the Committee on Decommissioning of nuclear installations and Legacy Management (CDLM - NEA) and the Decommissioning and Environmental Remediation Section (DERS - IAEA). The question of the dismantling of graphite reactors raises specific questions analyzed by the countries that used this technology (mainly Russia, UK and France).

In all countries, the waste arising from the operations of research reactors, the use of radioactive sources or the waste linked to NORM raise issues that are a complex to deal with in countries were nuclear safety and waste management structures are not always present. In addition, the volumes of waste are small and need proportionate solutions. A promising solution for sources based on boreholes is currently developed with strong international support (IAEA). Other types of waste, in limited volumes, could benefit from this type of solution.

EURATOM RESEARCH AND TRAINING PROGRAMME IN RADIOACTIVE WASTE MANAGEMENT: OVERVIEW STATUS AND VISION

Christophe DAVIES

European Commission, DG Research and Innovation, Unit D4, Euratom Research

The European Commission via the Euratom R&T programme on radioactive waste management has a role in fostering close cooperation and joint implementation of R&D on radioactive waste management.

The criteria for supporting research are cutting-edge science on issues of common EU added-value for Member States. However, the wide gaps in the status of the national programmes towards implementation of geological repositories for high-level and long-lived radioactive waste (HL&LL W) and spent fuel implies a central role for Euratom in the management of scientific and technical knowledge on RWM for exchange between organisations across the MSs and to transfer to new generations of scientists to ensure the long-term safety of disposal.

The European Joint Programme tool for R&D at EU level appears to be the most effective way to jointly prioritise and implement R&D at the European level between the main actors of the disposal community (WMO, TSO and RE) representing their official MS national programme.

Public non-technical stakeholders may contribute in R&D activities at Euratom level whenever a clear and genuine task can be identified and does not diverge from the programme of their country of origin.

The needs for R&D on pre-disposal at EU level may be justified as long as the criteria for cooperation are clear and that benefit is acknowledged for several MSs as opposed to activities leading to competitive and commercial markets of benefit to single entities.

EURATOM STC OPINION (SCIENTIFIC AND TECHNICAL ADVISORY COMMITTEE): KEY RECOMMENDATIONS FROM THE OPINION PUBLISHED EARLY 2017 AND FUTURE PERSPECTIVES

Martin P. MURRAY

Environment Agency,Wallingford – England

The Euratom Scientific and Technical Committee (STC) is the only scientific and technical advisory body formally enshrined in the Euratom Treaty (Article 134) and active since 1957.

For over 60 years the STC has provided independent authoritative advice and opinion on all aspects of nuclear technology. Its members are appointed from all Member States, for a five-year renewable term, as independent experts in nuclear medicine and radiation protection, in nuclear fission reactor systems and fuel cycles, waste management and thermonuclear fusion. The STC is also responsible for nominating the experts advising the Commission on the basic standards for radiation protection (the Article 31 Expert Group) and on the assessment of the health impact of radioactive release from nuclear facilities (the Article 37 Expert Group).

The opinion published in 2017 sets out the Legacy Messages from the committee's 2013-2018 mandate. It informs the new committee on its role in being proactive in its advice to the Commission and European Parliament. It notes, given current funding, that important decisions will need to be made regarding Europe's and Member States' future research priorities and investment in scientific infrastructure in the coming years. The opinion concludes by recognising the potential for synergies between the Euratom research and cross-cutting initiatives in other EU research fields

EURATOM RESEARCH AND TRAINING PROGRAMME IN SAFETY OF THE REACTOR SYSTEMS: OVERVIEW STATUS, VISION AND FUTURE PERSPECTIVES

Roger GARBIL

European Commission, DG RTD, Belgium

EU/Euratom has been the framework in which, for more than 60 years, peaceful use of nuclear energy, knowledge and competence management in nuclear science and technology have been developed in Europe. It benefits from close bi- or multi- lateral long-standing international cooperation frameworks e.g. together with OECD/NEA, GIF and IAEA. EU/Euratom Framework Research and Training Programmes are consistently significantly contributing in establishing the highest standards for safety and radiation protection, safeguards and security, as emphasized within today's legally binding EU/Euratom Directives for Member States. The EU

added value of realizing a true European Research Area is constantly acknowledged. Thanks to a shared view on the main scientific or technology challenges and opportunities, e.g by establishing strategic research and innovation agendas / roadmaps, together with Member States, significant progress of EU/Euratom FP7 / H2020 innovative research projects and key achievements further strengthen the relations for all citizens between science, civil society, industry and policy makers. Thankfully, partnerships between EU/Euratom / MS / research organisations / industry / academia and/or technology platforms lead towards highly successful developments of joint research activities, unique research infrastructures networks, transnational and open access to facilities. Thanks to Horizon Europe's proposal, these science and technology research efforts should further help capitalizing fundamental competences, hands-on training and know-how, sharing capabilities in both energy and non-energy applications, contribute to maintaining the highest levels of nuclear safety and enhance further the competitiveness of our industry.

Session 1 - Predisposal and disposal technology developments

Role, contributions, challenges and perspectives from Research Entities in advancing knowledge, solutions and technologies for the management and disposal of radioactive waste

R. TRTILEK, V. HAVLOVA, J. PODLAHA, K. SVOBODA, T. OTCOVSKY
ÚJV Řež, CZ

The article summarises the status and competence of UJV Rez, a. s. (up to 2012, the Nuclear Research Institute Rez) in the field of radioactive waste (RAW) management. UJV Rez a. s. has been one of the Czech Republic's key research and engineering institutions in the field of nuclear energy production since 1955.

The company processes and conditions prior to storage 95% of so-calledinstitutional RAW and is the principal partner of the state with respect to theresearch support of the Czech deep geological repository development project.

UJV Rez a. s. boasts its own accredited radiochemical analytical test laboratory,unique of its kind in the Czech Republic. Of equal importance is UJV Rez's activeparticipation in a range of international organisations and associations and itsinvolvement in wide range of international projects. Moreover, UJV Rez's servicescovering the repatriation of highly-enriched fuel from research reactors as part ofthe GTRI initiative for reducing global threats are recognised worldwide.

NUCLEAR SITE INTEGRATED CHARACTERIZATION FOR RADIOACTIVE WASTE MINIMIZATION (INSIDER)

Roudil, D. (1); Peerani, P. (2); Boden, S. (3); Russel, B. (4); Herranz, M. (5); Crozet, M. (1); Aldave de Las Heras, L. (2)

1 - CEA, France; 2 - JRC, Belgium; 3 - SCK-CEN, Belgium; 4 - NPL, United Kingdom; 5 - UPV/EHU, Spain

The H2020 EURATOM project INSIDER (Improved Nuclear Site Characterization for waste minimization in Decommissioning and Dismantling under Constrained EnviRonment) was launched in June 2017. This 4 year project has 18 partners. It aims at improving the management of contaminated materials arising from Decommissioning and Dismantling (D&D) operations by proposing an integrated methodology for radiological characterization, under waste-led consideration. The developments are share by 6 work packages devoted to specific but complementary axes. This methodology is based on advanced statistical processing and modelling, coupled with adapted and innovative analytical and measurement methods, with respect to sustainability and economic objectives. In order to achieve these objectives, the approaches will be then applied to three common case studies, in the form of bechmarking:

- UC1: decommissioning of a back/end of fuel cycle and/or research facility: JRC-ISPRA tank farm;
- UC2: decommissioning of a nuclear reactor (NPP or RR): BR3 reactor biological shield at SCK-CEN;
- UC3: post-accident remediation of a site: Contaminated soil from a CEA R&D soil.

They constitute different potential application of sampling objectives and strategy.

To assess the analytical method performance, interlaboratory and interteam-comparisons on matrix representative reference samples and on real samples are organized. Assessment of the outcomes will be used for providing recommendations and guidance resulting in pre-standardization texts.

The INSIDER project is working towards recommendations and guidelines for improving decision making of the industrial implementation for decommissioning and remediation activities Thereby, a key contributor is effective knowledge sharing within the scientific community.

The presentation will give a mid-term progress report of the project and will highlight the contribution of metrological tools, such as matrix certified reference materials production and statistical processing of interlaboratory comparison results, to D&D characterization issues.

CHARACTERIZATION OF CONDITIONED NUCLEAR WASTE FOR ITS SAFE DISPOSAL IN EUROPE (CHANCE)

Dr. Ricard, D. (1); Dr. Guéton, O. (2); Dr. Bucur, C. (3); Dr. Bruggeman, C. (4); Dr. Genoud, G. (5); Dr. Kikola, D. (6); Dr. Kopp, A. (7); Dr. Mathonat, C. (8); Dr. Rizzo, A. (9); Dr. Stowell, P. (10); Dr. Tietze-jaensch, H. (11); Prof. Thompson, L. (10); Dr. Velthuis, J. (7); Dr. Zakrzewska-Koltuniewicz, G. (12)

1 - ANDRA, Châtenay-Malabry, France ; 2 - CEA/DEN/DTN Cadarache, France; 3 - RATEN, Romania 4 - SCK-CEN, Mol, Belgium; 5 - VTT, Technical Research Centre of Finland Ltd, ESPOO, Finland; 6 - Politechnika Warszawska, Poland; 7 - University of Bristol, United kingdom; 8 - KEP Nuclear, France ; 9 - ENEA, Research Centre. Bologna, Italy; 10 - University of Sheffield, Department of Physics and Astronomy, Sheffield, United Kingdom; 11 - Forschungszentrum Jülich Germany; 12 - Instytut Chemii i Techniki Jadrowej, , Poland

The CHANCE project aims to address the specific issue of the characterization of conditioned radioactive waste (CRW). The first objective of CHANCE is to establish, at the European level, a comprehensive understanding of current CRW characterization and quality control schemes across the variety of different national radioactive waste management programmes, based on inputs from end-users such as Waste Management Organizations and storage operators. The second objective of CHANCE is to further develop, test and validate techniques already identified that will undoubtedly improve the characterization of CRW. Specifically, these technical tasks focus on:

- Calorimetry as an innovative non-destructive technique to detect hidden and difficult-to-measure radioactive material and reduce uncertainties on the inventory of radionuclides non-destructive technique to reduce uncertainties on the inventory of radionuclides;
- Muon Tomography to address the specific issue of non-destructive control of the content of large volume nuclear waste and heavily shielded nuclear waste casks ;
- Cavity Ring-Down Spectroscopy (CRDS) as an innovative technique to characterize outgassing of radioactive waste namely of 14C and 36Cl from radioactive waste with the objective to reach a very low level of detection.

The activities performed and the results obtained within the project CHANCE are integrated, communicated and disseminated both between the project partners as well as with the broader

European community involved in radioactive waste disposal.

The final ambition of CHANCE is to improve the efficiency of the characterization of conditioned radioactive waste and therefore to improve the safety of the global radioactive waste management process throughout the full storage cycle, including transport, interim storage and final disposal operational and long term stability.

CHANCE is structured into six work packages:

- Management and coordination (WP1);
- Methodology for conditioned radioactive waste characterization: Problematic wastes and R&D proposal (WP2);
- Calorimetry associated with non-destructive assay techniques and uncertainties study (WP3);
- Muon imaging for innovative tomography of large volume and heterogeneous cemented waste packages (WP4);
- Innovative gas and outgassing analysis and monitoring (WP5);
- Dissemination activities (WP6).

The present status of the project and current results are reported:

A questionnaire was elaborated by WP2 & 6 to obtain a broad overview of the end-users needs for the characterization of conditioned radioactive waste. This questionnaire was distributed to operators of radioactive waste disposal in Europe, notably through the End-User Group. Analyses of questionnaire answers are in progress.

In the framework of WP3, a benchmark of calorimeters and standard NDA methods for the characterization of large volume waste drums has been undertaken and a study of the neutron and gamma ray signals that can escape various 200L waste drum matrices has been performed. A 200 L calorimeter with an optimized detection limit has been assembled and first experiments on mock-up and test drums will start soon.

The muon tomography system is in an advanced stage of commissioning at University of Bristol (WPL4). The detector system has been tested functional and first muon data are acquired for various ISO tests of different geometry and material combinations. A figure-of-merit was defined to allow standardized comparisons of experimental conditions and optimizing various muon trajectory algorithms. Comprehensive numerical simulation is performed alongside all the experiments.

The construction of a prototype of CRDS instrument dedicated to H36Cl measurement is under progress in the framework of WP5. This is the first time that CRDS is used to detect this molecule. An already-developed CRDS instrument will be used for the detection of 14C compounds to study in detail their outgassing rate in various types of waste. The goal is to provide valuable information about the radiocarbon release kinetics and its speciation.

"This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 755371".

Safe management of radioactive waste is challenging to waste producers and waste management organisations. One potential alternative to improve disposability of low and intermediate radioactive waste (LILW) is thermal treatment. Numerous thermal treatment technologies of radioactive waste are available or in development worldwide. These technologies may be applied to a wide range of different radioactive waste streams, including non-standard waste types that present specific waste management challenges. Deployment of thermal treatment technologies can provide significant improvements: volume reduction, waste passivation, organics destruction, safety demonstration facilitation, etc.

THERMAL TREATMENT FOR RADIOACTIVE WASTE MINIMISATION (THERAMIN)

Nieminen, M. (1); Olin, M. (1); Laatikainen-luntama, J. (1); Wickham, S. (2); Doudou, S. (2); Fuller, A. (2); Kent, J. (2); Fournier, M. (3); Clarke, S. (4); Scales, C. (4); Hyatt, N. (5); Walling, S. (5); Gardner, L. (5); Catherin, S. (6); Frasca, B. (6)

1 - VTT Technical Research Centre of Finland Ltd, Finland; 2 - Galson Sciences Ltd, United kingdom; 3 - CEA, France; 4 - National Nuclear Laboratory, United kingdom;5 - The University of Sheffield, United kingdom; 6 - Andra, France

The overall objective of the EC funded THERAMIN project is to provide improved safe long-term storage and disposal of intermediate and low level waste streams suitable for thermal processing. The objectives of THERAMIN are consistent with application of the Waste Management Hierarchy, which is mandatory under EU directives, allowing the best use of disposal capacity and the results of the project enable large cost savings for storage and disposal programmes. By helping to characterise the products of thermal treatment of particular waste streams, the work will strengthen confidence in their disposability. It will also help to substantiate the volume reduction that is potentially achievable through thermal treatment, identifying opportunities for a more efficient use of disposal capacity in existing and future geological disposal facilities. The THERAMIN project aspires to improve understanding and optimisation of the application of thermal treatment in radioactive waste management programmes across Europe, and will move technologies higher up the Technology Readiness Level (TRL) scale. The THERAMIN project will provide an EU-wide strategic review and assessment of the value of thermal technologies applicable to a broad range of waste streams (ion exchange media, soft operational waste, sludges, organics, and liquids). The THERAMIN project will compile an EU-wide database of treatable wastes and document available thermal technologies.

The most essential part of the THERAMIN project is focused on applicability and benefits of technologies to the identified waste streams through full-scale thermal treatment demonstration test trials by project partners. Total six different thermal treatment technologies will be demonstrated. These technologies are based on plasma melting, Joule heating, inductive heating, thermal gasification and hot isostatic pressing (HIP). Demonstrations are done using simulated non-radioactive test materials but also with hot waste materials. After thermal treatment demonstrations treated materials are characterised in order to evaluate disposability of the treated waste. Safety case implications will also be assessed through the study of the disposability of thermally treated waste products. This paper will communicate the strategic aims of the ongoing project and highlight some key findings and results achieved to date.

TUNNEL PLUGS AND SHAFT SEALS DEMONSTRATIONS (DOPAS)

Hansen, J. (1); Palmu, M. (1); Koho, P. (1); White, M. (2); Bosgiraud, J.-M. (3); Foin, R. (3); Rübel, A. (4); Dvořáková , M. (5); Grahm, P. (6); Svoboda, J. (7); Jobmann, M. (8)

1 - Posiva Oy, Finland;2 - Galson Sciences Limited , United kingdom

3 - Andra, France;4 - Gesellschaft Für Anlagen- Und Reaktorsicherheit (GRS) MBH, Germany;5 - SURAO, Czech republic;6 - Swedish Nuclear Fuel and Waste Management Company, Sweden;7 - Czech Technical University , Czech republic;8 - DBE TECHNOLOGY GmbH , Germany

The goal of the Full-scale Demonstration of Pugs and Seals (DOPAS) project was to improve the industrial feasibility of plugs and seals, the measurement of their characteristics, the control of their behaviour in repository conditions, and their performance with respect to safety objectives. The DOPAS project delivered improvements in the process used to develop the

design basis, in the design bases for different plugs and seals, in reference designs, in strategies to demonstrate the compliance of reference designs to the design basis, in technology, in materials, in construction; and on performance assessment of the materials and components. Five demonstration experimental programmes were implemented as part of these development activities. The plugs and seals demonstrated in DOPAS were the Full-scale Seal (FSS) experiment, undertaken by Andra in a surface facility at St. Dizier, France, the Experimental Pressure and Sealing Plug (EPSP) experiment undertaken by SÚRAO and the Czech Technical University at the Josef underground research centre an underground laboratory in the Czech Republic, the Dome Plug (DOMPLU) experiment undertaken by SKB and Posiva at the Äspö Hard Rock Laboratory in Sweden, and the Posiva Plug (POPLU) experiment undertaken by Posiva, SKB, VTT and BTECH at the ONKALO™ Underground Rock Characterisation Facility in Finland. Additionally, in situ tests related to seals in vertical shafts complemented by materials research projects were conducted for the ELSA shaft seal project in Germany. The main outcome from design and construction feasibility for plugs and seals are the lessons learned from the detailed design, site selection and characterisation, and construction of the experiments. These include the four full-scale demonstrators, materials research and its up-scaling, and the learning provided by the practical experience in constructing the experiments. Appraisal of plug and seal systems' function considers what can be concluded from the experiments conducted in the DOPAS project with respect to the technical feasibility of installing the reference designs, the performance of the reference designs with respect to the safety functions listed in the design basis, and identifies and summarises achievements from starting the conceptual design and leading to the full-scale demonstrator. The main outcome for defining the design basis and requirements for plugs and seals were the requirements on plugs and seals considered in the DOPAS project, conceptual and basic designs including material development work, and the strategy adopted in programmes for demonstrating compliance with the design basis. It is essential to collect the feedback from the implemented structures back to the design basis, while development is usually an iterative process and it is important to consider the aspects on the way for industrialisation and implementing the structures in repository. In the DOPAS project, performance assessment was taken to cover the performance of plugs and seals following the installation of the plug/seal materials in the experiment/repository. This included, therefore, the saturation of the materials following installation, their long-term thermal, hydraulic, mechanical and chemical (THMC) behaviour, and their representation in safety assessments.

DEVELOPMENT AND DEMONSTRATION OF MONITORING STRATEGIES AND TECHNOLOGIES (MODERN2020)

Dr. Bertrand, J. (1); Morosini, M. (2); Garcia-sineriz, J.-L. (3); Verstricht, J. (4); Prof. Bergmans, A. (4)

1 - French National Agency for Radioactive Waste Management(Andra), France; 2 - Swedish Nuclear Fuel and Waste Management Co (SKB), Sweden; 3 - AMBERG Infraestructuras S.A, Spain; 4 - ESV EURIDICE GIE, Belgium

The Modern2020 Project was undertaken with the aim to support and document a move from hypothetical repository monitoring programmes to actual, implementable monitoring programmes by providing tools and methodologies at a generic level which may be adapted by each national programme. The Project aimed to develop methods to support disposal programmes close to licensing in the design of monitoring systems suitable for deployment in the next decade, and to support programmes less close to licensing and other stakeholders

The Modern2020 Project focused on monitoring of the near field during the operational period to build further confidence in the post-closure safety case and on specific national programmes. These programmes are those related to disposal of high-level waste and spent fuel in the Czech Republic, Finland, France, Germany, the Netherlands, Sweden and Switzerland. Such strategic aspects of repository monitoring were addressed in Work Package 2 (WP2) of the Modern2020 Project. The work was established to understand what should be monitored within the frame of the wider safety cases. A generic approaches and methodologies

has been developed for monitoring data evaluation criteria and response plans, decision making, and, in particular, developing collective opinions on planning for evaluating and responding to monitoring resultsto provide methodology on how monitoring information can be used to support decision-making and to plan for responding to monitoring results.

A strong effort has been made in the WP3 on research and development to improve and develop innovative repository monitoring techniques (wireless data transmission, alternative power supply sources, new sensors, geophysical methods) from the proof of feasibility stage to the technology development and demonstration phase. Innovative technical solutions facilitate the integration and flexibility of required monitoring components to ease the final implementation and adaptation of the monitoring system.

Four Full-scale in-situ demonstrators (WP4) has been driven with innovative monitoring techniques and their comparison with conventional ones. In this paper, we present the results obtained on experiment done in the URL of Bure called "AHA1604" dedicated to temperature, strain and load measurements on HLW disposal cell prototype. On such experiment, distributed optical fiber has been installed spirally directly on the external surface of a particular liner section. Long Term Rock Buffer Monitoring (LTRBM) experiment aimed at testing new monitoring technologies developed in and outside the Moder2020 project. A preliminary evaluation of the new and innovative technologies, including new sensors and wireless transmitting devices is also detailed.

Local stakeholders (from Belgium, Finland, France and Sweden) have been involved in the project in the framework of the WP5. These public stakeholders engagement activities were of great interest from a social sciences perspective, for the citizens involved and for the other project partners. Some important results have emerged to which we will return later, but we also want to highlight some problems to deal with when citizen stakeholders are involved in an RD&D project, such as this one.

Session 2 - Radioactive waste source term and science for disposal safety

FROM PAST TO FUTURE SCIENCE UNDERPINNING THE SAFETY CASE OF DEEP GEOLOGICAL REPOSITORIES – CHALLENGES UNTIL LICENSING AND HOW MAINTAIN KNOWLEDGE AND COMPETENCE ON CUTTING EDGE SCIENCE AFTERWARDS DURING OPERATION

Dr. Johan Andersson

Swedish Nuclear Fuel and Waste Management Co (SKB), Sweden

Final repositories for spent nuclear fuel are approaching implementation. In Sweden, construction of a KBS-3 type final repository for spent nuclear fuel may start around 2023 provided the Swedish Government grants a decision during 2020. In Finland, a KBS-3 type repository for the spent fuel has obtained a construction license in 2015. A prerequisite for these advancements is that it has been shown that the repository can be constructed and operated in practice in such a way that safety can be assured both during operation and over very long time scales. The success of the programmes rests on decades of structured and objective driven research and development including both theoretical assessments and practical tests in the laboratory and in full scale. This has been possible by a dedication to bring the repository programme to a conclusion with a structured siting strategy, sufficient and long term funding, and a clear strategy for research and development. A key element of the research strategy has been to have sufficient in-house competence in order to maintain its ability to assimilate the knowledge that is present in the community of importance for the management and final disposal of nuclear waste, and to be a competent purchaser of research. While a repository programme will need input from a very wide range of scientific and technical disciplines the core of the in house competence has been to maintain a coherent group of

persons with knowledge on the methodology for the assessment of post-closure safety with wide and interdisciplinary insight on how the different processes that affect repository safety interact. Furthermore, by conducting its own research, SKB has ensured this maintenance of competence. Another bearing principle has been that all research should be publicly available and a strive to publish results in open peer reviewed journals. Openness is judged a basis for developing confidence with the public, the research community and authorities. In building up and maintaining competence international cooperation has been essential. This cooperation entails direct cooperation with sister organisations, with the scientific community at large and using experts trained in other programmes as well as participation in the work of international organisations like the IAEA, OECD/NEA and the European Commission. These different international bodies all have their different benefits. While the direct funding of research projects by the European Commission has primarily not been an important means of funding but has allowed networking on a detailed level directly with a broad range of researchers and other experts. As the programme developed from feasibility studies and basic research into site characterisation, and design, requirements management, workable procedures for data qualification, version control as well as internal and external peer review gained importance. These knowledge management aspects imply a major undertaking and needs to be planned. When the programmes now enter a new phase of construction and operation new challenges will arise. Despite the need for the implementing organisations to maintain core competence on post closure safety assessment, international cooperation will become even more important on developing, sharing and managing the knowledge needed.

SPENT NUCLEAR FUEL DISSOLUTION (REDUPP AND DISCO)

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In the safety assessments for the planned spent nuclear fuel and high level waste repositories, the release rate of radionuclides from the nuclear waste to the transporting medium, normally water, plays a central part. Spent nuclear fuel dissolution has therefore been investigated for many years. Important progress has been made through collaborative international projects. This contribution summarizes results and progress in two Euratom-funded projects: REDUPP and DisCo. REDUPP finished a few years ago while DisCo is on-going and only initial, preliminary results are available. The projects focus on processes occurring at the interface between spent nuclear fuel and aqueous solution. This includes redox reactions but also dissolution from high-energy sites and processes occurring at or near equilibrium. Uncertainties investigated here are if additives in modern fuels, such as Cr or Cr+Al, or, as in the case of MOX fuels, Pu, can influence these processes significantly. Reducing conditions are expected overall although local repository environment will influence the water composition. Therefore, experiments and models are set up to test the effect of different water chemistries. Real spent nuclear fuel experiments, complemented with studies on model materials, provide further insight in the detailed mechanisms involved in spent nuclear fuel dissolution. This research thus relate to the treatment of the fuel dissolution process in safety assessments of the spent nuclear fuel repositories in different environments. It is expected that results will reduce some remaining uncertainties in the parameters of the assessments by indicating to what degree additives in the fuel matrix will affect fuel dissolution rates. Including modern types of fuel in the safety assessment is important for the steps taken towards implementation and licensing of the repositories.

OVERVIEW OF CARBON-14 SOURCE TERM GENERATION AND RELEASE FROM IRRADIATED METALS, ION-EXCHANGE RESIN AND GRAPHITE (CAST)

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The European Commission CAST project (CArbon-14 Source Term) aimed to improve the understanding of the potential release mechanisms of carbon-14 (radiocarbon, ^{14}C) from radioactive waste materials under conditions relevant to the packaging of waste (including the addition of a waste encapsulant) and disposal to underground geological disposal facilities. The project focused on the release of carbon-14 as dissolved and gaseous species from irradiated metals (steels, Zircaloys), from spent ion exchange resins and from irradiated graphites, under repository-relevant conditions.

Regarding steels and Zircaloy, hydrocarbons and carbon monoxide were found in the gas phase whereas the aqueous phase contained small oxygenated organic compounds. Although the organic nature of carbon-14 products generated from steel and Zircaloy corrosion identified in earlier studies has been confirmed, long-term generation of carbon-14 in disposal conditions might give a different picture with respect to its organic speciation and compound distribution. Consequently, conservative treatment still applies in safety assessment regarding specific organic speciation as has been the case in the more recent safety cases. CAST also gave the opportunity to reinforce the understanding of the corrosion mechanisms of these metals, in alkaline, anoxic conditions. As a result, the confidence that these corrosion mechanisms will remain generally unchanged in the long term (within a certain Eh/pH window of the near field) has increased. The interplay of the oxide layer in the carbon-14 release mechanism of Zircaloy is now acknowledged.

CAST emphasized the heterogeneous character of irradiated graphite and spent ion exchange resins. The relative importance in the safety case of carbon-14 (aqueous) versus carbon-14 (gaseous) for these wastes varies by disposal concept, predisposal activities, and operational conditions. Applying the results determined from few specific samples to broad inventories of waste with various operational and predisposal histories must be done with caution. This generalisation process might bring a certain level of uncertainty to be accounted for in safety case.

Safety assessment studies carried out in CAST highlighted again the critical influence of the chemical and physical evolution of the cementitious environment on different aspects of the carbon-14 source term (e.g. corrosion rates, carbon-14 release rates), but also on more global aspects pertaining to the confinement properties of a geological disposal (e.g. fate of the hydrogen produced by corrosion, near field hydraulic properties). As already observed before CAST, carbon-14 in the form of a mobile organic compound will give a more relevant radiological impact than if considered in the inorganic form, particularly so in any 'rapid transport' scenarios. Reducing the uncertainty on carbon-14 speciation provides a basis for re-considering the conservatism in safety assessments of carbon-14 release via corrosion, and transport rates.

The CAST consortium brought together 33 partners consisting of national waste management organizations, research institutes, universities, and commercial organizations. The participation of non-EC partners(e.g. from Japanese organisations) was welcomed. A number of studies presented at the CAST symposium (Lyon, France, 2018) have been reported in a special edition of the Radiocarbon journal. CAST deliverable reports are available on the CAST website (www.projectcast.eu). CAST provided an opportunity for training for early career researchers.

RESEARCH AND INNOVATION ACTION ON CEMENT-BASED MATERIALS, PROPERTIES, EVOLUTION AND BARRIER FUNCTIONS (CEBAMA)

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CEBAMA is a research and innovation action granted by the EC within the HORIZON2020 programme in support of the implementation of the first-of-the-kind geological repositories. The 4-year project started the 1st of June 2015 and lasted until 31st May 2019. It was carried out by a consortium of 27 partners consisting of large Research Institutions, Universities, one Technical and Scientific Support organization (TSO), and one small-medium enterprise (SME) from 9 EURATOM Signatory States, Switzerland and Japan. IGD-TP and National Waste Management Organizations supported CEBAMA, for instance by co-developing the work plan, participating in the End-User Group, granting co-funding to some beneficiaries, and providing for knowledge and information transfer.

The overall strategic objective of CEBAMA was to support the implementation of geological disposal by significantly improving the knowledge base for the Safety Case for European repository concepts. R&D in CEBAMA is largely independent of specific disposal concepts and addresses different types of host rocks, as well as bentonite. CEBAMA is not focusing on one specific cementitious material, but aims at studying a variety of representative cement-based materials for Nuclear Waste Storage in order to provide insight on general processes and phenomena which can then be transferred to different applications and national and international projects. Specific objectives and research activities of CEBAMA are summarized as follows:

- Experimental studies analysing interface processes between cement-based materials and host rocks (crystalline rock, Boom Clay, Opalinus Clay (OPA), Callovo-Oxfordian (COX), Toarcian mudstone, Borrowdale Volcanic Group) or bentonite backfill, and assessing the impact on physical properties.
- Investigation of radionuclide retention and migration processes in high pH concrete environments, focusing on radionuclides which have high priority from the scientific and applied perspective.
- Improved validity of numerical models to predict changes in transport processes as a result of chemical degradation, including advanced data interpretation and process modelling.

In this contribution, main results and scientific highlights from the CEBAMA project are presented, and the potential impact of CEBAMA on the Safety Case discussed. It is also indicated which project events were organised and how the individual technical results from CEBAMA can be accessed, i.e. via peer-reviewed publications, public Deliverables, Annual Workshop Proceedings, etc.. The experimental and modelling work in CEBAMA was to a significant extent performed by young researchers and within PhD theses. This contributes to the continuing availability of highly trained specialists for implementers and regulators.

BENTONITE EROSION: EFFECTS ON THE LONG-TERM PERFORMANCE OF THE ENGINEERED BARRIER AND RADIONUCLIDE TRANSPORT (BELBAR)

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The BELBaR project was a Collaborative Project based on the desire to improve the long-term

safety assessments for geological disposal facility concepts for spent fuel/high level waste that combine a clay engineered barrier system (EBS) with a fractured rock.

Colloids may be mobile in groundwater and are thus potentially significant for safety because they have been shown to be able to sorb radionuclides and increase their effective concentration in groundwater above that which would be transported in dissolved form.

The main aim of the BELBaR project was to increase the knowledge and reduce uncertainties with respect to the processes that control clay colloid generation, stability and their ability to transport radionuclides and reduce uncertainties in the description of the effect of clay colloids in long-term performance assessments.

A reduction of uncertainties in the understanding may lead to:

- A reduction of the assessed overall risk from a repository;
- The possibility to totally neglect the colloidal processes in assessments under some circumstances;
- Guidance to future site selection and site characterisation programmes;
- Guidance in the selection of engineered barriers for a nuclear waste repository.

The outcome of the project was a list of recommendations, primarily directed towards waste management organisations, but also to research entities, regarding the handling of clay colloids in future assessments and research. The list covered areas such as groundwater flow dependencies, exchanger occupancy, presence of divalent cations, relevance of deionised water in experiments, fracture apertures, retardation of clay colloids in rock, linear radionuclide sorption and sorption reversibility, effects of organics, quantitative and bounding models, handling of agglomeration/floc formation and bounding estimates in safety assessments.

BENTONITE MECHANICAL EVOLUTION (BEACON)

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Developing predictive capabilities of the mechanical behaviour of bentonite buffers, seals and backfills are a common need for all radioactive waste management programs that use bentonite in engineered barrier system (EBS) components. Because of the complexity of the objectives, networking at European level is a key for the development of an integrated system understanding, skills, training and capabilities.

Beacon aims at the development of understanding fundamental processes that lead to material homogenisation, as well as improved capabilities for numerical modelling. In earlier assessments of the long term performance of bentonite EBS, the mechanical evolution of the installed bentonite was neglected and an "ideal" final state was optimistically assumed.

In order to verify the performance of current designs for bentonite barriers the following is ongoing:

- A well-documented and communicated collection of the available knowledge prior to the project.
- Re-evaluation of a large part of the existing database to extract the important information, to compile the qualitative and quantitative observations and to develop the conceptual understanding.
- Enhanced, robust and practical numerical tools firmly grounded on a good conceptual understanding, which have the required predictive capabilities concerning the behaviour of engineered barriers and seals.

- A complete experimental database for the need of the assessment models.
- Verified models based on experimental results from experiments in different scales
- Workshops dedicated to the mechanical issues in bentonite open to the scientific community as well as civil society.

The BEACON project is needed for the pan-European aims at building confidence amongst regulators and stakeholders regarding the performance of safety barriers in a geological repository. It is also cost- and time-effective to progress development of understanding regarding bentonite behaviour in a collaborative manner, and the sharing of precedent information enhances efficiency of overall process.

MICROBIOLOGY IN NUCLEAR WASTE DISPOSAL (MIND)

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MIND is an interdisciplinary project consisting of two experimental work packages focusing on the influence of microbial processes on waste forms and their behaviour and long-term performance of repository components. The emphasis is on quantifying specific measureable impacts of microbial activity on safety cases under repository-relevant conditions. The third work package handles integration of society and policy-oriented studies in the project, while a study of expert conceptualization, public perception and risk communication concerning microbial influences in geological disposal, improves general awareness of microbial issues. Microbial activity may have a significant impact on the chemical and physical evolution of the repositories for radioactive waste. Therefore, what controls their activity under repository conditions must be well understood. Work package 1 has increased the knowledge base concerning CH_4 gas generation from LLW/ILW under in-situ conditions; microbial and modelling studies of an 18 year experiment (Olkiluoto, Finland) attributes an increase in CH_4 gas generation rate to neutralisation of pH and declining sulphide resulting from sulphate reduction (SR). An experiment at the Mont Terri rock laboratory further emphasise the importance of SR in limiting CH_4 generation. Microbes have the ability to metabolize organic degradation products of irradiated cellulose, bitumen and PVC at pH conditions relevant to ILW disposal. A novel bacterium capable of degrading isosaccharinic acid (ISA) has been characterized and sequenced. Furthermore, SR processes utilising ISA have the potential to sequester metallic radionuclides (Ni). Microbes isolated from Spanish bentonites have shown to be capable of reducing and precipitating Se and thereby might lower the mobility of Se from repositories. Work package 2 has summarized available data on geochemistry of gases in deep groundwater as an integral part of the determination of geochemical constraints of biological sulphide producing activity at disposal depths. Microbially influenced corrosion (MIC) of canister materials has been extensively investigated. The results suggest that MIC of canisters is possible. Bacteria were found to migrate through Ca-bentonite and it has been shown that microbially produced sulphide react with ferric iron in bentonite under the formation of elemental sulphur, ferric iron and iron sulphide. Swelling pressure is postulated to be then main constrain for microbial activity in buffer and backfill. High pH generated by concrete reduced microbial activity, but it was found that pH can be decreased by microbial activity, likely production of organic acids. In summary, the work of WP2 partners has produced a significant and important set of new knowledge regarding possible microbial effects on engineered barriers. Work package 3 has compared and evaluated different DNA extraction protocols, sequences processes and bioinformatics analysis procedures used by several partners. Moreover, the impact of including microbiology on expert conceptualization and public perception of geological disposal was estimated. All the expertise gathered within the project is summarized in yearly synthesis reports which can be valuable for waste management organizations to define further knowledge gaps that could be elaborated on in future projects.

Session 3 - Networking of research communities, Joint Programming of national programmes and Integration of radioactive waste producers

THE IMPLEMENTING GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE TECHNOLOGY PLATFORM – EVOLVING INTO OUR SECOND DECADE

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1 - Radioactive Waste Management, United Kingdom; 2 - Nagra, Switzerland

The Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP) was established in 2009 to initiate joint technical activities that facilitate stepwise implementation of geological disposal. There are currently 120+ different member organisations. The group is led and funded by an Executive Group comprising representatives from 11 European Waste Management Organisations (WMOs) and organisations responsible for implementation-related RD&D. The IGD-TP's vision is to have the first European geological disposal facilities (GDF) for spent fuel, high-level waste and other long-lived radioactive waste operational by 2025 (https://igdtp.eu/).

Delivery of this vision has been supported by establishing common research needs and developing project scopes that are aligned to safety case needs. In addition, IGD-TP has built confidence in the policy of geological disposal, minimised duplication, delivered savings and helped to make better use of existing European competence and infrastructure.

The technical knowledgebase that has been acquired from more than 40 years of collaborative RD&D is considerable and is now sufficient to facilitate progression towards GDF licensing and construction. For example, Posiva plan to submit their operational licence in 2020. SKB submitted their construction licence in 2011 and Andra are expected to follow in the near future. Significant progress has therefore been achieved. However, it is important that this knowledgebase is maintained and enhanced throughout the step-wise development, operation and closure of facilities.

Much of the underpinning scientific knowledge was developed with EURATOM funding. Recently the EC called for a 'step change' in RD&D cooperation. To achieve this, the European community has been working together to establish a European Joint Programme on Radioactive Waste Management (called EURAD), founded on common objectives. EURAD aims to deliver an ambitious, cohesive and coordinated joint programme. The IGD-TP has worked to ensure inclusive WMO representation within EURAD and contributed towards realising this change, together with research entities and regulatory technical support organisations.

IGD-TP is fully supportive of EURAD. It is however important to recognise that WMO RD&D programmes have a much wider scope of activities than the commonly agreed EURAD strategic research agenda will address. WMOs publish RD&D programmes at regular intervals, typically 3-5 years. Many activities included in national programmes often require a strict delivery timeline, are very specific (and therefore would only be relevant to a small number of WMOs) and are applied topics that are interlinked with decision making. They almost always have a clear licence-driven purpose. Therefore, the IGD-TP also sees value in expanding the group's activities to co-ordinate aspects of these RD&D programmes where WMO collaboration is beneficial. We will do this in parallel with ongoing involvement in EURAD.

The IGD-TP will remain focused on geological disposal, with interest in upstream activities (e.g. conditioning and treatment), but also seeks to widen our remit to include scope of relevance to nations with small programmes, e.g. disposal of sealed sources. This evolution will serve to expand our membership and help ensure that the IGD-TP continues to speak with one WMO voice, addressing the needs of all European WMOs at various stages of programme advancement. As we move into our second decade and GDFs begin to become reality, we will refresh our vision to provide a longer-term perspective for the whole WMO community.

THE SITEX INITIATIVE

Pellegrini, D. (1); Detilleux, V. (2); Swahn, J. (3); Pfingsten, W. (4); Železnik , N. (5)

1 - IRSN, France; 2 - Bel V, Belgium; 3 - MKG, Sweden; 4 - PSI, Switzerland; 5 - EIMV, Slovenia

As stated by article 6-2 of the EC Directive 2011/70/Euratom of 19 July 2011, the Regulatory Function has to be independent of the Implementing Function fulfilled by Waste Management Organisations (WMOs). Accordingly, the independence of the Regulatory Function calls for the support of an independent Expertise Function that develops and maintains the necessary know-how and skills in the field of safety of radioactive waste management (RWM). In this context and with the support of the European Commission, Technical Safety Organisations (TSOs) launched the initiative called SITEX with a purpose to enhance and foster cooperation at the international level in order to achieve a high quality Expertise Function in RWM safety, independent from organizations responsible for the implementation of waste management programmes, aiming at supporting the Nuclear Regulatory Authorities (NRAs), as well as the Civil Society (CS). The EC coordination and support actions SITEX (2012-2013) and SITEX-II (2015-2017) addressed the orientations for research, Safety Case review methodology and practices for geological disposal of radioactive waste, the conditions and means of interactions between institutional bodies and civil society, as well as training needs related to reviewing safety cases. Building on this achievement, the association SITEX_Network (https://www.sitex.network/) was created in 2018 to ensure the perennial development of its activities, embarking different categories of stakeholders, i.e. TSOs, Research Entities (REs) with an expertise function, NRAs and CS groups.

Beyond an overview of SITEX activities, a focus is given in this paper to SITEX contributions to the development of the European Joint Programming (EJP) EURAD in the field of RWM including geological disposal. In particular, SITEX-II developed the Strategic Research Agenda (SRA) of the Expertise Function, accounting for the concerns of the CS representatives. The R&D topics were ranked with regard to their level of interest and priority, leading to 7 "Main topics" associated to 35 specific issues. This SRA was an input to the European JOPRAD project aimed at assessing the feasibility of the above-mentioned EJP. All the SRA topics were acknowledged to be eligible for such an EJP if the conditions identified by SITEX-II and documented in its SRA for preserving the independence of the organizations fulfilling an Expertise Function are met. Further, SITEX-II addressed conditions and means for developing interactions with CS, including a working mode for implementing such interactions, which was considered when preparing the EJP proposal. Another contribution was the SITEX_Network coordination of reviews by mandated TSOs or by SITEX members external to the proposal. SITEX_Network acknowledged the outmost importance of the EJP as built, in case approved by the EC, in the international RWM-related R&D scene and intends to engage with the EJP as a key network of experts to the benefit of knowledge and safe waste management solutions.

EURADSCIENCE, A RESEARCH ORGANISATIONS NETWORK FOR RADIOACTIVE WASTE MANAGEMENT SCIENCE WITHIN EUROPE

Dr. Bruggeman, C.(1); Prof. Bosbach, D.(2); Prof. Churakov, S. (3); Dr. Galson, D. (4); Prof. Geckeis, H. (5); Prof. Grambow, B. (6); Prof. Stumpf, T. (7)

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Founded 5th December 2018, EURADScience is an intellectually independent, cross-disciplinary, inclusive community with the aim of ensuring long-term scientific excellence and credibility in radioactive waste management. Among the 25 founding members are representatives of nationally funded research organisations, smaller consultancy firms, and

members of academia and universities.

The EURADScience Vision is to develop a clear research-driven perspective in radioactive waste management, with a holistic view on all relevant scientific disciplines and a clear focus on scientific excellence to advance progress and establish credibility. For that purpose, EURADScience will work closely together with complementary platforms such as IGD-TP (the Waste Management Organizations "Implementing Geological Disposal Technology Platform") and the SITEX Network of Technical Support Organisations to national Regulators. This close cooperation includes interaction within the new, to be established Joint Programme on Radioactive Waste Management, including Disposal (termed EURAD).

Within the presentation, the vision and mission of EURADScience are discussed, together with a view on how EURAD may contribute to establishing a long-term perspective on radioactive waste management science and its development, supported by nationally mandated actors in Europe.

EUROPEAN JOINT PROGRAMME ON RADIOACTIVE WASTE MANAGEMENT (EURAD)

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For more than 40 years, considerable scientific and technical knowledge has been acquired in Europe in the field of radioactive waste management, including for near-surface disposal and geological disposal and RD&D will continue to be necessary to develop, maintain and consolidate knowledge throughout the stepwise development, operation and closure of disposal facilities, which will be spread over many decades and make this knowledge available to end users. Recently, the EC has promoted a step-change in pan-European research cooperation between EU Member States' national programmes by promoting the setting-up of inclusive research joint programmes in Europe. Based on the positive achievement of the JOPRAD project (2015-2017), the EC confirmed in 2017 its willingness to co-fund such a Joint Programme in the field of RWM. The RWM community therefore pursued the efforts to establish the Founding Documents (Vision, Strategic Research Agenda, Roadmap, Deployment) and a Work Plan for a first implementation phase of 5-years (2017-2018).

EDF SUGGESTIONS AND STRATEGY ON WAYS AND MEANS, INCLUDING R&D ON PRE-DISPOSAL AND RADIOACTIVE WASTE MANAGEMENT FOR ENLARGING THE EUROPEAN JOINT PROGRAMME ON WASTE DISPOSAL FOR JOINT IMPLEMENTATION OF JOINT PROGRAMMING

MICHEL PIERACCINI, SYLVAIN GRANGER, N.FISCHER

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Defining strategies, developing ways and means, including R&D, on radioactive pre-disposal assumes that all facets of waste management from "cradle to grave" are, beforehand, well addressed and, optimistically mastered. Over the last decade, nuclear Decommissioning, as worldwide emerging and competitive market, appears as the main source of waste production in the nuclear field. Materials generated by nuclear facilities dismantling, usually present a wide variety of type, nature, activity, in various significant quantities from which it is necessary to sort and extract the real radioactive remaining waste to be disposed of and to separate them from other materials that could potentially be reused or recycled.

Such complex operations impose a rigorous knowledge as well as a technical and financial mastery in waste management, starting from characterization, physical and radiochemical inventories, decommissioning scenarios definitions, dismantling operations (in potentially ionized radiation environment), waste sorting and extraction, control/measurement, packaging, transportation and survey.

As NPPs owner/operator, in several countries, EDF assumes its responsibility all along the

entire nuclear facility lifecycle. Consequently, as waste producer operating a nuclear fleet but also in charge of the dismantling of already shutdown NPPs, EDF has acquired a sound and robust experience in Waste management and decommissioning. Since 2015, EDF has conducted an internal restructuring, leading to the creation of a dedicated directorate (DP2D)and its holding Cyclife in the WM&D field, gathering all corresponding projects, skills, resources and means. The main objective is to reinforce EDF capacity and leadership in this field, including the integration of R&D aspects, operators' training, experiments and testing of innovative technologies (such as virtual reality, 3D simulation, remote operations,…).

Therefore, EDF not only aims to assume its responsibility as nuclear operator but also to offer services to foreign partners and to develop international collaboration, based on industrial cooperation or under the umbrella of Official International Organisation such as the European Commission (EJP, Euratom,…), OECD/NEA, IAEA, in which programmes and working groups, EDF contributes actively.

The feedback thus acquired by conducting its own WM&D projects as well as contributing to international cooperation, led EDF converging to the conclusion that a suitable strategy to establish ways and means, integrating R&D on pre-disposal and waste management, had to rely on 2 aspects:

- A regulatory improvement : fostering among countries, a circular economy in materials management, including waste whatever they are radioactive or not, thanks to the appropriate definition of criteria and rules. Such improvements in regulations, with the support of International organisations, could upgrade the share of experiences and enable sensible comparison of techniques efficiency being performed worldwide. It could not only improve the operators' confidence and the relevance of the chosen process but it would also increase public acceptance by avoiding a kind of confusion in population perception.

- A technical and experimental aspect : environmental considerations must lead, among other criteria, to the necessity to preserve radioactive disposals as rare resources. This statement has even more strengthened the consideration of the importance of prior waste characterization as well as checking the relevance and feasibility of decommissioning scenarios, including waste production assessment but also the estimation of induced waste quantities, nature and types. In order to reduce as much as possible the waste to be disposed of, not only the effectiveness of scenarios and tools (cutting means efficiency including the assessment of their releases and consumables), but also operators' ability thanks to appropriate training have been addressed by EDF. As part of its decommissioning strategy, EDF has launched a decommissioning demonstrator facility project to be in operation by 2022. Following a modular conception, and first envisaged to check the decommissioning operations of Graphite reactors, it will be situated in France, near Chinon, at nearly equal distance from all European graphite reactors. EDF has designed this facility to be scalable in order to ensure its flexibility. It is therefore mainly composed of 2 major parts: a 3Dsimulation platform, enabling digitalization, virtual reality and a huge experimental Hall with scale one representative mock ups. Such modularity is to ensure its adaptability to find alternatives or to adapt tools and test them in case of unexpected situations.

The occurrence of such cases will undoubtedly be faced on site as none of the graphite reactors have been designed to be decommissioned one day.

Conscious of this observation , EDF has obviously, since the beginning, considered such facility as a privileged means to bring together Best Available Techniques in order to share experiences of nuclear operators from various horizons, various worksites and to train them on new innovative technologies to continuously upgrade safety, environmental consideration, technical and financial mastery in WM&D.

Rapidly, such project has drawn up the attention of several concerned European countries, gaining an international interest and status. It could therefore fulfill further objectives of International organization in compliance with EDF and its partners' industrial objectives.

Furthermore, EDF also envisages the creation, in France, of a new treatment facility

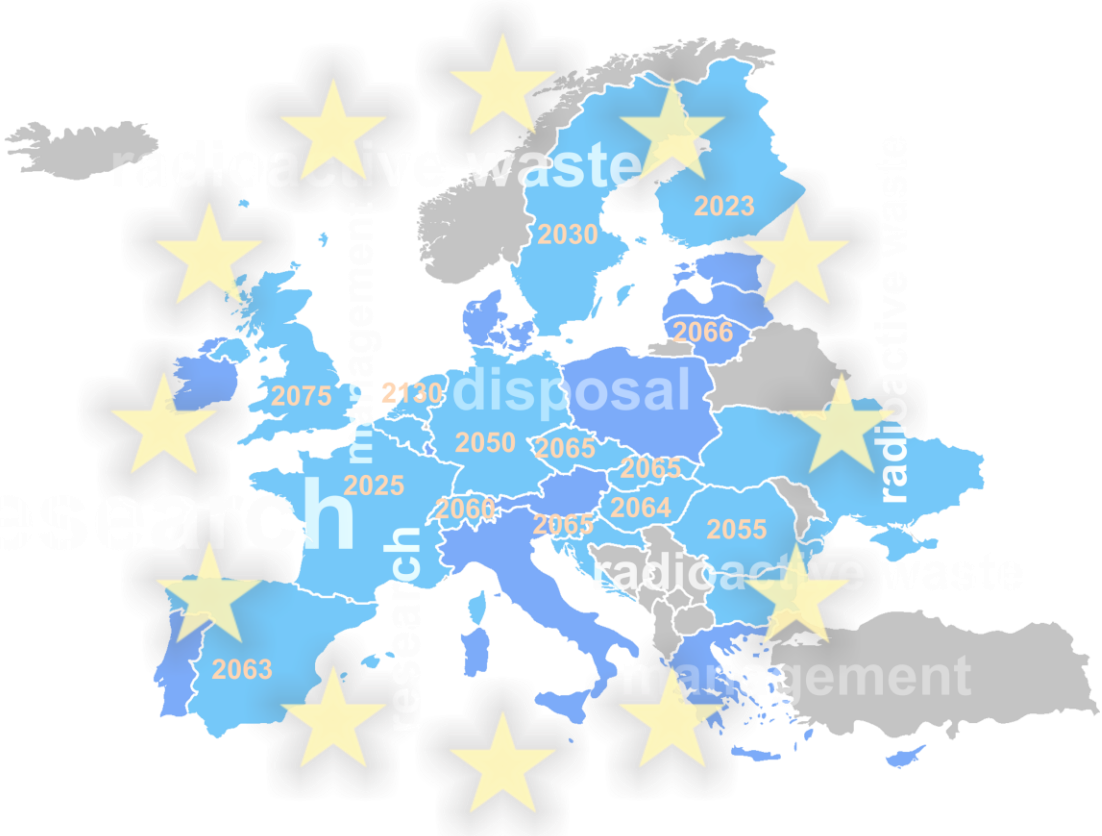
to recycle metals. Based on the circular economy principle mentioned here above, such new build plant, foreseen to be available by 2030, should enable the implementation of an

optimized decontamination process, a melting oven as well as a foundry allowing to recycle metals. Beyond the treatment capacities, at this early stage of the project, keeps in mind the potential use of this future means to enhance some Joint R&D programmes to study, for instance, the use of arc melting furnace technology to decontaminate/homogenize metallic materials in the frame of a recycling route". The availability of such a new facility will allow a twofold sustainability by preserving both :

- repository capacities thanks to a significant reduction of volumes to be disposed of,
- raw materials (steel, carbon, nickel, …).

Such unique facility could allow to centralize and regulate metallic flows coming from worldwide decommissioning worksites (particularly from Europe, Asia). Metals could therefore be recycled thanks to this new profitable and sustainable industrial dedicated pathway granting environmental consideration, process efficiency and mastery.

As a consequence, first being an industrial initiative from a nuclear operator, the implementation of such facilities would, with the support of official organizations in the frameof joint programmes, undoubtedly become means to foster international cooperation, improving R&D on WM&D, including pre-disposal aspect.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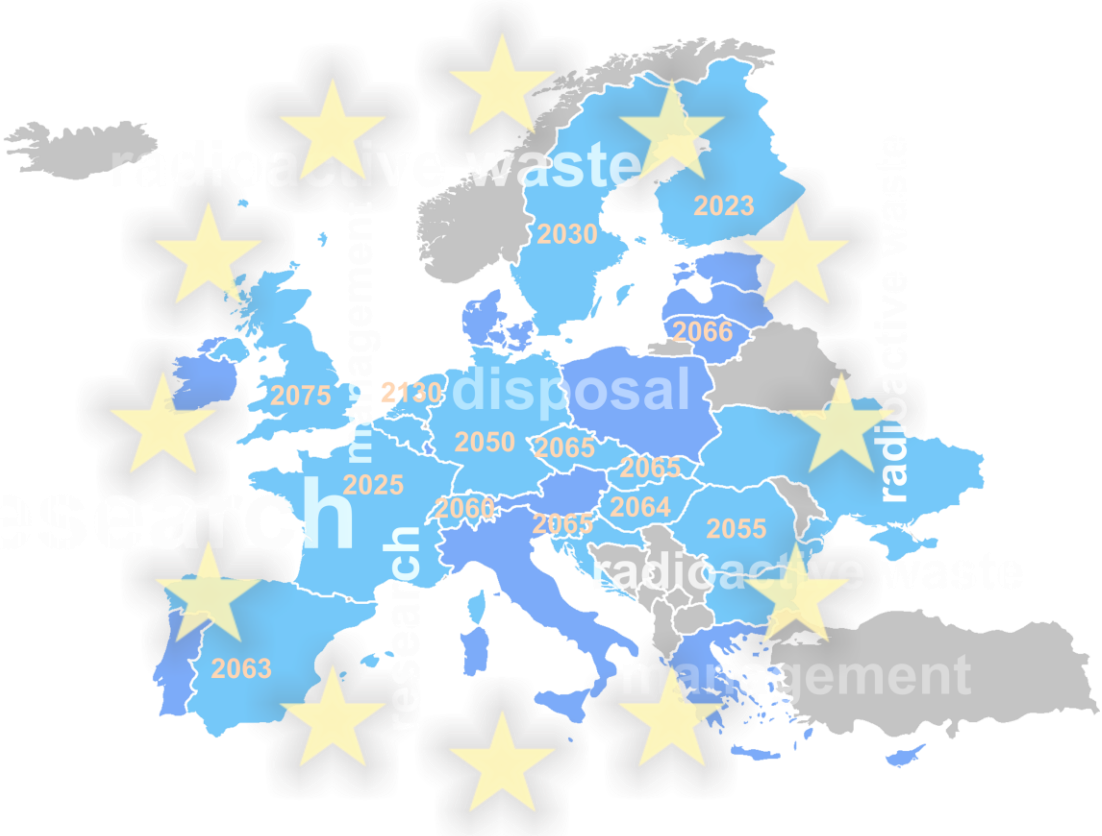
ABSTRACTS
Poster Sessions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ANAEROBIC MICROBIALLY INFLUENCED CORROSION OF CARBON STEEL IN SYNTHETIC BENTONITE PORE WATER INOCULATED BY GRANITE PORE WATER: A 26-MONTH STUDY

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The globally accepted strategy to dispose spent nuclear fuel and high level radioactive waste is deep geological repository (DGR). The concept of DGR entails a combination of engineered and natural barriers system. The absolute barrier of this disposal system is intact metal canister, which will prevent the direct release of radionuclides into the repository environment. Carbon steel is considered as a candidate canister material in Czech Republic as well as in several other EU countries. Safe performance of carbon steel canister may be, however, influenced by microbially induced corrosion (MIC), as many studies have shown active presence of anaerobic microorganism in pore water and bentonite buffer. Sulphate-reducing bacteria (SRB) are considered responsible for acceleration of MIC. The main aim of this study was to compare and characterize the corrosion behaviour and resistivity of carbon steel under sterile and non-sterile anaerobic conditions in synthetic bentonite pore water (SBPW) inoculated with natural ground water VITA from Josef Underground Research Center (Czech Republic) containing a microbial consortium dominated by SRB. Further we wanted to estimate the contribution of MIC to overall corrosion in long-term experiment.

MIC was studied using weight loss method, scanning electron microscopy (SEM) coupled with energy-dispersive spectroscopy (EDS) and Raman spectroscopy. Molecular-biological approach including qPCR analysis and next-generation 16S rDNA amplicon sequencing were used to determine the proliferation of relevant bacterial groups and to identify potentially harmful members of bacterial community. Experiment was run for 26 months.

In sterile conditions, uniform corrosion of carbon steel was observed and the corrosion rate decreased with increasing exposure time. On the other hand, several local corrosion attacks were observed in non-sterile environment after 3, 6, 12 and 26 months and the corrosion rate of the non-sterile environment was up to 4 times higher compared to sterile environment. Presence of microorganism was confirmed by SEM and EDS analysis. Raman analysis showed that the surface of carbon steel was essentially covered with magnetite in the end of the experiment. However, in the case of non-sterile conditions, the mackinawite was detected on the carbon steel as a proof of SRB presence and metabolic activity. Interestingly, members of nitrate reducing bacteria (NRB) were found to highly proliferate in the non-sterile samples and these microorganisms soon overgrown and suppressed the originally present SRB community. This proliferation of NRB was caused by the high concentration of nitrate in the synthetic bentonite pore water, which mimics the Czech BaM bentonite leachate. It is known that iron oxidation can be coupled to nitrate reduction in some NRB and thus could cause increased the rate of MIC. We have detected high corrosion rates in samples with high abundances of NRB (most abundant Pseudomonas, Methyloversatilis and Brevundimonas) but no detected SRB. Methyloversatilis is the best candidate for MIC originator as its abundance best corresponded to the high corrosion rate in studied sample. However, the ability of this species to oxidize iron needs to be proved. The Principal coordinates analysis (PCoA), based on frequency and composition of detected OTUs, shown that microbial composition within the samples is defined mostly by the sampling time and presence/absence of carbon steel. Furthermore, the PCoA analysis confirmed the existence of gradual shift in microbial composition in samples containing carbon steel during the experiment.

Our results are relevant to Czech waste disposal concept as it enhances the need to consider NRB in addition to SRB as a potential threat for bio-corrosion of waste canister. The future studies should concentrate on this phenomenon.

STUDIES OF RADIUM AND STRONTIUM UPTAKE ON CEMENTITIOUS MATERIALS WITHIN CEBAMA PROJECT

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The experimental work in the Cebama project carried out by Department of Nuclear Chemistry, Czech Technical University in Prague, was focused on Ra and Sr retention on cementitious materials. The aim was to obtain data for the development of models of interaction of Ra with cementitious barrier materials which would eventually lead to the preparation of methodology necessary for a case study of LLW-ILW repository Bratrství (Czech Republic). For this reason, within the project unconventional types of cementitious materials (concretes based on CEM I and CEM III and in addition under another funding the corresponding hydrated cement pastes) were studied. Strontium is often considered as an analogue of radium which was the motivation why the strontium is included in this study.

Sorption batch experiments with 223Ra and 85Sr under various conditions (working solution: saturated Ca(OH)2 or NaOH of comparable pH, phase ratio in the range of 10–1000 L/kg) were performed and evaluated in the terms of distribution ratio Rd. This study was completed with characterization of cementitious materials (thermogravimetric analysis and X-ray diffraction analysis) and determination of cations concentration (Ca2+, Sr2+, Na+, K+ and Mg2+) in leachates of same initial composition as sorption samples using atomic absorption spectroscopy.

Sorption study showed significantly higher sorption of Ra on cementitious material than for Sr, which corresponds to the literature. Distribution ratios in Ca(OH)2 solution reached ten to hundreds L/kg for the radium, whereas for strontium they were generally below 20 L/kg. The use of NaOH as a working solution delivers significantly higher Rd for both radionuclides (up to 10700 L/kg for Ra and 1600 L/kg for Sr). The Rd dependence on V/m is in the case of Na(OH) significantly different from the behaviour of the system with Ca(OH)2 as a liquid phase. It could indicate a different pattern of capture in both environments studied.

Interestingly, for samples of hydrated cement pastes, Rd values were lower than those for adequate concretes in the saturated Ca(OH)2 solution (despite the lower content of Calcium Silicate Hydrate (CSH) phase in concretes considered responsible for the uptake of Ra and Sr). The expected increase in Rd values with increasing phase ratio V/m was observed, which can be explained by the ion exchange character of capture of the cation on the solid phase surface. Simultaneously, the equilibrium value of Rd dependence on V/m ratio proves that the sorption isotherm is non-linear.

For both concrete samples was shown that all cation concentrations in leachates determined were lower than for the hydrated cement pastes (which corresponds to the aggregate content).

A careful conclusion can be drawn from all measurements and results. Most likely, a large difference in radium and strontium retention in presence of hydrated cement pastes in saturated portlandite water when compared to their behaviour in NaOH solution is due to different calcium behaviour in these environments. In NaOH, calcium is leached from the cementitious materials while in portlandite water, on the contrary, its concentration in liquid phase decreases and therefore it could be incorporated in the solid phase.

LABORATORY INVESTIGATION OF WATER RETENTION PROPERTIES AND MICROSTRUCTURE OF COMPACTED BENTONITE USED FOR HIGH LEVEL NUCLEAR WASTE DISPOSAL IN THE CZECH REPUBLIC

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The compacted bentonite are prepared from bentonite powder which is originally from Cerny vrch deposit (north western region of the Czech Republic). The initial water content of bentonite powder is around 11%. Initial dry densities of 1.27, 1.60 and 1.90 g/cm3 were used for studying water retention and microstructure properties. The vapor equilibrium method was used to control suction with ranging from 3.3 MPa to 286.7 MPa. Mercury intrusion porosimetry (MIP) and environmental scanning electron microscope (ESEM) were utilized for the microstructure analysis. The changes in microstructure of compacted bentonite under unconfined condition were studied. The samples equilibrated in 3.3, 21.8, 38, 113.5 and 286.7 MPa on wetting path of each dry density were studied by MIP technique. The compacted samples with initial states have gone through both wetting-drying and drying-wetting path by changing relative humidity in the chamber of ESEM tests. The corresponding microphotographs under each relative humidity were recorded to analyse the aggregate deformation and pore volume changing. Water retention results show that the initial dry density has minor influence of water retention curves between suction of 3.3-286.7MPa. Two pore families were identified by MIP, namely macropores and micropores. The transition pore size between the micropores and macropores was found to be suction dependent. From the ESEM observation, the volume of aggregates is relatively insensitive to suction changes and a significant proportion of wetting induced swelling occurs on the macrostructure level.

LABORATORY AND NUMERICAL ANALYSIS FOR THE SIMULATION OF THM-COUPLED PROCESSES DURING THE STRESS DEPENDENT METAMORPHOSIS OF CRUSHED SALT IN ROCK SALT

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Internationally, the most accepted solution for the safe disposal of heat-emitting radioactive waste is the disposal in deep geological repositories. In Europe, there are different host rocks specified: clay/claystone, crystalline rock and salt rock. Especially in Germany, salt formations for a possible repository site are available and have been object of research within the last 40 years.

In Germany, the safe inclusion of the radioactive waste is to be realized by a multiple barrier system, consisting of the geological barrier, of sealing elements in the shafts and disposal drifts, of the backfill of voids, and of the waste packages.

For ensuring the safe inclusion of radioactive waste, the access drifts and shafts must be backfilled and sealed. Initially, the inclusion is assured by the sealing elements which are composed of different materials, following the principle of diversity and redundancy. In the long-term, the backfill material is reconsolidated by convergence, confirming the safe inclusion of the radioactive waste.

For a repository in salt rock, the backfilling of disposal drifts will be done with crushed salt, due to its favourable properties and because it is of the same species. Due to the special property of rock salt, the creep behaviour, the backfill material will be compacted with time by convergence. During the compaction phase, the porosity of crushed salt is reduced from the initial relatively high porosity (30 – 40%) to a value which is comparable to that of undisturbed rock salt (0.3% or less). For ranges of such low porosities, technical impermeability is assumed for a verification period of 1 million years.

The compaction behaviour of crushed salt is very complex and influenced by different

parameters and coupled processes. The database and the process understanding have some gaps in knowledge, especially in the range of low porosities. The project KOMPASS is dealing with these deficits and has the objective to allow a fundamental prediction about the compaction behaviour of crushed salt due to the enhancement of process knowledge, the completion of the experimental database and application and calibration of numerical models.

The compaction behaviour of crushed salt is influenced by different parameters which are: mineralogy of salt, grain size distribution, compaction rate, temperature, humidity influence and stress state. Furthermore, there are different creep deformation mechanisms which occur depending on various parameters. Within the project KOMPASS laboratory experiments for the pre-compaction behaviour and microstructural analysis are planned for getting a deeper understanding of the process behaviour of crushed salt. The gained knowledge is used for the application and calibration of the computational models.

Numerical simulations are needed for the basis of the proof of long-term safety by predicting the influences of thermal-hydraulic-mechanical coupled processes in the repository. A fundamental understanding of coupled processes and the numerical operation mode of the modelling code is essential for a reasonable application of numerical tools. The project BenVaSim deals with elementary coupling of hydraulic-mechanical processes and their implementation in various modelling tools. Partial aspects of this project are the investigation of one-phase flow, two-phase flow and partial saturation, all coupled with mechanical influences.

The objective of the graduation is gaining a deeper understanding in the process knowledge of the compaction behaviour of crushed salt which leads to a possible enhancement in predicting the behaviour of crushed salt as a backfill material in a repository. The focus is on the numerical simulation of coupled processes determining the crushed salt behaviour. Therefore, the finite-element-code CODE_BRIGHT, developed by the Polytechnical University of Catalunya, will be used. The existing models for crushed salt will be applied and extended. The basic knowledge for the academic work is achieved by the collaboration in the projects mentioned above. The graduation is carried out in cooperation with the Chair for Waste Disposal Technologies and Geomechanics of Clausthal University of Technology.

HOW 'DRY' IS DRY SPENT NUCLEAR FUEL AND WHAT ARE ITS CONSEQUENCES?

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The current nuclear waste management plans of most nuclear countries involve storing of Spent Nuclear Fuel (SNF) in cooling ponds and then transferring it to dry casks once it stops generating significant decay heat. A cladding failure whilst in the fuel ponds and the hygroscopic nature of the actinide dioxides are two pathways leading to fuel-water interactions, while the spent fuel is still hot and radioactive. In such a scenario, the fuel - water system quickly becomes vulnerable to a complicated redox reaction as water radiolyses into a number of ions (H_3O^+), electrons, radicals (*OH), atoms (H*) and combined molecular products (H_2O_2, H_2) which have different effects depending on the interacting surface atom. For example, UO_2, under oxidising conditions, can form UO_2^{2+} (uranyl) ion which is readily soluble risking an accelerated dissolution of the fuel matrix. The interaction, however, is affected by the presence of other elements such as fission products and the transuranics. Therefore, understanding the behaviour of radioactive spent nuclear fuel (SNF) in the presence of water is vital in predicting the short and long-term effects in an unlikely event of a cladding failure.

Spent fuel morphologies typically consist of UO_2, PuO_2, fission products, transuranics and activation products in the order of its percentage composition in the matrix. For simplicity, this research is focused on spent fuel UO_2 and PuO_2 interactions with water and its radiolysis products. The adsorption and dissolution kinetics of PuO_2 is studied using a non-radioactive surrogate, CeO_2 which also possesses similar oxidation states to plutonium. Also, cerium is formed as a fission product along with other lanthanides and can thus be studied as a minor

independent spent fuel constitute. As regards physical effects, such as wetting, CeO2 provides insight into water adsorption on both UO_2 and PuO_2.

The fuel-water interaction is studied in two strands - at a fundamental level looking at hygroscopic properties of the fluorite structure using Temperature Programmed Desorption (TPD) analysis on powder CeO_2 and in the other strand, looking at the radiolysis induced dissolution mechanism by mimicking the interaction of radiolytic products with SNF. The dissolution study is carried out using synchrotron X-rays to cause radiolysis in a film of water placed over the sample and to study the induced corrosion on the film surface using X-ray reflectivity and diffraction on single crystal epitaxial thin film samples of UO_2 and CeO_2. Going forward, we plan to conduct dissolution studies on (U, Ce)O_2 mixed oxide films to study (U, Pu)O_2 solid-solution systems, as we plan to add more degrees of complexity in the fuel surface morphologies and to look at more realistic spent fuel corrosion scenarios.

This research will serve in strengthening the safety case of civil spent nuclear fuel handling, dry storage conditions of failed fuel and in the long term, the safety of geological repositories.

EFFECT OF CONCRETE ON MICROBIAL COMMUNITY UNDER REPOSITORY RELEVANT CONDITIONS

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Various concepts of deep geological repository (DGR) have been proposed for the disposal of low and intermediate level waste by different countries. In general concept, waste will be encapsulated in metallic drums or concrete container where gap between the waste package and the surrounding host rock is filled by a backfill material such as unreinforced concrete and bentonite. Wide variety of indigenous microbial communities with specific metabolic pathways exists in bentonite buffer and underground water and therefore may be active at the interface between cementitious material and bentonite buffer potentially compromising the safety performance of the DGR by their metabolic activity. The ability of bacteria to affect the concrete properties (biodegradation or biomineralization) is well known. However, the effect of concrete environment on indigenous microbial communities under repository relevant conditions is much less known.

Czech BaM bentonite (Mg-Ca bentonite) from Černý vrch and aged low-alkaline concrete from Josef Underground Research Centre (URC), Czechia, was inoculated with natural underground water VITA from Josef URC (1.5:1.5:10 w/w). The experiment was performed in anaerobic conditions. It was divided into two sets, both containing similar indigenous microflora from underground water and bentonite. Set A was carried at 30°C with addition of inoculum of four anaerobic alkaliphilic bacterial strains whereas set B was carried at room temperature without any additional microbial strains. Controls for each set without concrete and no-culture control (without inoculum) and no-culture no-concrete control were also included. The experiment was carried out for 2 months and samples were taken at the beginning, after one week, one month and two months. Molecular-biological approach including qPCR analysis and 16S rDNA amplicon sequencing was used to determine the diversity and proliferation of relevant bacterial groups. Porosity was determined by means of pure liquid N_2 adsorption at 77 K.

Surprisingly, indigenous bacteria from bentonite and underground water were negatively affected by the presence of concrete although they are adapted to alkalic pH. The microbial abundance was much higher in control samples without concrete than in concrete-containing samples in the set B. Unexpectedly, in the set A, most of the inoculated alkaliphilic bacteria did not survived in bentonite environment, although the pH and temperature were optimal for them. Furthermore, higher temperature in set A probably inhibited growth of most indigenous bentonite bacteria compared to set B performed at laboratory temperature. Principal coordinates analysis (PCoA) based on detected operational taxonomic units (OTUs) distinguished three distinct groups corresponding to the experimental set-up. The presence of concrete was the most determining factor as it markedly increased the pH. By the end of

experiment, the concrete containing samples were dominated by alkaliphilic Alkaliphilus, Dethiobacter and Bacillus. Surprisingly, no difference in pore size was determined in any condition with increasing incubation time, which means we have not detected any structural changes (either concrete biodegradation or biomineralization) in the material caused by microbial activity.

Our results demonstrate that presence of concrete has the potential to strongly reduce microbial activity including thermophilic alkaliphilic bacteria from culture probably due to pH increase or presence of additional chemical compounds such as calcium formate which has an inhibitory effect especially on sulphide oxidizing bacteria. On the other hand, indigenous alkaliphilic bacteria Alkaliphilus from natural sources of concrete and culture and Dethiobacter and Bacillus from BaM bentonite were able to survive and started to proliferate. Nevertheless, over period of disposal, the pH of the alkaline concrete is expected to decline gradually by the carbonation and by neutralization with the microbially produced acids consequently resulting in biodegradation of cementitious material. Further research is therefore necessary to estimate the possible biomineralization or biodegradation activity of indigenous microorganisms in cementitious materials that might be important for the DGR safety.

EFFECTS OF THE INITIAL GRANULAR STRUCTURE OF CLAY SEALING MATERIALS ON THEIR SWELLING PROPERTIES: EXPERIMENTS AND DEM SIMULATIONS

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Bentonite-based materials are considered as a sealing material for the isolation of galleries in radioactive waste disposal concepts because of their low permeability, radionuclide retention capacity and ability to swell upon hydration. This latter is an important property to fill technological voids. Within this context, bentonite pellet mixtures have been studied owing to operational convenience. Pellets are installed in a dry state as a granular assembly. The mixture homogenises upon hydration from the host rock pore water. At full saturation, homogenised pellet mixtures are thought to behave as classic compacted bentonite materials. However, before homogenisation, the granular nature of the material controls the macroscopic behaviour of the mixture. Interactions between pellets and their consequences on the macroscopic behaviour of the mixture have to be studied to carry out predictive simulations of the evolution of engineered barriers, especially during the first years following installation.

In this work, the influence of the granular nature of the material is studied through Discrete Element Method (DEM) simulations. A model based on the Hertz law and perfect plasticity at contact is proposed. Friction at contact is described using the Coulomb law. Model parameters such as pellet stiffness, volumetric strain and elastic limit are characterised upon suction decrease in the laboratory. Swelling pressure tests of pellet mixtures, carried out at laboratory scale, are then simulated using the proposed model. The model is shown to satisfactorily reproduce the mixture behaviour upon hydration from 89 MPa (initial state) to 9 MPa of suction, the value below which the granular structure is thought to lose its influence on the mixture macroscopic behaviour.

Results highlight that the swelling pressure evolves in two phases upon suction decrease. The first phase is characterised by the increase of elastic contact forces and is influenced by the sample preparation. The second phase is characterised by the occurrence of plasticity at contacts and is influenced by the progressive decrease of pellet strength and stiffness. Furthermore, it is shown that a low ratio of pressure sensor diameter to pellet diameter induces a significant variability of the measured swelling pressure in experimental tests.

RADIONUCLIDE MIGRATION IN LOW-pH CEMENT / CLAY INTERFACES: DERIVATION OF REACTIVE TRANSPORT PARAMETERS WITHIN THE CEBAMA PROJECT

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This work provides chemical composition, microstructure and surface charge information, reactive surface area, porosity and diffusivity of an anionic radionuclide (36Cl-) and tritiated water (HTO), for four different low pH cement pastes manufactured within the Cebama project. The microstructure and chemical characterization of the hydrates is investigated by using several complementary analytic techniques: XRD, TG-DTA, FT-IR, 29Si and 27Al MAS NMR, SEM-EDX, zeta potential measurements, BET, XAS (Cl and Fe K-edges), MIP and quantitative Rietveld phase analysis. The main hydrated phases identified/quantified in the cement samples are C-A-S-H with a Ca/Si ratio between 0.8 and 1.0 and an Al/Si ratio of 0.05. Unreacted silica fume is identified as well and on the other hand, the presence of unreacted clinker has only been observed in Cebama paste sample together with blast furnace slag and the quartz filler. The only minor phase present in all samples is ettringite. Fe is located in different phases (ettringite, C-S-H, and C4AF). Zeta potential measurements revealed negatively charge surface in all the sample and MIP data indicates that the size of the pores varies from the micro to the nanoscale (capillary porosity and the nano-pores C-A-S-H phases).

The transport parameters such as the effective diffusion coefficient De, the porosity ε, the rock capacity factor α, are derived by performing through diffusion experiment of HTO, 36Cl-, on the reference low pH cement paste of the Cebama project and by inverse modelling of the diffusive flux. Fickian diffusion in a homogeneous isotropic material has been considered as the only transport process.

Finally, interface chemical processes happening between the reference low pH cement paste and bentonite water during a period of 6 months showed a degradation zone of 450 µm, associated to the decalcification of the C A S H phases, the hydration of the unreacted clinker, and the formation of M S H phases with high alkaline content (i.e. Na). Calcite precipitates at the surface of the degraded cement.

A NUMERICAL APPROACH FOR THE HYDRO-MECHANICAL BEHAVIOUR OF BENTONITE SEALS IN THE CONTEXT UNDERGROUND RADIOACTIVE WASTE DISPOSALS

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Deep geological disposals have been considered as a reasonable solution for the final management of high and medium-activity-level nuclear waste.

The waste confinement is ensured by the host rock and/or engineered barrier. Bentonite is the main component of this barrier due to its very low permeability in saturated conditions and its swelling potential, namely swelling strain and swelling pressure development upon water saturation (respectively in unconstrained and constant volume conditions).

In order to assess the long-term evolution of a geological repository, a good prediction of the hydro-mechanical response of bentonite subjected to various boundary conditions is needed.

This is the main aim of BEACON project, which, among many other relevant objectives, promotes the development of an efficient European network between the most important agencies and universities involved in the nuclear waste disposals research. The objective of this work is to propose a new constitutive model able to reproduce the bentonite hydro-mechanical response.

Based on advanced numerical methods, this model is implemented in the finite element code LAGAMINE. In this work, the Barcelona Basic Model is considered for the bentonite mechanical behaviour. Pressure dependence is taken into account for some mechanical parameters, as well as the dry density dependence that has also to be considered given the experimental evidences which link the final swelling strain (or stress) to the initial compaction state of the material.

In parallel, the permeability evolution is analysed. Permeability is linked to pore structure of bentonite, in which it can be distinguished the volume inside the grains (microporosity), between the grains of clay (macroporosity) and, in the case of pellet-mixtures, between the pellets (megaporosity). The evolution during saturation of these porosities leads to the variation of the permeability.

The developed model has been used for the numerical modelling of experimental tests proposed in the context of the BEACON project. The numerical results obtained are in good agreement with experimental measurements. Especially, the non-monotonic evolution of the swelling pressure during the hydration phase is well captured by this model, which is always a challenge for this type of problem.

DIRECT METHOD FOR DETERMINATION OF ^{14}C MASSIC ACTIVITY IN IRRADIATED GRAPHITE

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^{14}C is one of the limiting radionuclides for categorization of radioactive graphite waste. In order to optimize pretreatment or disposal strategy, the precise and fast method for determination of ^{14}C massic activity is needed. Recently we proposed a rapid analysis method for the ^{14}C massic activity determination in small graphite samples of the 1-100 μg range. The proposed method is based on the graphite combustion and subsequent CO_2 and ^{14}C measurements by using the commercial elemental analyzer and the semiconductor detector, respectively. There is no need for sample weighing. The detection procedure for sample containing a higher ^{14}C activity than 20Bq takes approximately 10 minutes. Although the estimated efficiency of the semiconductor detector system is fairly poor (15%) due to the less than the ideal 4π geometry, the uncertainty of the rapid method is in an acceptable range (10-20%) for radioactive waste characterization purposes.

The proposed method was compared with measurements done by conventional liquid scintillation counter Quantulus-1220 (PerkinElmer, USA) and gas catchers (3M NaOH) to evaluate the accuracy of measurements for very small mass samples with the low ^{14}C activity. LSC measurements were traceable to the national standard of activity. The ^{14}C activity in a graphite sample was calculated taking into account activity determined in the catchers, the counting efficiency, the recovery efficiency and the aliquot volume. The linear approximation function between the activity measurements from the LSC method and the semiconductor detectors was determined. This function could serve as the ^{14}C activity calibration curve and could be used for rapid ^{14}C activity determination in routine measurements. The proposed rapid analysis method could be implemented for the direct radioactive waste characterization by using the scaling factor method or even used in biomedical applications when dealing with the massic activity determination of ^{14}C in a sample.

Predisposal and disposal technology developments

THE MODERN2020 IN SITU TESTS IMPLEMENTED AT THE TOURNEMIRE URL – TESTING AND IMPROVING NEW MONITORING SENSORS AND TECHNOLOGIES

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1 - IRSN, France; 2 - AMBERG, Spain

The Modern2020 project focuses on providing the means in developing and implementing an effective and efficient repository operational monitoring programme for specific national programmes. The work carried out has enabled to define which parameters could be monitored within an underground repository and to provide a methodology on how data can be used to support decision making and to plan the response. In this framework, several full-scale in situ demonstrations of innovative monitoring techniques have been implemented in 4 different Underground Research Laboratories (URLs) across Europe (France, Switzerland and Finland) to enhance the knowledge on disposal monitoring techniques and to demonstrate the performance of new innovative sensors.

The Tournemire URL run by IRSN, the French Technical Safety Organisation (TSO), was chosen to host three large in situ experiments within the Modern2020 project. The goal was to monitor different parameters (temperature, humidity, pressure, pH, chemical composition, suction, and deformation) with new techniques (mainly wireless devices using high and low frequencies, fibre optics and geophysical methods) in and around an engineered barrier system (EBS) composed of a bentonite buffer and a low-pH cement plug. All three tests were installed in the Tournemire URL in three horizontal boreholes (10 m long, 60 cm diameter). The different experiments were designed, built and implemented by IRSN, AMBERG, ARQUIMEA, ENRESA, NRG and the University of Strathclyde. The sensors implemented in the experiments were provided by AMBERG, Andra, ARQUIMEA, Czech Technical University (CTU), IRSN, NRG, University of Strathclyde and VTT.

- The LTRBM experiment

The LTRBM experiment was built to test and assess new monitoring devices developed in WP3 of Modern2020 under conditions as close as possible to the ones expected in the real repository. The buffer is artificially saturated and instrumented with conventional sensors as well as with newly developed sensors. Data transmission is based mainly on wireless techniques.

- The ERT experiment

The ERT experiment was designed to assess the capabilities of Electrical Resistivity Tomography (ERT) as a non-intrusive technique to monitor the resaturation of a bentonite buffer. The buffer is artificially saturated and is equipped with a heater to mimic heat transfer from waste packages. Local sensors were installed into the bentonite buffer to measure water content and temperature and are used as a way to perform cross-checking with geophysical measurements

- The WTB experiment

The Wireless Testing Bench (WTB) facility provides the possibility to evaluate signal transmission parameters of different wireless technologies for data transmission (short- and long-range radio waves) under representative in situ conditions. The WTB setup consists of a one large diameter borehole filled with an EBS and 3 access boreholes (drilled perpendicularly to the main borehole axis) in which wireless units are placed and tested. The experimental design enables the wireless units to be introduced and removed at will within the bentonite buffer. A watertight access to the bentonite cores (transparent to radio waves), allows testing and continuous improvement of the wireless units under different saturation conditions.

Radioactive waste source term and science for disposal safety

SPENT FUEL ALTERATION MODEL INTEGRATING PROCESSES OF DIFFERENT TIME-SCALES

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DisCo European project aims to enhance our understanding of Spent Fuel (SF) matrix dissolution under conditions representative of failed containers in reducing repository environments. In this framework, Amphos 21 has implemented a reactive transport model in iCP (an interface coupling COMSOL Multiphysics and PhreeqC) to assess the behaviour of Spent Fuel (SF). The contribution of Amphos 21 is divided into two tasks:

Task 1. To develop a conceptual geochemical model that accounts for the impact of metal alloy particles (epsilon metals) on SF dissolution under highly reducing conditions and in presence of hydrogen.

Task 2. Assessment of the behaviour of the fuel under the conditions developed inside the canister, as discussed with experimentalists. This includes a discussion on the effect that different types of metallic dopants can have on the SF environment response.

The developed reactive transport model includes the following processes defined in the conceptual model:

- Generation of water radiolysis species by alpha and beta radiation considering a complete radiolysis system. This phenomenon has been implemented in COMSOL.
- Corrosion of the SF surface, considering UO_2(am) doped with Pd as SF matrix. This phenomenon has been implemented in PHREEQC using the thermodynamic database ThermoChimie v.9b0. The model considers the following processes: a) generation of OH by decomposition of H_2O_2 on UO_2(am) surface, b) oxidation of UO_2(am) to UO_3(s) by OH and O_2, c) dissolution of UO_3(s) with water and carbonates, d) non-oxidative dissolution of UO_2(am), e) activation of H_2 by Pd surface, evaluating the impact of epsilon particles, and f) reduction of UO_3(s) to UO_2(am), with the inclusion of the H_2 activation process.

The above model has been calibrated with experimental data described in Cera et al. (2006). These data, also used in the MICADO European project (2006-2009), provided with concentration of generated O_2, H_2 and H_2O_2 at long reaction times, to allow adjusting the rate constants of processes a), b) and e) and also provided with concentration of uranium under different conditions being able to validate the effect of carbonate and chloride in uranium dissolution. Next, the model will be compared with the experimental data generated in the DisCo project and the effect of the dopants on the dissolution of SF matrix will be discussed.

In a first approach, a 1D reactive transport simulation was run considering a homogeneous SF solid surface (UO_2 containing 1% of Pd, as representative of epsilon particles). A uniformly distributed alpha dose rate was considered on the first 13 microns of water adjacent to the SF surface. In the described model, the spent fuel is considered only as a surface, not as a porous medium and the effective diffusion coefficient of all aqueous species was set to 10^{-9} m^2/s. The determined UO_2 dissolution rate is comparable with values selected in performance assessments when considering the inhibiting effect of H_2 on long term dissolution of SF matrix.

CHEMISTRY OF BERYLLIUM IN CEMENTITIOUS SYSTEMS STUDIED WITHIN CEBAMA: SOLUBILITY, HYDROLYSIS, CARBONATE COMPLEXATION AND SORPTION

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Beryllium is a chemotoxic element expected in specific waste forms to be disposed of in repositories for radioactive waste. Very limited information on the behaviour of Be(II) in alkaline cementitious systems was previously reported in the literature. In this study within CEBAMA, the solution chemistry of Be(II) was investigated in a comprehensive series of solubility and sorption experiments with focus on alkaline pH conditions and cementitious systems. All experiments were performed at KIT–INE. Based upon these studies, an improved understanding and quantitative description of Be retention processes in cementitious environments is developed. This provides important new input for the assessment of Be in the Safety Case.

The solubility of Be(II) in the absence of carbonate was investigated under Ar atmosphere in dilute to concentrated alkaline NaCl, KCl and $CaCl_2$ solutions. Experiments were performed from undersaturation conditions using BeO(cr) and freshly precipitated $Be(OH)_2$(am) as starting materials. Solubility constants of the investigated solid phases (log10 *K°s,0) were determined with complementary experiments in acidic NaCl solutions. Solid phase characterization after attaining equilibrium conditions shows the transformation of the amorphous phase in b-$Be(OH)_2$(cr). Solubility data confirms the amphoteric character of Be(II), with a solubility minimum at pHm ≈ 9. At this pHm value, [Be(II)] in equilibrium with BeO(cr) and b-$Be(OH)_2$(cr) is ≈ 10–7.5 and ≈ 10–7 M, respectively. Our results support that the anionic species $Be(OH)_3$– and Be(OH)42– control the aqueous speciation of Be(II) in the pH-range defined by cementitious systems (10–13.5). Experiments conducted in the presence of carbonate indicate that solubility remains unaffected at pHm ≥ 10 and Ctot ≤ 0.1 M (Ctot = $[HCO_3^-]$ + $[CO_3^{2-}]$. Comprehensive chemical, thermodynamic and (SIT) activity models for the system Be^{2+}–Na^+–K+–Ca^{2+}–H^+–Cl^-–OH^-–H_2O(l) are derived on the basis of experimental data determined in this work.

Sorption experiments conducted with standard Portland cement (degradation phase I and II), low pH cement and C-S-H phases with Ca:Si = 0.6, 1.0 and 1.6 show a relatively strong uptake of Be(II) by cementitious materials (log10 Rd ≈ 3.5–5.5). In all investigated systems, the concentration of Be(II) in the aqueous phase after equilibration with cement is well below the solubility limit defined by b-$Be(OH)_2$(cr), thus confirming that experimental observations are primarily driven by sorption phenomena instead of solubility. Relatively slow sorption kinetics are observed (sorption equilibrium achieved > 10 days), suggesting that additional processes beyond surface complexation might be involved in the uptake of Be(II).

This study provides valuable inputs for the safety assessment of repositories for the disposal of radioactive waste: (i) contributing to geochemical calculations under boundary conditions of relevance in the context of waste disposal; (ii) providing upper concentration limits for Be(II) based on solubility phenomena for source term estimations and; (iii) providing an extensive set of sorption values (as log10 Rd) for a broad range of cement materials, degradation stages of cement and model compounds.

BENCHMARK OF REACTIVE TRANSPORT MODELS WITHIN CEBAMA: APPLICATION TO A CONCRETE / CLAY INTERFACE

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Within the framework of the HORIZON2020 Collaborative Project CEBAMA (Cement-based materials, properties, evolution, barrier functions), a benchmark study of the modelling of the interactions of low-pH concrete and clay rock has been conducted. CEBAMA is a research and innovation action granted by the EC in support of the implementation of first-of-the-kind geological repositories for nuclear wastes (www.cebama.eu). One of the goals of CEBAMA is to improve our understanding of interaction processes between cementitious and clayey materials. Different modelling approaches were used for modelling and interpretation of experimental data generated within CEBAMA, showing good agreement between model and experimental results. Focus was on reactive transport processes of cementitious materials and their interface with clayey systems. A common modelling task was conducted to build confidence in the consistency of the different modelling approaches. The work consisted in benchmarking various reactive transport codes by simulating physical and chemical processes governing long-term interactions at the concrete-clay interface. A reference case was simulated using different reactive transport modelling tools, as well as a set of sensitivity cases for assessing the impact of numerical codes specificities, material variabilities, and uncertainties (e.g. regarding porosity coupling) on the extent of alteration. The studied system considered a generic low-pH concrete structure in contact with a clayey host rock. A one-dimensional setup with isothermal and fully saturated conditions was considered. The concrete composition corresponds to the low-pH concrete used in CEBAMA as an experimental benchmark. The composition of the clay host rock corresponds to the Callovo Oxfordian claystone. In this contribution, the results and main outcomes obtained with different reactive transport modelling tools are presented and the implications of the study are discussed. This study has served to build confidence in the representation of this complex system with reactive transport tools used within CEBAMA when simulating the long-term behaviour of low-pH cementitious systems. The results show not only the high level of understanding of the governing processes but also the good agreement obtained with different codes, which is essential to demonstrate the applicability of these numerical tools in safety assessments. This research has received funding from the European Atomic Energy Community, Horizon 2020 Program (NFRP-2014/2015), under grant agreement 662147 – CEBAMA.

MICROBIAL DEGRADATION OF NITRATE LEACHING FROM THERMALLY AGED INACTIVE BITUMINISED RADIOACTIVE WASTE AT HIGH PH

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In Belgium, an important fraction of the current stored volume of long-lived intermediate level radioactive waste is immobilised in a bituminous matrix as Eurobitum. Besides radionuclides, Eurobitum contains large amounts of soluble salts with sodium nitrate as the most dominant. Geological disposal of this waste in a water-saturated sedimentary formation such as Boom Clay will induce water uptake by the hygroscopic salts present in the bituminized waste, resulting in the dissolution and leaching of sodium nitrate. In addition, organic compounds mainly originating from the degradation of Eurobitum are expected to be released into the clay pore water. Leaching of sodium nitrate and organic compounds into the host formation could

cause geochemical perturbations of the surrounding clay, possibly affecting some of the favourable characteristics of the host formation. In addition, leaching of sodium nitrate and organic compounds into the host formation could stimulate nitrate reducing prokaryotes resulting in the formation of nitrite, nitrogen gases or ammonium possibly affecting the redox conditions of the host formation. As the reducing capacity of the undisturbed clay formation will strongly affect the speciation, solubility, retention and transport properties of redox-sensitive radionuclides (Se, Tc, U, Np, Pu, etc.), clay oxidation might favour the migration of these radionuclides in the host formation. Furthermore, depending on the electron donor used in the denitrification process, the final overall result could be a gas pressure decrease or increase. However, hyperalkaline conditions that prevail during disposal conditions could affect the denitrification potential of the microbial population.

This study investigated the potential of the microbial community present in Boom Clay borehole water and in Harpur Hill sediment (natural analogue to a cementitious geological disposal facility), to reduce nitrate leaching from thermally aged inactive bituminized waste supplemented with acetate at different pH (9 – 10.5 – 12.5). At pH 9, the maximum nitrate reduction rate and ongoing reaction mechanism were similar for both microbial communities. On the other hand, at pH 10.5, the microbial community present in the Harpur Hill sediment reduced three times more nitrate compared to the Boom Clay borehole water microbial community after 110 days. In addition, different reactions seemed to be carried out by both microbial communities. In addition, both communities were able to form a biofilm on the bitumen at pH 9 and 10.5 after 110 days. However, at pH 12.5, nitrate reduction nor biofilm formation was observed. Nevertheless, both microbial communities were not completely eliminated as cells could be resuscitated afterwards. Principal component analysis based on flow cytometry community profiles indicated that at pH 12.5, profiles at pH 12.5 differ from those at pH 9 and pH 10.5, which are quite similar. In addition, at pH 12.5 flow cytometry profiles for the Harpur Hill community clearly differ from that of the Boom Clay borehole water community. Hence, it seems that high pH alone as stress factor will not eliminate all microbial presence in a geological repository, though it seems to provide enough stress to cause a significant shift in the microbial population and reduce its nitrate reducing activity.

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ESTIMATION OF 14C RELEASE AND MIGRATION FROM RBMK-1500 REACTOR GRAPHITE DISPOSED OF IN A POTENTIAL GEOLOGICAL REPOSITORY IN CRYSTALLINE ROCKS IN LITHUANIA

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In RBMK-1500 reactors, graphite is used as a neutron moderator and reflector. Lithuania has two units with RBMK-1500 type reactors at the Ignalina nuclear power plant. These reactors are under decommissioning now and Lithuania face a challenge of management of the large amount of irradiated graphite (i-graphite). The generated i-graphite cannot be disposed of in a near surface repository because of the unacceptable high ^{14}C activity. Thus, a deep geological repository could be considered as an option. According to the proposed generic repository concept for RBMK-1500 spent nuclear fuel disposal in the crystalline rocks in Lithuania, the long lived low and intermediate level waste could be disposed of in the same repository at certain distance from SNF emplacement tunnels.

Up to now, the research of RBMK-1500 i-graphite disposal in Lithuania has been limited. In the absence of relevant experimental data, the earlier studies dedicated to modeling of release and migration of ^{14}C from the RBMK-1500 i-graphite disposed of in a deep geological repository were based on very conservative assumptions. In the course of the EC FP7 collaborative project CAST (Carbon-14 Source Term) (2013-2018) investigations into ^{14}C inventory in i-graphite, its release and speciation have been performed. The outcomes of these investigations together with the most recent results from the research carried out under national UK, French programs have formed the basis for a more realistic modeling of the

potential release and migration of the ^{14}C in the near field. Thus, the information gathered during the CAST project on ^{14}C inventory in i-graphite, rapid and slow release fractions and release rate as well as on speciation and sorption of ^{14}C in a cementitious environment was incorporated in the context of the previous assessments and ^{14}C flux from the near field (engineered barriers) into geosphere (host rock) was evaluated.

The modeling results revealed that the information obtained during the CAST project reduced conservatism in the assumptions, and the estimated ^{14}C flux from the near field decreased almost by one order of magnitude in comparison with the previous conservative estimations. However, it should be noted that the information on ^{14}C release and speciation obtained during the CAST project was for other types of i-graphite than the RBMK-1500 reactor. In order to increase confidence in the assessment and provide justification for the selected parameter values, experimental investigations with the RBMK-1500 reactor graphite are needed.

PRELIMINARY INVENTORY OF C-14 IN IRRADIATED GRAPHITE OF IGNALINA NPP UNIT 1 RBMK-1500 REACTOR

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Ignalina NPP contains two Units with RBMK-1500 reactors. After shutdown, several Unit 1 systems and equipment were radiologically characterized and dismantled. The highest volume of reactor structures is attributed to the graphite stack of the reactor core, radiological characterization of which was not performed before the CAST Project.

Earlier studies revealed that the radiological inventory of irradiated RBMK-1500 reactor graphite could be dominated by the radionuclide C-14, however estimations were based on conservative assumptions and lacked experimental activity measurement data. The production of C-14 in nuclear reactors is typically dominated by neutron activation of N-14 and O-17, but for a graphite moderated reactors, the influence of C-13 is also significant. Therefore, within the EC 7th FP project CAST, one of the tasks was to estimate C-14 inventory based on a combination of available radionuclide activity measurements and full 3D reactor graphite stack neutron activation modelling.

The stack of RBMK-1500 reactor can be visualized as a vertical cylinder 8 m high and 14 m diameter, made up of 2488 columns where each column is made up from several graphite blocks. The total mass of the graphite stack blocks is about 1700 tonnes.

The spatial and energy distribution modelling of the neutron flux in the stack was performed using MCNP 5 ver. 1.6 code. Neutron activation modelling was performed using ORIGEN-S computer code employing COUPLE code (both codes from the SCALE 6.1 codes system) for the preparation of the problem specific weighted cross-sections.

A preliminary study to estimate experimental C-14 activity in several graphite sub-samples of the GR-280 grade graphite bushing from the temperature channel of the Ignalina NPP Unit 1 RBMK-1500 reactor revealed that the average value of C-14 specific activity in this graphite was 1.67E+05 Bq/g (study performed by Ignalina NPP and Nature Research Centre staff, Lithuania).

By having the modelled distributions of specific C-14 activity in the graphite stack, by knowing the correspondence of measured specific C-14 activity to the exact point (location) of the modelled specific activity distribution, and by applying quantities and masses of the graphite components, the integral C-14 activity in the graphite stack was evaluated.

Obtained results show that, based on the combination of modelling and measurement techniques, the total inventory of C-14 in the graphite stack is estimated at ~3.22E+14 Bq at 9 years after Unit 1 reactor final shutdown with the average C-14 specific activity in the graphite stack being ~1.9E+05 Bq/g.

CHROMIUM DOPED UO_2-BASED MODEL SYSTEMS: THE MODEL MATERIALS FOR THE STUDY OF THE MATRIX CORROSION OF MODERN SPENT NUCLEAR FUELS

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The current efforts to improve fuel performance in nuclear power generation resulted in an increased utilization of a variety of new types of light-water reactor (LWR) fuels such as Cr-, Al-, and Si-doped fuels. The corrosion behaviour of these types of fuels in the systems relevant to deep geological waste repository has hardly been studied so far. Experiments with spent nuclear fuel (SNF) cannot entirely unravel all of the various concurring dissolution mechanisms due to the chemical and structural complexity of spent nuclear fuel and its high beta- and gamma radiation field and technical restrictions allowing only for a very limited number of experiments. Therefore, within the EU-DISCO project (www.disco-h2020.eu) experiments on irradiated Cr-doped fuels are complemented with systematic dissolution studies carried out with carefully prepared and characterized, simplified UO_2-based model materials. A bottom-up approach is followed to understand how the addition of Cr-oxide into the fuel matrix affects SNF dissolution behaviour under repository relevant conditions.

Here, we present recent results on the development and optimization of the process steps for a wet-chemical route to produce pure reference UO_2, Cr-doped UO_2 as well as Cr- and alpha doped (^{238}Pu) pellets. A wet chemical route was favoured due to the very low doping levels of ^{238}Pu required to mimic fuel ages between 1,000 and 10,000 a later in DISCO. Process optimisation was achieved by a systematic investigation of various process parameters such as calcination temperature and pelletisation pressure. Syntheses were performed by co-precipitation and wet-coating methods and had to be free of any grinding steps to be applicable in a dedicated glove box. In order to provide insights into the effects of the material's micro-structure on the dissolution behaviour (e.g. regarding the larger grain size in doped fuels and contributions of grain boundaries) the model materials are produced in form of sintered pellets. The microstructure (grain size, grain orientation) of and dopant distribution (i.e. either in solid solution within the UO_2 matrix or segregated on grain boundaries) in the model materials were characterised using various methods (e.g. SEM, EBSD, EMPA, ToF-SIMS, XRD).

INTEGRATION OF CAST RESULTS TO SAFETY ASSESSMENT - PROBABILISTIC UNCERTAINTY/SENSITIVITY ANALYSIS OF C-14 RELEASE AND TRANSPORT

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Based on the Dutch OPERA reference concept for the final disposal of radioactive waste in Boom Clay, a conceptual model has been implemented in the computer code ORCHESTRA to assess the influence of system parameters on the C-14 flux, released from Zircaloy contained in a CSD-C canister, through the surrounding concrete and Boom Clay.

A full probabilistic uncertainty/sensitivity analysis (UA/SA) has been applied to assess how the C-14 flux through the disposal system depends on (1) the Instant Release Fraction (IRF) of C-14 from Zircaloy, (2) the long-term congruent release resulting from the corrosion of Zircaloy, (3) the adsorption coefficient Kd,c of C-14 in concrete surrounding the CSD-C canister, and (4) the adsorption coefficient Kd,BC of C-14 in Boom Clay as the host rock.

The UA/SA has been performed for two different cases, (1) a "Reference Case", assuming expert values of the failure time of the CSD-C container and the C-14 diffusion coefficient in Boom Clay, and (2) an "Enhanced C-14 Migration Case", assuming an immediate failure of the CSD-C container after disposal, and a significantly increased value of the C-14 diffusion coefficient in Boom Clay.

The sensitivity of the calculated C-14 fluxes at different locations for the four system parameters was analysed by using scatter plots, the Pearson Correlation Coefficient (PCC), the Rank Correlation Coefficient (RCC), and conditional Cobweb plots.

The results of the UA/SA show that the calculated C-14 fluxes close to and further away from the CSD-C canister hardly depend on the prescribed values of the IRF and the Zircaloy corrosion rate. On the other hand, C-14 fluxes throughout the disposal system are influenced by the adsorption coefficients of C-14 in concrete and Boom Clay, but not to an equal extent.

For the OPERA disposal concept in Boom Clay the flux of C-14 out of the 50 m thick Boom Clay is limited if not negligible. This is caused by the long transport time of C-14 from the waste containers through the concrete engineered structures and the Boom Clay host rock compared to its half-life. Only in case of an assumed early release and a significantly enhanced migration rate a noticeable amount of C-14 may ultimately leave the Boom Clay host rock.

The poster will elucidate on the OPERA disposal concept, the assumptions and modelling efforts of the UA/SA, and present highlights of the results of the simulations.

CARBON-14 RELEASE FROM IRRADIATED STAINLESS STEEL

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^{14}C (half-life 5,730 years) is a key radionuclide in the assessment of the safety of a geological disposal facility (GDF) for radioactive waste. In particular, the radiological impact of gaseous ^{14}C bearing species has been recognised as a potential issue. Irradiated steels are one of the main sources of ^{14}C in the UK's radioactive waste inventory. However, there is considerable uncertainty about the chemical form(s) in which the ^{14}C will be released.

The objective of the work was to measure the rate and speciation of ^{14}C release from irradiated 316L(N) stainless steel on leaching under high-pH anoxic conditions, representative of a cement based near field for low-heat generating wastes. Periodic measurements of ^{14}C releases to both the gas phase and to solution were made in duplicate experiments over a period of up to 417 days.

An initial fast release of ^{14}C from the surface of the steel is observed during the first week of leaching, followed by a drop in the rate of release at longer times. ^{14}C is released primarily to the solution phase with differing fractions released to the gas phase in the two experiments: about 1% of the total release in one and 6% in the other. The predominant dissolved ^{14}C releases are in inorganic form (as ^{14}C-carbonate) but also include organic species. The predominant gas-phase species are hydrocarbons with a smaller fraction of ^{14}CO (which may include some volatile oxygen-containing carbon-species).

Networking of research communities, Joint Programming of national programmes and Integration of radioactive waste producers

DEVELOPMENT AND IMPROVEMENT OF NUMERICAL METHODS AND TOOLS FOR MODELLING COUPLED PROCESSES: A R&D INITIATIVE WITHIN EURAD

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Understanding of multi-physical Thermo-Hydro-Mechanical-Chemical coupled processes (THMC) occurring in radioactive waste disposal is a major and permanent issue to support optimization of design and safety case abstraction. Numerical simulations are necessary to

make predictive multi-physical analyses for time periods and space scales larger than experiments can cover. These numerical simulations require integrating, in a consistent framework, an increasing scientific knowledge acquired for each of the individual components of a system for radioactive waste disposal. This implies to consider couplings of different and non-linear processes from a wide range of materials with different properties as a function of time and space in ever-larger systems.

The development of cutting-edge and efficient numerical methods is thus necessary, in the scope of having useful, powerful and relevant numerical tools for assessments. It is also necessary to manage the uncertainties associated to the input data feeding the models and the representation of the processes, to assess the range of variability of the results and to identify the main parameters and processes driving the behaviour of the systems of interest. Managing uncertainties in these complex systems require the improvement and the development of innovative, appropriate and efficient numerical methods.

According to this needs the main objectives of the work package Development and Improvement Of NUmerical methods and Tools for modelling coupled processes (DONUT) within the EURAD project are:

- The development of relevant, performant and cutting-edge numerical methods that can easily be implemented in existing or new tools, to carry out high-performance computing to facilitate the study of highly coupled processes in large systems. These methods and their implementation in tools will be mainly applied to reactive transport, 2-phase flow, and THM modelling in porous and fractured media;
- The development of numerical scale transition schemes for coupled processes (meso to macro scale), supporting the study of specific multi-scale couplings such as chemo-mechanics;
- The development of innovating numerical methods to carry out uncertainty and sensitivity analyses
- The set-up and performing of benchmark exercises on representative test cases to test and show the efficiency of developed methods (robustness, accuracy, computational time) on relevant tools.

To tackle such ambitious objective, the DONUT work package gathers experts from the various modelling fields (mathematician, physicist, computer scientist, geochemist, mechanician etc.) which are needed to encompass the full complexity of the modelling of coupled processes and the assessment of uncertainties related to data input and the mathematical representation of the thermic, hydrological, mechanical, and chemical processes. Ten countries are represented, and the allocation of EU funds between categories of actors is approximately: Research entities: ~57%, Waste Management Organisations: ~30%, Technical Support Organisations: ~13%. Special attention is given by DONUT to make the outcomes meaningful and useful for, especially for "end-users".

SPENT FUEL CHARACTERIZATION AND EVOLUTION UNTIL DISPOSAL

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An European Joint Programme on Radioactive Waste Management (RWM) EURAD has been launched to coordinate activities on agreed priorities of common interest between European partners. The main actions involved into the ERAD EJP includes scientific and technical activities on RWM from cradle to grave radioactive waste characterization and processing, interim storage of radioactive waste and predisposal and disposal solutions.

A work package on Spent Fuel Characterization and Evolution until Disposal (SFC) was proposed, developed, submitted and accepted by the EC. The objectives of this work package are described as follow:

- Produce experimentally verified procedures to reliably determine the nuclide content of spent nuclear fuel, including realistic uncertainties.
- Establish beyond state-of-the-art characterization techniques for spent nuclear fuel during its evolution from reactor unloading until disposal.
- Establish beyond state-of-the-art uncertainty quantification of the characteristics of the spent fuel during its evolution during pre-disposal activities.
- Better understand the performance of the spent fuel during prolonged storage prior to its transport, during the transport and emplacement in a deep geological repository, in order to build the capability for ensuring the safety of all safety relevant operations.
- Improve the understanding of the behaviour of fuel, cladding, pellet-cladding interaction and ageing effect under normal and postulated accident scenarios until disposal, in order to identify relevant or typical bounding cases at time of re-conditioning and pre-disposal activities (treatment, conditioning and transport).
- Provide contributions to operational safety concepts for fuel handling at SNF packaging facilities.
- Contribute to education, training and building of competence in the subject.

The project is expected to cover several open questions and needs for RWM activities, i.e. the optimisation of the number of assemblies for the loading of disposal canisters based on a precise determination of decay heat and reactivity of spent fuel assemblies.

Regarding safety aspects, 3 main concerns are intended to be addressed, such as the reduction of uncertainties on safety related parameters, the contribution and further development of guidance on the operational safety for both interim storage and fuel packaging facilities.

Regarding increasing scientific and technical Knowledge in RWM, both fuel and cladding degrading mechanisms (oxidation, corrosion, irradiation, etc.) that may affect their chemistries (oxidation state, chemical composition, microstructure, etc.) and hence alter their thermo-mechanical properties are going to be investigated.

In addition, the combination of both numerical calculations and experimental methods intends to provide a complete and thorough understanding of the mechanisms driving the behaviour of the SNF rods during its extended storage in both normal and accidental conditions.

The project will provide a better understanding of long-term uncertainties which would in turn address and answer to the fears and doubts of the EU citizens regarding the idea to develop a nuclear storage. The results obtained will contribute to develop a rigorous scientific approach and technical bases for ensuring the safe storage of spent nuclear fuel in all aspects related to transport, retrieval and predisposal phases.

EURAD HITEC: INFLUENCE OF TEMPERATURE ON THE BEHAVIOUR OF CLAY-BASED MATERIAL

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Most of Deep Geological Repository Safety Cases limit maximum temperature to 100°C. Higher temperatures can have significant advantages such as higher enrichment/burn-up fuels, shorter interim storage requirements, easier (re)packaging of the waste, reduced footprint of the disposal. The overall aim of the HITEC Work package of EURAD project is to improve Thermo-Hydro-Mechanical (THM) description of clay based materials - host clay rock and bentonite buffer - at elevated temperatures. HITEC work programme aims to provide results that are applicable to a wide range of buffer materials and host clay rocks, which can be useful for different national programmes. The host clay formations will be studied at saturated conditions only, while buffer bentonite is studied both in saturated and unsaturated conditions. For host clay rock temperatures under 120°C and for bentonite buffer temperatures under

150°C are considered. Mechanical behaviour is the focus area, while chemical conditions will be taken care of whenever possible by some simplified couplings (including vapour transport).

The HITEC Work package will be carried out by about 30 organisations from 12 countries - Waste Management, Research and Technical Support organisations all well presented. The HITEC will be led by VTT Technical Research Centre of Finland Ltd. The two technical tasks are:

- Host clays formations: to deploy knowledge to mechanics of clay to better evaluate/model possible damage evolution - led by University of Lorraine, CNRS, GeoRessources
- Buffer bentonite: to deploy knowledge to hydro-mechanical behaviour at high T - led by CTU in Prague, Centre of Experimental Geotechnics

UNCERTAINTY MANAGEMENT MULTI-ACTOR NETWORK (UMAN)

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While the involvement of stakeholders is essential to the decision-making process at all stages of a radioactive waste management programme, decisions associated with each of these stages have to be made in the presence of both irreducible and reducible uncertainties. Choices made on the basis of limited information in early programme phases have to be duly justified and communicated. Several of these choices may have to be confirmed during subsequent stages of the process for instance during site selection, construction or operation of the facility. Activities associated with the programme (site characterisation, process modelling, safety assessment, etc.) are also evolving over time leading to new viewpoints and sometimes new uncertainties. At the end of the process, uncertainties will inevitably remain but it should be demonstrated that these uncertainties do not undermine safety arguments. Hence, the management of uncertainties represents a key part of successful programme planning as well as a key issue when developing and reviewing the safety case of waste management facilities. Dealing with uncertainties associated with waste disposal facilities is particularly challenging due to the long timescales during which the radiotoxicity of the waste remains significant.

Therefore, as underlined in the Roadmap of the newly established European Joint Programme on Radioactive Waste Management (EURAD), uncertainty management would benefit from continued sharing of methodologies and experience. Uncertainty is also a cross-cutting issue within the different themes and stages identified in this Roadmap as well as in the priorities identified in the Strategic Research Agenda of EURAD. Associated RD&D activities are expected to reduce uncertainties by improving the state-of-knowledge. Comprehending the contribution of these activities to the overall uncertainty management is important for the different actors involved in the decision-making process as well as for the identification of future priorities and activities.

Accordingly, the raison d'être of the Uncertainty Management multi-Actor Network (UMAN) is to provide an opportunity to different actors of Member States to share their experience and views on uncertainty management and to identify emerging needs associated with this topic that could be addressed in subsequent waves of the Programme. This Work Package (WP) of EURAD will also contribute to understanding the benefits of RD&D activities for the safety case and the decision-making process. It also contributes to the vision of EURAD by fostering mutual understanding and trust between Programme participants.

The WP includes the review of existing strategies, approaches and tools. Furthermore, existing knowledge and views on the identification, classification, characterisation and significance of uncertainties associated with specific topics will be synthesized. A particular focus will be put in the first wave of the Programme on the following topics in direct link with RD&D WPs of EURAD and/or for which exchanges have been identified as beneficial by the actors themselves: waste inventory and impact of predisposal steps, site and geosphere, human aspects and spent fuel. Then, possible options to manage these uncertainties will be identified and discussed.

Interactions between different types of actors including civil society are central to this WP. These interactions will take place notably through workshops and seminars. They are aimed at meeting the shared objective of fostering a mutual understanding of uncertainty management strategies, approaches and preferences.

CORI – COLLABORATIVE RESEARCH ON CEMENT-ORGANICS-RADIONUCLIDES-INTERACTIONS IN EURAD

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The CORI (Cement-Organics-Radionuclides-Interactions) Workpackage in EURAD aims to improve the knowledge on the organic release issues which can accelerate the radionuclide migration in the context of the post closure phase of geological repositories for ILW and LLW/VLLW including surface/shallow disposal. The R&D in CORI is expected to extend the current state-of-the-art, contribute to optimize disposal solutions and consider questions of regulatory concern. CORI will help member states to further develop their national R&D programs and support programs at an early implementation stage.

CORI objectives are addressing topics in the context of cement-organics-radionuclides-interactions. Organic materials are present in some nuclear waste and as admixtures in cement-based materials and can potentially influence the performance of a geological disposal system, especially in the context of low and intermediate level waste disposal.

The potential effect of organic molecules is related to the formation of complexes in solution with some radionuclides of interest (actinides and lanthanides) which can (i) increase the radionuclide solubility and (ii) decrease the radionuclide sorption. Organic substances require increased attention since a significant quantity exists in the waste and in the cementitious materials, with a large degree of chemical diversity. Cement-based materials will be degraded with time, leading to specific alkaline pH conditions under which the organics can degrade, thus increasing their impact on repository performance. The three R&D Tasks in CORI are:

- Organics Degradation. Focus is on the characterization of soluble organic species generated by radiolytic and hydrolytic degradation of selected organics (PVC, cellulose, resins, superplasticizers). Studies also include the analysis of degradation/stability of small organic molecules such as carboxylic acids and determination of degradation rates.
- Organics-Cement-Interactions. Studies focus on investigating the mobility of selected organic molecules in cement-based materials. Mobility of organic molecules includes sorption and transport properties. Organics will also include small ^{14}C bearing molecules as identified in the EC EURATOM project CAST. Both retention on individual cement phases and actual cementitious systems are investigated.
- Radionuclides-Organics-Cement-Interactions. Consistent with the set of organics, individual cement phases and materials identified in the above two Tasks, radionuclide migration processes are studied in the ternary system. The role of organic molecules on the transfer properties of radionuclides are investigated through sorption and transport experiments. Selected radionuclides cover a range of chemical characteristics and redox states relevant for the expected conditions in L/ILW disposal.

Predicting and assessing radionuclide transport is a key topic in nuclear waste disposal. Improved quantification of radionuclide solubility and sorption phenomena in cementitious environments can provide important input into predicting radionuclide transport. CORI is expected to provide new scientific information in this context and generate specific impact regarding implementation needs and safety. An important objective in CORI is enhancing cooperation between the different participating beneficiaries and countries. Knowledge transfer and training of young researchers in view of future demands for qualified staff is likewise a key aspect of CORI. CORI is fully integrated into EURAD, working both in exchange with other

RD&D WPs and the Networking and Knowledge Management activities.

EUROPEAN JOINT PROGRAMME ON RADIOACTIVE WASTE MANAGEMENT

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For more than 40 years, considerable scientific and technical knowledge has been acquired in Europe in the field of radioactive waste management, including for near-surface disposal and geological disposal and RD&D will continue to be necessary to develop, maintain and consolidate knowledge throughout the stepwise development, operation and closure of disposal facilities, which will be spread over many decades and make this knowledge available to end users. Recently, the EC has promoted a step-change in pan-European research cooperation between EU Member States' national programmes by promoting the setting-up of inclusive research joint programmes in Europe. Based on the positive achievement of the JOPRAD project (2015-2017), the EC confirmed in 2017 its willingness to co-fund such a Joint Programme in the field of RWM. The RWM community therefore pursued the efforts to establish the Founding Documents (Vision, Strategic Research Agenda, Roadmap, Deployment) and a Work Plan for a first implementation phase of 5-years (2017-2018).

THE EURAD EU PROJECT: WORKPACKAGE FUTURE

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The work package (WP) FUTURE (FUndamental undersTanding of radionUclide REtention) is dealing with radionuclides retention and transport in repository systems foreseen in clay/clayrock and crystalline rocks. The project integrates more than 20 European Research Entities (RE), Waste Management Organisations (WMO) and Technical Support Organisations (TSO). The WP FUTURE is organized in two tasks: (1) MOBILITY, comprising work on mobility of radionuclides in compacted clay, the mobility of radionuclides in crystalline rock and the reversibility of sorption as well as (2) REDOX, comprising work on redox reactivity of radionuclides on mineral surfaces. A number of cross-linked activities are foreseen to exchange with complementary WPs within EURAD, namely: CORI (Cement-Organics-Radionuclides-Interactions) and DONUT (modelling).

The main research objectives of the WP FUTURE comprise: (i) Fundamental insights into the impact of chemical boundary conditions (pH, ionic strength) and the role of microstructures on radionuclide (RN) speciation and mobility in "real" clay rocks as well as crystalline rocks and the sorption reversibility; (ii) Quantitative and mechanistic understanding of the impact of specific surface properties of materials (diffusive double layer, surface potential), the role of grain boundaries, and structural heterogeneity on the mobility of chemical species at pore scale; (iii) Refined understanding of the relation between fracture/pore structures and transport as well as the feedback of mineral reactions (dissolution/precipitation, clogging) on pore structure and connectivity; (iv) Fundamental understanding of surface induced (heterogeneous) redox processes relevant for uptake of redox-sensitive radionuclides at Fe(II)/Fe(III) bearing minerals surfaces.

The research activities in the WP are built upon cutting-edge experimental studies addressing specifically the performance of current state of the art models and concepts for radionuclide behaviour in the real system focusing on:

- Transferability of sorption and transport models for strongly sorbing RNs: actinides, intermediately sorbing RN: Ra and weakly sorbing RN: I/Se in compacted clays (Opalinus clay / COx and illite as reference model).
- RN mobility in crystalline systems with strongly sorbing RNs: actinides, intermediately sorbing RNs: Ra and weakly sorbing RNs: I/Se.

- Sorption studies with a focus on reversibility of Ni/Fe and Ra in order to close specific knowledge gaps in support of (i) and (ii).
- Experiments on heterogeneous redox reactions on model clay mineral and model Fe oxide surfaces, restricted to Tc, actinides and I/Se to close significant knowledge gaps sorption mechanism of redox sensitive RN.

The WP will provide scientific basis needed to bound the applicability range and to estimate uncertainties in the simplistic concepts used in the current safety assessment (SA) studies. The development of multicomponent mechanistic sorption models and pore scale simulations of radionuclides transport will allow validation of the concepts used in SA and ensure that all relevant processes are sufficiently understood and are taken into account in SA at an appropriate level, e.g. surface diffusion, sorption mechanisms, competition and reversibility in clay rocks. Moreover, the proposed research will contribute to the understanding of transport of radionuclides in the crystalline rock environment by properly identifying relevant properties and species involved in sorption and transport processes, altogether with description of fractured rock environment. The combined analysis of reactivity, structure, flow field, and RN mobility/retention would provide a unique dataset that would enable to include local boundary drive transport processes into SA models.

EURAD1 RD&D WP GAS - MECHANISTIC UNDERSTANDING OF GAS TRANSPORT IN CLAY MATERIALS

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The RD&D WP GAS of EURAD1 is dedicated to the Mechanistic understanding of gas transport in clay materials. The main objectives of this WP are 1) to improve the mechanistic understanding of gas transport processes in natural and engineered clay materials, their couplings with the mechanical behaviour and their impact on the properties of these materials and 2) to evaluate the gas transport regimes that can be active at the scale of a geological disposal system and their potential impact on barrier integrity and repository performance.

The programme of work will provide results that are applicable to a wide range of national programmes. The WP is linked to EURAD Roadmap Theme 4 - Geoscience to understand rock properties, radionuclide transport and long-term geological evolution - phases 1-2.

Within this WP, knowledge gained from new and past lab and in situ experiments will be put in context for configurations that are commonly found in current repository designs with the aim to address two key questions from the end-users, i.e. 1) how could gas migrate within the repository and which water soluble and volatile radionuclide transport could be associated with it? and 2) how and to what extent could the hydro-mechanical perturbations induced by gas effect barrier integrity and long-term repository performance?

To answer these questions, the work programme will be split in three main technical tasks. The task "Transport Mechanisms" will focus on the characterisation of the gas diffusion, advection and retention in clay materials. The task "Barrier Integrity" will aim at gaining understanding of the hydro-mechanical phenomena and processes associated with the gas-induced damage of clay barriers and the effectiveness of self-sealing processes along pathways opened by gas in the clay barriers of a geological repository. The task "Repository Performance Aspects" will focus on the effects of gas transport on the transfer of soluble and volatile radionuclides and on the consequences of gas-induced hydro-mechanical perturbations on barrier integrity and long term performance, from the end-users perspective.

This WP will build up heavily on the conclusions and return of experience from the previous national and international projects on gas transport issues. In particular, the experimental investigation of gas transport in FORGE EC project highlighted complex mechanisms such as

the development of discrete, unstable pathways controlled by the mechanical behaviour of the porous media. It was suggested that this complexity can be addressed as long as one can bound the effects of these mechanisms using simpler and robust descriptions for evaluation purposes. To support such approaches, this WP aims to increase the confidence in the overall understanding of gas behaviour in clay materials and to show how the scientific bases can be integrated in a traceable way throughout the system conceptualisation process. This will justify the use of robust evaluation approaches and confirm the expert judgement at the end of FORGE that gas is not a show stopper for geological disposal but a question of managing uncertainties.

EURAD ACED – ASSESSMENT OF CHEMICAL EVOLUTION OF ILW AND HLW DISPOSAL CELLS

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The chemical evolution of a disposal cell, i.e. waste packages and their immediate surroundings such as other waste packages or near field components, forms an important input for the evolution of a repository for nuclear waste and the assessment of safety- and performance-related aspects. Better conceptual and mathematical representations of this evolution improve the assessment and quantification of generic safety functions as isolation and containment of waste constituents. This better understanding contributes to a better substantiation of conservatism, reduction of uncertainty and the rationale for the definition of requirements on materials.

The main objective of the ACED work package in EURAD is to improve methodologies to obtain multi-scale quantitative models for the description of the chemical evolution at the disposal cell scale and to derive robust mathematical models including the most relevant processes. This 4-year work package starts in June 2019 including 25 partners from 11 countries with a budget of 5.1 M€.

Key points in the ACED approach are (i) process integration, i.e. integration of existing scientific knowledge and models into models at the relevant space and time scale, and abstraction, i.e. development of methodologies to reduce model complexity in a systematic way such that an acceptable description of the chemical evolution is preserved, (ii) definition of representative disposal cells for intermediate and high level waste (ILW and HLW) including the most relevant interfaces between materials as present in different national programs, (iii) combining existing or currently running experiment with a few targeted new experimental set-ups (focused on steel-cementitous and steel-clay interfaces)covering a range of spatial and temporal scales for evaluating the process integration methodology, and (iv) upscaling of process understanding, process integration and model abstraction in terms of conceptual, chemical and physical representation of the modelled system. The upscaling approach is defined in terms of information exchange from relatively small-scale processes (interface scale) to more complex systems at waste package scale and further to full disposal cell scale. The exchange information can take different forms such as identified critical processes, abstracted process representation, up-scaled parameter values, or simplified representation of features.

The (current) state-of-the-art of knowledge and integration approaches form the basis of ACED. Further work is centered on the three scales, each with specific objectives. The focus of the interface scale is on steel/material interfaces to provide geochemical and coupled reactive transport models to simulate corrosion processes under different environmental gradients. These models are supported by experimental studies and provide the basis for up-scaled representation of interfaces at the waste package scale. The waste package scale will identify critical processes and features driving and controlling the evolution at that scale and will also be partly supported by experimental evidence. The

disposal scale integrates the processes and up-scaled information into state-of-the-art conceptual, mathematical and numerical models. These models form benchmarks to evaluate different systematic model abstraction techniques for model features and processes. Finally, abstracted models will be applied in a wide range of conditions within a framework of sensitivity studies to further map critical parameters and processes to performance targets (e.g. pH evolution) and/or risks (e.g. loss of containment).

Predisposal and disposal technology developments

CRITICAL ASPECTS IN SUITABLE INDUSTRIAL-SCALE PROCESSES AND TECHNIQUES FOR MANAGEMENT OF NUCLEAR FUSION POWER ACTIVATED MATERIALS

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Recycling feasibility of activated materials (structural metals and breeder) generated by the operation of commercial nuclear fusion plants is one of the most debated issues concerning the demonstrability of the ecological management of fusion radioactive waste. In that respect, ENEA and RINA are engaged in a study about the possibility of applying melting techniques (consolidated in the steel-making industry) aimed at their recycling or, as an alternative, to disposal in shallow-land repositories for low-level radioactive waste (LLW).

The studies has dealt with the treatment of structural materials (AISI 316 and Eurofer steels) of fusion reactor dismantled components, to identify the appropriate conditions for removing noxious elements such as carbon, chromium, manganese, tungsten and also impurities (especially ^{94}Nb) that can preclude the possibility of their recycling or disposal in low-level waste repositories. Several options are under consideration to recover valuable elements (i.e. tritium), separate noxious radioactive elements (i.e. ^{14}C or ^{94}Nb) and recycle material of concern. Melting techniques are a promising choice.

The feasibility analysis for melting is promising, showing that is possible to define an optimum set of process conditions depending on the final destination of the material; anticipated re-use, long-term storage for recycling or disposal and that the characteristics of products and by-products can be precisely defined.

A COMPREHENSIVE APPROACH TO SAFETY ANALYSIS IN THE DUMPING OF LOW AND MEDIUM ACTIVE RADWASTE

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At present, active work on the decommissioning of the Chernobyl Nuclear Power Plant and the transformation of the "Shelter" into an environmentally safe system are being carried out in Ukraine. During the work, there is a large amount of radioactive waste that needs to be buried. The Radioactive Waste Disposal Facility "Buryakovka", which is located in the central part of the Chernobyl exclusion zone, is used to dispose of low and medium-active waste.

The object of this research is the process of burial of a batch of radioactive waste at the RWDF "Buryakovka", taking into account the existing technology. The RAW was constructed in 1986 for the disposal of low and intermediate level radioactive wastes. In total for more than 30 years at RWDF "Buryakovka" buried about 600 tons m3 of radwaste in trenches, the total activity of about 70 000 Ci. Currently, the RWDF "Buryakovka" was reconstructed and new trenches were designed, which allows to store 120 thousand m3 of radioactive waste. Waste is taken in the form of soil, wooden products, metal constructions, concrete and others. The RAW disposal procedure begins with an input automated control, which determines the weight of the waste, the dose rate, activity, and then, on the established route, is sent to the trench where the disposal takes place. The RAW bulldozer is placed and trampled in the trench, which results in exposure to personnel.

The purpose of this work is to analyze the doses of personnel on the work performed on the dumping of medium and low-level radwaste at the RWDF "Buryakovka". The baseline data for calculations was used by a security analysis report that was developed for the Buryakivka

RWDF project. Also, for the calculations used software - the development of graphical 3D model repository performed with the program 3DSMax Studio. After that the graphic model was integrated into the VRDose software package. The software complex allows to create a virtual model of the space RWDF "Buryakovka" and virtual phantom of a person, and to make real-time calculations according to the relevant scenarios of personnel behavior. Thus, the values of exposure doses of personnel under normal conditions of work performance and in the event of possible accidents were determined.

The data was verified using the Safran software package. The obtained results showed the comparability of the estimates obtained with the calculations in the VRDose and the developed safety analysis report for the dumping of radioactive waste at the RWDF "Buryakovka". For example, an accident scenario with a possible breakdown of a bulldozer during RW planning, simulated and calculated in VRDose and Safran, shows the similarity of the results of personnel doses and is 3.3 mSv. In this case, the most conservative conditions for this event were taken: the dose rate at the place of breakage of the bulldozer of 10 mSv/h and the time for evacuation of the bulldozer - 20 min.

Also, with the help of the received dose rate values for personnel, recommendations were made regarding the time of execution of work on radwaste discharges, in order not to exceed the allowable values of exposure to personnel. In addition, the developed approach allows the development of measures to minimize and optimize the scheme of work processes for radwaste dumping in the future.

PREDISPOSAL OF CANDU REFURBISHMENT WASTE

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Many CANDU reactors have been successfully refurbished until now in Canada, Korea and Argentina. In Romania, Unit 1 of Cernavoda NPP is approaching the moment of refurbishment and the owner has started preparations for this.

According to experience in the previous projects, the replacement of various components, defined as "retube" operation, is broken down into the five phases:

- Retube Support operations;
- Feeder Removal;
- Fuel Channel Removal;
- Fuel Channel Installation;
- Feeder Installation.

Retubing the reactor involves removing and replacing feeders, fuel channels and calandria tubes (CTs). A CANDU 6 reactor has 760 feeders, 380 fuel channels and 380 calandria tubes. Each calandria tube is approximately six meters long by 13 cm in diameter.

There are two sources of radioactive contamination relating to the wastes removed during the retubing process. The first source is the induced radioactivity in components due to the neutron activation processes. The second source is the deposited radioactivity from fission radionuclides, activated contaminants and uranium atoms circulating in the reactor coolant.

For the purposes of temporary storage, the radioactive solids waste generated during "retubing / refurbishment" of NPP are sorted in the following groups:

- Fuel channel components: Pressure tubes and calandria tubes, Calandria tubes inserts, End fittings and Shielding plugs, Spacer rings of fuel channels, HEPA filters used during the operation volume reduction;
- Solid wastes: Non-compactable (Feeder tubes, Hardware feeders, Plugs, Contaminated tools, Wood, Metal, Gas cylinders) and Compactable LLW-SL (paper, clothing, rags, glasses, Plastic)

The wastes containing the highest activities are pressure tubes, calandria tubes and inserts.

In the predisposal management of radioactive waste, decisions often must be made at a time when no disposal facility is available and the waste acceptance criteria for disposal are unknown. Consideration must be given to whether, for the purposes of safety, the radioactive waste will be stored in a raw, a treated or a conditioned form.

The existing predisposal facilities at Cernavoda are authorized and regulated by a license issued by CNCAN to store the low and medium level radioactive wastes arising from the operation of the plant and spent fuel dry storage in DICA. A new storage facility is needed to accommodate retubing waste.

In Romania there are no disposal facilities for radioactive waste arising from the operation and refurbishment of CANDU plants and no suitable acceptance criteria. Therefore, decisions on predisposal management of refurbishment waste will have to be based on the practice adopted in the countries that have implemented CANDU 6 refurbishment, as follows:

- All refurbishment waste is managed in rough state;
- High level waste, Medium level waste and Low-level waste are managed separately;
- Volume reduction is recommended to reduce storage facility size and cost;
- Appropriate shielding of packages to reduce the exposure rates and to permit handling and transportation;
- Transport to the storage site must be done without access to public roads;
- The new storage facility should be designed and constructed to permit the retrieval of all the wastes generated during the retubing work.

EXPERIMENTAL STUDIES ABOUT DISPOSAL OF RADIOACTIVE WASTES

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During the last decades various technical units at ENEA, Italy, addressed their activities to management, treatment and disposal of radioactive wastes. In such framework, matrices for conditioning low, medium and high level wastes have been evaluated and the final waste forms characterized according to an extensive characterization program. Furthermore, interactions between conditioned radwaste and surrounding environment have been taken into account.

So, on one hand, burial at shallow depth have been considered to host low- and medium- level wastes; on the other hand clays have been evaluated as possible candidates to host high level wastes in deep geological formations.

The present paper, far from being exhaustive, is a synthesis of such studies.

DEVELOPMENT OF RADIATION MONITORING SYSTEM IN CENTER FOR RADIOACTIVE WASTE TECHNOLOGY

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Center for Radioactive Waste Technology-National Nuclear Energy Agency (CRWT-BATAN) has nuclear installations such as Radioactive Waste Treatment Installation (RWTI), Transfer Channel-Interim Storage for Spent Fuel (TC-ISSF) and Interim Storage of Radioactive Waste for low, medium or high activity of various radioactive materials (IS1/IS2). CRWT-BATAN has responsibilities to process radioactive waste from over the Indonesian area including internal BATAN or from agencies outside BATAN. In addition, RWTC-BATAN also stores Spent Nuclear Fuel from research reactor operated by BATAN. In order to facilitate the task of radiation monitoring, it has been developed the radiation dose rate and air contamination monitoring at

the work area using a centralized computer-based radiation monitoring system. The radiation monitoring system is able to centralized monitor the dose rate of RWTI and TC-ISSF. In addition, the radiation monitoring system can be accessed online. Dose rate and air contamination monitoring measurement data of RWTI and TC-ISSF could be used as a source of information and early warning system for radiation workers. Monitoring of radiation dose rates and contamination air monitoring at the work area using a radiation monitoring system centralized computer-based. The radiation monitoring system is now able to centrally monitor the dose rate of RWTI and TC-ISSF. The radiation monitoring system was equipped with an alarm system, so it can serve as an early warning system. If there are more dose rate limit, an alarm will occur in programs with a sound alarm, indicator lamp will light and the indicator warning light will illuminate. RWTI dose rate measurement data and TC-ISSF information may be important earlier information to radiation workers.

CEA'S RESEARCH TOOLS FOR THE TREATMENT AND CONDITIONING OF RADIOACTIVE WASTE BY VITRIFICATION AND HIGH-TEMPERATURE PROCESSES – CONTRIBUTIONS TO THE THERAMIN H2020 PROJECT

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Since the 1960s, the French Alternative Energies and Atomic Energy Commission (CEA) has carried out R&D to develop vitrification and high-temperature processes for radioactive waste conditioning. In particular, the Vitrification and High Temperatures Processes Unit (SEVT) brings together all the skills necessary for the formulation, characterization, and production of conditioning matrices from laboratory scale to industrial scale. It also supports existing industrial facilities for the vitrification of high-level waste coming from spent fuel reprocessing.

SEVT's laboratories have the technical expertise and instruments to design and produce vitreous, ceramic, and vitroceramic matrices. They have recognized expertise in the development of vitrification and plasma technologies and processes: several prototypes at different scales and Technology Readiness Levels are operating and supported by models. The properties, chemical durability, long-term behavior under water and self-irradiation of the matrices produced by these processes are characterized. To achieve this goal, the SEVT has laboratories for the characterization of non-radioactive materials, two hot cells and two high-activity laboratories dedicated to the characterization of radioactive solids and the analysis of leaching solutions.

The SEVT puts its resources at the service of the H2020 THERAMIN project. The SHIVA incineration-vitrification process allowed the treatment of an absorbent media mixture consisting of zeolites, diatoms, and ion exchange resins. The In-Can Melter vitrification process made it possible to treat simulated technological waste incineration ash. The wasteglasses obtained were characterized by microscopy, X-ray diffraction, their compositions were analyzed and their chemical durability evaluated. The success of these trials, the achieved waste load rates and the good physicochemical properties of the wasteforms demonstrate the interest of the thermal treatments developed by the CEA for the conditioning of radioactive waste whose quantities in Europe are significant.

NEW COMPOSITE MATERIAL BASED ON HEAVY CONCRETE REINFORCED BY BASALT-BORON FIBER FOR RADIOACTIVE WASTE MANAGEMENT

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A new composite material for neutron radiation shielding properties is presented on the basis of heavy concrete with serpentinite aggregate and with basalt-boron fiber with different concentrations of fiber boron oxide, for using in biological shield in nuclear waste management applications. The protective properties of the new composite material were investigated with different neutron source, there are: 1) neutrons with 14 MeV energy; 2) fast fission neutrons for U-235; 3) fast fission neutrons for U-235 after passing a water layer. The simulation of the neutron radiation in presented composite material with adding crushed stone aggregate and serpentinite aggregate is performed with the help of the Monte Carlo Serpent code. It is shown that basalt-boron fibers in concrete are improves the protective properties of concrete from neutron irradiation for neutrons with different energies, but the most effective is the addition of a basalt-boron fiber in the case of thermal neutrons. Also, the basalt-boron fiber samples were produced at laboratory conditions. The several series of tests were carried out for prepared samples. The neutron experiment on radiation shielding properties of concrete reinforced by basalt-boron fiber was performed at Pu-Be neutron source.

Radioactive waste source term and science for disposal safety

PERFORMANCE OF COMPACTED MX-80 BENTONITE AND BENTONITE-SAND MIXTURE HYDRATED WITH BRINE

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The Canadian Nuclear Safety Commission (CNSC), Canada's nuclear regulator, conducts regulatory research in order to build independent knowledge on safety aspects related to the deep geological disposal of radioactive wastes. In addition to the geological barrier, a major safety component of the repository system consists of engineered buffer and seal materials such as MX-80 bentonite containing highly expansive clay minerals that will swell when they interact with pore water. Site characterization at a candidate site in sedimentary rock in Southern Ontario, Canada shows very high salinity (200–350 g/L) in pore water at about 400 m below the ground surface. Experimental evidence shows that salinity plays an important role on the performance of bentonite buffer and seals by reducing the swelling potential of the bentonite clay mineral, increasing the bentonite permeability, and changing the bentonite water retention characteristics. Therefore, the CNSC is conducting experimental and theoretical research in order to further understand how the concentrated brine influences the performance of bentonite-based seals as a barrier to radionuclide migration.

In this study, laboratory experiments were performed to investigate hydro-mechanical behaviour, including swell pressure, compressibility, water retention, and permeability of MX-80 bentonite and bentonite-sand (70-30) mixture using brine model water (MW) that mimics an in situ pore fluid geochemical condition, and deionized water (DI) as pore water. The experimental results show that the swell pressure of the MX-80 bentonite and the bentonite-sand mixture measured under constant volume and one-dimensional (bottom-up) hydration conditions is substantially decreased by high pore water salinity. MX-80 bentonite and the bentonite-sand mixture are less compressible when hydrated MW. The swelling index of the bentonite and the bentonite-sand mixture hydrated with the MW is much smaller than that of the same materials hydrated with the DI. The permeability of MX-80 bentonite and bentonite-sand mixture increased by two to three orders of magnitude when they are hydrated with MW. A model based on the dual porosity approach was developed and further calibrated with laboratory experimental results. The model considers porewater flow and solute transport in both the micropores and macropores, and exchange of water mass and solutes between the two pore types. The model can interpret the swelling behaviour of MX-80 when infiltrated with brine, and the dependence of hydraulic and mechanical properties of bentonite on such factors as porosity, salinity, and water content.

DETERMINISTIC AND PROBABILISTIC ANALYSIS SUPPORTING THE SAFETY CASE FOR DEEP GEOLOGICAL REPOSITORY

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The management of radioactive waste must implement measures that ensure the protection of human health and the environment in line with the principles and requirements for international radioactive waste management and radiation safety. Management should cover all phases of the repository that involve or may result in radiation exposure. At the post closure phase, radionuclides can be released from the repository to the biosphere for a long period of time. The release rate will depend on events and processes that have associated probabilities of occurrence. In order to evaluate the long-term safety of the deep geological repository for spent nuclear fuel, the primary model of the near field, geosphere and reference biosphere was developed, considering the scenario of the agricultural habitat (normal evolutionary scenario). This model includes various biosphere components and multiple exposure pathways. The model was created using the GoldSim simulation tool. Within consideration of uncertainties related to the selected scenario, probabilistic analysis was performed using the Monte Carlo method, which is directly implemented in the simulation tool GoldSim. The aim of the paper is to evaluate the impact of selected uncertainties on the long-term safety of the deep geological repository. The analysis was mainly focused on parameters that have a significant impact on the effective dose of an individual from a critical exposure group.

LONG-TERM PERFORMANCE OF VERTICAL SEALING SYSTEMS - IMPACT OF GAS MIGRATION

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Vertical sealing systems of a deep geological disposal are one of the key elements in the containment of this facility, since they constitute the main potential pathway between the nuclear wastes and biosphere. Understanding migration processes of gas produced by metallic corrosion, microbial degradation and radiolysis of water through these sealing systems is of great importance for performance assessment and long-term evolution of such facilities. If the gas production rate exceeds the dissolved gas diffusion rate in the pore water of the host rock and the engineered barriers, a gas phase will form and accumulate until the associated pressure buildup becomes sufficiently large to migrate through the surrounding material (host rock and/or engineered barrier systems). The transport of gases in clay-based sealing systems has been the subject of different international research programs during the last two decades (refer for instance to FP7 FORGE Project). Evidence from laboratory experiments suggests that transport in bentonite is controlled by the saturation history of the material, which strongly affects its microstructural features (particularly the pore size distribution and the connectivity of the pore space). These changes in the pore network play an important role on the two-phase flow properties and on the initiation of localized pathways during the gas phase invasion. Thus it is important to explore these gas migration properties under different saturation states that can be reached under varying water pressurisation rates. In this context, the Institute for Radiation protection and Nuclear Safety (IRSN) has launched VSEAL project to investigate the impact of gas migration on the long term performance of bentonite based vertical sealing systems, which play a major role. This project relies on two in-situ experiments that will be emplaced in IRSN´s Underground Research Laboratory (URL) in Tournemire (South France) and small-scale tests conducted in laboratory.

The generic layout of VSEAL in-situ experiments is based on a bentonite based swelling core confined between two lids. Clay core is composed of a mixture of MX 80 bentonite high density pellets and powder which are being evaluated as possible sealing materials in deep geological

repositories. All these elements will be inserted in a vertical large diameter borehole (1 m diameter, 10 m depth), excavated in Tournemire argillite. Water will be injected from the top surface through injection lines connected to the top lid which will slowly saturate the bentonite core. The upper face of the core will undergo a very rapid hydraulic loading while the lower part will remain strongly initially desaturated and will gradually saturate itself in a few years. Under these conditions (heterogeneous saturation field) gas will be injected from the bottom surface to observe the induced perturbations. Based on the design of the in-situ experiments, two types of laboratory tests are being performed: (i) mock-up tests (1/10 VSEAL in situ tests) focusing on the global behaviour of the bentonite core (fast hydration and gas migration) and (ii) interface tests focusing on the hydromechanical behaviour of the bentonite/argillite interface.

In this paper, a description of the design and installation of the first VSEAL in situ test will be presented together with the first results of the laboratory 1/10 mockup of VSEAL in situ tests.

MODEL FOR GRANITE FRACTURE LABORATORY TRACER TEST EVALUATION USING THE LASER SCAN DATA

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The general aim of the study is to understand the water flow and the solute transport in granite fractures, relevant for safety assessment of the deep geological repository in hard rock. The model is presented interpreting the laboratory experiment on the artificial fracture obtained by splitting a granite block. Experiments and measurements were carried out at ÚJV Řež and CV Řež and the authors of the submission process these data under the joint project of the Czech Technology Agency No. TH02030543. Experimental and modelling methods are developed to be later applied e.g. to the site-specific granite samples or in-situ tests, if requested by the DGR implementator for providing data for the safety assessment.

The studies in literature with flow and transport through a single fracture, with measured spatial-variable aperture, accept certain difference between the real (geometric) aperture the equivalent hydraulic aperture back-calculated from the flow rate. They sometimes mention a need to correct the mutual position of the blocks but without detailed quantitative evaluation.

The granite block with dimensions of 80 x 50 x 40 cm is divided by a horizontal fracture. The edge of the fracture is sealed except several inlet/outlet points. Hydraulic and tracer experiments were performed between them. Pressure was measured in 9 boreholes reaching the fracture level. The tracer concentration evolution at the inlet and outlet was monitored by the conductivity probe.

The fracture was represented by a planar 2D model with spatially variable physical parameters given by the aperture obtained as a distance between the two separately scanned surfaces. The point cloud with 0.1mm resolution was converted to a regular grid and then interpolated to the numerical discretisation mesh. The mesh was unstructured triangular with a 3mm or 1mm step. The surface overlaps were removed and the borehole space was corrected. Calculations were made using the Flow123d software, developed at authors' institute. Variants were developed for different spatial and time discretization, hydrodynamic dispersion, and alternative field openings, resulting from the uncertainty in the scanning coordinate system.

Primary data of the aperture lead to a significantly higher permeability in the model. Fictitious move of the surfaces in the tenths of millimetre order is able to coarsely calibrate the model to fit both the longitudinal pressure gradient and the tracer breakthrough time. This means that the model/experiment difference is controlled by the input measurement artefact, rather than some of the more complex physical effects studied in literature. The non-linearity of flow was excluded by comparison of different flow rate cases. The agreement between the hydraulic aperture and the transport aperture differs from some studies. Hydraulic and migration properties were influenced by the choice of discretization, so the 1 mm or better resolution is necessary. The hydrodynamic dispersion is partly resulting from the model inhomogeneity and only small amount added to the equation as smaller scale effects. Additional storage phenomena were necessary to add to fit the experimental breakthrough curve shape. The results did not show the channelling effect, observed in many cases of natural fractures.

THERMOCHIMIE – A THERMODYNAMIC DATABASE TO BE USED IN RADIOACTIVE WASTE MANAGEMENT

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ThermoChimie is a thermodynamic database initially created and developed by Andra (French National Radioactive Waste Management Agency), for more than twenty years (1995). In October 2014, Radioactive Waste Management Limited (NDA, UK) joined the project and the ThermoChimie consortium was formed. In March 2018, ONDRAF/NIRAS (Belgian Agency for Radioactive Waste Management) also joined the "ThermoChimie consortium" (TC-III).

In radioactive waste management, geochemical modelling is used in support of the assessment of radionuclide and non-radiological pollutant behaviour in a range of scenarios, such as within radioactive waste packages and disposal facilities, through the geosphere, and in legacy contaminated land. This can be in support of repository performance assessments, research activities (such as modelling experiments), or decisions about waste conditioning, reprocessing, and disposability. However, for these models to be meaningful and accurate, consistent, and complete thermodynamic data set is required. Although the NEA-TDB provides an excellent set of thermodynamic data, the strict process of data selection undertaken by the NEA-TDB teams may result in non-complete thermodynamic data sets. This lack of data leads to erroneous calculations, as several species needed to reproduce the chemical behavior of the systems of interest do not have sufficiently well determined thermodynamic properties as to be included in the NEA-TDB selections. One of the aims of Thermochimie is therefore to fill in the NEA-TDB data gaps, in a way that geochemical calculations in support of Performance Assessment can be done appropriately.

ThermoChimie has been initially designed to be applied over the 6 - 14 pH range at temperatures below 80°C and in systems with an Eh in the range -0.5V to +0.5V since these are the conditions generally expected to be representative of geochemical systems to be tackled in radioactive waste management. By extension, the database can be applied to other systems within the water stability domain. ThermoChimie provides robust thermodynamic data for a wide range of radionuclides and non-radiological pollutants, as well as major components expected within surface/geological disposal facilities and their environment. This encompasses all the mineral phases of the natural and engineered components (i.e., natural barriers, bentonites, cements) and their evolving secondary phases. These thermodynamic data are mainly derived from comprehensive, active literature studies and are supplemented by an experimental program when required.

The latest release of ThermoChimie (V10a) can be downloaded (older versions are also readily available) from the ThermoChimie website (https://www.thermochimie-tdb.com). ThermoChimie database is available in formats compatible with a variety of geochemical codes such as PhreeqC, Crunchflow, Toughreact, Chess, Spana and Geochemical Workbench (GWB).

ThermoChimie is under constant development to broaden the range of conditions to which it can be applied, and further refined for current applications. Phase III of the ThermoChimie project (TC-III), started in April 2018, aims to keep the database up to date with the thermochemical data from NEA TDB blue books and to further develop the ThermoChimie database and related tools. These further improvements include the effect of temperature up to 90°C, redox and kinetics, the incorporation of additional organic ligands, and soluble salts to allow the evaluation of specific near-field conditions through, at the same time, an experimental programme of data generation, literature surveys, and the development of predictive models. Finally, validation and benchmarking activities aimed at assessing the performance of ThermoChimie database with respect to experimental datasets and other high-quality databases will be performed.

DEVELOPMENT AND IMPROVEMENT OF THERMODYNAMIC UNDERSTANDING FOR THE NUCLEAR WASTE DISPOSAL SAFETY CASE

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Thermodynamic and geochemical model calculations are important tools used in the context of Safety Cases of repositories for nuclear waste disposal. Understanding and properly quantifying the thermodynamic driving forces controlling the mobilization and retention of radionuclides, as well as the degradation of waste matrices and technical barriers, underpins the long-term performance assessment of such disposal systems and increases its credibility. Thermodynamic approaches can sometimes add time-independent boundary conditions into long-term predictions. Further developing thermodynamic databases (TDBs) and underlying scientific understanding of key processes arises as a research need in the context of geological disposal of radioactive waste. In the framework of the JOPRAD Programme Document "The Scientific and Technical Basis of a Future Joint Programme on Radioactive Waste Management and Disposal", the sub-domain "Chemical Thermodynamics" was rated with the highest level of common interest within the category of "Radionuclide and Chemical Species Migration".

This contribution outlines the specific need for experimental and theoretical investigations providing information for the prediction of processes over long timescales based upon fundamental scientific constants, i.e. via chemical thermodynamics, in key fields for geological disposal of radioactive waste. As a starting point for further discussion, the following topics of interest have been outlined: (i) data gaps identified within the Thermochemical Database project of the Nuclear Energy Agency (NEA-TDB), as well as for other elements / systems of relevance for waste disposal and not covered by NEA-TDB; (ii) radionuclide-organics complexation, including cement additives (beyond CORI), degradation products and small organic ligands disposed of with the waste; (iii) TDB for elevated T conditions and the need of developing advanced methods for the estimation of thermodynamic properties; (iv) solid solutions including relevant end-members for waste disposal, e.g. clay or cement systems, alteration products of waste packages etc.; (v) the interplay of thermodynamic and kinetic effects, in particular with focus on ill-defined solid phases, Ostwald ripening and description of redox processes; and (vi) the link between local equilibrium at small scale or between few components and global disequilibrium. This contribution is intended to trigger the development of a working group on these topics, where of course the list of topics is susceptible to be modified or extended to better adjust to the needs of WMO, TSO, regulators and RE.

The review books within the NEA-TDB and its quality assurance procedures represent a key anchoring point, which provides the most comprehensive international effort for building up a high-quality TDB in the context of nuclear waste disposal, and it is at the core of most national and trans-national TDB initiatives in this field, e.g. ThermoChimie (France, UK, Belgium), THEREDA (Germany), JAEA-TDB (Japan), WIPP-TDB (US), among others. Beyond the need of maintaining the know-how in the area of thermodynamics, this initiative supports present and future capabilities to perform reliable use of thermodynamic concepts in predictions underpinning the performance of various disposal configurations and the Safety Case.

SURVIVAL OF INDIGENOUS MICROORGANISMS IN BENTONITE SUBJECTED TO GAMA RADIATION AND THE EFFECT OF ANAEROBIC CONDITIONS ON THE MICROBIAL ECOSYSTEM EVOLUTION IN BENTONITE

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Indigenous microorganisms in bentonite can negatively influence long term safety and performance of deep geological repositories. Our study aims to increase the knowledge about

the effect of Gama radiation on these microorganisms.

Microcosms consisting of BaM bentonite powder and deep underground water (3:10 w/w) were used for the experiments. In irradiation experiment was performed under aerobic conditions, the microcosms were irradiated at constant dose rate 13 Gy/h for up to 9 weeks reaching 19,656 Gy total absorbed dose. Both irradiated samples and non-irradiated controls were sampled regularly. Furthermore, we run series of anaerobic controls, where half of the control microcosms were enriched in nutrients to compare the evolution of similar microcosm in aerobic and anaerobic conditions and to see the effect of nutrient availability on microbial composition in the closed microcosms. We performed qPCR by various markers and NGS of 16S ribosomal RNA gene amplicons to detect the microbial abundance and diversity in all the samples. We used ion chromatography to detect nitrate, sulphate and acetate within anaerobic control samples.

The composition of microbial communities within the bentonite suspension samples was changing continuously during the experiments. Most indigenous microorganisms from underground water disappeared at the very beginning of experiment and both total biomass and species richness markedly decreased in bentonite suspension samples at this phase. Subsequently, gradual changes in microbial community composition were observed mirroring the prevailing conditions in the samples.

In the aerobic irradiated and control samples the community changes were based on the available electron donors evolving from chemorganotrophs to chemolitotrophs with the decrease of available organic material. Only microorganisms surviving initial bottleneck underwent a selection caused by the effect of Gama radiation. Application of 19,656 Gy absorbed dose of Gama radiation at the constant dose rate 13 Gy/h did not manage to completely eradicate present bacteria, but it caused slight changes in the microbial community structure. Decline in microbial abundance was observed in both irradiated and control samples at the end of experiment.

In anaerobic control microcosms limitation by both available electron acceptors and donors was detected. The anaerobic communities evolved from heterotrophic facultative anaerobic nitrate reducers to chemolitotrophic anaerobic iron or sulphur reducers and fermenting microorganisms. Community changes were not reflected in detected species richness, which remained rather constant after the initial bottleneck. These results showed the better suitability of anaerobic conditions for the indigenous microorganisms than aerobic conditions, the nutrient enriched samples showed the biggest microbial abundance. They also clearly demonstrate a key role of iron reduction in the microbial processes occurring in the bentonite under anaerobic conditions which might have implication for the repository safety. To better estimate the effect of irradiation on microbial community changes in bentonite under repository conditions, subsequent irradiation experiments performed under strictly anaerobic condition and exposed to higher total absorbed doses are needed.

AN ACTIVE MICROBIAL COMMUNITY IN BOOM CLAY PORE WATER COLLECTED FROM PIEZOMETERS IMPEDES VALIDATING PREDICTIVE MODELLING OF ONGOING GEOCHEMICAL PROCESSES

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Safe geological disposal of radioactive waste requires a detailed understanding of the geochemical conditions present in the host formation. Consequently, analysis of pore water is essential, as its composition determines among others, the speciation and solubility of radionuclides. In Belgium, Boom Clay is considered a potential host formation. Although the elemental composition of Boom Clay pore water is relatively well known, the real mechanisms controlling the pCO2 (g) and the pH, the two most important parameters, are not completely

understood. Currently, these parameters are under investigation based only on inorganic chemistry. Borehole waters of different Underground Research Facilities (URF) harbour an active microbial community; however, their possible impact on the geochemistry of Boom Clay pore water extracted from piezometers is not yet examined. The present study discusses the evolution of the geochemistry and the microbial community in the pore water from the piezometers around the PRACLAY gallery of the HADES URF during 7 years after installation of the piezometers. Overall, the elemental composition seemed to vary during the first 4 years, while afterwards it remained quite stable. However, the pCO2 values varied substantially over time, while the pCH4 increased in all filters. The presence of an active microbial community in the piezometers, could explain why experimental pCO2 – pH data do not correspond to the data obtained by predictive modelling, hampering validation of current predictive models of the ongoing geochemical processes. Moreover, the nature of the sampling equipment and the sampling procedure possibly stimulated the present microbial community, resulting in increased methane production rates. To improve predictive modelling, microbial processes are needed to be taken into account together with inorganic geochemistry considered at the current stage, which necessitates detailed microbial and geochemical monitoring in future studies.

CARBON RELEASE AND SPECIATION FROM JRQ CARBON STEEL AND ZIRCALOY-4 CORROSION IN HIGHLY ALKALINE SOLUTIONS

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The gas release and speciation of carbon species from irradiated and unirradiated Zircaloy-4 samples (representative for the fuel cladding as used in Belgian nuclear power plants) and JRQ carbon steel samples (representative of the reactor pressure vessel (RPV) in Belgian nuclear power plants), were studied in a saturated $Ca(OH)_2$ solution in anaerobic conditions. This environment is relevant for the Belgian Supercontainer design, as perceived for the geological disposal of high-level nuclear waste. To achieve this, we performed simple immersion corrosion tests. An estimation of the corrosion rate was also calculated using simple immersion and potentiostatic corrosion tests for Zircaloy-4 samples, or simple immersion and Co 60 release measurements for JRQ carbon steel samples.

The corrosion rate of the JRQ carbon steel samples was estimated by measuring the release of Co-60 because the measurement of the corrosion rate of carbon steel in a highly alkaline environment is a difficult task because of the extremely low values involved. A corrosion rate of 7 nm/yr were determined. This is a bit lower than the reference range of 10 – 100 nm/yr, but this may be explained by the observation of precipitation. In addition, it is not proven that the diffusion behavior of cobalt through the passive film is the same as that of iron.

Potentiostatic corrosion tests on unirradiated Zircaloy-4 provided a corrosion rate of ~54 nm/yr over a 7 day-experiment (if it is assumed that all the recorded current originates from the corrosion of the unirradiated Zircaloy 4) whilst a corrosion rate of only ~4 nm/yr was calculated for the irradiated samples, maybe due to the initial presence of a passive film on this sample. The calculation of ~54 nm/yr looks very high compared to the conservative corrosion rate of 20 nm/yr suggested by IAEA.

Gas chromatography revealed that during simple immersion tests, the carbonaceous species methane, carbon dioxide, ethene, and ethane were produced from the corrosion of the irradiated samples, with methane being the major compound. Assuming that all carbon released from the metal was transformed into gaseous compounds, this yields to a corrosion rate ranging from 57 to 84 nm/yr for the irradiated Zircaloy-4 sample (depending if the CO2 concentration was taken into account; the uncertainty on the CO2 concentration in the gas phase is high due to the injection method used) and approximately 100 nm/yr for the JRQ carbon steel samples. For the Zircaloy-4 samples, these values are in the same range as the corrosion rate calculated from the electrochemical measurement of the unirradiated sample, but they are significantly higher compared to the conservative corrosion rate of 20 nm/yr suggested by IAEA. For the carbon steel samples, the rate falls into the expected reported rates. However, caution has to be taken on these corrosion rate and more tests should be performed to confirm these results.

THE BENEFICIAL ROLE OF MICROBES IN NUCLEAR WASTE DISPOSAL

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Microorganisms are present wherever liquid water exists on this planet. Geological repositories are no exception and are expected to harbor some microbial activity at least in the short-term after closure. The potential role of microorganisms in the long-term is not well constrained and the design of repositories to date has relied on engineered barriers to minimize or entirely inhibit microbial activity. In intermediate and low-level waste repositories, such as the one planned in Switzerland, it is expected that large quantities of H_2 gas will be produced from the degradation of organic waste and the anoxic corrosion of steel and will be released through the engineered barrier. Here, we propose that microbial activity could be harnessed through the engineered system to mitigate that potential buildup of gases.

The MA-A experiment in the Mont Terri Underground Rock Laboratory was designed to investigate the consumption of H_2 gas by microorganisms, particularly sulphate-reducing bacteria. Previous work has shown that sulphate reduction to sulphide is stimulated by the addition of H_2 in Opalinus Clay borehole water. In the repository, the porewater of Opalinus Clay is expected to supply sulfate that can be reduced by these organisms with H_2 serving as the electron donor. In the present experiment, we investigate H_2-fuelled sulphate reduction in porous medium. The rationale for this choice is to represent conditions in the repository more closely by evaluating the potential for H_2 oxidation in backfill material. However, a likely limiting factor for this metabolism is space. Thus, by engineering backfill with sufficient pore space to allow microbial metabolism, this metabolism can proceed and we propose that the product, sulphide, would precipitate with iron. The modular design of the MA-A experiment allows running parallel reactors containing a sand/bentonite mixture to which porewater is directly supplied from the borehole and H_2 amended at a rate representative of that expected in the repository. By monitoring sulphate and considering the stoichiometry of H_2-dependent sulphate reduction, we can back-calculate a rate of H_2 consumption. Furthermore, H_2 can also fuel methanogenesis, through the transformation of H_2 and CO_2 into methane. Methanogenesis is only thermodynamically favourable in the presence of low sulphate concentrations. Organisms capable of this metabolism were identified in Opalinus Clay porewater but the metabolism itself was never described in situ. We explore the potential for sulphate diffusional limitations in the presence of H_2 leading to methanogenesis. Thus, this work explores a novel approach to tackling gas accumulation by engineering a system that features the role of microbes as a beneficial activity in a nuclear waste geological repository.

STUDY OF IMPACT OF THE RADIATION ON CONCRETE STRUCTURE BEHAVIOUR

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Concrete irradiation experiment is presented in the contribution. Nine concrete samples were tested non-destructively using ultrasonic and resonance methods, as well as destructively, using 3 point-bending and simple compression. Scanning electron microscopy (SEM) was applied in order to investigate the changes in the microstructure of concrete after 21 + 27 days of irradiation by the gamma flux 0.6, 1.6 and 2.6 kGy/hour, up to gamma doses of 1.0 to 2.0 MGy.

The role of Research Centre Rez Ltd. in EUropean joint research programme in the management and disposal of RADioactive waste (EURAD) is to provide the gamma irradiation facility and analyse the effect of gamma irradiation on organic compounds in concrete or cement pastes, monitoring and chemical analysis of the released gasses.

This topic will be solved within EURAD's work package CORI: Cement-Organic-Radionuclide Interactions, Task 2 and 3, studying the effect of plasticizers,

superplasticizers or other organic compounds contained in the concrete in nuclear waste repositories, on environment or the barrier system.Comparison of the concrete before and after irradiation is provided in the poster.

THE AGE DATING OF DEEP PALEOGROUNDWATER OF THE POTENTIAL SITE FOR HIGH-LEVEL RADIOACTIVE WASTE GEOLOGICAL DISPOSAL IN CHINA

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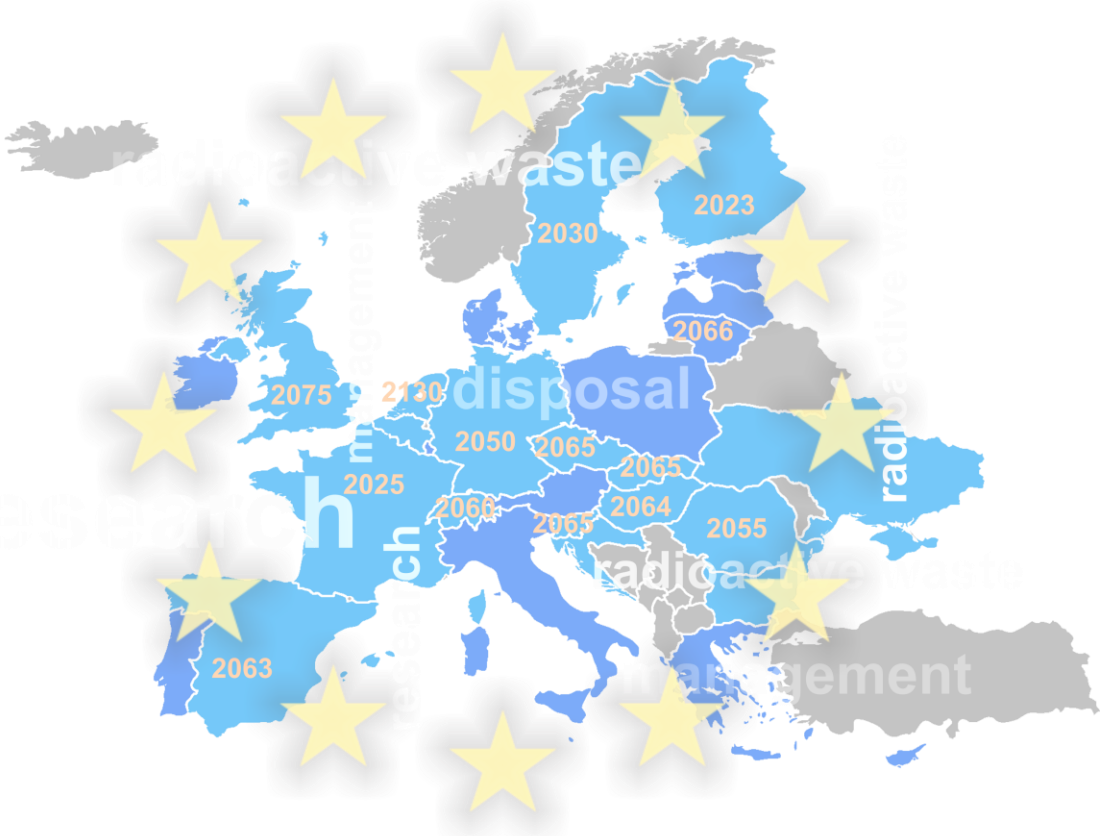
Beijing Research Institute of Uranium Geology, China

With rapid development of nuclear energy, the China attaches great importance to the safe disposal of radioactive waste. With the working efforts of more than 30 years, the Beishan area located in Gansu province has been identified as the preselected area for geological disposal of high-level radioactive waste in China. The main rock type in Beishan area is granite. According to national plan, the construction of an underground research laboratory (URL) will be started by the end of this year in Beishan. In the last decades, systematical studies of site characterization in Beishan area have been conducted, with the purpose to characterize the geological, hydrogeological, geo-mechanical and geochemical environments. The age dating of groundwater is one of main concerns in the study of the hydraulic environment.

^{81}Kr is mainly formed by the interaction between the stable isotopes of krypton elements in the upper atmosphere of the earth and cosmic rays. It can enter the lower atmosphere to participate in the circulation of air, and form a more uniform isotope distribution in the atmosphere. Because of its long half-life and single source, the cosmic ray's disturbance to its local concentration does not affect its overall abundance, and the ^{81}Kr produced by human nuclear activity is almost negligible. In addition, the chemical reaction of the inert gas itself is extremely slow and chemically stable. In this regard, the concentration of krypton isotope is very stable, and the ^{81}Kr dissolved in groundwater will simply decrease with time due to decay. Therefore, it is an accurate and reliable technology for measuring the age of groundwater or ice core for 20,000 to 1 million years.

By obtaining the deep groundwater samples from deep borehole with Double Packer Hydrogeological System, this study focused on the analysis of krypton isotope data, and the paleogroundwater dating results in Beishan area were systematically analyzed. It found that the age of deep groundwater in Jijicao preselected site in Beishan is within 25ka to 46ka, and the characteristics of slow groundwater circulation rate and long residence time are quite favorable to the safe disposal of high-level radioactive waste. Combined with the obtained data of in-situ hydraulic tests and numerical modeling result, the hydraulic environment in the Beishan area was finally discussed which is essential to the suitability evaluation of the site.

Day 4	Friday, 7 June
AM/PM	**TRIGA research reactor and Hot Cells facilities (at the Institute for Nuclear Research) and Nuclear Fuel Factory (in Pitesti-Mioveni)** Technical visits of the RATEN ICN experimental facilities (TRIGA research reactor HEU to LEU converted, Hot Cells, Material Testing Laboratories and Radioactive Waste Treatment Plant) will be organized. Pitesti Nuclear Fuel Plant, FCN Pitesti ensures the production of about 10.080 CANDU nuclear fuel bundles nuclear fuel annually for the operation of the two units at Cernavoda NPP. **Departure - 8:30; Return in Pitesti - 15:00** **From/To: Muntenia Place and Ramada Hotel** **ELI – Extreme Light Infrastructure (in Bucharest-Magurele)** Extreme Light Infrastructure (ELI) will be the only European and International Centre for high-level research on ultra-high intensity laser, laser-matter interaction and secondary sources with unparalleled possibilities. This infrastructure will create a new open access European laboratory with a broad range of science covering frontier fundamental physics, new nuclear physics and astrophysics as well as applications in nuclear materials, radioactive waste management, material science and life sciences. **Departure - 8:00 from Ramada Hotel** **Return: 13:00 Bucharest Center and 14:00 Bucharest Airport** **Cernavoda NPP and Waste management facilities (Cernavoda–Constanta)** Cernavoda Nuclear Power Plant ensures the safe operation of Units 1 and 2, each with an installed power of 700 MW. The two nuclear reactors from Cernavoda NPP ensures about 20% of Romania's energy demand. Cernavoda NPP uses Canadian CANDU 6 technology (Canadian Deuterium Uranium) with natural uranium as fuel and heavy water as moderator and cooling agent. Cernavoda NPP Unit 1 was commissioned on 2 December 1996 and Unit 2 on 28 September 2007. **Departure - 7:00 from Ramada Hotel** **Return: 18:00 Bucharest Center and 19:00 Bucharest Airport** **or 16:00 Constanta (for those planning the weekend in Romania, the Black Sea side could be a good choice!)**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List of Posters

EURADWASTE'19 - PhD Presentations - Student Competition

- Anaerobic microbially influenced corrosion of carbon steel in synthetic bentonite pore water inoculated by granite pore water: a 26-month study
- Studies of radium and strontium uptake on cementitious materials within CEBAMA project
- Laboratory investigation of water retention properties and microstructure of compacted bentonite used for high level nuclear waste disposal in the Czech Republic
- Laboratory and numerical analysis for the simulation of THM-coupled processes during the stress dependent metamorphosis of crushed salt in rock salt
- How 'dry' is dry spent nuclear fuel and what are its consequences?
- Effect of concrete on microbial community under repository relevant conditions
- Effects of the initial granular structure of clay sealing materials on their swelling properties: experiments and DEM simulations
- Radionuclide migration in low-Ph cement / clay interfaces: derivation of reactive transport parameters within the cebama project
- Direct method for determination of ^{14}C massic activity in irradiated graphite
- A numerical approach for the hydro-mechanical behaviour of bentonite seals in the context underground radioactive waste disposals

EURADWASTE'19 - Predisposal and disposal technology developments: EURATOM project posters

- The MODERN2020 in situ tests implemented at the Tournemire URL– testing and improving new monitoring sensors and technologies

EURADWASTE'19 - Radioactive waste source term and science for disposal safety: EURATOM project

- Spent fuel alteration model integrating processes of different time-scales
- Chemistry of beryllium in cementitious systems studied within CEBAMA: solubility, hydrolysis, carbonate complexation and sorption
- Benchmark of reactive transport models within CEBAMA: application to a concrete / clay interface
- Microbial degradation of nitrate leaching from thermally aged inactive bituminised radioactive waste at high pH
- Estimation of 14C release and migration from RBMK-1500 reactor graphite disposed of in a potential geological repository in crystalline rocks in Lithuania
- Preliminary inventory of C-14 in irradiated graphite of IGNALINA NPP UNIT 1 RBMK-1500 reactor
- Chromium doped UO2-based Model Systems: the Model Materials for the Study of the Matrix Corrosion of Modern Spent Nuclear Fuels
- EURAD ACED – Assessment of Chemical Evolution of ILW and HLW Disposal Cells
- Integration of CAST results to safety assessment - probabilistic uncertainty/sensitivity analysis of C-14 release and transport
- Carbon-14 release from irradiated stainless steel

EURADWASTE'19 - Networking, Joint Programming and Integration: EURATOM project posters

- Development and improvement of numerical methods and tools for modelling coupled processes: a R&D initiative within EURAD
- Spent fuel characterization and evolution until disposal
- EURAD HITEC: influence of temperature on the behaviour of clay-based material
- Uncertainty Management multi-Actor Network (UMAN)
- CORI – Collaborative research on cement-organics-radionuclides-interactions in EURAD
- European Joint Programme on Radioactive Waste Management
- THE EURAD EU Project: Workpackage FUTURE
- EURAD1 RD&D WP GAS - Mechanistic understanding of gas transport in clay materials

EURADWASTE'19 - Predisposal and disposal technology developments: open call poster presentations

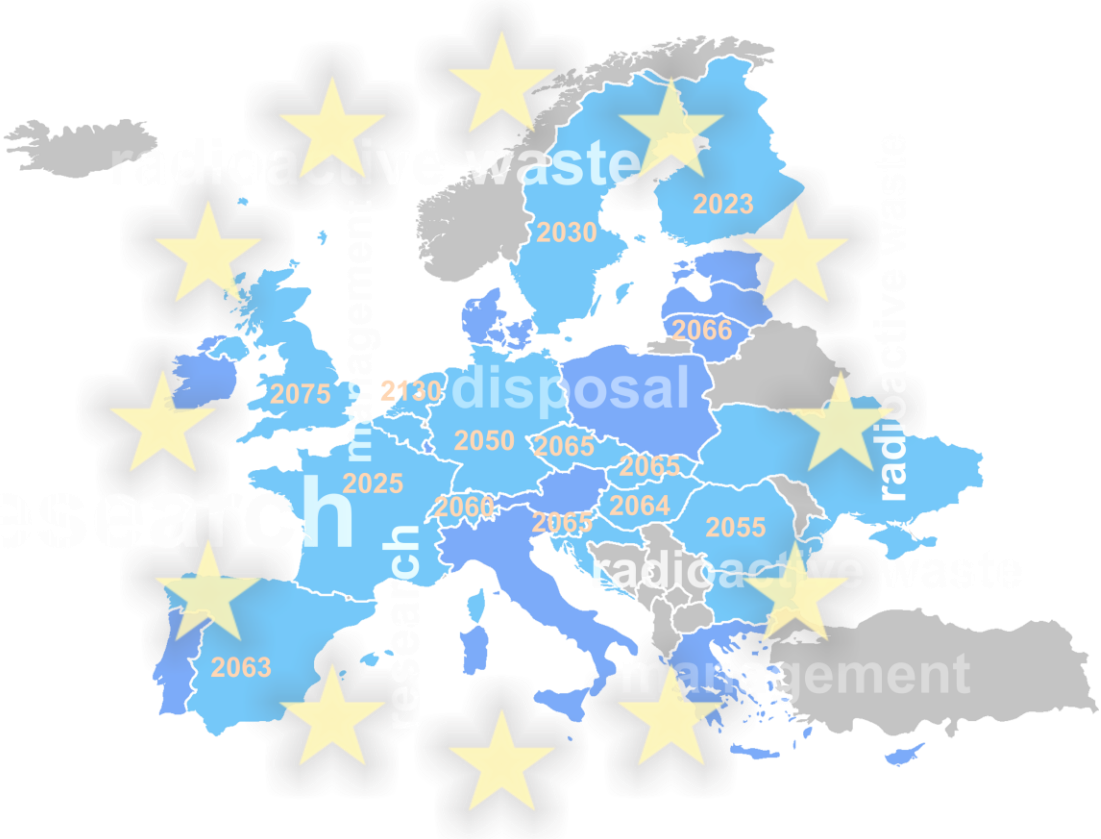
- Critical aspects in suitable industrial-scale processes and techniques for management of nuclear fusion power activated materials
- Predisposal of CANDU refurbishment waste
- Development of Radiation Monitoring System in Center for Radioactive Waste Technology
- Direct Method for Determination of 14C Massic Activity in Irradiated Graphite
- CEA's research tools for the treatment and conditioning of radioactive waste by vitrification and high-temperature processes – Contributions to the THERAMIN H2020 project
- New composite material based on heavy concrete reinforced by basalt-boron fiber for radioactive waste management
- Experimental studies about disposal of radioactive wastes

EURADWASTE'19 - Radioactive waste source term and science for disposal safety: open call poster presentations

- Performance of compacted MX-80 bentonite and bentonite-sand mixture hydrated with brine
- Deterministic and probabilistic analysis supporting the safety case for deep geological repository
- Long-term performance of vertical sealing systems - impact of gas migration
- Model for granite fracture laboratory tracer test evaluation using the laser scan data
- THERMOCHIMIE – a thermodynamic database to be used in radioactive waste management
- Development and improvement of thermodynamic understanding for the nuclear waste disposal Safety Case

List of Posters

- Survival of indigenous microorganisms in bentonite subjected to Gama radiation and the effect of anaerobic conditions on the microbial ecosystem evolution in bentonite
- An active microbial community in Boom Clay pore water collected from piezometers impedes validating predictive modelling of ongoing geochemical processes
- Carbon release and speciation from JRQ carbon steel and Zircaloy-4 corrosion in highly alkaline solutions
- The beneficial role of microbes in nuclear waste disposal
- Study of impact of the radiation on concrete structure behaviour
- The Age Dating of Deep Paleogroundwater of the potential site for High-level Radioactive Waste Geological Disposal in China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EURADWASTE ’19, the 9th European Commission (EC) conference on the management of radioactive waste and geological disposal in Europe will be held under the auspices of the Romanian Presidency 2019 of the European Union (EU) in Pitesti, on 4-7 June 2019. It will be organised concurrently with the 9th FISA 2019 conference on Euratom Research and Training in Safety of Reactor Systems.

FISA 2019 and EURADWASTE '19 conferences objectives are:

- to present progress and key achievements of some 90 projects carried out, since the previous conference edition in 2013, as part of the 7th and Horizon 2020 Euratom Research and Training Framework Programmes (FP)
- to stimulate discussions on the state of play of R&D, key challenges addressed at national, European and international levels on Research and Innovation policies, synergies and partnerships benefitting research and innovation programmes, and future perspectives.

FISA 2019 and EURADWASTE ’19 conferences will address and engage with all relevant stakeholders involved: research and training organisations, academia, industry, technology platforms, European fora and European civil society, and International Organisations.

There will be many opportunities for interaction within dedicated parallel & poster sessions, and thematic workshops. The latest EC proposal for a new Framework Programme for Research and Innovation for the period 2021-27, 'Horizon Europe’ and ‘Euratom Research and Training’ programme will also be addressed.

Studies and reports

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