The Role of Optimisation in Radioactive Waste Geological Disposal Programmes

Programme and Abstracts

igd·tp

Symposium
20-22 September
2022

Zurich,
Switzerland

Webinar
29 September
2022

Hosted by nagra.

www.igdtp.eu

Content

Welcome

From the incoming IGD-TP Chair
Tiina Jalonen, Posiva

From the outgoing IGD-TP Chair
Irina Gaus, Nagra

Following our last, highly successful, event in Berlin in 2018, we are delighted to hold the IGD-TP symposium on the role of optimisation in radioactive waste geological disposal programmes. This event will be a great opportunity for researchers, experts and practitioners worldwide to share their current work and concerns and also to reflect together about future challenges.

Due to the Covid-19 pandemic this event was delayed and thus became a joint initiative between the incoming and outgoing IGD-TP Chairs. We express our sincere thanks to Nagra, the Swiss radioactive waste management organisation, for organising this event and to our waste management colleagues who have dedicated time and effort in helping to organise it. Our thanks also go to all supporting organisations and participants worldwide for making it possible.

The IGD-TP

The Implementing Geological Disposal of radioactive waste Technology Platform (IGD-TP) is dedicated to initiating and carrying out European strategic initiatives to facilitate the stepwise implementation of safe, deep geological disposal of spent fuel, high-level waste and other long-lived radioactive waste. It aims to address the remaining scientific, technological and social challenges, and support European waste management programmes.

The IGD-TP was launched on 12 November 2009, initiated by the European Commission and waste management organisations. Now solely funded by the waste management organisations, the group welcomes all interested parties (industry, research and academia, research centres, technical safety organisations, non-governmental organisations, associations, SMEs, …) endorsing the IGD-TP Vision and willing to contribute positively and constructively to the group's goals, such as establishing and implementing the Strategic Research Agenda and participating in information exchange and knowledge transfer.

Our Vision is for industrialisation of radioactive waste disposal in Europe by 2040, via three pillars: (1) safe operation of the first geological disposal facilities in Europe; (2) optimisation and industrialisation of the planning, construction and disposal operations; and (3) development of tailored solutions for disposal of the diverse waste inventories in Europe.

ANDRA French national radioactive waste management agency
BGE BUNDESGESELLSCHAFT FÜR ENDLAGERUNG
COVRA NV
enresa
nagra.
Nuclear Waste Services
ONDRAF/NIRAS
POSIVA
PURAM PUBLIC LIMITED COMPANY FOR RADIOACTIVE WASTE MANAGEMENT
SKB Svensk Kärnbränslehantering AB
SÚRAO

The Role of Optimisation in Radioactive Waste Geological Disposal Programmes

We are delighted to hold the IGD-TP's international symposium on the role of optimisation in geological disposal programmes for radioactive waste. Hosted by Nagra, the event is open to anyone interested in geological disposal of radioactive waste.

Geological disposal projects are first of a kind projects, span several decades, and are multi-billion endeavours. In order to build and operate repositories safely, to make consistent progress, and to ensure efficiency, optimisation of all aspects plays a critical role and is a continuous activity throughout its implementation. While safety optimisation is well established, also through international guidelines, optimisation of the implementation of geological disposal has gained increased attention. This symposium and webinar aim to summarise the status of the main aspects of repository optimisation from a technical-scientific viewpoint and to discuss future directions.

To enable access and involvement of all interested parties, the event will be held in two parts. The first, physical event, will consist of a two-day symposium in Zurich on 20-22 September 2022 with sessions on:

- the role of optimisation in selected national geological disposal programmes
- technology and material optimisation
- lessons learned from optimisation in large infrastructure projects
- integrating optimisation for safety
- global optimisation approaches – concepts and numerical applications

The third day will provide an opportunity for attendees to tour the Mont Terri or Grimsel underground research laboratories, or the ZWILAG interim storage facility. Tour numbers are limited.

Talks and posters presented at the symposium will be recorded and made available online.

The second part of the event will consist of a live webinar on 29 September 2022 that will include a panel discussion and question and answer session. Questions can be submitted in advance via the IGD-TP website and during the webinar.

Interested parties can attend the symposium, the webinar, or both events.

Organisation

LOCAL ORGANISING COMMITTEE

Irina Gaus, *Nagra (Chair of the Organising Committee)*
Ingo Blechschmidt, *Nagra*
Annika Breu, *Nagra*
Tamara Baldwin, *GSL*

SCIENTIFIC COMMITTEE

Irina Gaus, *Nagra*
Tamara Baldwin, *GSL*
Ingo Blechschmidt, *Nagra*
Johanna Hansen, *Posiva*
Tiina Jalonen, *Posiva*
Alex Liebscher, *BGE*
Jon Martin, *NWS*
Maarten Van Geet, *ONDRAF/NIRAS*

SYMPOSIUM SESSION CHAIRS

Session 1: The role of optimisation in selected national geological disposal programmes

Axel Liebscher, *BGE*

Session 2: Lessons learned from optimisation in large infrastructure projects

Jon Martin, *NWS*

Session 3: Technology and material optimisation

Joaquín Farias Seifert, *ENRESA*

Session 4: Integrating optimisation for safety

Péter Ormai, *PURAM*

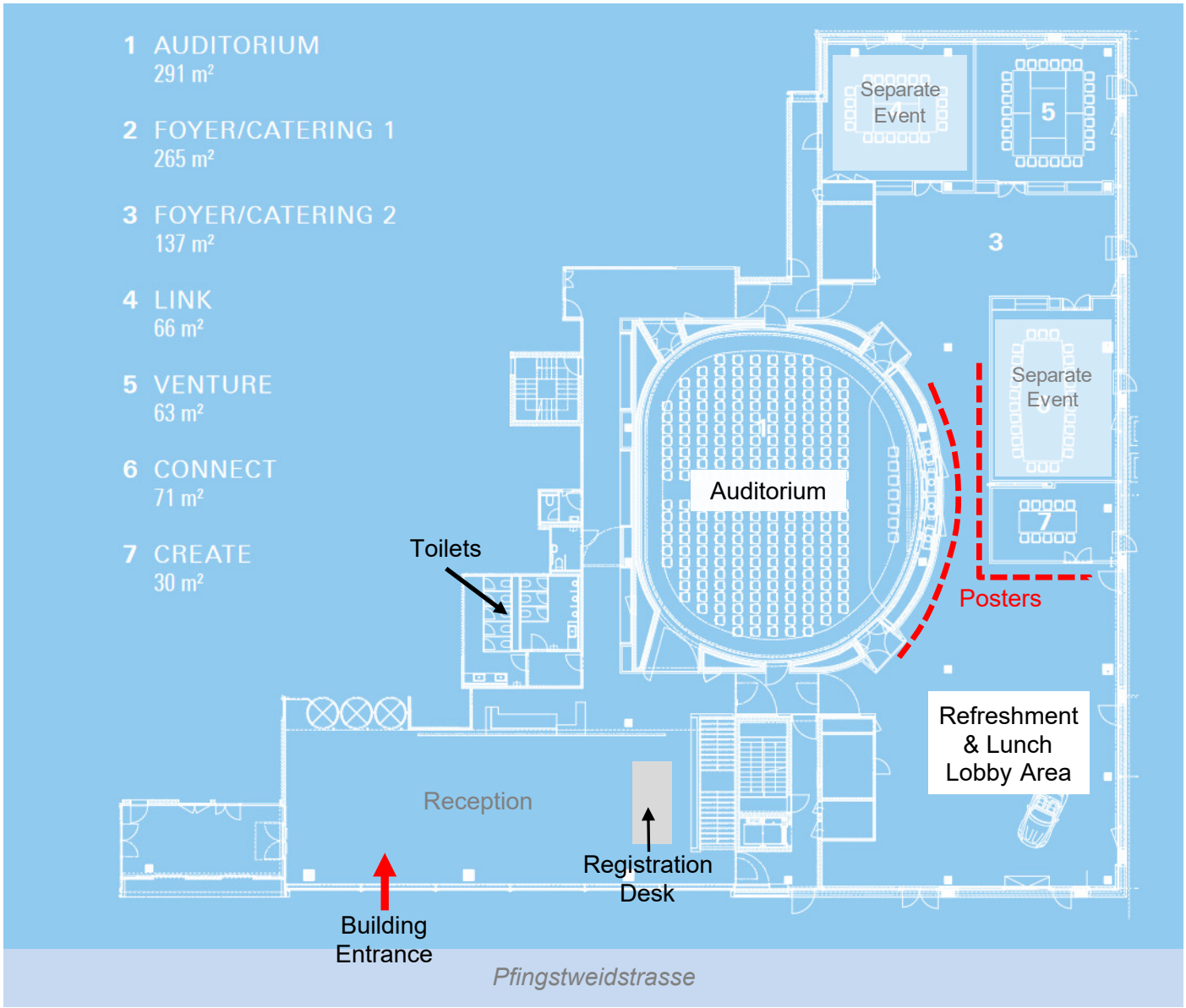
Session 5: Global optimisation approaches – concepts and numerical applications

Ingo Blechschmidt, *Nagra*

Meeting Spaces

The meeting spaces arranged for the symposium are on a single level, with all talks to be presented in the Auditorium. Lunch and refreshments will be provided in the lobby space outside the Auditorium, with the posters displayed in the same area.

The SIX ConventionPoint building hosts the principal Swiss stock exchange. The Swiss Finance Museum, which opened in 2017 and features the world's most important collection of historical securities, is also situated at the SIX ConventionPoint and free admission to the museum is available to meeting attendees.



Programme

Symposium: 20-22 September 2022, Zurich, Switzerland

	Time (CET)	Item	Chair / Speaker
	Day 1 – Tuesday 20 September 2022		
	10:30-11:30	Individual arrival and registration	
	11:30-13:00	Lunch (finger food) and poster session	
	13:00-13:15	**Welcome**	Matthias Braun (CEO Nagra, Switzerland)
	13:15-13:30	**The IGD-TP vision and the strategic research agenda; why this is the right time for this symposium**	Irina Gaus (Nagra, Switzerland)
	13:20-14:30	**Session 1: The role of optimisation in selected national geological disposal programmes**	*Chair:* Axel Liebscher (BGE, Germany)
		Optimisation process of deep geological disposal (Cigéo project) in the French context: from feasibility principle to licensing application then progressive development of operation	Pascal Claude Leverd (ANDRA, France)
		The role of optimisation in Posiva's programme	Tiina Jalonen (Posiva; Finland)
		COVRA - Optimisation through international initiatives	Marja Vuorio (COVRA, ERDO; the Netherlands)
	14:30-15:00	Refreshment break and poster session	
	15:00-16:25	**Session 2: Lessons learned from optimisation in large infrastructure projects**	*Chair:* Jon Martin (NWS, UK)
		Prague City Ring Road – transport engineering construction for the metropolis of the 21st century	Alexandr Butovič (CTU, Czech Republic)
		Application of optimisation to decommissioning at the UK Trawsfynydd nuclear power station - delivery of an optimised site end state	Dan Galson (GSL, UK)
		Success criteria and success factors for the optimal planning, construction and operation of large infrastructure systems	Heinz Ehrbar (Heinz Ehrbar Partners llc, Switzerland)
	16:25-16:40	Refreshment break	
	16:40-18:00	**Session 3: Technology and material optimisation *(part 1)***	*Chair:* Joaquín Farias Seifert (ENRESA, Spain)
		Optimisation of canister design and its lifetime assessment: state of the art and plans within the EURAD CONCORD work package	Nikitas Diomidis (Nagra, Switzerland)
		Container Requirements for High-level Radioactive Waste Disposal in Rock Salt, Claystone, and Crystalline Rock – Outcomes of the Research Project KoBrA	Holger Völzke (BAM, Germany)
		Optimisation in Posiva EBS clay component design – segmented buffer, granular backfill, mixture of crushed rock and bentonite in central tunnels	Johanna Hansen (Posiva, Finland)
	18:30 start	Symposium Dinner – meet at the Sheraton Zurich at 18:30 for a welcome drink, with dinner served at 19:00	
	Day 2 - Wednesday 21 September 2022		
	08:00-08:30	Arrival and refreshments	
	08:30-10:00	**Session 3: Technology and material optimisation *(part 2)***	*Chair:* Joaquín Farias Seifert (ENRESA, Spain)
		Value Engineering – How to reinvent yourself	Johan Hedlund (SKB, Sweden)

	Time (CET)	Item	Chair / Speaker
		Technical enhancement of wasteforms and their behaviour with the PREDIS project on predisposal waste management	Erika Holt (VTT, Finland)
		Optimization enabled digital twinning of radioactive waste repositories	Henning Wessels (TUB, Germany)
	10:00-10:30	Refreshment break and poster session	
	10:30-12:00	**Session 4: Integrating optimisation for safety**	*Chair:* Péter Ormai (PURAM)
		Optimisation and the safety case: what have we learnt in the Integration Group for the Safety Case Context	Lucy Bailey (NWS, UK)
		The hybrid and complex nature of the optimization principle: from radiological protection to safety, from ALARA to SAHARA	Christophe Depaus (ONDRAF/NIRAS, Belgium)
		Graded development of geological disposal towards optimised solution	Anne Kontula (TVO, Finland)
	12:00-13:20	Lunch (finger food) and poster session	
	13:20-13:30	**Group photo**	
	13:30-15:00	**Session 5: Global optimisation approaches – concepts and numerical applications**	*Chair:* Ingo Blechschmidt (Nagra, Switzerland)
		Optimisation of the thermal aspects of a generic high-level waste repository through Pareto front analysis	Andreas Poller (CSD Engineers, Switzerland)
		ONDRAF/NIRAS geological disposal facility layout update: an optimisation-based approach for the conceptual design	Didier Léonard (ONDRAF/NIRAS, Belgium)
		Optimisation of thermal dimensioning of the Cigéo project: operational goal and scientific key issues	Jean-Michel Bosgiraud (ANDRA, France)
	15:00-15:30	**Summary, award of best poster and close**	Tiina Jalonen (Posiva, Finland & IGD-TP Chair)
	15:30-16:00	Refreshment break	
	Day 3 - Thursday 22 September 2022		
	07:45 start	An optional visit to the ZWILAG interim storage facility, or the Grimsel or Mont Terri underground research laboratories (URLs). Meet at 07:45 at Zurich Bus Station.	

Webinar: Thursday 29 September 2022, Online

Time (CET)	Item
13:30-16:00	**The role of optimisation in disposal programmes** **Webinar chairs** The outgoing and incoming IGD-TP Chairs, Irina Gaus (Nagra) and Tiina Jalonen (Posiva) **Panellists from the following organisations are confirmed:** • Stefan Mayer (IAEA) • Chris Boyle (NWMO, Canada) • Jaakko Leino (STUK, Finland) • Reinhard Knerr (WIPP, USA) • Piet Zuidema (EURAD) Each panellist will give a 5 minute presentation on their view of optimisation followed by panel discussion of audience questions. Questions can be submitted in advance and by the audience during the webinar.

Symposium Speakers and Abstracts

Matthias Braun, Chief Executive Officer, Nagra, Switzerland

After obtaining a doctorate degree in Earth Sciences in Basel, Matthias Braun worked in an international environment for 25 years, where he was involved in exploration and production projects in several countries – on both a technical-scientific level and as a manager. From 2009 to 2020, he worked for Shell International, where he most recently held the position of "General Manager Specialist Geoscience & Global Discipline Head Specialist Geoscience". In this function, he led and coordinated highly qualified expert groups with geoscientific backgrounds and managed large globally integrated teams and projects. As a member of the Research Decision Review Board, he was responsible for overseeing all research topics related to geosciences.

In spring 2021, he assumed the position of CEO for Nagra, taking on the project of radioactive waste disposal in Switzerland. This important project presents great technological, political and societal challenges, but also promises to solve an issue that would otherwise pursue Switzerland's society for generations to come.

Welcome Message

Irina Gaus, Head of Research and Development, Nagra, Switzerland

Irina Gaus is Head of Research and Development at Nagra, the Swiss implementer for the disposal of radioactive waste since 2016. She joined Nagra at the Department of International Services and Projects in 2007 where she was leading large-scale experiments and many consultancy projects in Europe and overseas. Before that she has held positions at the French Geological Survey (BRGM) focusing on carbon storage and aquifer storage and at the British Geological Survey as hydrogeologist. She obtained her PhD in geology from the University of Ghent (Belgium).

Her technical expertise covers environmental applications of the shallow and deep subsurface such as radioactive waste disposal, thermo-hydro-mechanical-chemical impacts, carbon storage, groundwater management, safety case development, RD&D programme management.

Between 2019-2021 she chaired the Implementing Geological Disposal of radioactive waste Technology Platform (https://igdtp.eu/).

The IGD-TP vision and the strategic research agenda; why this is the right time for this symposium

Session 1: The role of optimisation in selected national geological disposal programmes

Pascal Claude Leverd, Deputy Director of the Cigéo Project, ANDRA, France

Pascal Claude graduated from Heriot-Watt University in Edinburgh with an MPhil in chemistry and from the University of Paris with a PhD in nuclear chemistry in 1994.

After a post-doctoral contract for the “Technische Universität Berlin”, he joined the Atomic Energy Commission (CEA) in Saclay for research on actinide chemistry in 1995.

In 2000, he moved to the “Institut de radioprotection et de sûreté nucléaire” (IRSN), where he headed the unit in charge of the safety assessment of waste packages and waste disposals until 2006. He then responsibility of the unit in charge of the safety assessment of fuel treatment operations (La Hague plants).

Since 2011, he has worked for Andra, specifically on the Cigéo Project, first as the project manager for the production of the authorisation files and, since 2018, as the deputy to the director. His main fields of interests in the project are the strategic issues of the project deployment plan, reversibility, security, public consultations and interfaces with society.

Optimisation Process of Cigéo

The 1991 law organised the research for the long-term management of high-level waste (HLW) and Intermediate-level long-lived waste (IL-LL-W). In 2000, Andra created the underground research laboratory in Bure. The Authorities assessed the feasibility of the deep geological disposal in 2005. After a public debate, the law of 2006 fixed the regulatory process for the creation of an underground disposal facility.

After public consultations, Andra proposed a zone for the detailed characterisation of the site in view of the implantation of a disposal facility. After assessment by authorities, the government validated the proposal in 2010.

The industrial design studies were launched in 2011. Based on the sketch design, a public debate took place in 2013. Following this debate, the law of 2016 clarified the definition of reversibility and introduced an industrial pilot phase at the beginning of the project.

Andra produced the safety options of Cigéo in 2016. The safety authority produced its advice on the design of Cigéo in 2018.

Andra submitted in 2020 the public utility declaration file, including the first global environmental impact studies of the project. The environmental authority (Eq) and the technical services of the State assessed the file and the public enquiry occurred in autumn 2021. Andra expects the ministerial decree in the first months of 2022.

Andra programs to submit the construction licence application in 2022. Andra will introduce the conclusions of its current public consultations on the industrial pilot phase and on the governance of the project into the file. The authorization process included assessment by authorities, consultations of local communities, advice from the national evaluation commission and a public enquiry.

Provided the government grants the authorization of the construction (2025-2027), the industrial pilot phase will comprise a first inactive period including initial construction and tests. It will continue with a second active period of active test and disposal operations. Andra will produce a report to present the results of the industrial pilot phase to the Parliament. It will support a law on the conditions of pursuit of the project (2040-2050).

In the future, Andra has identified other governance and decision steps for the progressive extension of the underground facility, the acceptance of new types of waste, the closure...

Governance reviews will continue to punctuate the complete lifetime of Cigéo offering progressive choices to the successive generations and to introduce potential technical modifications to the project. Periodical technical assessments, exchanges with the society and political decision will continue to mark the development of the deep geological repository project.

Tiina Jalonen, Senior Vice President of Development, Posiva, Finland

Senior Vice President of Development, Ms Tiina Jalonen, has been widely engaged in Posiva's final disposal programme for over two decades. She is a Master of Science in Process Engineering and a member of Posiva's Steering Group. Today her responsibilities include development and licensing of the disposal concept including the natural barrier and the engineered barrier system, site confirmation studies, long-term safety of the final disposal, the safety case, rock characterization for design and construction of the final disposal facility and Olkiluoto site monitoring. She is actively working in international networks of final disposal, and acts now as the Chair of the IGD-TP Executive Group, a coordination group for European Nuclear Waste Management Organizations.

The role of optimisation in Posiva's programme

Optimization, widely spoken, has been done at least for two decades in Posiva's programme but today it plays an important role in implementing final disposal of spent fuel. Economical aspects are and have been the driver for many optimization tasks but there are many examples of other drivers such as safety, practicality, supply, schedule or timing and resource management, as well.

Already in the site selection phase, in the end 90's, optimization had a role in the selection between the suitable candidate sites, since the site with existing infrastructure and less need for spent fuel transportation, Olkiluoto, was selected. The design and construction of the URL ONKALO® as a part of the geological disposal facility (GDF) has been an optimal solution in several respects, such as the possibility to perform site confirmation studies during the construction of ONKALO, and time and money needed to reach the disposal depth, just to mention a few.

Optimization that has originally been motivated on economical aspects, but that has been done on technical and scientific basis, has had an impact on the design of the GDF and other facilities, on the machinery designed and manufactured for disposal operations in the GDF, on the disposal processes and solutions on the engineered barrier system. Optimization of requirements on the final disposal system and its components has been made when knowledge has increased. There will be two other presentations during this symposium that will focus on some of these aspects.

Development of new processes, solutions and requirements will be continued during the whole disposal programme to manage the costs and the operations and to ensure the supply of EBS and other components needed for the GDF.

Marja Vuorio, Researcher, COVRA, The Netherlands

Marja Vuorio obtained her D.Sc. in Chemical Engineering, Physical Chemistry at the Aalto University, Finland (then Helsinki University of Technology). She has more than 17 years of experience in projects on long-term safety issues related to geological disposal, performance assessment and safety case work. She came to COVRA in 2019 and works mainly in international collaboration topics, such as the ERDO Association.

COVRA - Optimisation through international initiatives

All EU member states have the duty to regulate and monitor the nuclear sector within their country, including radioactive waste management and geological disposal. For this purpose in 2016 a national policy programme on radioactive waste (NPRA) was set. COVRA's long-term research programme on geological disposal is carried out within the framework of this national programme on radioactive waste. In the Netherlands radioactive waste is produced by power generation, industry, hospitals and research organisations. Radioactive waste should be isolated from the environment until the radiation level has sufficiently decayed to a level it is no longer dangerous for environment. To that end, all Dutch radioactive waste is isolated, processed, safely stored and controlled at COVRA in Zeeland. According to Dutch policy, the definitive decision on the disposal method will be taken around 2100 and start of disposal is expected around 2130.

This storage period provides time to learn from experiences in other countries, to carry out research and to accumulate the knowledge to make well-founded decisions. The Netherlands considers both a

national as well as a shared repository option (dual track). COVRA participates on an European and a global level in international collaboration groups (e.g. OECD NEA, IAEA, ERDO and EURAD). The long-term research programme has to integrate the knowledge that has been/will be developed beyond national borders to contribute to the construction of geological disposal facility.

Session 2: Lessons learned from optimisation in large infrastructure projects

Alexandr Butovič, Production Director, SATRA, spol. s r.o., Hungary

Dr Butovic completed postgraduate studies at the Czech Technical University in Prague with a focus on underground construction in 2007. Since 2009 he has been working as production director at SATRA Company, which deals with design, engineering and operation of transport structures. He is also a licensed engineer in the field of Geotechnics and a forensic expert in underground construction. He has participated in the design and implementation of the largest tunnel structures in the Czech Republic (Mrázovka Tunnel, Blanka Tunnel Complex, Ejpovice Tunnel). Consecutively, he has been working as a teacher at CTU in Prague, where he teaches Soil Mechanics, Rock Mechanics, Foundation of Buildings and Underground Structures.

Prague City Ring Road – transport engineering construction for the metropolis of the 21st century; optimisation of the technical design with regard to innovative technologies, societally-acceptable urban design, minimisation of environmental impacts and the assessment of experience from already-operating sections.

The capital city of Prague, as other European capitals, is struggling with increasing car traffic. In parallel with the development of public transport (of which Prague has one of the best systems in the world) and the 'greening' of transport, a network of superior roads is also gradually being completed. This consists of an outer ring road and an inner city ring road, which connect a total of 7 radials. The project documentation for the zoning decision of the remaining approximately 16 km long part of the city ring road was completed in 2022. During its processing, the technical and transport solution was modified, which significantly increased the scope of tunnel structures in order to minimize the impact of traffic on both the terrain surface and people's lives. This modification made it possible to deal with the newly created space in the given sections in a completely new urbanistic way and to revitalise substantial areas. Many years of experience of experts from SATRA Company with the operation of the Blanka Tunnel Complex have been applied in the design of the technical solution.

Daniel Galson, Managing Director, Galson Sciences Ltd, UK

Daniel Galson is Managing Director of Galson Sciences Limited, the consultancy he founded nearly 30 years ago, and recently merged with the Egis Group. He worked previously for the OECD Nuclear Energy Agency, the US Nuclear Regulatory Commission and the Swiss Federal Institute of Technology. He has earth science degrees from MIT and the University of Cambridge.

Galson Sciences collaborates closely with Magnox Limited (the co-author of this study), UK waste management organisations, and overseas organisations in a wide range of areas relating to radioactive waste management, decommissioning and disposal - including options assessment, safety, licensing, design, and stakeholder and regulatory dialogue.

Application of optimisation to define the decommissioning end state for a UK nuclear power station site

New regulatory guidance in the UK on release of nuclear sites from regulatory control has led Magnox Ltd to conclude that if large volumes of low-activity radioactive structures and/or contaminated ground are present on a site, then the optimised end state of decommissioning may include some radioactivity remaining on-site unless there are overriding considerations requiring a ‘clean’ end state.

A ‘Starting Case’ End State (SCES) can be used as a basis for comparison with delivering a ‘clean’ end state and/or as a starting point for optimisation if the envisaged end state is to include some radioactivity remaining on site. The use of a SCES helps to make the process of optimisation systematic, transparent, comprehensive and no more complex than necessary, which are all characteristics that are important in gaining approval from regulators and other stakeholders, as well as being characteristics of a good method. A two-stage approach to optimisation is applied, consistent with regulatory guidance:

- In the first stage, the question is asked as to whether it is preferable to leave any radioactivity on-site at the final end state in the form of large volume, low-activity materials. It should be noted that, even if this is assessed as radiologically acceptable, there may be overriding concerns not to do so.
- However, if the answer is yes, then the second stage is to consider the optimal approach for leaving some radioactivity on-site. It is for this second stage that a SCES is most useful, although the first stage can also be usefully informed by comparison of a SCES with a ‘clean’ end state.

Magnox Ltd’s Trawsfynydd nuclear power plant site in North Wales has been used as an example site to illustrate the approach taken to address the new regulatory requirements.

Heinz Ehrbar, Heinz Ehrbar Partners Llc, Switzerland

Heinz Erhbar obtained his MSc in Civil Engineering from ETH Zurich in 1980. From 1981 to 1996, he was the Project Manager for various hydropower projects in Switzerland and abroad for Electrowatt Engineering, Zurich. Between 1997 and 2000 he was the Head of AlpTransit Department and Project Manager for the design lot Sedrun (squeezing rock zone). In 2001 he joined AlpTransit Gotthard Ltd as Deputy Chief Construction Officer until 2005, and then as the Chief Construction Officer Gotthard Base Tunnel and Member of the Management until 2012.

He founded Heinz Ehrbar Partners Llc in 2012. Between 2013 and 2017, Heinz was Head of the Department “Management of Major Projects” for DB Netz Ltd, and then Head of the Competence Center Major Projects 4.0 at DB Ltd until 2020.

From 2017 to 2022, Heinz was Executive in Residence at ETH Zurich for Construction Management of Underground constructions and Management of Major Infrastructure Projects.

Since April 2020 he continues with Heinz Ehrbar Partners Llc.

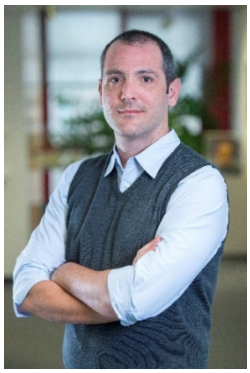
Success criteria and success factors for the optimal planning, construction and operation of major infrastructure projects

Major infrastructure projects are a big challenge for all partners involved in such a project. Which are the reasons for this challenges?

How do we assess the success of a major project and what factors lead to success? The presentation intends to give an answer, how we can monitor the success of a project in a systematic way by using standardised key success criteria in order to create comparable information for each individual project within a project portfolio. 45 Swiss underground projects have been analysed with this method.

The key success factors are derived from this project portfolio, and especially from the experience of the design and construction of the Gotthard Base Tunnel, actually the longest tunnel in the world. Some basic recommendations for clients organisations, how to deal with the key success criteria and factors are given.

Session 3: Technology and material optimisation



Nikitas Diomidis, Section Head Materials Performance, Nagra, Switzerland

Nikitas Diomidis is Nagra's materials specialist and Head of the Materials Performance Section. This RD&D-focused group works on the development of the engineered barriers and the performance assessment of the repository. He is responsible for all aspects of the development and manufacturing of long-lived canisters for the disposal of spent fuel and high-level waste. This covers evaluation of materials, conceptual and detailed design, sealing and inspection operations, as well as corrosion and long-term performance assessment. He is currently leading the EURAD workpackage ConCorD which deals with the corrosion of containers under geological disposal conditions and the feasibility assessment of novel canister materials.

Optimisation of canister design and its lifetime assessment: state of the art and plans within the EURAD ConCorD workpackage

Even though the feasibility and safety of established SF/HLW disposal container solutions has been demonstrated, recent progress in materials and processes has shown that optimisation of container manufacturing and performance is possible. Widespread interest exists in container optimisation related to increasing container lifetimes, increasing heat and irradiation tolerance to allow for optimised loading, optimising container wall thickness, or introducing new container materials and corrosion resistant coatings. In parallel, developments in materials characterisation techniques and advanced modelling allow to probe remaining uncertainties from a fresh perspective and to study more complex coupled phenomena accurately. The EURAD WP ConCorD combines the systematic exploration of novel materials with the investigation of existing solutions from an innovation perspective and aims to provide a robust state-of-the-art for the pursuit of container optimisation according to available geology, disposal concept and regulatory requirements. Focus is given to material degradation processes being coupled in their influence toward container performance and evolving with time. The final objective is the understanding of long-term behaviour of container materials, both established and novel, to such an extent as to be able to ensure confidence in the safe performance of the engineered barrier system.

Holger Völzke, Head of Division, Bundesanstalt für Materialforschung und -prüfung (BAM), Germany

Holger Völzke obtained his PhD in 1991 on Lightweight fibre-reinforced-metal hybrid pressure vessels at the Technical University of Berlin.

Since 1991, he has been with the Bundesanstalt für Materialforschung und -prüfung (BAM) in Division 3 Containment Systems for Dangerous Goods.

Since 2007 ha has been the Head of Division 3.4 Safety of Storage Containers (for radioactive materials), with responsibility for:

- design-testing and safety evaluation of interim storage and final disposal containers for low, intermediate and high-level radioactive waste within official licensing procedures;
- evaluation of quality assurance measures for container manufacturing and operation;
- evaluation of thermal and mechanical safety assessments and ageing phenomena;
- R&D on stress analyses, failure mechanisms and ageing phenomena of container systems and components; and
- International collaboration.

Container Requirements for High-level Radioactive Waste Disposal in Rock Salt, Claystone, and Crystalline Rock – Outcomes of the Research Project KoBrA

The site-selection process for a high-level radioactive waste (HLW) repository in Germany requires by law the consideration of all three potential host rocks rock salt, claystone, and crystalline rock. The selection of a specific repository site is closely related to the repository systems that appear suitable for the respective host rock including the disposal containers as an essential component. Their design and

layout significantly define the boundary conditions for the waste packaging, transport and storage technology and have a decisive influence on the evidence of operational and long-term safety. To develop suitable containers the knowledge of all relevant requirements including the related container safety and operational functions is a basic pre-condition.
Within the research project KoBrA BAM and BGE Technology GmbH started with an extensive research on existing international container concepts and requirements. In the second work package previous container-relevant boundary conditions and load parameters for disposal containers were analysed and evaluated using Germany as an example. Core of the project was the systematic derivation and compilation of the requirements for HLW disposal containers under consideration of all three potential host rocks. For this purpose, a top-down approach was developed, which includes a step-by-step procedure for deriving generic container concepts, considering the potential impacts and requirements, through specific considerations for specific host rocks to the derivation of the location-specific, concrete container design, considering quantified requirements and impacts of the finally selected site. In the final work package considerations were made as to which container concepts appear possible and suitable and to what extent national and international container concepts that have already been developed, are possibly suitable to meet the requirements derived or respectively, which difficulties and challenges are recognizable. This includes the German POLLUX® container concept and the existing transport and interim storage containers.

Johanna Hansen, R&D Coordinator, Posiva Oy, Finland
Johanna has 25 years' experience in spent nuclear fuel disposal activities. She coordinated the FP7 Project DOPAS during 2012-2016 and has been involved in several Horizon 2020 and Horizon Europe projects. She works currently for Posiva's Development of Engineered Barriers as R&D coordinator and manages or coordinates several projects related to the engineered barrier behaviour and monitoring in disposal facility, closure of the disposal facility and designing the plugs. She is currently the Secretary General for IGD-TP (2022-2023).

Optimisation in Posiva EBS clay component design – segmented buffer, granular backfill, mixture of crushed rock and bentonite in central tunnels

The disposal concept for a spent nuclear fuel repository in ONKALO is based on the KBS-3V type of concept. The development of engineered barriers has been done is stages where the plans are tested and demonstrated, and the performance of the concept is assessed in the safety case. The early-stage designs have been conservative and not optimised for conditions related to the environmental, efficiency and implementation aspects.
The optimisation of requirements and design is a delicate process where several boundaries between engineered barriers, disposal facility construction and manufacturing and installation needs to be taken care of. The work towards the industrial implementation of clay based engineered barriers progressed together with testing and demonstrating activities since submitting the construction licence application 2012. Part of the work was done together with SKB and part in international co-operation. As an outcome the buffer, backfill, plugs and closure designs were revised for the operating licence application, submitted at the end of 2021. The final designs will be demonstrated in the trial run of final disposal starting in 2023. The disposal operations take place for one century and therefore continuous optimisation of the concept is needed.

Johan Hedlund, Head of Projects, SKB, Sweden

With an MSc in Engineering Physics, Johan Hedlund has worked with projects for 20 years towards heavy industry (pulp & paper, steel, and electricity producers such as thermal power and nuclear).

Value Engineering – How to reinvent yourself

When driving development work your final result needs to meet all requirements. Sometimes you end up in a dead end where you cannot tick all boxes. So what do you do? SKB ended up with a technical solution but the cost requirements were not met. We needed to reinvent our solutions and form a way forward to implement a technical solution with stepwise releases of cost optimized versions. Inspiration is taken from the manufacturing industry.

Erika Holt, Customer Account Lead, VTT Technical Research Centre of Finland, Finland

Dr Holt has 25 years of experience at VTT Technical Research Centre of Finland, earlier as a researcher, then team leader and now as a customer manager and senior project manager. She has worked in waste management and repository issues since 2004, focused on initial state materials' performance, demonstrations, monitoring and requirements. She has participated in over 10 EU projects, and is currently is the co-coordinator of the EU-PREDIS project on predisposal issues, and represents VTT in the EURAD General Assembly. She has been on the Finnish national committee for nuclear energy strategy, and is a member of IGD-TP. She is the deputy chairperson of SNETP Technical Area 5 addressing decommissioning and waste management issues.

Technical enhancement of wasteforms and their behaviour with the PREDIS project on predisposal waste management

The Euratom 4-year project **"***PREDIS: Pre-Disposal Management of Radioactive Waste"* addresses innovation and break-through technologies for better handling of low-level and intermediate level radioactive wastes, with a focus on treatment of metallic materials, liquid organic waste and solid organic waste which can result from nuclear power plant operation, decommissioning and other industrial processes. The project also addresses digitalization solutions for improved safety and efficiency in handling and assessing cemented-waste packages in extended interim surface storage. Through all of these pre-disposal treatment activities, waste acceptance criteria are a critical parameter for optimizing the safe and efficient handling and minimisation of wastes over the whole life cycle, from cradle to grave. The PREDIS will produce tools guiding decision-making on the added-value of the developed technologies and their impact on the design, safety, environmental impact and economics of pre-disposal waste management and future disposal. This presentation will highlight the achievements of the first 18 months, including the detailed gap analysis, baseline strategic research agenda and State-of-Knowledge activities. The overviews about technical innovation activities from each waste stream will be presented, along with information on cooperation with EURAD and the wider stakeholder community. Advances in waste form characterization, treatment/processing and performance assessment prior to geological disposal will be highlighted. The PREDIS project includes 47 consortium partners representing 17 Member States, in addition to 25 industrial partners engaged via the end user group to steer the project direction to focus on their most pressing needs and challenges. Details of the project can be followed at https://predis-h2020.eu/.

Henning Wessels, Assistant professor, TU Braunschweig, Institute for Computational Modeling in Civil Engineering, Germany

Following a Research Associate position at the Institute for Continuum Mechanics at Leibniz Universität Hannover (IKM), Henning joined the Technical University of Braunschweig in May 2021 as a junior professor for "Data-driven modeling and simulation of mechanical systems".

Optimization enabled digital twinning of radioactive waste repositories

The conception of a radioactive waste repository is informed by engineering models whose validity must be permanently verified. This can be achieved by measuring changes in state during the excavation of the underground cavities, the emplacement operation and the closure phase. As a result of monitoring during the individual project phases, the level of knowledge and the data basis about the deep geological repository system are constantly increasing. The obtained data offer the possibility of recognizing undesirable developments and assessing need for action.

However, not all data are equally accessible for monitoring systems. While for example displacement can be measured using direct image correlation (DIC), stress is rather inaccessible and thus referred to as a hidden quantity. Unfortunately, mostly the hidden quantities are the relevant quantity of interest (QoI) to inform decision making. When physical systems are considered, the link between data and hidden QoI is often given by means of partial differential equations, i.e. by numerical models. In this context, data plays a crucial role for automated model calibration, which is a key concern of this talk. A calibrated numerical model can be regarded as a digital twin of a repository. It may be used to iteratively optimize its design parameters. We aim to demonstrate the potential of automated calibration and optimization by means of a thermo-hydraulic-mechanical model of a storage drift with backfill and sealing plug.

Session 4: Integrating optimisation for safety

Lucy Bailey, Head of Research Support Office, NWS, UK

Lucy Bailey is a Fellow of the Institute of Physics in the UK and the Head of the Research Support Office at NWS, responsible for working with universities to develop and deliver a needs-driven academic research programme to underpin the UK's geological disposal facility (GDF).

Lucy's background is in the safety case for geological disposal. She has 30 years' experience in the safety assessment of radioactive wastes, particularly specialising in the development of sound safety case approaches that aid communication. As well as delivering the UK's generic Disposal System Safety Case, Lucy has been an independent expert peer reviewer of the Swedish safety case, facilitated safety case discussions with stakeholders in the Swiss radwaste disposal programme and participated in IAEA expert missions for the Ukraine and China. She has a long-standing involvement with the OECD/Nuclear Energy Agency (NEA) and was the Chair of the NEA's Integration Group for the Safety Case (IGSC) between 2015 and 2022.

Optimisation and the Safety Case: What have we learnt in the Integration Group for the Safety Case Context

The OECD-NEA Integration Group for the Safety Case (IGSC) held a topical session on optimisation in 2010 that recognised the diversity of optimisation goals that may be pursued in the framework of a geological disposal programme. While optimisation of protection, as defined by ICRP, is regarded as a process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable with economic and social factors being taken into account, optimisation can also be seen as a way of increasing the technical quality and robustness of

the whole waste management process. An optimal solution means addressing safety requirements whilst balancing other factors such as the need to use resources efficiently, political and acceptance issues and any other boundary conditions imposed by society.

Recognising that optimisation variables can be quite specific to national programmes, the IGSC nevertheless agreed the following points:

- Optimisation is a process that can be checked and reviewed and needs to be transparent. Optimisation is therefore a learning process, and as such can contribute to building confidence in the safety case by the demonstration of ongoing learning across the organisation.
- Optimisation occurs at each stage of the disposal facility development programme, and is therefore forward looking rather than focussed on re-examining past decisions. Optimisation should be about the right way forward at each stage, making the best decisions to move forward from the present situation based on current knowledge and understanding.
- Regulators need to be clear about their requirements and these requirements become constraints on the optimisation process, together with any societal constraints that may be applied in certain programmes. Optimisation therefore requires a permanent dialogue between regulator and implementer.
- Once the safety objectives (dose/risk targets and other constraints) have been met, further optimisation should be aimed at moving the project forward as efficiently as possible, and this could largely be reflected as cost optimisation.

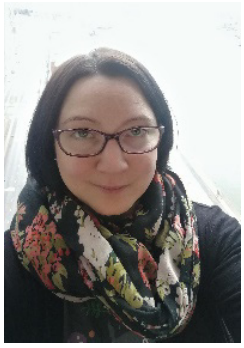
This presentation will explore how these principles have been applied to enable programmes to progress in the implementation of geological disposal.

Christophe Depaus, Safety Strategy Senior Expert, ONDRAF-NIRAS, Belgium

Christophe is a mining engineer awarded by the Faculty of Polytechnics of the University of Brussels (ULB), holds a Master in Advanced Studies in Philosophy of Sciences (DEA) awarded by the Catholic University of Louvain (UCL) and an Academic degree in International Nuclear Law awarded by the University of Montpellier(UM1). Since 2009, he works for safety strategy of the long-term management of high-level waste and spent fuel and is responsible of the interactions with the Belgian regulatory body for the geological disposal. As such, he tries actively to integrate the scientific, technical, societal and legal aspects in the geological disposal project. He also participates in many international projects such as IAEA GEOSAF for which he leads the working group on operational safety or European projects like MoDeRn2020 and UMAN. He is also an expert and a team leader for the IAEA ARTEMIS platform.

The hybrid and complex nature of the optimization principle: from radiological protection to safety, from ALARA to SAHARA

From its inception in the 50' up to the well-known formalisation as ALARA; from ICRP- 26 up to ICRP-122, the optimisation principle has continuously evolved and, in the past 15 years, there has been a trend towards a broader view of optimisation, far beyond its original instrumental meaning. Expanding from the radiological domain to the overall safety of the radioactive waste disposal including operational safety, the optimisation becomes a way to increase the robustness of, and the confidence in, the whole waste management process. To support this evolution and consequently, promoting its implementation, the optimisation principle can rely on other principles coming originally from other fields of expertise such as the BAT(NEEC) principle. Whereas re-discovering the roots of optimisation, we also pointed out its pioneering nature regarding another principle, formalised in the environmental law: the precautionary principle. The ubiquity of the optimisation is thus undeniable. Even its semantics is inspiring: who could deny the lineage between ALARA and SAHARA? Facing such a broadening, we should take some time for reflection: do we still control the proper use of such a principle?



Anne Kontula, Head of Research and Development, Teollisuuden Voima Oyj (TVO), Finland

Anne is a seasoned researcher and Safety Case Programme leader with a demonstrated capacity for developing, compiling, and managing detailed site description and suitability case developments to ensure optimal operational alignment with critical safety and regulatory standards.

Graded development of geological disposal towards optimized solution

Posiva is finalizing the safety case for the application of the operating licence for the first geological disposal facility for high-level nuclear waste in the world. The application, based on the KBS-3 concept, is planned to be submitted at the end of 2021. The application gathers the work that has been carried out since the early 1980s when the Finnish Government defined the guidelines, overall plan and target schedules for nuclear waste management. The KBS-3 concept was originally presented in Sweden in the early 1980s, but has later been developed in cooperation between the Swedish nuclear waste management organization SKB and Posiva. After almost 40 years of work on site investigations, technology development and safety assessment, Posiva is currently engaged in construction of a geological repository the design of which is based on similar main components as the original KBS-3. The goal is to have the facility in operation in the mid-2020s.

Session 5: Global optimisation approaches – concepts and numerical applications

Andreas Poller, Senior Project Manager Radioactive Waste Disposal and Safety Assessment, CSD Engineers AG, Switzerland

Andreas Poller graduated in environmental sciences from University of Bayreuth in 2002. In the course of his career he attended professional educations in risk and safety of technical systems at ETH Zürich, systems engineering and architecture at MIT and project management at Delft University. After graduation in 2002 he joined AF-Consult AG, where he was mainly involved in modelling of density-driven flow and transport, as well as in modelling of non-isothermal two-phase flow and transport. From 2009 to 2018, he worked at Nagra as project manager for post-closure safety assessment and on the development of requirements and configuration management. Since 2018, he has been working at CSD Engineers AG as senior project manager and expert for radioactive waste disposal and safety assessment.

Optimisation of the Thermal Aspects of a Generic High-Level Waste Repository Through Pareto Front Analysis

Thermal aspects are key to developing a safe disposal system for high-level radioactive waste (HLW) at reasonable cost. In order to obtain a sufficiently optimised solution, the consideration of the entire nuclear backend is required, which we refer to as global optimisation. In this talk we present a global optimisation workflow that combines key requirements, key constraints and key choices with respect to thermal aspects into a set of proxy models for HLW packaging, HLW transport, HLW emplacement, for the thermal evolution of the HLW repository post closure and for associated costs. The use of proxy models allows the automated generation of a large number of stylised configurations of the entire nuclear backend that are then analysed in terms of performance indicators for a generic HLW repository and associated cost through Pareto Analysis. Those configurations that mark the Pareto frontier and thus represent an optimum trade-off between repository performance indicators and cost feed into the conception of a few realistic configurations that are eventually analysed by means of existing detailed models in order to confirm the global optimisation potential identified with the proxy models.

Didier Leonard, RD&D Collaborator, ONDRAF/NIRAS, Belgium

Didier Leonard is a civil engineer. His background is construction and nuclear engineering. Didier has worked for more than 18 years in the nuclear industry, first for Tractebel (Engie group) for the operation support of the Belgian nuclear power plants and now as senior project manager at the Belgian agency for radioactive waste and enriched fissile materials (ONDRAF/NIRAS) in the R&D Department. He is mainly involved in the geological disposal facility design (GDF) and in cost assessment. These last years, he has developed and applied a methodology for the optimisation of the GDF design based on a multi-criteria analysis (i.e. optioneering). This optioneering approach enabled to further optimise the Belgian GDF concept. He also developed a new probabilistic costing methodology based on the AACE recommended practices, which was applied in 2020 for the GDF cost update. Finally, he is developing an new methodology for the GDF operational safety analysis.
Didier is also member of the OECD EGOS working group.

ONDRAF/NIRAS GDF layout update: an optimisation-based approach for the conceptual design

For more than 30 years, ONDRAF/NIRAS (the federal agency responsible for managing radioactive waste and enriched fissile materials in Belgium) is considering a geological disposal facility (GDF) in poorly indurated clays for the long-term management of category B waste (low-level and intermediate-level long-lived waste–LILW-LL) and category C waste (high-level waste–HLW and spent fuel). In the absence of a political decision, poorly indurated clays remain the reference host rock for Research, Development and Demonstration (RD&D) activities managed by ONDRAF/NIRAS.
The RD&D programme for the geological disposal for categories B&C waste has been implemented in a cautious, stepwise process, punctuated by the production of key documents such as the SAFIR reports in 1989 and 2001, the waste Plan in 2011 and the RD&D Plan in 2013.
From the previous RD&D feasibility programme conducted in the 2000s, studies had already been performed on the development of the layout of the underground facilities. The reference layout of the GDF used from 2003 to 2015 was designed for disposal at a depth of about 230 m in the Boom Clay and was mostly oriented towards long-term safety. In order to further develop the GDF layout and to integrate other considerations than the long-term safety, ONDRAF/NIRAS has developed a design process to optimise the GDF design. Within this context, a multi-criteria assessment was developed to reach an optimal balance between the technical, environmental, operational safety, long term safety and economic constraints (optioneering). The presentation focuses on the optioneering process and how its application enabled to optimise the overall GDF layout. The presentation also presents the next step of the optimisation process, which will focus on the operational safety to improve the safety concept.

Jean-Michel Bosgiraud, Project Engineer, ANDRA, France

Jean-Michel Bosgiraud is a graduate in Mechanical and Petroleum engineering. He has some 40 years of diversified professional experience including some 30 years with ANDRA. His last position was “head of engineering”, before joining his current job assignment as head of the Underground Installations and Facilities Department of the Cigeo Program Division

Optimisation of thermal dimensioning of the Cigéo Project: operational goal and scientific key issues

The licence application of the French geological repository dedicated to the storage of high and intermediate long lived waste storage (HLLW & ILLW), called Cigeo Project, is currently planned by Andra in 2022.
The thermal power load of HLLW packages causes a temperature transient affecting the geological host rock (the Callovo-Oxfordian clay argilites), which transiently increase the interstitial pressure and the

mechanical stresses. The thermal dimensioning of the HLLW zone aims to preserve the favourable properties of the Callovo-Oxfordian towards the limitation of the transfer of radionuclides. This dimensioning is carried out using numerical simulations based on a thermo-poroelastic model, with the aim of non exciding the Terzaghi effective stress failure criteria.
Sensitivity analyses have shown as parameters sizing the thermo-hydro-mechanical (THM) parameters of the host rocks such as especially thermal conductivity, rigidity of the rock and its permeability. This has led Andra to perform a detailed volume characterization of the site, to adopt cautious sizing assumptions for Licence application.
With the objective of consolidating the THM dimensioning, and evaluating margins, with a view to optimizing the thermal sizing, Andra has defined an R&D program on the Callovo-Oxfordian:

- participation in international benchmarks on the THM behaviour of the Callovo-Oxfordian, and deep clay formations in general (DECOVALEX2023, Work package « HIgh TEmperature on Clay-based material behaviour » (HITEC) within the European joint program EURAD)
- in situ tests (longer-term monitoring of the cell heating, the performance of a second CRQ test), further HLLW demonstrators cell with heating systems
- development of models on the nucleation and propagation of fractures
- Carrying out deep boreholes with Callovo-Oxfordian samples and of THM parameters measurements

Finally, during the pilot industrial phase, the monitoring of the first HLLW district will make it possible to verify that the THM behaviour on a large scale of the Callovo-Oxfordian complies with the thermal dimensioning field.

Symposium Poster Abstracts

Throughout the symposium the IGD-TP hosts a series of themed poster sessions that aim to showcase the cutting-edge radioactive waste management RD&D of our community. Posters are aligned to the IGD-TP Strategic Research Agenda (SRA), which identifies the following Key Topics:

1. Post-closure Safety Case
2. Wasteforms and their Behaviour
3. Technical Feasibility and Long-term Performance
4. Implementation and/or Optimisation
5. Safety of Construction and Operations
6. Monitoring
7. Methodologies for Site Characterisation
8. Strategy for Repository Project Development
9. Knowledge Management

The posters will be set up in the refreshment area within the Symposium venue to increase visibility and attendee interaction. One of the significant advantages of a poster presentation is that it allows one-on-one time with the audience for exchange of information and to answer questions. Poster presenters are encouraged to verbally and visually convey the importance of their subject, including its implications and significance.

The poster sessions will coincide with the refreshment and lunch breaks, with the posters being displayed for a full day. Posters aligned with SRA Key Topics 1, 2 and 3 will be displayed on the first day, Tuesday 20 September, and the posters aligned with Key Topics 4 to 9 will be displayed on the second day, Wednesday 21 September.

Symposium posters will also be displayed on the IGD-TP website, increasing the visibility of your work.

The prize for the best poster will be announced in the final summary session on day 2.

The posters will be displayed electronically and **must be provided by 12 September 2022** to secretariat@igdtp.eu. A PDF file format is requested. The electronic monitors are 55", with portrait dimensions 1250mm (H) x 790mm (W) (ratio 9:16), and HD 1080 x 1920 pixels or UHD 2160 x 3840 pixels.

N°	TITLE	AUTHORS *(presenter in bold)*
	SRA Topic 1. Post-closure Safety Case *(Day 1)*	
1	**Design and Performance Assessment of Engineered Barrier Systems in a Salt Repository for HLW/SNF**	**Eric Simo**, Edward N. Matteo, Kristopher L Kuhlman, Richard S. Jayne, Paola León Vargas, Philipp Herold
2	**Sensitivity Analysis in Repository Performance Assessment: Findings from an International Exercise**	Elmar Plischke, Klaus-Jürgen Röhlig, **Dirk-Alexander Becker**
3	**The OpenGeoSys Software Framework for Reactive Transport and Chemo-mechanical Modeling in Deep Geological Disposal**	**Vanessa Montoya**, Jaime Garibay-Rodriguez, Renchao Lu, Dmitri Naumov, Keita Yoshioka, Olaf Kolditz
4	**High-resolution Characterization of the Induced Fracture Network Around Galleries in the Callovo-Oxfordian Clay using Discrete Fracture Network Inversion**	**Ralf Brauchler**, Mohammadreza Jalali, Rémi de la Vaissière, Médéric Piedevache, Axayacatl Maqueda, Sacha Reinhardt
5	**Development of a Database for Radionuclide Sorption on Clay and Cement Systems in Support to Radioactive Waste Management**	**David García**, A. Valls, D. Pérez, M. López-García, A. Nardi, S. Brassinnes, L. Duro
6	**Safety Case for Disposal System Optimisation, L&ILW disposal at Bátaapáti, Hungary**	**Péter Molnár**, Gyula Dankó, Bálint Nős, Tamás Takács

N°	TITLE	AUTHORS *(presenter in bold)*
7	**Novel Coupled Modelling Approach for Total System Performance Assessment in GoldSim**	**Zoltan Bothi**, Tamas Olasz, Anna Ditroi, Anna Katzer, Melinda Wieser, Attila Baksay
	SRA Topic 2. Wasteforms and their Behaviour *(Day 1)*	
8	**Need to Optimize Cementitious Final Waste-forms Containing Novel Radioactive Waste of ^{10}B Enriched Boric Acid**	**Mojtaba Rostamiparsa**, István Tolnai, Margit Fábián, György Falus, Csaba Szabó, Mihály Óvári, Csaba Tóbi, Péter Kónya, Péter Völgyesi, Zsuzsanna Szabó-Krausz
9	**Treatment and Conditioning of the Radioactive Solid Organic Waste within the PREDIS Project**	**Thierry Mennecart**
10	**Research within the CORI WP in EURAD: Optimized Understanding of Cement-Organics-Radionuclide-Interactions**	**Marcus Altmaier**, D. Garcia, P. Henocq, N. Mace, T. Missana, D. Ricard, J. Vandenborre
11	**Activities in the Context of the Characterization of Legacy Waste within the ERDO Association**	Nadia Cherubini, **Riccardo Levizzari**, Giuseppe A. Marzo, Giorgio Mingrone, Michela Raio
12	**Alternative Conditioning Materials for Disposal of Decommissioning Radioactive Waste Project (ALMARA)**	Petr Večerník, **Václava Havlová**, David Dobrev, Petr Fabián, Milan Kouřil, Patricie Halodová, Alena Ševců
13	**Monitoring and Digital Tools for Pre-disposal Handling of Cemented Wastes**	**Vera Lay**, Ernst Niederleithinger, Christian Köpp and PREDIS WP7-team
	SRA Topic 3. Technical Feasibility and Long-term Performance *(Day 1)*	
14	**New Materials and Innovative Monitoring for Safe Sealing Structures in Underground Repositories**	**Vera Lay,** Franziska Baensch, Detlef Hofmann, Frank Mielentz, Patrick Sturm, Prathik Prabhakara, Sergej Johann, Hans-Carsten Kühne, Ernst Niederleithinger
15	**Pilot Material Corrosion Test in URF Bukov**	**Markéta Dohnálková**
16	**Simulating in the Laboratory an *in situ* Engineered Barrier Heating Experiment**	M.V. Villar, R.J. Iglesias, C. Gutiérrez-Álvarez, **Florian Kober**
17	**Preliminary Design of a Czech Waste Disposal Package for Spent Nuclear Fuel**	**Lucie Hausmannova**, Lukáš Vondrovic
18	**The EURAD EU Project FUTURE: Fundamental Understanding of Radionuclide Retention**	**Sergey V. Churakov**, Vaclava Havlova, Dirk Bosbach, Norbert Maes, Martin Glaus, Cornelius Fischer, Rainer Dahn, Sylvain Grangeon, Maria Marques Fernandes
19	**Michigan International Copper Analogue (MICA) Project – Assessment of Long-term Behaviour of Copper in Repository Relevant Environments**	Heini Reijonen, Ismo Aaltonen, **Axel Liebscher**, Christina Lilja, Simon Norris, Peter Keech, Nikitas Diomidis, Xuan Liu
20	**Engineered Barrier 200C**	**Jiří Svoboda**, Radek Vašíček, David Mašín, Jan Najser, František Laufek, Lenka Rukavičková, Jaroslav Kruis, Jiří Šťástka, Jiří Mikeš
	SRA Topic 4. Implementation and/or Optimisation *(Day 2)*	
21	**EURAD HITEC – Influence of Temperature on the Behaviour of Clay-based Materials**	Markus Olin, Dragan Grgic, **Jiří Svoboda**

N°	TITLE	AUTHORS *(presenter in bold)*
22	**Optimisation of Radiological Protection Applied to the Development and Implementation of a DGR - The SITEX.Network Standpoint**	**Frédéric Bernier**, J. Miksova, M. Rocher, V. Detilleux, W. Pfingsten, D. Pellegrini, N. Zeleznik and J. Swahn
23	**Study of Existing Chemical Decontamination Methods of Radioactive Metals with a View on their Optimization**	**Aditya Rivonkar**, T. Suzuki-Muresan, M. Robin, R. Katona, A. Abdelouas, M. Mokili
24	**Supporting Implementation and Optimisation of Nuclear Waste Disposal by Developing and Improving Numerical Methods and Tools for Modelling Coupled Processes**	**Francis Claret**, G. Pepin, C. Cances, O. Kolditz, N. Prasianakis, A. Baksay, D. Lukin
25	**The Role of Excellent Science in Geological Disposal System Optimization – View and Perspectives from EuradScience**	**Christophe Bruggeman**, Marcus Altmaier, Daniel Galson
26	**Development of Decontamination Process for Metallic Radioactive Effluents using Hydroxyde Precipitation**	**Mathurin Robin**, A. Rivonkar, T. Suzuki-Muresan, A. Abdelouas, M. Mokili
27	**Optimization of Quality Assured Thermodynamic Understanding for Use in Performance Assessment of Nuclear Waste Disposal**	**Xavier Gaona**, B. Grambow, M. Altmaier, L. Duro, D. Bosbach, H. Geckeis
28	**Optimisation of Disposal Concepts for a Deep Geological Repository**	**Susie Hardie**, Ian McKinley
29	**Optimization Methodology Based on a Probabilistic Approach for the Design of Radioactive Waste Disposal Facilities**	**Ryo Nakabayashi**, Daisuke Sugiyama, Shingo Tanaka
30	**A Series of Experiments Aimed at the Verification of the Behaviour of Engineered Barriers**	**Jiří Šťástka**
	SRA Topic 6. Monitoring *(Day 2)*	
31	**MODATS – Monitoring Equipment and Data Treatment for Safe Repository Operation and Staged Closure**	**Johan Bertrand**, Martin Schoenball, Matt White, Kateryna Fuzik, Johanna Hansen, Edgar Bohner, Mansueto Morosini
	SRA Topic 7. Methodologies for Site Characterisation *(Day 2)*	
32	**Multicriterial Site Assessment of Potential Deep Geological Repository Sites in the Czech Republic: Requirements for Site Characterization Techniques**	**Lukáš Vondrovic**
	SRA Topic 8. Strategy for Repository Project Development *(Day 2)*	
33	**ERDO – Dual-track for Optimized Radioactive Waste Management**	**Marja Vuorio**, Ewoud Verhoef, Ole Kastbjerg Nielsen, Håvard Kristiansen
34	**Towards Harmonised Practices, Regulations and Standards in Waste Management and Decommissioning (EU-HARPERS)**	**Réka Szőke**, Erika Holt, Elke Jacops
	SRA Topic 9. Knowledge Management *(Day 2)*	
35	**EURAD: the European Joint Collaboration Towards Safe Radioactive Management**	**Louise Théodon**, Tara Beattie, Paul Carbol, Michelle Cowley, Bernd Grambow, Elisabeth Salat and Piet Zuidema
36	**EURAD Knowledge Management & Networking Programme**	**Paul Carbol**, Tara Beattie, Bernd Grambow, Tobias Knuuti, Louise Théodon, Piet Zuidema

N°	TITLE	AUTHORS *(presenter in bold)*
37	**State-of-Knowledge & Guidance in EURAD Knowledge Management (Work Packages 11 State-of-Knowledge & 12 Guidance)**	Alexandru Tatomir, Tobias Knuuti, **Astrid Göbel**, Carola Franzen, Dinara Abbasova, Thuro Arnold, Vinzenz Brendler, Kateryna Fuzik, Jiří Faltejsek, Bálint Nős, Nadja Železnik, Jitka Mikšová
38	**EURAD's Training & Mobility and Interactions with Civil Society**	Niels Belmans, Julien Dewoghélaëre, **Jitka Mikšová**, Paul Carbol, Michèle Coeck
39	**Knowledge Management in Pre-disposal of Radioactive Waste (PREDIS EU Project)**	**Vaclava Havlova**, Alba Valls, Paul Carbol, Erika Holt, Maria Oksa, Anthony Banford, Abdesselam Abdelous, Maxime Fournier, Thierry Mennecart, Ernst Niederleithinger, Jenny Kent, Rosa Lo Frano
40	**Facilitating Knowledge Transfer Between More Advanced Programmes and Early-stage Programmes: IAEA's Roadmap for Implementing a Geological Repository Programme**	**Karina Lange**, Stefan J. Mayer, Haeryong Jung

DESIGN AND PERFORMANCE ASSESSMENT OF ENGINEERED BARRIER SYSTEMS IN A SALT REPOSITORY FOR HLW/SNF

ERIC SIMO[1]*, EDWARD N. MATTEO[2], KRISTOPHER L KUHLMAN[2], RICHARD S. JAYNE[2], PAOLA LEÓN VARGAS[1], PHILIPP HEROLD[1]
[1] *BGE TECHNOLOGY GmbH, Germany*
[2] *Sandia National Laboratories, USA*
* *Corresponding author: eric.simo@bge.de*

BGE TECHNOLOGY GmbH (BGE TEC) and Sandia National Laboratories (SNL) developed and tested jointly a methodology for the safety assessment of engineered barrier systems (EBS) for an HLW/SNF repository in salt. Long-term-isolation in such a repository is provided by a multi-barrier system including natural and engineered barriers. The salt provides the natural barrier, whereas the engineered barriers are different sealing components installed in the repository. The developed methodology is tested at a generic repository concept placed in a generic bedded salt formation. Based on this, a global model was generated, including relevant stratigraphic layers and underground openings of the repository. BGE TEC used this model to perform the integrity assessment of the shafts and drift sealings as main parts of the EBS. Simultaneously, SNL conducts the radiological performance assessment (PA). Both parts interact by an optimization of the EBS based on PA simulations and EBS-parameters. For this purpose, sensitivity analyses were incorporated into the PA simulation. This contribution presents the modelling and methodological approach used for BGE TEC and SNL for the design and performance assessment of EBS.

SENSITIVITY ANALYSIS IN REPOSITORY PERFORMANCE ASSESSMENT: FINDINGS FROM AN INTERNATIONAL EXERCISE

ELMAR PLISCHKE[1], KLAUS-JÜRGEN RÖHLIG[1], DIRK-ALEXANDER BECKER[2]*
[1] *TU Clausthal, Germany*
[2] *GRS gGmbH, Germany*
* *Corresponding author: dirk-alexander.becker@grs.de*

Management and treatment of uncertainties by sensitivity analysis is an important element for identifying the key input data of complex systems and identifying high priority research and development activities for disposal programmes (see IGD-TP SRA key topic 1.3). Over the past four years, an informal international working group has developed to investigate state-of-the-art sensitivity analysis methods, examine new methods, and identify best practices in the context of repository safety assessment. The focus is on the use of sensitivity analysis in case studies involving geologic disposal of nuclear waste. The main goal of the exercise is to harmonize the different views on sensitivity analysis in the safety case and to elaborate recommendations for application in practice. To examine ideas and have applicable test cases for comparison purposes, a number of case studies were identified, all of which had already been investigated with probabilistic methods. Four of these case studies are presented: a generic repository for spent nuclear fuel in clay host rock (GRS), a generic repository for commercial spent nuclear fuel in a shale host rock (Sandia), a near-surface repository at Dessel (Belgium) for intermediate and low-level radioactive waste (SCK.CEN), and a model for groundwater flow in the heterogeneous geological media of Nizhnekansky massif, Krasnoyarsk territory (IBRAE). Different sensitivity analysis methods were applied to available probabilistic results by various groups. Some results obtained by different groups using different sensitivity analysis methods and different implementations are presented and the main findings are summarized.

THE OPENGEOSYS SOFTWARE FRAMEWORK FOR REACTIVE TRANSPORT AND CHEMO-MECHANICAL MODELING IN DEEP GEOLOGICAL DISPOSAL

VANESSA MONTOYA[1]*, JAIME GARIBAY-RODRIGUEZ[1], RENCHAO LU[1], DMITRI NAUMOV[1,2], KEITA YOSHIOKA[1], OLAF KOLDITZ[1]
[1] *Helmholtz Centre for Environmental Research (UFZ), Department of Environmental Informatics, Leipzig, Germany*
[2] *Chair of Soil Mechanics and Foundation Engineering, Geotechnical Institute, Technische Universität Bergakademie Freiberg, Freiberg, Germany*
* *Corresponding author: vanessa.montoya@ufz.de*

OpenGeoSys (OGS) is a scientific open-source initiative for the numerical simulation of thermo-hydro-mechanical/chemical (THMC) processes in porous and fractured media. OGS provides a flexible numerical framework using primarily the Finite Element Method (FEM) for solving multi-field coupled processes with

application in different scientific and technical disciplines, including nuclear waste disposal. Since the mid-80's, OpenGeoSys has been in development evolving from Fortran to C++ implementation with the current released version being OpenGeoSys 6.4. Regarding reactive transport processes, different approximations have been implemented in OGS along its development in order to consider multicomponent mass transport and bio/geochemical reactions.

For example, [1] used an internal library to simulate kinetically controlled bio / geo-chemical reactions. In other cases, OGS has been coupled in a sequential non-iterative approach with external geochemical solvers (i.e. PHREEQC, GEMS, BRNS and ChemApp). Recently, an alternative coupling solution of reactive transport has been developed and implemented by approximating the complex chemical reactions with look-up tables [2]. The novel implementation provides fast and efficient simulations, a feature especially relevant for long-term simulations. Reactive transport calculations referred above have been mainly performed with OGS-5. The new OGS-6 version with iPHREEQC coupling includes a new implementation with direct memory access allowing efficient computational simulations. Recent applications of OGS on reactive transport modelling in the framework of nuclear waste disposal include long term cementitious materials/clay interactions [3], laboratory scale precipitation/ dissolution processes in combination with i) density driven flow and clogging effects [4] and with ii) mechanical processes in fracture media [5], concrete degradation due to reactive aggregates in combination with multi-phase transport of CO2 [6] and radionuclide migration in clays [2].

Finally, the OGS team has been participating in several international model development, validation and benchmarking initiatives, i.e., DEVOVALEX, CO2BENCH, SeS Bench and HM-Intercomp, providing ongoing series of benchmark books and tutorials.

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HIGH-RESOLUTION CHARACTERIZATION OF THE INDUCED FRACTURE NETWORK AROUND GALLERIES IN THE CALLOVO-OXFORDIAN CLAY USING DISCRETE FRACTURE NETWORK INVERSION

RALF BRAUCHLER[1]*, MOHAMMADREZA JALALI[1], RÉMI DE LA VAISSIÈRE[2], MÉDÉRIC PIEDEVACHE[3], AXAYACATL MAQUEDA[1] AND SACHA REINHARDT[1]

[1] AFRY Switzerland Ltd, Taefernstrasse 26, 5405 Baden, Switzerland
[2] Andra, R&D Division, Meuse/Haute-Marne Underground Research Laboratory, 52290, Bure, France
[3] Solexperts SA, Technopôle Nancy-Brabois10, allée de la forêt de la Reine 54500 Vandoeuvre les Nancy
** Corresponding author: ralf.brauchler@afry.com*

The Meuse / Haute Marne Underground Research Laboratory (URL) provides the location for an experiment designed to investigate the induced fracture network around open or sealed drifts. Within the presented study, the cross-hole responses of gas permeability tests, performed by Solexperts SA, were inverted using a discrete fracture network inversion approach.

The data base of the tomographic analysis is based on 18 gas injection tests and several pressure interferences, which were recorded between nine closely spaced boreholes. The inversion procedure is initiated by randomly generating a DFN realization based on given statistical properties, in our case fracture intensity and fracture orientation. In each subsequent iteration, a new DFN realization is proposed by sequentially updating the geometry of the previous one. The key elements of updating the geometry are (i) fracture movement, (ii) fracture deletion and (iii) fracture addition. That means after each iteration step, the number of unknowns and, hence, the number of equations that must be solved during each iteration step is changing. Therefore, an innovative trans-dimensional reversible jump Markov Chain Monte Carlo (rjMCMC) algorithm, in which the number of parameters can vary among subsequent iterations during the inversion process, was applied.

The reconstructed fracture probability tomograms display the induced fracture network around the gallery with a high level of detail and provides spatial information about the spatial location of fracture traces, which goes beyond the significance of any conventional borehole analysis or inversion approaches based on equivalent porous media assumptions. A highlight is the reconstruction of fracture traces of inclined structures that dip in the opposite direction of the excavation advance direction. These structures are interpreted in accordance to the conceptual model as lower chevron structures.

DEVELOPMENT OF A DATABASE FOR RADIONUCLIDE SORPTION ON CLAY AND CEMENT SYSTEMS IN SUPPORT TO RADIOACTIVE WASTE MANAGEMENT

D. GARCÍA[1]*, A. VALLS[1], D. PÉREZ[1], M. LÓPEZ-GARCÍA[1], A. NARDI[1], S. BRASSINNES[2], L. DURO[1]

[1] *Amphos21, Carrer Veneçuela 103, 08019, Barcelona, Spain*

[2] *Belgian Agency for Radioactive Waste and Enriched Fissile materials (ONDRAF/NIRAS), Belgium*

** Corresponding author: david.garcia@amphos21.com*

Sorption is one of the most relevant processes retarding the migration of radionuclides through engineering and natural barriers of geological repositories of radioactive waste. There is a complete body of scientific literature on the subject, accompanied by a large set of data of the sorption of different radionuclides onto different solid substrates of interest. To date, although there are some sorption databases available in the literature, a comprehensive database containing raw sorption data in a rationale manner as well as experimental conditions / parameters for the experiments is lacking. This contribution presents a Sorption DataBase (SDB) for radionuclides sorption developed for ONDRAF/NIRAS, with a first focus on clays and cementitious systems. The added value of the SDB relies not only on the experimental raw data contained, but on how the SDB is structured and the associated software tools developed to help in feeding, analysing and extracting the sorption data. Additionally, a Thermodynamic Sorption Model - DataBase (TSM-DB) is also under development.

Both, the SDB and the TSM-DB have been developed using MongoDB (www.mongodb.com). The SDB contains information on the solid phases, the experimental details and the results of the sorption experiments. So far the SDB is populated with approximately 26,000 data points from about 300 literature references; being the content update up to 2020. The TSM-DB is currently focused on TSM for illite and montmorillonite; and includes about 100 different TSM for several type of radionuclides.

Besides the databases itself, different IT tools have been developed and are integrated in the software package: Template Tool for sorption data, Template Tool for sorption models and a Sorption DataBase (SDB) Tool. The Template tools are used to generate the datasets (data or models). The SDB Tool is designed to handle and manage the information included in both the SDB and TSM-DB databases.

SAFETY CASE FOR DISPOSAL SYSTEM OPTIMISATION, L&ILW DISPOSAL AT BÁTAAPÁTI, HUNGARY

PÉTER MOLNÁR[1]*, GYULA DANKÓ[1], BÁLINT NŐS[1], TAMÁS TAKÁCS[1]

[1] *PURAM, Hungary*

** Corresponding author: molnar.peter@rhk.hu*

PURAM, the Hungarian radioactive waste management organisation, is developing and operating a subsurface repository for L/ILW at Bátaapáti. The repository was excavated in granitic rocks ca. 250 m bgs and started the operation in 2012.

This poster shows how the original design was optimised, due to the waste producer's interest to reduce disposal costs by decreasing the volume of the waste to be dispose. Conceptual design of a new disposal system was developed applying value engineering. Repository layout was also improved for better fitting to the geological settings.

Original layout of the repository consisted of 17 disposal galleries with a cross-section of 96 m^2. The solid and solidified waste was placed in 200 litre steel drums. Drums were put into concrete overpacks and the gaps were filled up with inactive mortar. The overpacks were stacked within the galleries and the empty place was sealed with cementitious backfill.

PURAM has modified that original design, applying the following changes:

- instead of concrete overpacks, carbon steel containers with 4 drums in each were introduced, and the gap is filled up with active mortar;
- concrete vault is constructed inside the disposal gallery for the steel containers, and also drums with LLW emplaced on the top of the closed vaults; gaps between the containers inside the vault and between the drums on the top are filled up with cementitious backfill;
- cross sectional area of the disposal galleries increased up to 115 m^2 and 134 m^2;
- disposition of the galleries was modified reflecting the geological situation.

Introducing the new, optimised disposal system, space utilization factor of the galleries increased from 19% up to 47% which results a more efficient and cost-effective disposal solution. The new disposal system was evaluated by safety assessment which showed the compliance with the regulatory requirements.

NOVEL COUPLED MODELLING APPROACH FOR TOTAL SYSTEM PERFORMANCE ASSESSMENT IN GOLDSIM

ZOLTAN BOTHI[1]*, TAMAS OLASZ[1], ANNA DITROI[1], ANNA KATZER[1], MELINDA WIESER[1] AND ATTILA BAKSAY[2]

[1] *WSP-Golder, Hungary*

[2] *TS-Enercon, Hungary*

* *Corresponding author: zoltan.bothi@wsp.com*

Within the EURAD framework's DONUT project a new coupled modelling approach has been developed in the GoldSim modelling environment for Total System Performance Assessment. The model focuses on the Near-Field of a generic disposal system where thermal-hydraulic-mechanical-chemical-gaseous-microbiological processes drive the evolution of safety functions within the repository.

The applied generic modelling approach enables the model to be fine-tuned for any LILW/HLW disposal system considering site-specific characteristics from the earliest disposal concept and site selection procedure to the licensing application. It provides tools for assessing the evolution of safety functions and to define safety function criteria. The flexible structure using a FEM-like approach to spatially discretize the system without linkage to any specialized external software makes it possible to compare different disposal concepts and potential sites to aid the site selection procedure and to optimize the system in each phase of the disposal program. This approach together with using a QA/QC database provides better transparency and traceability.

By implementing the model within the GoldSim environment the built-in probabilistic modelling capabilities provide means for carrying out uncertainty and sensitivity analyses. Different scenarios and calculation cases can be easily defined and compared to one another.

The model is based upon the application of GoldSim cloned elements which describe the coupled processes taking place within different spatial volumes of the system. Each clone has the same inner structure and logic which may be updated based on available information following top-down modelling approach. On the other hand, by defining different initial and boundary conditions and material properties for the volumes the spatial heterogeneity may be described. Calculated state-variables as temperature and pressure directly influence material properties, which in turn are used for calculating the rate of coupled processes.

The newly developed model provides a robust approach for assessing the long-term safety of disposal systems.

SRA Topic 2. Wasteforms and their Behaviour

NEED TO OPTIMIZE CEMENTITIOUS FINAL WASTE-FORMS CONTAINING NOVEL RADIOACTIVE WASTE OF 10B ENRICHED BORIC ACID

MOJTABA ROSTAMIPARSA[1*], ISTVÁN TOLNAI[2], MARGIT FÁBIÁN[2], GYÖRGY FALUS[1], CSABA SZABÓ[1], MIHÁLY ÓVÁRI[2], CSABA TÓBI[2], PÉTER KÓNYA[3], PÉTER VÖLGYESI[2], ZSUZSANNA SZABÓ-KRAUSZ[1]

[1] *Lithosphere Fluid Research Lab (LRG), Eötvös Loránd University, Budapest, Hungary*

[2] *Centre for Energy Research, Budapest, Hungary*

[3] *Mining and Geological Survey of Hungary, Budapest, Hungary*

* *Corresponding author: mojtabarostami466@gmail.com*

After proving technical capabilities of enriched boric acid (EBA), some pioneer nuclear power plants (NPPs) started to apply EBA as a novel neutron absorber instead of normal/natural boric acid (NBA). Subsequently, the volume of radioactive wastes containing EBA is increasing continually. All current optimizations are focused on achieving more durable cementitious matrices made by normal borate wastes and there is no available data for EBA wastes. Even though, due to the large relative mass difference between boron isotopes, the behaviour of EBA in cementitious structures and, subsequently the stability and durability of final waste-forms, are expected to differ significantly from that of NBA.

In this study, boron leaching from cementitious matrices has been selected for chemical durability comparison of waste-forms containing EBA and NBA. Leaching tests were done based on a standardized ASTM procedure on specimens with changing concentrations and enrichment of boric acid. Changes in mineral compositions of solidified waste-forms were assessed experimentally by XRD and SEM techniques. The total concentration and isotopic ratio of leached boron were measured by ICP-OES and ICP-MS, respectively.

The results of this study are the first published data on the solidification of EBA and prove: the mineralogy of cementitious matrices changes considerably when NBA is replaced by EBA. Due to the changes of the mineralogy, the total amount and the rate of boron leaching from the final waste-forms containing EBA were significantly lower than that of the waste-forms containing NBA up to 29% and 46%, respectively. Furthermore, the $^{10}B/^{11}B$ ratio in the released boron changed with time what indicates an isotopic

fractionation during the leaching tests. These results suggest significantly different long-term durability of EBA waste-forms in comparison with the waste-forms made by NBA what raises the necessity of some optimization on the final wastes-forms containing EBA before disposal.

TREATMENT AND CONDITIONING OF THE RADIOACTIVE SOLID ORGANIC WASTE WITHIN THE PREDIS PROJECT

THIERRY MENNECART[1]*

[1] SCK CEN, Belgian Nuclear Research Centre, Belgium

** Corresponding author: thierry.mennecart@sckcen.be*

Among the various areas covered by the PREDIS project (Pre-Disposal Management of Radioactive Waste), the Work Package 6 is devoted to the treatment and the conditioning of the Radioactive Solid Organic Waste (RSOW). The objective is to propose innovations and solutions for the management of low- and intermediate-level waste forms whose safe long-term storage and disposal is difficult to achieve because they are considered not sufficiently stable and / or too highly reactive in the alkaline conditions expected to prevail in many final repositories. The range of waste considered is quite large and each type of waste has associated challenges regarding their stability. Thermal treatment may present a suitable solution to transform unstable or reactive RSOW into more stable inorganic end products which could be easier to handle and compatible with current long-term waste management routes. This presentation will give an overview of the RSOW considered within the project and the technologies deployed for their physical and chemical degradation. Some of these technologies have already demonstrated their effectiveness, others need be adapted from their original purpose or they are under development. Once treated, the residues (e.g. ashes) must be immobilized using traditional cement-based materials or novel binders such as geopolymer matrices. Finally, the stability and the long-term performance of the reconditioned waste forms will be tested according to a common protocol based on the End Users recommendations and as representative as possible of the final repository conditions. The relevant characteristics of the end products will allow the End Users to draw conclusions about the most appropriate solutions according to the Waste Acceptance Criteria at their national level.

RESEARCH WITHIN THE CORI WP IN EURAD: OPTIMIZED UNDERSTANDING OF CEMENT-ORGANICS-RADIONUCLIDE-INTERACTIONS

M. ALTMAIER[1]*, D. GARCIA[2], P. HENOCQ[3], N. MACE[4], T. MISSANA[5], D. RICARD[3], J. VANDENBORRE[6]

[1] Institute for Nuclear Waste Disposal (INE), Karlsruhe Institute of Technology (KIT), Karlsruhe – Germany

2. Amphos[21] Consulting S.L., c/ Veneçuela, 103. 2nd floor. 08019 Barcelona – Spain

3. ANDRA, 1-7, rue Jean-Monnet - 92298 Châtenay-Malabry CEDEX – France

4. Université Paris-Saclay, CEA, Service d'Etude du Comportement des Radionucléides, 91191, Gif-sur-Yvette – France

5. CIEMAT, Avda. Complutense 40 - 28040 Madrid – Spain

6. SUBATECH, UMR 6457, Institut Mines-Télécom Atlantique, CNRS/IN2P3, Université de Nantes; 4, Rue Alfred Kastler, La chantrerie BP 20722, 44307 Nantes cedex – France

** Corresponding author: marcus.altmaier@kit.edu*

The CORI (Cement-Organics-Radionuclides-Interactions) Work Package integrated into EURAD (EURAD – European Joint Programme on Radioactive Waste Management, https://www.ejp-eurad.eu) performs research 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 extends the current state-of-the-art and will contribute to optimize disposal solutions and consider questions of regulatory concern. CORI results will help member states to further develop their national R&D programs and support programs at an early implementation stage. CORI research addresses 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 + lanthanides) which can (i) increase radionuclide solubility and (ii) decrease radionuclide sorption. Organic substances require special 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. CORI has prepared a State-of-the-Art document which gives an introduction to the main research topics targeted in CORI (available at: https://www.ejp-eurad.eu/publications/eurad-

deliverable-31-cori-sota-cement-organic-radionuclide-interactions-content-lilw).
The three R& D Tasks in CORI to be introduced with the aim of indicating how CORI contributes to develop optimized understanding of cement-organics-radionuclide-interactions are: (i) Organic Degradation, (ii) Organic-Cement-Interactions, (iii) Radionuclide-Organic-Cement-Interactions.

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ACTIVITIES IN THE CONTEXT OF THE CHARACTERIZATION OF LEGACY WASTE WITHIN THE ERDO ASSOCIATION

NADIA CHERUBINI[1], RICCARDO LEVIZZARI[1]*, GIUSEPPE A. MARZO[1], GIORGIO MINGRONE[2], MICHELA RAIO[2]

[1] ENEA - National Agency for New Technologies, Energy and Sustainable Economic Development. Fusion and Technology for Nuclear Safety and Security Department, Italy

[2] Sogin S.p.a., Italy

** Corresponding author: riccardo.levizzari@enea.it*

Legacy Waste is the term used for describing radioactive waste generated in older nuclear activities, which has been treated and conditioned according to the rules in force at that time and stored pending a suitable management solution. It's not always possible to access information about such a kind of waste, because it's often not available, but great efforts should be made to ensure that legacy waste is no longer left as undue burden for future generations. Possible re-treatment and re-conditioning processes, according to current regulatory requirements and in compliance with Waste Acceptance Criteria of storage and disposal facilities, may be compromised by lack of sufficient physico-chemical and radiological characterization data. Moreover, qualitative and quantitative information about radiological contamination (quantity and type of radionuclides) and about physico-chemical characteristics of the waste contribute to the correct application of modeling for the safety assessment and to define the types and magnitudes of uncertainties associated with each process involving the system waste-repository. Within the ERDO Association, the necessity for characterization of legacy waste has been identified; therefore, available data have been collected, to find similarities and differences among the waste streams belonging to the ERDO members. The scope of the project is sharing information and expertise, to harmonize the methodologies for characterization, treatment and conditioning for storage or disposal of legacy waste, especially in the case of small inventories. Radiological destructive (accurate and sensitive) and non-destructive (generally fast and applied in-situ) techniques are of pivotal importance for addressing the best possible characterization quality. Physico-chemical characterization is likewise fundamental to address any non-radiological hazards, considering that waste can contain a wide range of hazardous chemicals. Each of these techniques present advantages and disadvantages and can be applied to distinct types of waste (e.g., liquids, powders, sludges, contaminated soil, etc.) and packages (e.g., sealed sources, drums, etc.).

ALTERNATIVE CONDITIONING MATERIALS FOR DISPOSAL OF DECOMMISSIONING RADIOACTIVE WASTE PROJECT (ALMARA)

PETR VEČERNÍK[1], VÁCLAVA HAVLOVÁ[1]*, DAVID DOBREV[1], PETR FABIAN[2], MILAN KOUŘIL[3], PATRICIE HALODOVÁ[4], ALENA ŠEVCŮ[5]

[1] ÚJV Řež, a.s. Czech Republic

[2] Chemcomex, a.s. Czech Republic

[3] University of Chemistry and Technology, Czech Republic

[4] Centrum výzkumu Řež, Czech Republic

[5] Technical University of Liberec, Czech Republic

** Corresponding author: vaclava.havlova@ujv.cz*

The aim of the ALMARA project is the optimization of conditioning matrixes for disposal of intermediate and high level wastes from NPP plant decommissioning. The project is also focused on radionuclide interaction and migration with/in the matrix materials and corrosion and microbiological studies. Finally, technological application will be evaluated for studied matrixes.
Four different conditioning materials were designed at the beginning of the project: CEM – ordinary Portland cement; AFM – alternative filling matrix (cement - bentonite mixture; NNM – new nano-based matrix, which is based on cement and nanomaterial; GP – geopolymer matrix.
Experimental program started by developing of conditioning matrixes composition and verifying the proposed properties (workability, mechanical and structural stability, compressive strength).
Experiments studying corrosion processes on stainless and carbon steel (representative materials of NPP decommissioning) are performed in all four types of matrixes. Disc shape specimens of steels were fixed into the tested materials. Testing cubes are placed in

synthetic granitic water to simulate the interactions in the repository.
Real activated waste samples of activated steel from NPP witness samples programme and contaminated titanium material (are also studied in this project. These samples were immobilised in cement and geopolymer matrix. This part of the project is focused on studies of radionuclide release from real wastes into the matrix or surrounding environment.
The degradation of mechanical and chemical properties of matrix materials will be studied after de-fined periods of time (up to 3 years). The chemical composition, mineralogy, structural and mechanical properties and microbial activity will be tested and also interaction and migration of radionuclides on degraded materials will be characterised by sorption and diffusion experiments and compared to unaffected matrix materials.

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MONITORING AND DIGITAL TOOLS FOR PRE-DISPOSAL HANDLING OF CEMENTED WASTES

VERA LAY[1]*, ERNST NIEDERLEITHINGER[1], CHRISTIAN KÖPP[1] AND PREDIS WP7-TEAM
[1] Bundesanstalt für Materialforschung und -prüfung (BAM), 12205 Berlin, Germany
** Corresponding author: vera.lay@bam.de*

Multifaceted developments for pre-disposal management of low and intermediate-level radioactive waste are undertaken in the EC funded project PREDIS. In work package 7, innovations in cemented waste handling and pre-disposal storage are advanced by testing and evaluating. To provide better means for safe and effective monitoring of cemented waste packages including prediction tools to assess the future integrity development during pre-disposal activities, several monitoring and digital tools are evaluated and improved. Both safety enhancement (e.g. less exposure of testing personnel) and cost effectiveness are part of the intended impact. Current methods to pack, store, and monitor cemented wastes are identified, analysed and improved. Innovative integrity testing and monitoring techniques applied to evaluate and demonstrate package and storage quality assurance are further developed. The work includes but is not limited to inspection methods such as muon imaging, wireless sensors integrated into waste packages as well as external package and facility monitoring such as remote fibre optical sensors. The sensors applied will go beyond radiation monitoring and include proxy parameters important for long term integrity assessment (e.g. internal pressure). The measured data will be used in digital twins of the packages for specific simulations (geochemical, integrity) providing a prediction of future behaviour. Machine Learning techniques trained by the characterization of older packages will help to connect the models to the actual data. As data handling, processing and fusion are crucial for both the monitoring and the digital twin model, all data (measured and simulated) will be collected in a joint data base and connected to a decision framework. Finally, the implementation of the improved techniques will be tested at actual facilities. An overview about various relevant tools, their interconnections, and first research results will be shown.

SRA Topic 3. Technical Feasibility and Long-term Performance

NEW MATERIALS AND INNOVATIVE MONITORING FOR SAFE SEALING STRUCTURES IN UNDERGROUND REPOSITORIES

VERA LAY[1]*, FRANZISKA BAENSCH[1], DETLEF HOFMANN[1], FRANK MIELENTZ[1], PATRICK STURM[1], PRATHIK PRABHAKARA[1], SERGEJ JOHANN[1], HANS-CARSTEN KÜHNE[1] AND ERNST NIEDERLEITHINGER[1]
[1] Bundesanstalt für Materialforschung und -prüfung (BAM), 12205 Berlin, Germany
** Corresponding author: vera.lay@bam.de*

Within the project SealWasteSafe, we advance construction materials and monitoring concepts of sealing structures applied for underground disposal of nuclear waste. As these engineered barriers have high demands concerning integrity, an innovative alkali-activated material (AAM) is improved and tested on various laboratory scales that is highly suitable for the application in salt as a host rock. This AAM has a low reaction kinetics related to a preferential slow release of the heat of reaction in comparison to alternative salt concretes based on Portland cement or magnesium oxychloride cements. Hence, crack formation due to thermally induced strain is reduced. A comprehensive multi-sensory monitoring scheme is developed and investigated to compare the setting process of AAM and salt concrete for manufactured specimens (100-300 l). The analysed parameters include temperature and humidity of the material, acoustic emissions, and strain variations recorded by fibre optic cables. Passive sensor systems based on radiofrequency identification technology (RFID) embedded in the concrete allow for wireless access and are compared to conventional cabled systems for temperature and humidity measurements. Furthermore, ultrasonic methods are

used for quality assurance to detect obstacles, potential cracks and delamination. Field layout and applied imaging techniques are optimised to enhance the image quality. To characterise the inside of the test engineered barrier and achieve a proof-of-concept, an ultrasonic borehole probe is developed to allow for phased arrays that can further improve the detection of potential cracks. Modelling results and first analysis of half-spherical specimen prove the reliability of the directional response caused by the phased arrays of the newly constructed ultrasonic borehole probe. Overall, the project SealWasteSafe improves the construction material, multi-sensory monitoring concepts and ultrasonics for quality assurance. Particularly for salt as a host rock, this will help to develop safe sealing structures for nuclear waste disposal.

PILOT MATERIAL CORROSION TEST IN URF BUKOV

MARKÉTA DOHNÁLKOVÁ[1]*
[1] *SURAO, Czech Republic*
** Corresponding author: dohnalkova@surao.cz*

When designing disposal canisters, it is essential to obtain an understanding of both corrosion processes and the interactions between the various materials under real rock environment conditions.
Pilot material corrosion test in URF Bukov involves the performance of experiment – the interactions of candidate materials will be monitored at elevated temperatures (70 - 90°C) under anaerobic conditions. This will simulate the development of the environment and the events that will take place within the DGR. The estimated duration of the experiment is 10 years, during which time samples will be extracted and analysed.
The experiments will result in:

- a detailed description of the corrosion behaviour of the canister materials and the prediction of corrosion resistance in the order of up to thousands of years,
- comparison of the behaviour of individual material combinations,
- the monitoring of the development of microbial activity and an analysis of the influence of candidate materials and bentonite,
- a description of metal - bentonite interaction processes and their overall influence.

Materials:

- Carbon steel and copper
- Czech Ca-Mg bentonite, Wyoming bentonite

Project Design:

- In situ conditions in URF Bukov
- 10 experimental boreholes with material samples, various combinations
- 1 observation and monitoring borehole

The experiment was initiated this year. Boreholes will be drill next year and experiment will be installed till the end of September 2022. The project is expected to end in 2033.

SIMULATING IN THE LABORATORY AN IN SITU ENGINEERED BARRIER HEATING EXPERIMENT

M.V. VILLAR[1], R.J. IGLESIAS[1], C. GUTIÉRREZ-ÁLVAREZ[1], F. KOBER[2]*
[1] *CIEMAT, Avd. Complutense 40, 28040 Madrid, Spain*
[2] *NAGRA, Hardstrasse 73, 5430 Wettingen, Switzerland*
** Corresponding author: florian.kober@nagra.ch*

The HE-E experiment is a 1:2 scale *in situ* test carried out at the Mont Terri URL whose aim is to reproduce the conditions corresponding to the initial emplacement of wastes: high heat generation by the radioactive decay and low moisture in the EBS. To simulate in the laboratory the conditions of the barrier material in the in situ test, a 50-cm long column of MX-80 bentonite pellets was heated on its base at 140°C for 7 months. Afterwards, Pearson water has been supplied through the column upper surface at a very low pressure for eleven years.
Water vapour moved initially quickly away from the heater. The thermal gradient established at the end of the heating phase remained almost constant during the hydration phase. Because of the low water permeability of the wet pellets on top, the hydration front progressed slowly. It took more than 5 years for the relative humidity at 10 cm from the heater to increase up to the initial 40% value. The start of hydration caused a quick increase of the axial pressure on top of the cell. Afterwards, it increased very slowly, with a current value below 1.6 MPa, corresponding to the swelling pressure of the MX-80 bentonite compacted to dry density ~1.35 g/cm^3. According to the water intake measurement, the current (October 2021) average degree of saturation would be 90%. Final dismantling will allow to check the actual dry density and water content distribution, as well as geochemical and mineralogical changes occurred at such high temperature.
The results obtained have been used in modelling exercises allowing a better understanding of the thermo-hydro-mechanical processes taking place in the EBS. Temperatures measured inside the cell are considerably lower than those in the *in situ* test, whereas the overall RH inside the column is much higher.

PRELIMINARY DESIGN OF A CZECH WASTE DISPOSAL PACKAGE FOR SPENT NUCLEAR FUEL

LUCIE HAUSMANNOVA[1]* AND LUKÁŠ VONDROVIC[1]
[1] *SURAO, Czech Republic*
* *Corresponding author: hausmannova@surao.cz*

The Czech deep geological repository concept considers only sites in crystalline rock environments. In such types of host rock, the engineered barrier system plays a key role in terms of ensuring long-term safety. One of the barriers comprises the waste disposal package (WDP), the lifetime requirement of which, according to the Czech concept, will be hundreds of thousands of years.

Research on the design of the Czech WDP has been underway for several years, culminating in the manufacture of a physical model in 2021. The main design considerations concerned the lifetime of the construction materials and the predictability of both the types and rates of corrosion under DGR conditions. It was concluded that only materials that corrode uniformly under such conditions would be considered.

A double-walled steel-based canister with an outer casing of carbon steel and an inner casing of stainless steel was selected as the most suitable design based on a multicriterial evaluation. Stainless steel corrodes very slowly and is able to fulfil the set lifetime requirements. However, stainless steel can be used only in ambient temperature conditions of below 60°C in the DGR environment (according to current knowledge); above this temperature limit, pitting corrosion may occur. Therefore, the carbon steel outer casing will serve to protect the inner casing until the DGR environment is suitable in terms of the corrosion of the stainless steel material.

Two technical designs (basic and alternative options) are being considered that differ with respect to the inner casing. The basic design assumes separate inner casings for several individual fuel assemblies, which will then be emplaced in one outer casing, whereas the alternative design considers a single inner casing that will house a number of fuel assemblies.

THE EURAD EU PROJECT FUTURE: FUNDAMENTAL UNDERSTANDING OF RADIONUCLIDE RETENTION

SERGEY V. CHURAKOV[1]*, VACLAVA HAVLOVA[2], DIRK BOSBACH[3], NORBERT MAES[4], MARTIN GLAUS[1], CORNELIUS FISCHER[5], RAINER DAHN[1], SYLVAIN GRANGEON[6], MARIA MARQUES FERNANDES[1]
[1] *PSI, Switzerland*
[2] *Řež a.s, Czech Republic*
[3] *FZ-JUELICH, Germany*
[4] *SCK.CEN, Belgium*
[5] *HZDR, Germany*
[6] *BRGM, France*
* *Corresponding author: sergey.churakov@psi.ch*

The work package (WP) FUTURE (FUndamental undersTanding of radionUclide REtention) is dealing with radionuclides retention and transport in repository systems foreseen in clay/clay rock and crystalline rocks. The project integrates more than 20 European Research Entities (RE), Waste Management Organisations (WMO) and Technical Support Organisations (TSO).

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 of repositories in argillaceous and crystalline rocks. 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.

MICHIGAN INTERNATIONAL COPPER ANALOGUE (MICA) PROJECT – ASSESSMENT OF LONG-TERM BEHAVIOUR OF COPPER IN REPOSITORY RELEVANT ENVIRONMENTS

HEINI REIJONEN[1]*, ISMO AALTONEN[1], AXEL LIEBSCHER[2†], CHRISTINA LILJA[3], SIMON NORRIS[4], PETER KEECH[5], NIKITAS DIOMIDIS[6], XUAN LIU[1]

[1] Geological Survey of Finland (GTK), Finland
[2] Federal Company for Radioactive Waste Disposal (BGE), Germany
[3] Swedish Nuclear Fuel and Waste Management Co. (SKB), Sweden
[4] Nuclear Waste Services (NWS), UK
[5] Nuclear Waste Management Organization (NWMO), Canada
[6] National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland
** Corresponding author: heini.reijonen@gtk.fi [†] Presenting author*

One of the key requirements for the deep geological disposal of high-level nuclear waste is the assessment of its long-term performance and safety. As any other barrier of the disposal system, waste containers must fulfil their respective safety functions for the required duration, which can vary from a few hundreds of years to several hundreds of thousands of years, depending on disposal system requirements. Sufficient corrosion resistance under repository conditions is one key requirement for container material to provide complete waste containment. Copper is an important part of many waste packaging and disposal concepts, e.g. KBS-3 developed in Sweden and Finland and Mark II developed in Canada. Much of the data available regarding its behaviour under repository conditions comes from short-term investigations, such as laboratory experiments at different scales and under controlled conditions. Observations made from copper analogue studies provide additional information on copper behaviour during the assessment time scale and under real geological environments. By this, they can support the argumentation in the safety case.

Keweenaw native copper occurrences (Lake Superior, US) reflects more than one billion years of deposit evolution covering various geological (from bedrock to sediments and even anthropogenic mine site remnants) and geochemical environments (e.g., brines to meteoric water, anoxic vs. oxic, sulphur-free vs. sulphur-bearing). These deposits have been mined for a long time and there is a great deal of knowledge related to them as well as samples collected. However, data to be used in process based safety assessments for geological disposal is lacking and no formal review has been made from the geological disposal point of view. The current MICA Project Phase I systematically collect and review the existing literature and data on the Michigan copper analogue sites and available sampling potential. Based on the outcome, MICA Project Phase II will then study and analyse prospective sites and samples to address relevant questions regarding long-term behaviour of copper under disposal conditions. The MICA Project thus will provide a unique complementary data source to estimate processes governing behaviour of metallic copper and to support safety cases.

ENGINEERED BARRIER 200C

Jiří Svoboda[1]*, Radek Vašíček[1], David Mašín[2], Jan Najser[2], František Laufek[3], Lenka Rukavičková[3], Jaroslav Kruis[1], Jiří Šťástka[1], Jiří Mikeš[4]

[1] Czech Technical University in Prague, Czech Republic
[2] Charles University, Charles University
[3] Czech Geological Survey, Czech Republic
[4] Terramed, Czech Republic
** Corresponding author: svobodaj@fsv.cvut.cz*

The current Czech DGR concept is based on temperatures within the engineered barrier system (EBS) of below 100°C. However, an increase in the permitted temperature could lead to significant cost savings. Thus, the Engineered Barrier 200C project is focusing on the investigation of the behaviour of EBS materials and the EBS system at temperature levels of up to 200°C. The project is being led by the Czech Technical University in Prague; the other participants are the Czech Geological Survey, Charles University and Teramed.

The project has two main objectives – enhancement of the safety and decrease of the costs of the DGR.

In order to achieve these objectives, the project involves the conducting of a long-term mock-up type in-situ experiment (KBS-3V like) and accompanying research (geotechnical, mineralogical, geochemical, microbiological) so as to assess the performance of the EBS at high temperatures.

The project commenced in mid-2018 and will continue to the end of 2025. The in-situ experiment was constructed and commenced operation in November 2019 at the Josef URC, Czech Republic. Czech BCV 2017 bentonite is being used in project.

The experiment is modelling a disposal space, i.e. a vertical well (H = °~2m, D = °~0.75m) in a host rock environment. The experiment consists of a cylindrical heater that simulates the waste container (at 200°C) in the middle of the model surrounded by pelletised bentonite with a dry density of ~1450 kg/m^3. The experiment is being saturated by the surrounding groundwater.

Accompanying laboratory research on the bentonite material up to 200°C is also underway. The material is being subjected to temperature loading. Sampling is

being conducted at regular intervals followed by the investigation of the changes in the various properties of the bentonite.
The project outcomes will provide important data for the optimisation of the design of the DGR. In addition to the potential for increasing the temperature tolerance in the DGR, the current lower temperature design will also benefit from the research. The DGR safety analysis will be enhanced via the availability of an updated material database, an improvement in the overall understanding of the behaviour of the EBS and an increased temperature margin.

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SRA Topic 4. Implementation and/or Optimisation

EURAD HITEC – INFLUENCE OF TEMPERATURE ON THE BEHAVIOUR OF CLAY-BASED MATERIALS

MARKUS OLIN[1]*, DRAGAN GRGIC[2] AND JIŘÍ SVOBODA[3]†
[1] *VTT Technical Research Centre of Finland Ltd, FI-02150, Finland*
[2] *University of Lorraine, CNRS, GeoRessources, France*
[3] *CTU in Prague, Centre of Experimental Geotechnics, Czech Republic*
* *Corresponding author: markus.olin@vtt.fi* † *Presenting author*

Most of Deep Geological Repository Safety Cases for high level nuclear waste or spent nuclear fuel limit maximum disposal container surface temperatures to 100°C to protect clay materials from undesirable evolution. Higher temperature limits could have significant advantages such as allow disposal of higher enrichment/burn-up spent fuels, shorter interim storage/cooling requirements, easier (re)packaging of the waste and a reduced disposal facility footprint.
HITEC aims to improve Thermo-Hydro-Mechanical (THM) description of clay based materials at elevated temperatures. The host rock clays will be studied under saturated conditions under 120°C, while buffer bentonites will be studied both in saturated and unsaturated conditions under 150°C.
The host clay formations task deploys knowledge on mechanics of claystones to better evaluate/model possible damage evolution. The characterization of *in-situ* THM behaviour of the host clay rocks is significant for the design and the long-term safety. When temperature increases, the pore water is compressed due to the difference between thermal expansion coefficient of water and the solid skeleton of the rock, leading to an over pressure. In far field, this could induce rock damage and reactivate fractures/faults. In the near field characterised by a fractured zone, this could induce fracture opening or propagation in this fractured zone, altering the permeability.
The buffer bentonite task deploys knowledge on hydro-mechanical behaviour at high temperatures. The investigation of buffer behaviour at high temperatures is important for the design optimization of the underground nuclear waste disposal facility and for the long-term safety. The increase of temperature may result in strong evaporation near the heater and vapor movement towards the external part of the buffer. HITEC seeks to understand if such conditions are tolerable or if they would impair buffer safety functions.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 847593.

OPTIMISATION OF RADIOLOGICAL PROTECTION APPLIED TO THE DEVELOPMENT AND IMPLEMENTATION OF A DGR - THE SITEX.NETWORK STANDPOINT

F. BERNIER[1]*, J. MIKSOVA[2], M. ROCHER[3], V. DETILLEUX[4], W. PFINGSTEN[5], D. PELLEGRINI[3], N. ZELEZNIK[6] AND J. SWAHN[7]
[1] *FANC, Belgium*
[2] *SURO, Czech Republic*
[3] *IRSN, France*
[4] *BelV, Belgium*
[5] *PSI, Switzerland*
[6] *EIMV, Slovenia*
[7] *MKG, Sweden*
* *Corresponding author: frederic.bernier@fanc.fgov.be*

The SITEX.Network (Sustainable network for Independent Technical EXpertise on radioactive waste management) aims at enhancing and fostering cooperation at the international level in the field of safety of radioactive waste management. It acknowledges the important role of the Civil Society in the decision-making process for national programmes, in synergy to the independent expertise of the nuclear Regulatory Authorities.

This poster gives the SITEX.Network position regarding recurring questions about how to meet compliance with the optimisation principle of radiological protection in the context of Deep Geological Repository (DGR) :

- What role does the regulator play?
- How to consider prevailing circumstances?
- How to manage operational and long-term safety optimisations?
- How to balance benefits over harm considering long term uncertainties?
- How to decide that the optimum level of radiological protection has been reached?
- Is there a conflict between reversibility and optimisation?
- How to consider other forms of optimisation as protection against non-radioactive pollutants or minimisation of cost?

STUDY OF EXISTING CHEMICAL DECONTAMINATION METHODS OF RADIOACTIVE METALS WITH A VIEW ON THEIR OPTIMIZATION

A. RIVONKAR[1]*, T. SUZUKI-MURESAN[1], M. ROBIN[1], R. KATONA[2,3], A. ABDELOUAS[1], M. MOKILI[1]

[1] SUBATECH, IMT Atlantique, CNRS/IN2P3, Université de Nantes, BP 20722, 44307 Nantes Cedex 3, France

[2] Department of Radiochemistry and Radioecology, Bio-, Environmental- and Chemical Engineering Research and Development Centre, University of Pannonia. H-8200 Veszprém , 1 Wartha Vince str.

[3] Social Organization for Radioecological Cleanliness, H-8200 Veszprém, II/10 7/A József Attila str.

** Corresponding author: rivonkar@subatech.in2p3.fr*

Nuclear Power is a decarbonized method of power generation and is our best option in the fight against climate change. However, the radioactive waste generated from nuclear power plants and their facilities is a cause of concern. Though the high-level and intermediate level activity wastes are contained in small volumes (≤10%), significant volumes of lower activity wastes are generated. Metallic wastes are a major component of these radioactive wastes, generally made of Stainless steel 316 alloy or Inconel 600. These make up the majority of the primary circuit of a PWR plant. Under the effects of the primary circuit water and irradiation, these components corrode and the corrosion products can be activated, transported throughout the circuit, and deposited on the surface of other metal components, causing contamination of the latter. The contamination can be adsorbed on the surface but can also diffuse in the oxide layers. The oxide layer is composed of an inner layer of Cr oxide under a layer of Ni and Fe oxide. Chemical decontamination is the preferred form of treatment due to the possibility of decontamination of difficult geometries. In order to decontaminate these materials, it is important to dissolve the oxide layers and a few microns of base metal. Some existing chemical methods including Chemical Oxidation Reduction Decontamination (CORD) and Metal Decontamination by Oxidation using Cerium (MEDOC) are studied and a few parameters to be optimized are identified to improve their efficiency. Surrogate steel and Inconel samples will be tested to optimize the processes. These samples are created by SORC, as a part of the PREDIS European project, using water vapor and high temperature after sample preparation. The optimization steps will include reducing the volumes or treatment strategies for the effluents while accounting for the Waste Acceptance Criteria (WAC) for nuclear waste.

SUPPORTING IMPLEMENTATION AND OPTIMISATION OF NUCLEAR WASTE DISPOSAL BY DEVELOPING AND IMPROVING NUMERICAL METHODS AND TOOLS FOR MODELLING COUPLED PROCESSES

F. CLARET[1]*, G. PEPIN[2], C. CANCES[3], O. KOLDITZ[4], N. PRASIANAKIS[5], A. BAKSAY[6], D. LUKIN[7]

[1] BRGM, France

[2] Andra, France,

[3] INRIA, France,

[4] UFZ, Germany,

[5] PSI, Switzerland,

[6] TS Enercon, Hungary,

[7] SURAO, Czech Republic

** Corresponding author: f.claret@brgm.fr*

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, since about two years a work package called **D**evelopment and Improvement **O**f **NU**merical methods and **T**ools for modelling coupled processes **(DONUT)** has been launched within the EURAD project. Some examples that covered the first finding in the technical tasks (2,3 and 4) of DONUT will be shown. In addition, carried out benchmarking initiatives (task 5) will be discussed.

THE ROLE OF EXCELLENT SCIENCE IN GEOLOGICAL DISPOSAL SYSTEM OPTIMIZATION – VIEW AND PERSPECTIVES FROM EURADSCIENCE

CHRISTOPHE BRUGGEMAN[1]*, MARCUS ALTMAIER[2] AND DANIEL GALSON[3]
[1] *SCK CEN, Mol, Belgium*
[2] *INE-KIT, Karlsruhe, Germany*
[3] *Galson Sciences Ltd, Oakham, UK*
** Corresponding author: christophe.bruggeman@sckcen.be*

EuradScience is an independent, cross-disciplinary and inclusive network of European research organisations established with the aim of providing and further developing the scientific basis underlying the safe disposal of radioactive waste. EuradScience has a key function in maintaining and further developing scientific competence and infrastructure in the field, and promotes innovation in science, technology, analytical methods, and other means of building and deepening competence. EuradScience sees itself as complementary to the existing Networks IGD-TP and SITEX, and will develop its own strategic research agenda (SRA) to manage key areas of interest and implementation priorities.

Optimisation is a central element of the stepwise design, construction, and operation of a geological disposal facility. Within this context, optimisation needs to be understood *in the broadest sense, as an iterative, systematic and transparent evaluation of options (…) for enhancing the protective capabilities of the system and for reducing impacts (radiological and others)* (ICRP 122, 2013). To allow a comparison of siting, design, and operational options, subsystem and system performance need to be evaluated (including the impacts of naturally occurring features, events and processes). In addition, design and siting of the facility should be optimised to reduce risks associated with future inadvertent human intrusion. The International Commission on Radiological Protection recommends a management system that integrates safety, health, environmental, security, quality, and economic elements, with safety being fundamental (ICRP 122, 2013).

Advances in our understanding of the evolution of, and interactions between, different components of a geological disposal system play a key role in the iterative evaluation of optimisation, as they help in reducing conservatisms and elucidating uncertainties. Scientific or technological breakthroughs on innovative materials and disposal concepts could fundamentally (and positively) affect disposal system design, and the associated safety functions. In this contribution from EuradScience, we discuss selected cases that illustrate the above points in view of optimisation options and/or requirements, highlighting the role of excellent science in this process.

DEVELOPMENT OF DECONTAMINATION PROCESS FOR METALLIC RADIOACTIVE EFFLUENTS USING HYDROXYDE PRECIPITATION

M. ROBIN[1]*, A. RIVONKAR[1], T. SUZUKI-MURESAN[1], A. ABDELOUAS[1], M. MOKILI[1]
[1] *SUBATECH, IMT Atlantique, CNRS/IN2P3, Université de Nantes, BP 20722, 44307 Nantes Cedex 3, France*
** Corresponding author: robin@subatech.in2p3.fr*

Nuclear power is an important method of generating electricity, producing very little environmentally damaging carbon waste. However, other types of waste are produced during its operation, radioactive waste. Most of the waste produced is low or medium level, generated during maintenance and dismantling operations, and largely composed of contaminated metals. One of the components of the primary circuit generates a significant amount of waste, the steam generator. It consists of a tubular part made of stainless steel or Inconel, in direct contact with the water of the primary circuit. To safely recycle or declassify these materials, decontamination is necessary. When carried out chemically (CORD and MEDOC processes), the contaminated oxide layer is dissolved and removed from the metallic materials. These techniques are very effective but generate a very large quantity of radioactive effluent, which must be treated and decontaminated before conditioning. For this purpose, it is possible to use specific resins. However, this process is very costly because of the specificity of the resins and the complexity of the effluents, which are composed of many radionuclides (^{54}Mn; ^{55}Fe; ^{60}Co; ^{63}Ni; ^{65}Zn; ^{144}Ce and more). Therefore, the objective is to reduce the volume of effluent and the quantity of metals as much as possible before passing through the resin. To do this, it is possible

to precipitate and co-precipitate the metals in the solution in the form of hydroxides ($M^{n+}(OH)_n$) by adjusting the pH of the radioactive solution. Initially, the tests were carried out on synthetic samples. The removal efficiency of the different metals present was studied according to two different precipitation pH values (8.5 and 12). Further precipitation tests are planned to optimize this metal decontamination to best meet the waste acceptability criteria (WAC). This subject is part of the European PREDIS project about the metallic material treatment.

OPTIMIZATION OF QUALITY ASSURED THERMODYNAMIC UNDERSTANDING FOR USE IN PERFORMANCE ASSESSMENT OF NUCLEAR WASTE DISPOSAL

X. GAONA[1]*, B. GRAMBOW[2], M. ALTMAIER[1], L. DURO[3], D. BOSBACH[4], H. GECKEIS[1]

[1] Institute for Nuclear Waste Disposal, Karlsruhe Institute of Technology, Karlsruhe, Germany

[2] Subatech (CNRS-IN2P2, University of Nantes, IMT Atlantique), Nantes, France

[3] Amphos21, Barcelona, Spain

[4] Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research - IEK-6: Nuclear Waste Management and Reactor Safety, Jülich, Germany

** Corresponding author: xavier.gaona@kit.edu*

Thermodynamic and geochemical model calculations are important tools used in the context of safety case development and safety analyses of repositories for nuclear waste. 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" [1].

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 but also offering overlap with predisposal topics. 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 and associated mixing models, 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 to further discuss this topic.

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 to close existing data gaps and 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 model calculations in predictions underpinning the performance of various disposal configurations, for safety analyses and the development of the Safety Case. Providing thermodynamic data and correct speciation models for geochemical calculations is a topic of cross-cutting interest for several activities in the nuclear waste disposal context and can substantially benefit from a joint and targeted international research approach.

[1] JOPRAD 2017, Deliverable n 4.2, Programme Document – The Scientific and Technical Basis of a Future Joint Programme on Radioactive Waste Management and Disposal, Work Package 4.

OPTIMISATION OF DISPOSAL CONCEPTS FOR A DEEP GEOLOGICAL REPOSITORY

SUSIE HARDIE[1]* AND IAN MCKINLEY[2]

[1] *Schwarz hara Consult, 6774 Tschagguns, Vorarlberg, Austria*

[2] *McKinley Consulting, 5408, Ennetbaden, Aargau, Switzerland*

** Corresponding author: susie@schwarzharaconsult.at*

Many of the repository designs developed in the more advanced programmes are purpose-built structures for limited inventories, excavated deep underground, and characterised by very high-performance engineered barriers. This results from the persistence of concepts originally developed decades ago that focussed on post-closure safety, and hence there was little consideration of practicality / operational safety. These concepts were also developed at a time when sustainability and environmental impact were not discussed at all. Therefore, despite the small waste volumes involved, such facilities often have large footprints of several square kilometres and utilise large quantities of materials. These materials are often inherently valuable, for example copper, or are difficult to work with and need to be transported over large distances, like bentonite clay. There is clearly great potential for design optimisation, but this is often blocked by a combination of institutional inertia and the impact of the "sunk cost fallacy", resulting from the huge past expenditure in R&D based on old designs. Especially for current environmental and worker safety ("vision zero") concerns and the novel boundary conditions resulting from volunteer siting, a more holistic approach to concept optimisation is required. Here we discuss various aspects for consideration when approaching repository concept optimisation.

OPTIMIZATION METHODOLOGY BASED ON A PROBABILISTIC APPROACH FOR THE DESIGN OF RADIOACTIVE WASTE DISPOSAL FACILITIES

RYO NAKABAYASHI[1]*, DAISUKE SUGIYAMA[1] AND SHINGO TANAKA[1]

[1] *Sustainable System Research Laboratory, Central Research Institute of Electric Power Industry*

** Corresponding author: r-naka@criepi.denken.or.jp*

In Japan, the regulation for low-level radioactive waste disposal facilities was revised in October 2021. The revised regulation requires facility design based on the concepts of ALARA (as low as reasonably achievable) and BAT (best available technique). Although no regulations have been established for the design of geological disposal facilities, it is expected that facility design based on the ALARA and BAT concepts would be required, similarly to the regulation for low-level radioactive waste disposal facilities. The optimization of radiological protection in radioactive waste disposal during the post-closure of disposal facilities can be recognized as the process of determining measures for protection and safety to keep the probability and magnitude of exposure as low as reasonably achievable, taking into account economic and social factors. In this study, we propose an optimization methodology based on a probabilistic approach for the design of radioactive waste disposal facilities in accordance with the logic of international radiological protection discussed by ICRP and IAEA. In this methodology, the uncertainty in barrier performance caused by engineering measures of a disposal facility is expressed as a probability distribution, and the probability distribution of doses is obtained through a probabilistic safety assessment using this as input. As a result, quantitative comparisons between design options can be made using not only the safety of the facility (expressed by the mode of the probability distribution of doses) but also the robustness of the assessment (expressed by the width of the probability distribution of doses) as indices, which enables a reasonable discussion of which engineering measures to spend resources on to increase safety and robustness within the limited resources of the disposal project. These features make it a reasonable methodology that can contribute to the design of disposal facilities in line with the concept of optimization.

A SERIES OF EXPERIMENTS AIMED AT THE VERIFICATION OF THE BEHAVIOUR OF ENGINEERED BARRIERS

JIŘÍ ŠŤÁSTKA[1]*

[1] Czech Technical University in Prague, Faculty of Civil Engineering, Centre of Experimental Geotechnics, Thákurova 7, Praha 6, 166 29

** Corresponding author: jiri.stastka@fsv.cvut.cz*

Several in-situ experiments have been conducted to date aimed at improving the understanding of Engineered Barrier System (EBS) that will help to ensure the safe disposal of spent nuclear fuel. Furthermore, important experience regarding the construction of related experiments has been gained, and experiments have been conducted at a scale of 1:1 by means of gradual upscaling from smaller-scale experiments. The aim of this paper is to open up a discussion on whether it is possible to combine the experience gained from experiments conducted internationally and to propose a series of similar experiments that would be performed in a number of underground laboratories with the participation of countries that have no experience with

similar in-situ research. The objective of this international and interdisciplinary discussion would then be to determine the same approach towards the verification of the behaviour of the EBS under various conditions. Such cooperation would provide the opportunity to compare the results attained since the experiments would have had the same dimensions and, for example, would have employed the same previously verified monitoring systems (the same sensor locations, types of sensors, etc.). This would also greatly assist in terms of the comparison of the results and the calibration of mathematical models. Moreover, it is assumed that, for example, the types of materials studied in the respective sets of experiments might differ depending on individual requirements. The project work plan would further consider the following main points: 1. the presentation of the proposal (this paper); 2. the creation of an international team; 3. the discussion of solutions for, and the objectives of, the experiments; 4. the design and construction solution for a series of experiments; 5. critical discussions aimed at determining potential improvements to the proposal; 6. the selection of suitable underground research laboratories according to the various national requirements; 7. the conducting of the experiments, the validation of mathematical models and the comparison of the results obtained; 8. the analysis and evaluation of the experiments; 9. the identification of follow-up research.

SRA Topic 6. Monitoring

MODATS – MONITORING EQUIPMENT AND DATA TREATMENT FOR SAFE REPOSITORY OPERATION AND STAGED CLOSURE

JOHAN BERTRAND[1]*, MARTIN SCHOENBALL[2], MATT WHITE[3], KATERYNA FUZIK[4], JOHANNA HANSEN[5], EDGAR BOHNER[6] AND MANSUETO MOROSINI[7]

[1] *Andra, France*
[2] *Nagra, Switzerland*
[3] *Galson Sciences Ltd, UK*
[4] *SSTC-NRS, Ukraine*
[5] *POSIVA, Finland*
[6] *VTT, Finland*
[7] *SKB, Sweden*
* *Corresponding author: johan.bertrand@andra.fr*

Four major international collaborative projects have developed and documented monitoring strategies and monitoring programme methodologies, and undertaken research on advanced monitoring technologies and strategies:

- IAEA TECDOC on monitoring of geological repositories for high-level waste, IAEA, 2001;
- European Thematic Network on the role of monitoring in a phased approach to geological disposal of radioactive waste, EC, 2004;
- the EC Monitoring Developments for Safe Repository Operation and Staged Closure (MoDeRn) Project, EC, 2014; and
- the EC Modern2020 Project, EC, 2019) have.

These projects have developed the main characteristics of monitoring programmes to support the licence application and repository operation.

However, these projects have not focused on the practical aspects of monitoring programmes, in particular, understanding how data will be acquired, treated, managed, and used to enhance system understanding, and consideration of the layout (optimisation) of monitoring systems to deliver the requirements associated with these needs. The ambition of this work package of the EURAD project is therefore to consolidate the implementation strategy for monitoring systems in the facilities (at different stages) by developing methods through which confidence can be demonstrated in the data acquired and benefits derived for repository implementation.

The overall objective of MODATS R&D WP is to evaluate, develop and describe these methods and technologies, and to investigate the means to measure, treat analyse and manage data in a consistent matter. The ambition of the project about monitoring data is to address the detailed questions regarding data that have been identified, but not resolved in previous EC projects. This R&D will be supported from information from existing case studies, including five Reference Experiments that provide information on how monitoring has been conducted in significant underground research laboratory (URL) projects:

- AHA1605 (Andra): AHA1605 is an *in situ* HLW disposal cell demonstrator in Andra's Bure URL dedicated to the demonstration and evaluation of the monitoring system for the HLW disposal cells in the French disposal concept.
- FE (Nagra): The Full-scale Emplacement (FE) Experiment at the Mont Terri URL simulates aspects of the construction, waste emplacement, backfilling and early-stage evolution of a SF / HLW repository tunnel in a clay-rich formation (Opalinus Clay), using heaters in place of SF / HLW canisters.
- POPLU (POSIVA): The POPLU experiment is a full-scale test of a possible design of a disposal tunnel end plug component of the disposal concept for the spent fuel repository in Olkiluoto (Finland) and Forsmark (Sweden).

- Prototype Repository (SKB): The Prototype Repository is a full-scale field experiment in crystalline rock at a depth of 450 m in the Äspö Hard Rock Laboratory (Äspö HRL). The experiment aims to simulate conditions that are largely relevant to the Swedish/Finnish KBS-3V disposal concept for spent nuclear fuel.
- PRACLAY (EURIDICE): The PRACLAY experiment is a large-scale experiment designed to study the impact of the heat generated by high-level waste on the host clay formation. It also looks at how excavation affects the behaviour of the clay. The experiment is located in the HADES URL (Mol, Belgium) in a dedicated 40-m long gallery simulating a waste disposal gallery.

At the end of the project, a series of guidance documents on, and examples of how, data acquisition, management and treatment can be undertaken during operation will be available for programmes to use in designing monitoring programmes for specific repositories.

SRA Topic 7. Methodologies for Site Characterisation

MULTICRITERIAL SITE ASSESSMENT OF POTENTIAL DEEP GEOLOGICAL REPOSITORY SITES IN THE CZECH REPUBLIC: REQUIREMENTS FOR SITE CHARACTERIZATION TECHNIQUES

LUKÁŠ VONDROVIC[1]*
[1] *SÚRAO, Czech Republic*
** Corresponding author: vondrovic@surao.cz*

Radioactive waste disposal in the Czech Republic is managed by SURAO. In line with the requirements of the Spent Nuclear Fuel and Radioactive Waste Management Concept, SURAO is currently working on an extensive project for the development of a deep geological repository for the permanent disposal of high-level radioactive waste. With respect to the Czech Republic, the DGR will be constructed in a suitable crystalline rock mass around 500 metres below the earth's surface and the commencement of operation is planned for 2065. The current DGR development phase is devoted principally to the determination of the optimum disposal concept and the selection of the most suitable site. In 2020, a total of 9 potential sites were assessed with the aim of reducing their number to 4. Performed evaluation was based on exclusionary and comparative criteria using marks and weights. The applied methodology distinguished relatively better sites which were later approved by government for further exploration. The future performed works on sites are in planning stage now applying the results of site assessment in order to reduce uncertainty described in current evaluation.

SRA Topic 8. Strategy for Repository Project Development

ERDO – DUAL-TRACK FOR OPTIMIZED RADIOACTIVE WASTE MANAGEMENT

MARJA VUORIO[1]*, EWOUD VERHOEF[1], OLE KASTBJERG NIELSEN[2], HÅVARD KRISTIANSEN[3]
[1] *COVRA N.V.Postbus 202, 4380 AE Vlissingen, Netherlands*
[2] *DEKOM Postcenter 15, 4000 Roskilde, Denmark*
[3] *NND Postboks 905 Grønland, 1759 Halden, Norway*
** Corresponding author: marja.vuorio@covra.nl*

The ERDO Association (Association for Multinational Radioactive Waste Solutions) is an association of currently eight European national organizations with a mission to work together to address the common challenges of safely managing the radioactive wastes in their countries. Each Member State is responsible for ensuring the safety of spent fuel and other radioactive waste. For European countries with only small amounts of waste to manage, each constructing their own repository is a major challenge. Article XI of the Joint Convention states that countries can under certain circumstances fulfil this responsibility by sharing a disposal facility. A multinational disposal facility is of particular interest to countries with relatively small inventories of radioactive waste. The obvious solution is for countries to share the burden in the development of one or more regional repositories; partner countries could save hundreds of millions of EUR by sharing development and operation costs. Many small-inventory countries have therefore adopted a dual-track approach, where domestic and multinational solutions are pursued in parallel. Shared solutions have been researched over the last 20 years and much of the knowledge base lies within the ERDO Association, which was established in 2021 in the Netherlands by COVRA (NL), NND (NO), and DEKOM (DK), and to date ARAO (SI), Fond-NEK (HR), ENEA (IT), the Ministry of Climate and Environment (PL) and ONDRAF/NIRAS (BE) have joined. ERDO is an

association whose purpose is to act as a knowledge centre for both national and multinational solutions. ERDO envisages a long-term programme of shared activities that aim to spin-off concrete solutions to waste management problems and eventually to enable progress towards shared facilities.

TOWARDS HARMONISED PRACTICES, REGULATIONS AND STANDARDS IN WASTE MANAGEMENT AND DECOMMISSIONING (EU-HARPERS)

RÉKA SZŐKE[1]*, ERIKA HOLT[2†], ELKE JACOPS[3]
[1] *IFE Institute for Energy Technology, Norway*
[2] *VTT Technical Research Centre of Finland, Finland*
[3] *SCK CEN Belgian nuclear research centre, Belgium*
* *Corresponding author: reka.szoke@ife.no* † *Presenting author*

The Euratom 3-year project HARPERS: HARmonised PracticEs, Regulations and Standards in waste management and decommissioning" aims to establish and clarify the benefits and added value of more aligned and harmonised regulations, practices and standards in decommissioning and radioactive waste management, including possibilities for shared processing, storage and disposal facilities between Member States (MS). Directly addresses the SNETP SRIA regarding decommissioning, dismantling and waste management high level topics on (i) minimisation of waste production, (ii) development of new technologies and approaches to deliver decommissioning safer, cheaper, faster and sustainable, to enhance waste treatment processes, (iii) common licensing rules and procedures of new technologies and (iv) common regulations and standards at the EU level. Complementary engagement with MS national programs and the wider European Community, including ERDO, ENSREG, WENRA, IAEA, OECD-NEA, IGD-TP, ETSON, SITEX and DigiDecom is planned. The EU-HARPERS project aims to reinforce the activities of the European Joint Programme EURAD, PREDIS and the SHARE projects. The HARPERS project will identify the relevant regulatory differences across MS, assess the rationale for the identified regulatory differences and establish the potential for their harmonisation relative to cross border services /facilities for RWM, moving to a circular economy in RWM and implementation of advanced technologies in RWM. The project will evaluate the Strengths, Weaknesses, Opportunities and Threats with respect to the harmonisation of the identified regulatory differences and produce reports on harmonising regulatory systems in Europe. The TECOP (Technical, Economic, Commercial, Operational, or Political) process will identify a multitude of potential changes, which will require further review in conjunction with Strategic tasks (WP2) on business impacts for stakeholders across all MS, focused on strategic impacts across EU. This presentation will give a short overview on EU_HARPERS project and highlight the achievements of the first 4 months, and encourage dialogue with IGD-TP members for additional feedback in the critical first-year (phase one) of the project for directing the second phase work. The HARPERS project includes 25 consortium partners representing 13 Member States, in addition to industrial partners, TSOs and regulators engaged via the end user group to steer the project direction to focus on their most pressing needs and challenges. Details of the project can be followed at https://harpers-h2020.eu/.

SRA Topic 9. Knowledge Management

EURAD: THE EUROPEAN JOINT COLLABORATION TOWARDS SAFE RADIOACTIVE MANAGEMENT

LOUISE THÉODON[1]*, TARA BEATTIE[2], PAUL CARBOL[3], MICHELLE COWLEY[5], BERND GRAMBOW[4], ELISABETH SALAT[5] AND PIET ZUIDEMA[7]
[1] *Andra, France*
[2] *TB Environmental, UK*
[3] *European Commission, JRC, Germany*
[4] *Subatech, IMT Atlantique, France*
[5] *IRSN, France*
[6] *Nuclear Waste Services,, UK*
[7] *Zuidema Consult, Switzerland*
* *Corresponding author: louise.theodon@andra.fr*

In line with the European waste directive, the European Joint Programme on radioactive waste management (EURAD) was launched in 2019. EURAD aims to make a step change in European collaboration between advanced and early-stage programmes as well as between waste management organisations (WMOs) driving for a timely establishment of geological disposal solutions, regulatory technical support organisations (TSOs) supporting independent regulatory review of geological disposal safety and nationally funded research entities (REs) striving to deliver scientific

excellence to support disposal programme implementation.
Co-financed by the European Commission, EURAD gathers 113 organisations from across 23 EU countries and 3 International Partners. All parties involved are guided by a willingness to share and support a central long-term vision, a common roadmap for RWM and a shared strategic research agenda.
Based on the activities and priorities of common interest of the three Colleges: WMO, TSO and RE, it aims to generate new and better manage existing knowledge and support Member States at their different stages of disposal implementation. EURAD focuses on scientific and technological R&D, closely aligned to implementation needs, safety considerations and an ambitious knowledge management programme.
EURAD's vision is being deployed through a 5-years phase broken down into a set of 17 work packages. To deliver against EURAD's objectives, five different activity types have been adopted: R&D, Strategic Studies, Knowledge Management, Interactions with Civil Society and Coordination/Dissemination.
Most work packages have now reached their third year of implementation and are delivering encouraging results. The scientific excellence developed in EURAD created new knowledge, educated scientists and allow to broaden the capabilities
The ambitious goals of EURAD require a long-term perspective over another ten or more years. Building confidence, trust and common understanding among the various categories of actors is a cornerstone of future success and for the next phase of the European Joint Programme.

EURAD KNOWLEDGE MANAGEMENT & NETWORKING PROGRAMME

PAUL CARBOL[1]*, TARA BEATTIE[2], BERND GRAMBOW[3], TOBIAS KNUUTI[4], LOUISE THÉODON[5], PIET ZUIDEMA[6]
[1]European Commission, JRC, Germany
[2]TB Environmental, UK
[3]Subatech, IMT Atlantique, France
[4]BGE, Germany
[5]Andra, France
[6]Zuidema Consult, Switzerland
** Corresponding author: paul.carbol@ec.europa.eu*

Knowledge Management (KM) is a core activity of the European Joint Programme on Radioactive Waste Management (EURAD) which has identified mechanisms and established an overarching strategy for a long-term, rolling Knowledge Management and Networking Programme (NM&NP). This strategy recognises the unique platform offered by EURAD and its access to existing knowledge structures and networks, as over 30 years of developed radioactive waste management (RWM) knowledge is accessible in the various documents, procedures and processes, organisations, and people of the broad RWM community. The role of the EURAD KM&NP is therefore to better harvest this existing knowledge and integrate with it newly created knowledge, giving weight to:

- Improved orientation of knowledge – how knowledge contributes to specific implementation goals and activities in radioactive waste management;
- Improved definition of needed competences – what level of proficiency is needed and available to support programmes;
- Improving accessibility to knowledge – by signposting to people and documents, use of a common structure, and digitisation activities to improve re-use;
- Improving socialisation, training, and networking – how knowledge is transferred and spread.

To deliver this strategy, EURAD has established the EURAD Roadmap as a central tool for organising its KM&NP 2020-2024. This is a roadmap for the implementation of radioactive waste management (RWM) leading to geological disposal, using the experiences of advanced EU programmes. The roadmap captures generic best practice in its presentation of programme Phasing and Thematic goals breakdown structure covering: Programme Management, Predisposal, Engineered Barrier Systems, Geoscience, Design and Optimisation, Siting and Licensing, and Safety Case. EURAD is now at a stage of populating the roadmap with existing knowledge which is delivered through dedicated KM work packages (WP11 State of Knowledge, WP12 Guidance, WP13 Training and Mobility) and more broadly by the networking and new knowledge generation embedded throughout all EURAD activities.

STATE-OF-KNOWLEDGE & GUIDANCE IN EURAD KNOWLEDGE MANAGEMENT (WORK PACKAGES 11 STATE-OF-KNOWLEDGE & 12 GUIDANCE)

ALEXANDRU TATOMIR[1], TOBIAS KNUUTI[1], ASTRID GÖBEL[1]*, CAROLA FRANZEN[2], DINARA ABBASOVA[2], THURO ARNOLD[2], VINZENZ BRENDLER[2], KATERYNA FUZIK[3], JIŘÍ FALTEJSEK[4], BÁLINT NŐS[5], NADJA ŽELEZNIK[6], JITKA MIKŠOVÁ[7]

[1] Bundesgesellschaft für Endlagerung mbH (BGE mbH), Peine, 31224, Germany
[2] Helmholtz-Zentrum Dresden - Rossendorf e. V. (HZDR), Dresden, 01328, Germany
[3] State Enterprise State Scientific And Technical Center For Nuclear And Radiation Safety (SSTC NRS), Kiev, 03142, Ukraine
[4] SÚRAO, Praha, 110 00, Czech Republic
[5] Public Limited Company for Radioactive Waste Management, Budaörs, 52040, Hungary
[6] Elektroinštitut Milan Vidmar, Ljubljana, 1000, Slovenia
[7] National Radiation Protection Institute, Praha, 140 00, Czech Republic
** Corresponding author: astrid.goebel@bge.de*

In the European Joint Programme on Radioactive Waste Management (RWM) - EURAD - over 100 organisations from different countries and backgrounds work together to support member states with the implementation of their national RWM programmes. For this task, it is recognised by EURAD that Knowledge Management (KM) is of utmost importance. This can be seen in a number of dedicated activities. One essential activity is the capture of the current State-of-Knowledge (SoK) in the field of RWM and its transfer to end-users. This is done by different types of Knowledge Documents that are authored by recognised experts and made available through a dedicated IT-tool (e.g. a Wiki). These experts are asked to share their view on the most relevant knowledge in a specific topic, highlighting safety functions and operational aspects. Furthermore, signposting to pre-existing documents allows to identify important sources for further reading (State-of-the-Art Documents, Scientific Papers, etc.). The hierarchy of the KM documents (Theme Overview, Domain Insight, State-of-Knowledge, Guidance) is closely linked to the generic EURAD Roadmap/GBS (Goals Breakdown Structure), which provides a hierarchical structure that facilitates definition, organisation and communication of topics. All of this allows to capture and present knowledge on the level of detail that is required by the end-user, from a broad overview down to an increasing level of detail (pyramid of knowledge). To ensure the quality and consistency of the documents with the overall EURAD KM approach, quality assurance and editorial procedures are applied. Collection of end-user feedback will aid the optimisation and further development of the KM activities. All these activities will contribute to a useful and end-user friendly EURAD KM programme, that is designed to be operational well beyond the runtime of EURAD-1. This poster will provide further insight into the approaches, status of work and an outlook on future activities.

EURAD'S TRAINING & MOBILITY AND INTERACTIONS WITH CIVIL SOCIETY

NIELS BELMANS[1], JULIEN DEWOGHÉLAËRE[2], JITKA MIKŠOVÁ[3]*, PAUL CARBOL[4], MICHÈLE COECK[1]

[1] SCK CEN Academy, Belgian Nuclear Research Centre SCK, Mol, 2400, Belgium;
[2] MUTADIS, Paris, 75010, France
[3] SÚRO, Prague, 140 00, Czech Republic
[4] European Commission, JRC, Germany
** Corresponding author: jitka.miksova@suro.cz*

The European Joint Programme on Radioactive Waste Management (RWM) (EURAD – H2020, Grant Agreement N°847593) aims to achieve a step change in European collaboration towards safe RWM through the development of a robust and sustained science, technology and knowledge management (KM) programme.

The main goals of KM within EURAD are to (i) preserve generated knowledge, (ii) transfer knowledge towards Member States with early-stage RWM programmes, (iii) transfer knowledge between generations, and (iv) disseminate knowledge.

EURAD aids in achieving these goals through the 'School of Radioactive Waste Management'. The School supports competence building in RWM matters. Its end-users are students, professionals and experts in RWM, as well as civil society (CS). Four distinguished initiatives can be highlighted: the organization of training courses, the hosting of webinars, the coordination of a mobility programme, and actions to support the EURAD PhD community.

A portfolio of basic and specialized training courses was set up containing an up-to-date list of existing training initiatives, newly developed trainings are based on a gap analysis performed in frame of priorities and end-user needs.

Webinars are hosted on a regular basis. These are short, informal online get-togethers, which are open to all. The topics discussed range from very specialized scientific matters to more general and overarching themes.

Mobility Programme allows its beneficiaries to perform mobility actions in order to improve necessary practical skills.

As future key actors in the field of RWM, EURAD PhD community is strongly supported and can benefit from early networking with established experts.

The School is also aiming at innovative ways for close exchange between experts and CS based on a model of pluralistic interactions. It consists of translating scientific/technical results for exchanging with a group of CS representatives and improving the mutual understanding on RD&D performed to support the development of safe solutions for RWM.

KNOWLEDGE MANAGEMENT IN PRE-DISPOSAL OF RADIOACTIVE WASTE (PREDIS EU PROJECT)

VACLAVA HAVLOVA[1]*, ALBA VALLS[2], PAUL CARBOL[3], ERIKA HOLT[4], MARIA OKSA[4], ANTHONY BANFORD[5], ABDESSELAM ABDELOUS[6], MAXIME FOURNIER[7], THIERRY MENNECART[8], ERNST NIEDERLEITHINGER[9], JENNY KENT[10] AND ROSA LO FRANO[11]

[1] UJV, Czech Republic
[2] Amphos21, Spain
[1] European Commission, JRC, Germany
[4] VTT, Finland
[5] NNL, UK
[6] Subatech, France
[7] CEA, France
[8] SCK.CEN, Belgium
[9] BAM, Germany
[10] Galson Sciences Ltd, UK
[11] University of Pisa, Italy
** Corresponding author: vaclava.havlova@ujv.cz*

Knowledge management (KM) is critical to ensure safe and efficient radioactive waste management over the whole lifecycle. Moreover, KM is recognized as a key part of the Radioactive Waste (RW) implementation process and has gained interest in the last years.

The EC is encouraging use KM as a tool to improve the progress of EU Member States' implementation of their national RW disposal programmes. KM is crucial for the implementation of a RW disposal facility (licensing, constructing, operating and closing processes). Each individual phase of a RW management program from waste generation through processing, disposal and repository closure, will require continuous RD&D development with improved process understanding and KM.

The 'Pre-Disposal Management of Radioactive Waste' project (PREDIS; 2020 – 2024; grant agreement N°945098) focusses on the development and implementation of activities for predisposal treatment of RW streams other than SNF and high-level RW.

PREDIS State of knowledge documents represent an integral part of the EURAD Roadmap as Pre-disposal has been identified as one of the EURAD Roadmap Themes – Predisposal activities prior to geological disposal (Theme 2; https://www.ejp-eurad.eu/roadmap) and will coordinate the production of the Domain inside (DI) documents within Theme 2. The first DI documents is already available.

The PREDIS training programme aims to identify and fill training gaps within the entire pre-disposal community. PREDIS launched a survey to organisations both internal and external to the project to identify unfilled training needs and to find candidate organisations willing and able to provide training. The first training actions have been already taken.

The PREDIS mobility programme aims at facilitating cooperation between partners and Member States, and the acquisition of knowledge needed to develop a professional career in the different subjects related to the predisposal of radioactive waste.

The PREDIS mobility programme is primarily (but not exclusively) targeted towards young professionals.

FACILITATING KNOWLEDGE TRANSFER BETWEEN MORE ADVANCED PROGRAMMES AND EARLY-STAGE PROGRAMMES: IAEA'S ROADMAP FOR IMPLEMENTING A GEOLOGICAL REPOSITORY PROGRAMME

KARINA LANGE[1]*, STEFAN J. MAYER[1], HAERYONG JUNG[2]

[1] International Atomic Energy Agency, Vienna, Austria
[2] KORAD, South Korea
** Corresponding author: k.lange@iaea.org*

In view of the substantial progress in deep geological programmes worldwide and to share advanced programmes with Member States that are newly embarking on a geological repository initiative, the IAEA has produced a technical document entitled 'Roadmap for Implementing a Geological Disposal Programme'. The new document is at an advanced draft stage and is expected to appear in 2023. The publication provides a roadmap for the stepwise development and implementation of a geological disposal programme consistent with international experience. It is intended mainly to support radioactive waste management

organizations toward their responsibility for the final disposal of high level and intermediate level waste in a geological repository. It also promotes collaboration and sharing of knowledge amongst the various stakeholders in radioactive waste management.

The activities and deliverables for each phase of a geological repository programme are described with an emphasis on how these activities support decision making within each phase and for proceeding to the subsequent phase. The roadmap is generic in nature, describing only the activities common to each phase but not specifying the method to complete the activity or time allotment. Rather, it is presented to reflect good practice and lessons learned, thereby aiming to help reduce risks for new programmes. The publication also captures knowledge (case studies) of how several advanced programmes have progressed along their respective roadmaps toward siting, constructing, and operation of a geological repository. This document forms the basis of a training course that is given to countries embarking on a nuclear programme and those at earlier stages in the development of a deep geological repository programme.

Symposium Attendees

First Name	Last Name	Organisation	Email
Tomas	Almberger	SKB	tomas.almberger@skb.se
Marcus	Altmaier	KIT-INE	marcus.altmaier@kit.edu
Eva	Andersson	SKB	Eva.Andersson@skb.se
Lucy	Bailey	RWM	Lucy.bailey@nda.gov.uk
Attila	Baksay	TS Enercon Ltd	baksay@tsenercon.hu
Tamara	Baldwin	Galson Sciences Ltd	tdb@galson-sciences.co.uk
Frédéric	Bernier	FANC	frederic.bernier@fanc.fgov.be
Johan	Bertrand	Andra	johan.bertrand@andra.fr
Ingo	Blechschmidt	NAGRA	ingo.blechschmidt@nagra.ch
Jean-Michel	Bosgiraud	ANDRA	jean-michel.bosgiraud@andra.fr
Zoltan	Bothi	WSP-Golder	zoltan.bothi@wsp.com
Ralf	Brauchler	AFRY Switzerland Ltd	ralf.brauchler@afry.com
Matthias	Braun	NAGRA	matthias.braun@nagra.ch
Annika	Breu	NAGRA	annika.breu@nagra.ch
Christophe	Bruggeman	SCK CEN	christophe.bruggeman@sckcen.be
Gunnar	Buckau	NucCon	gunnar@buckau.se
Alexandr	Butovič	SATRA, spol. s r.o.	Alexandr.butovic@satra.cz
Emma	Cairns	Quintessa Ltd	emmacairns@quintessa.org
Paul	Carbol	European Commission	paul.carbol@ec.europa.eu
Nadia	Cherubini	ENEA	nadia.cherubini@enea.it
Massimo	Chiappini	Istituto Nazionale di Geofisica e Vulcanologia (INGV)	massimo.chiappini@ingv.it
Sergey	Churakov	Paul Scherrer Institute	sergey.churakov@psi.ch
Francis	Claret	BRGM	f.claret@brgm.fr
Alastair	Clark	MCM Environmental Services Ltd	alastair.clark@mcmenvironmental.co.uk
Miguel	Cuñado	ENRESA	
Gyula	Dankó	PURAM (RHK)	danko.gyula@rhk.hu
Christophe	Depaus	ONDRAF-NIRAS	c.depaus@nirond.be
Julie	Didierjean	ANDRA	julie.didierjean@andra.fr
Nikitas	Diomidis	NAGRA	nikitas.diomidis@nagra.ch
Markéta	Dohnálková	SURAO	dohnalkova@surao.cz
Stephen	Dooley	Nuclear Waste Services	stephen.dooley@nda.gov.uk
Julia	Dose	BGE	julia.dose@bge.de
Lara	Duro	Amphos 21	lara.duro@amphos21.com
Heinz	Ehrbar	Heinz Ehrbar Partners Llc.	heinz.ehrbar@heinzehrbarpartners.com
Joaquín	Farias - Seifert	Enresa	jfas@enresa.es

First Name	Last Name	Organisation	Email
Tai	Funada	Marubeni Utility Services	funada-tai@marubeni.com
Daniel	Galson	Galson Sciences Ltd	dag2@galson-sciences.co.uk
Xavier	Gaona	KIT-INE	xavier.gaona@kit.edu
David	García Cobos	Amphos 21	david.garcia@amphos21.com
José Luis	García-Siñeriz	Amberg Infraestructuras S.A.	jgarciasineriz@amberg.es
Irina	Gaus	NAGRA	irina.gaus@nagra.ch
Astrid	Göbel	BGE mbH	astrid.goebel@bge.de
Pär	Grahm	SKB	par.grahm@skb.se
Bernd	Grambow	COSIRAD	grambow@subatech.in2p3.fr
Peter	Grünberg	Nagra	peter.gruenberg@nagra.ch
Typhaine	Guillemot	Nagra	typhaine.guillemot@naga.ch
Tuire	Haavisto	VTT	tuire.haavisto@vtt.fi
Johanna	Hansen	Posiva Oy	Johanna.hansen@posiva.fi
Susie	Hardie	Schwarz Hara Consult	susie@schwarzharaconsult.at
Lucie	Hausmannova	SÚRAO	hausmannova@surao.cz
Vaclava	Havlova	UJV Rez, a.s.	vaclava.havlova@ujv.cz
Johan	Hedlund	SKB	
Bjorn	Herschend	SKB	bjorn.herschend@skb.se
Erika	Holt	VTT	Erika.Holt@vtt.fi
Antti	Ikonen	Posiva Oy	antti.ikonen@posiva.fi
Tiina	Jalonen	Posiva Oy	tiina.jalonen@posiva.fi
Esther	Jonsson	SKB	esther.jonsson@skb.se
Shinya	Kato	Kansai Electric Power	
David	Kay	BEP Surface Technologies Limited	david.kay@bep-st.com
Jake	Kinghorn-Mills	MCM Environmental Services Ltd	jake.kinghorn-mills@mcmenvironmental.co.uk
Florian	Kober	Nagra	florian.kober@nagra.ch
Anne	Kontula	Teollisuuden Voima Oyj (TVO)	anne.kontula@tvo.fi
Linda	Kumpula	Ministry of Economic Affairs and Employment of Finland	linda.kumpula@gov.fi
Karina	Lange	IAEA	k.lange@iaea.org
Erich	Lassnig	Hagerbach Test Gallery Ltd	elassnig@hagerbach.ch
Kamel	Latoui	Thommen Furler	kamel.latoui@gmail.com
Vera	Lay	BAM	vera.lay@bam.de
Didier	Leonard	ONDRAF/NIRAS	d.leonard@nirond.be
Ann-Kathrin	Leuz	ENSI	ann-kathrin.leuz@ensi.ch
Pascal Claude	Leverd	Andra	pascal.leverd@andra.fr
Riccardo	Levizzari	ENEA	riccardo.levizzari@enea.it
Axel	Liebscher	BGE	axel.liebscher@bge.de
Jon	Martin	Nuclear Waste Services	jonathan.martin@nda.gov.uk

First Name	Last Name	Organisation	Email
Juan Carlos	Mayor	Enresa	jmaz@enresa.es
Thierry	Mennecart	SCK CEN	thierry.mennecart@sckcen.be
Richard	Metcalfe	Quintessa Limited	richardmetcalfe@quintessa.org
Helle Harvig	Midtgaard	GEUS	hhm@geus.dk
Jitka	Miksova	National Radiation Protection Institute, SÚRO	jitka.miksova@suro.cz
Péter	Molnár	PURAM (RHK)	molnar.peter@rhk.hu
László	Molnár	PURAM (RHK)	molnar.laszlo@rhk.hu
Vanessa	Montoya	Helmholtz Centre for Environmental Research	vanessa.montoya@ufz.de
Naoto	Mori	The Kansai Electric Power Company Co., Inc.	mori.naoto@e5.kepco.co.jp
Ryo	Nakabayashi	Central Research Institute of Electric Power Industry	r-naka@criepi.denken.or.jp
Péter	Ormai	PURAM (RHK)	ormai.peter@rhk.hu
Cristiano	Padovani	Jacobs	Cristiano.padovani@jacobs.com
Jessica	Palmqvist	SKB	jessica.palmqvist@skb.se
Wilfried	Pfingsten	Paul Scherrer Institut (PSI)	wilfried.pfingsten@psi.ch
Andreas	Poller	CSD Engineers AG	a.poller@csd.ch
Joachim	Poppei	CSD Engineers AG	j.poppei@csd.ch
Laure	Prévot	Egis	laure.prevot@egis.fr
Aditya	Rivonkar	Subatech Laboratory	rivonkar@subatech.in2p3.fr
Mathurin	Robin	Subatech (IMT-Atlantique)	robin@subatech.in2p3.fr
Mojtaba	Rostami	ELTE University	mojtabarostami466@gmail.com
Silvia	Rueda Sánchez	ENRESA	srus@enresa.es
Yuichi	Sago	Chubu electric power co., inc.	Sagou.Yuuichi@chuden.co.jp
André	Scheidegger	NAGRA	andre.scheidegger@nagra.ch
Stéphan	Schumacher	ANDRA	stephan.schumacher@andra.fr
Patrick	Senn	Amberg Engineering AG	pasenn@amberg.ch
Eric	Simo	BGE TECHNOLOGY GmbH	eric.simo@bge.de
Jiri	Stastka	Czech Technical University	jiri.stastka@fsv.cvut.cz
Jiří	Svoboda	Czech Technical University	svobodaj@fsv.cvut.cz
Louise	Théodon	Andra	louise.theodon@andra.fr
Heidi Sjølin	Thomsen	Danish Decommissioning	hst@dekom.dk
Alba	Valls	Amphos 21	alba.valls@amphos21.com
Maarten	Van Geet	ONDRAF/NIRAS	m.vangeet@nirond.be
Marika	Vespa	Brenk Systemplanung GmbH	m.vespa@brenk.com
Tobias	Vogt	NAGRA	tobias.vogt@nagra.ch
Holger	Völzke	BAM	holger.voelzke@bam.de
Lukáš	Vondrovic	SURAO	vondrovic@surao.cz
Marja	Vuorio	COVRA	marja.vuorio@covra.nl

First Name	Last Name	Organisation	Email
Henning	Wessels	TU Braunschweig	h.wessels@tu-braunschweig.de
Jens Wilhelm	Wolf	GRS gGmbH	jens.wolf@grs.de
Piet	Zuidema	Zuidema Consult GmbH	piet.zuidema@nagra.ch

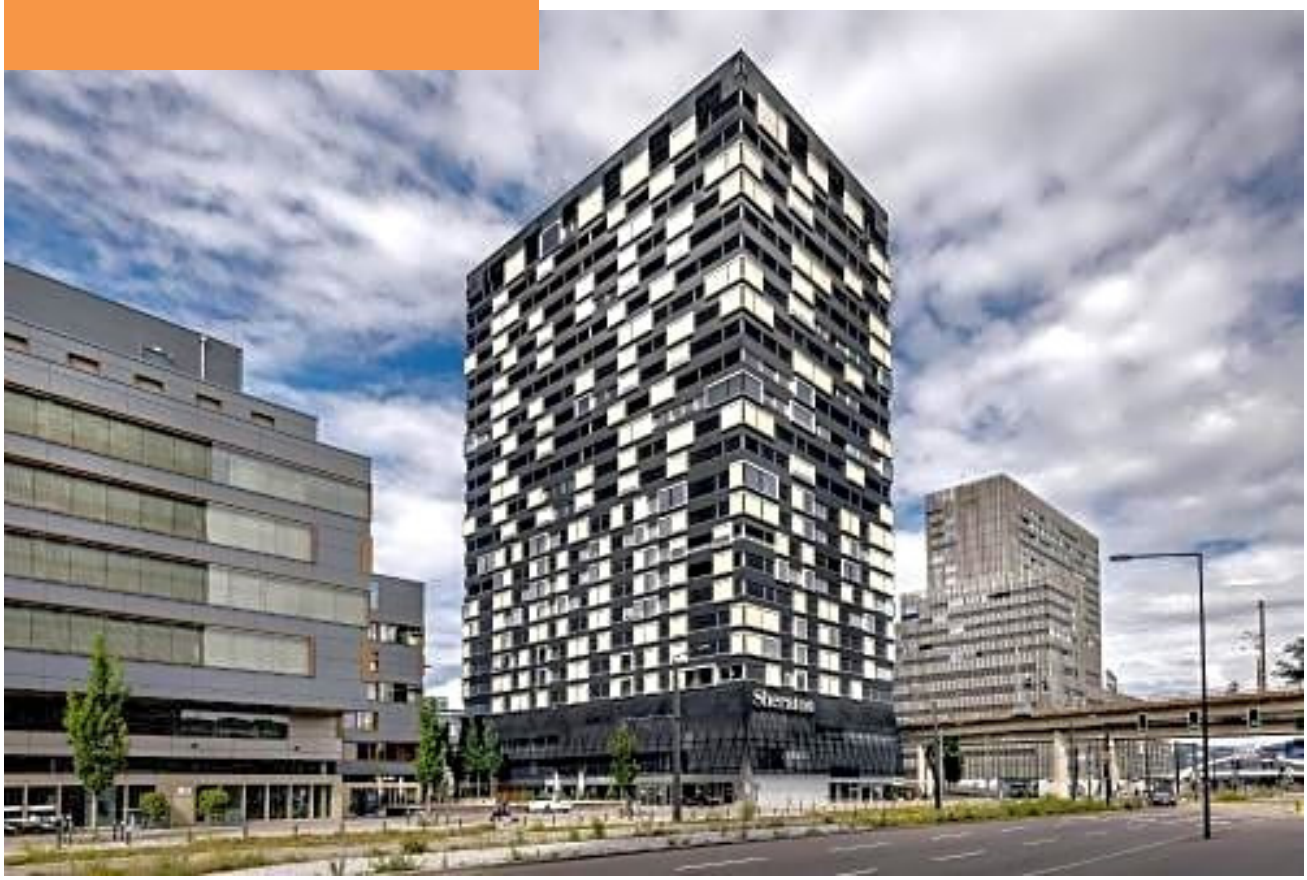
Symposium Dinner

The Symposium Dinner will be held on 20 September 2022 at the Sheraton Hotel, Pfingstweidstrasse 100, 8005 Zurich.

Welcome Drink: 18:30

Start Dinner: 19:00

In the Hotel Restaurant Route26



Optional Excursions (22 September 2022)

Rock Laboratory Mont Terri (mont-terri.ch)

Interior view of the Mont Terri rock laboratory (www.mont-terri.ch)

The Mont Terri rock laboratory is situated to the north of St-Ursanne in the canton of Jura, around 300 m underground. It is accessed via the safety gallery of the Mont Terri motorway tunnel. The rock laboratory comprises 1200 m of galleries and niches. The horse-shoe shaped galleries are 4 to 5 m high and well-lit. The key question being investigated is: can radioactive waste be stored safely in Opalinus Clay? The Mont Terri rock laboratory is engaged solely in research; no deep geological disposal facility will be built at Mont Terri. There are 22 partners from Europe, Japan, Canada, United Kingdom, the USA and Switzerland carrying out research at the Mont Terri rock laboratory.

This will be a full-day tour and will include a small lunch. The journey time to/from Mont Terri is ca. 120 min (heavily dependent on traffic). The guided tour is ca. 150 min. Sensible footwear (rubber soles) is recommended. The temperature in the tunnels is approx. +14°C all year round so warm clothing is recommended.

ZWILAG Wurenlingen (zwilag.ch)

ZWILAG (www.zwilag.ch)

ZWILAG, the Swiss interim storage facility, is a key link between the generation of waste and its disposal in deep geological repositories. Until underground repositories are available, radioactive waste must be kept in interim storage for 30 to 40 years. All categories of radioactive waste generated in Switzerland are processed and temporarily stored in the ZWILAG facility and the neighbouring federal interim storage facility.

This will be a half-day tour and will include a small lunch.

The journey time to/from ZWILAG is ca. 60 min.

The guided tour is ca. 120 min.

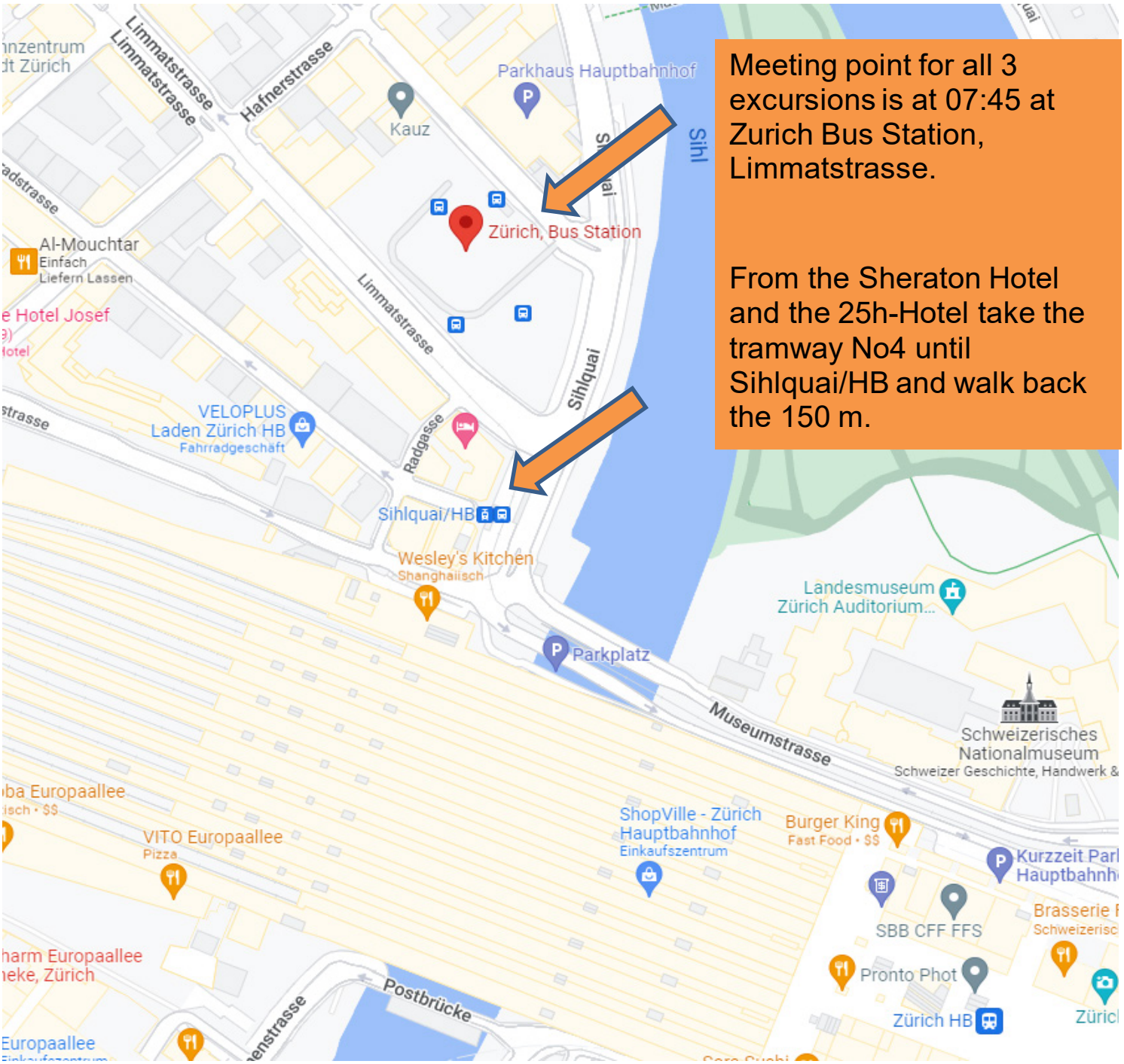
Grimsel Test Site (www.grimsel.com)

Grimsel Test Site (www.grimsel.com)

The Nagra Grimsel Test Site (GTS) is an underground research laboratory (URL) located in crystalline rock in the Swiss Alps. Since 1984, Nagra has worked with more than 20 international partners at the GTS to ensure the availability of scientific and technical expertise in the field of radioactive waste management. The research has focused on understanding key processes in the geosphere and engineered barriers, as well as on investigating the behaviour of radioactive materials under realistic conditions relevant to deep disposal. The GTS also hosts large-scale experiments to demonstrate the technical feasibility of complex components at a realistic scale for all types of radioactive waste. The on-site visit will provide an insight into the current status of research activities at GTS and show the contribution of the various experiments to the challenging development, optimisation and implementation of deep geological repositories. Last but not least, the stunning landscape also invites a visit.

This will be a full-day tour and will include a small lunch. The journey time to/from Grimsel Test Site is ca. 150 min (heavily dependent on traffic). The guided tour is ca. 120 min. Sensible footwear (rubber soles) is recommended. The temperature in the tunnels is approx. +14°C all year round so warm clothing is recommended.

Meet at Zurich Bus Station at 07:45 for all three tours.



At Zurich Bus Station there might be many different busses and groups. Please watch out for busses from the company TWERENBOLD.

Webinar

The second part of the IGD-TP event on the role of optimisation in geological disposal programmes consists of a live webinar on 29 September 2022.

At the webinar, our international expert panel (see biographies below) will discuss the role of optimisation in radioactive waste disposal programmes. Chaired by Irina Gaus (Nagra) and Tiina Jalonen (Posiva), the webinar will include a panel discussion and question and answer session.

Questions can be submitted live during the webinar, but you can also submit a question in advance via the IGD-TP website and during the symposium in Zurich. We don't guarantee to answer all questions, but we will do our best!

The option to submit advance questions, as well as register for the webinar, closes on 28 September 2022 – see igdtp.eu/event/igd-tp-symposium/. The access link will be provided the week before the webinar.

The webinar will be recorded and made available on the IGD-TP website.

	**Chris Boyle, Vice-President, NWMO, Canada** Chris Boyle is Vice-President and Chief Engineer at the NWMO. He is responsible for the implementation of the Adaptive Phased Management (APM) technical program for Canada's used nuclear fuel. Prior to joining the NWMO in 2011, Mr Boyle's past experiences included automotive manufacturing, biomechanics, and defence science research and development with a focus on innovation and design optimization. Chris holds a Bachelor and Master of Applied Science in Mechanical Engineering from Queen's University.
	**Reinhard Knerr, Manager, Department of Energy Office of Environmental Management, USA** Reinhard Knerr is the Department of Energy Office of Environmental Management's manager of the Carlsbad Field Office. He has held that position for 2 years and maintained mission essential operations during the COVD-19 pandemic and is returning the Waste Isolation Pilot Plant (WIPP) back to routine shipment and emplacement operations. He is also responsible for the completion of two large Capital Asset Projects, the construction of the Safety Significant Confinement Ventilation System and the completion of the Utility Shaft, in addition to multiple infrastructure modernization activities and the transition of the WIPP site to an all-electric fleet in the WIPP underground. Reinhard comes to Carlsbad from the Portsmouth/Paducah Project Office in Lexington, Kentucky, where he was DUF6 Federal Project Director, leading the resumption of production operations and overseeing the two DUF6 conversion facilities at the Portsmouth and Paducah sites as they achieved steady-state operations. He has also held multiple leadership and strategic planning roles at the Paducah site since 2004, including managing environmental remediation work, transitioning the Gaseous Diffusion Plant from the United States Enrichment Corporation back to the Department of Energy and initiating utility and infrastructure optimization projects, among others. Reinhard has previous project experience with the WIPP site as transuranic waste certification team leader. He also has more than nine years of experience as a nuclear criticality safety engineer supporting contractor operations at the Pantex Plant in Amarillo, Texas. Reinhard holds a Bachelor of Science degree in nuclear engineering from Penn State University.

	Jaakko Leino, Director, Nuclear Waste and Materials Safeguards Regulation, STUK, Finland Mr Jaakko Leino works for the Finnish Radiation and Nuclear Safety Authority (STUK) as director for department of Nuclear Waste and Materials Regulation, which is responsible for the regulatory oversight of nuclear waste management and for national nuclear safeguards system. Jaakko Leino has over 12 years of experience in STUK and he has been closely involved in the licensing process of the Olkiluoto spent nuclear fuel encapsulation and disposal facility and in regulatory oversight of nuclear waste facilities design, post-closure safety, construction and operation in Finland. Previously he has worked as a head of the Nuclear Waste Safety Assessment Section at STUK's department of Nuclear Waste and Material Regulation.
	**Stefan Mayer, Team Leader, Department of Nuclear Energy, IAEA** Mr Stefan Mayer received the degree of Dipl. Ing. in Mechanical Engineering from the Technische Hochschule Darmstadt (Germany, 1988) and a Ph.D. in Applied Mechanics from the University of California at San Diego (USA, 1994). He is (2012-present) team leader for radioactive waste disposal in the Nuclear Energy Department of the IAEA. His responsibilities are focused on responding to IAEA Member States' requests for information, cooperation, and support in the field of radioactive waste disposal. These are delivered through a variety of mechanisms, including the development of IAEA technical reports, organization of training courses, or the URF network focused on geologic disposal and DISPONET focused on low level waste disposal. Prior to joining the IAEA, Mr Mayer was employed by the French national RWMO, Andra, working during a decade on the deep geologic disposal program now known as Cigeo; and before that he worked at the Technical Support Organization to the US NRC: the Center for Nuclear Waste Regulatory Analysis (CNWRA), supporting the evaluation of the Yucca Mountain site recommendation.
	**Piet Zuidema, Chief Scientific Officer, EURAD** Piet Zuidema has a degree in civil and environmental engineering and also a PhD from ETH Zürich, Switzerland. He was member of several committees of international organisations (e.g. OECD/NEA) and also served there as chairperson. He participated in several expert advisory groups and committees in other waste management programs in several countries. Piet worked for more than 30 years at Nagra, the Swiss National Cooperative for the Disposal of Radioactive Waste. For about 20 years he was director 'Science & Technology' where he had the responsibility for the whole Science & Technology programme. This included the RD+D programme, the inventory of radioactive wastes, repository design, the geoscience programme (including field work) and safety analyses for the operational and post-closure phase. Piet was in charge of several major repository projects, e.g. Nagra's scientific-technical work within the 1st and 2nd phase of the Swiss site selection process and the periodic updates of the cost estimates for the disposal programme. By the end of 2017, Piet retired from Nagra. Since then, he acts as an independent advisor to several organisations and companies, including Nagra. He currently also acts as the Chief Scientific Officer for EURAD, the European Joint Programme on Radioactive Waste Management.

General Information

ADDRESS OF THE CONVENTION CENTRE

SIX ConventionPoint, Pfingstweidstrasse 110, 8005 Zürich, Switzerland

https://www.conventionpoint.ch/en/home.html

ACCESS

By train/tram

From Zurich main station (Zürich HB) take tram line 4, direction Altstetten. Coming from the station in Altstetten, take tram line 4, direction Tiefenbrunnen. From either direction get off at Sportweg.

The SIX ConventionPoint is situated within the SIX building next to the tram stop.

SBB Fahrplan (www.sbb.ch/en/home.html)

VBZ Fahrplan (www.stadt-zuerich.ch/vbz)

By car

The highway connections are a few minutes drive from the SIX ConventionPoint. There is a public pay parking at the Hard Turm Park garage, to be entered via Pfingstweidstrasse.

In the garage follow the signs to building 110/SIX.

By air

From Zurich airport you can take a taxi for about 20 minutes. By public transport, take the S-Bahn to Hardbrücke station. From there, take streetcar 4 in the direction of Bahnhof Altstetten to the Sportweg stop.

The SIX ConventionPoint is located directly opposite the stop.

PRACTICAL INFORMATION

Registration Desk

The registration desk, located in the reception, will be open for registration and information during the following hours:

- Tuesday, September 20: 11:30 – 18:00
- Wednesday, September 21: 08:30 – 16:00

Badges

Attendees are required to wear and display their conference badge at all time in the convention centre.

Wifi

Free wifi is available in the convention centre:
SSID: SIX ConventionPoints
Password: Welcome2022

Speakers

Speakers are required to provide the secretariat with their presentation by 16 September 2022.

Posters

Authors are required to provide the secretariat with their poster by 12 September 2022. Electronic posters will be displayed in the refreshment area on each day of the symposium - authors are encouraged to discuss their posters during coffee breaks.

Coffee Breaks

Refreshments will be served in the lobby at the times specified in the programme.

Lunches

Lunches will be served in lobby at the times specified in the programme.

Symposium Dinner

The Symposium Dinner will be held on Tuesday, September 20, 18:30-23:00 at the Sheraton Hotel.

Please note that the access to the Dinner is restricted to attendees who have specifically registered and paid for it.
Late registration will depend on availability.

Optional Excursions

All the optional excursions leave at 07:45 on Thursday 22 September 2022 from Zurich Bus Station, Limmatstrasse.

Mobile Phones

Attendees are requested to switch their mobile phone to silent mode when entering the sessions.

Language

English is the official conference language.

Hotels

We recommend the following two hotels, which are both within walking distance to SIX Convention Point:

- Sheraton Zurich - https://www.marriott.com/hotels/travel/zrhzs-sheraton-zurich-hotel/
- 25hours-Hotel Zurich West - https://www.25hours-hotels.com/en/hotels/zurich. *Note that there are two 25hours-Hotel's in Zurich – please make sure that you book the* ***Zurich West****.*

You will find more hotels via Zurich tourism: https://www.zuerich.com/en

Accessibility

We would like to make this event as accessible as possible. We strongly encourage you to contact us if you need further information or have any queries.

- The conference rooms and toilets are on the same floor and are wheelchair accessible. A hearing loop is available. Service animals are not allowed.
- The conference dinner venue is wheelchair accessible and has accessible toilets. Service animals are allowed.

For the optional tours on day 3, participants should be in reasonable physical condition as there are

some steps to take and 1-2 hours walking with no seats in the underground facilities.

Luggage Storage

A lockable space for luggage will be available at the Symposium venue.

COVID-19

Please take sensible precautions to minimise the risk to yourself and others from COVID-19. Hand sanitiser and optional masks will be available at the meeting. Please keep your distance where possible and self-isolate if you are experiencing COVID-19 symptoms.

Photography and Videos

Photos and videos will be taken during the sessions of the group as a whole. If you do not want to be recorded, please ensure you sit at the back of the room and also make yourself known to the photographer.

Emergencies

During the Symposium the emergency contact number is +41 76 317 87 12.

Further Information

For any other questions please contact secretariat@igdtp.eu

Notes

Notes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