THIRD ANNUAL EVENT

Summary

14 to 16 March 2023 – Larnaca, Cyprus

The third annual event, dedicated to the benefits of joint programming, was held from 14 to 16th March 2023 in Larnaca, Cyprus. More than 180 persons (EURAD members, invited speakers and members of the end-user group) were physically present over the three days. Online attendance, to follow the event but not to interact with the speakers and audience was offered as well. Over 110 attendees registered for this option.

The event provided a platform for interaction and networking opportunities. It also allowed to share results from the different work packages and triggered new ideas for future work and demonstrated the benefits of joint programming.

DAY 1 – STRATEGIC PLENARY/PANEL SESSION AND STUDENTS' SESSION

Strategic sessions

A broad range of presentations, including from external (non-EURAD) speakers were made during the first day.

The strategic plenary session introduced the event by presentations of internationally renowned experts: **Dr. Gérard Bruno**, Head of the Radioactive Waste and Spent Fuel Management Unit IAEA described the ARTEMIS programme, an Integrated Review Service of the IAEA for Radioactive Waste and Spent fuel Management, Decommissioning and Remediation, helping among others the EU members in their self-assessment, which every 10 years is mandatory by the council directive 2011/70. **Saida Engström**, Senior Advisor of Vattenfall and member of the EURAD External Advisory Board gave a passionate presentation in particular experienced by SKB on the role of scientists in outreach activities for stakeholder involvement in the siting of a repository for spent nuclear fuel. Experience has shown that scientists play a pivotal role in building trust among stakeholders on radioactive waste disposal as they are best equipped to explain complexe matters in an understandable way. **Dr. Csilla Pesznyak**, President of the European Nuclear Education Network ENEN, presented the missions of ENEN and the ENEN2PLUS project, building European nuclear competence through continuos advanced and structured education and training actions, including radioactive waste management. Finally, **Prof. Allison Macfarlane**, director of the School of Public Policy and Global Affairs at the University of British Columbia and former chairwoman of the United States Nuclear Regulatory Commission (NRC)presented the results of a US National Academy of Sciences Study on Waste implications of advanced reactors/SMRs, concluding that

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advanced reactors do not reduce the waste problem and may make it more complex and costly.

The panel session dedicated on the benefits of joint programming allowed to see the challenges for SIMS (presented by **Ole Kastbjerg Nielsen** from DEKOM), the role of the taxonomy (**Manuel Martin Ramos**, JRC) but also to share the process of EURAD Strategic Research Agenda (**Valéry Detilleux**, Bel V) and to hear the views of one of EURAD's reviewer (**Hans Forsström**) on EURAD progress.

Students' session

The Students' session included a broad range of presentations, including three presentations by PREDIS students (each representing one technical PREDIS WP) and eight presentations by EURAD students (representing five technical EURAD WPs).

The first presentations by the PREDIS students provided a clear overview of PREDIS' technical WPs and, more importantly for this session, the scientific contributions made by several PhD students to these WPs and how the students contribute to achieving the goals of their WP.

The EURAD students presented their work in their respective WPs. Each presented WP (SFC, MAGIC, GAS, FUTURE and MODATS) was introduced by the WP Leader (or a WP representative). After setting the stage, the PhD students presented their work in a clear and concise manner.

The final part of the Students' session was a panel discussion between all students and the experts in the room. The questions from the experts ranged from generic questions related to the scope of their research to technical questions that required a lot of insight. The PhD students answered these questions very well and showed that they were on their way to becoming experts in their field.

At the end of the session, as a closure, the question was raised by the EURAD CSOff "to what extent are the students trying to be/become generalists, rather than focussing solely on being an expert?" An important question, to which the students replied (almost unanimously) that they understand the importance of being a generalist and that they believe that events such as the EURAD Annual Event are the perfect starting point for getting to know all aspects of radioactive waste management in Europe. This further indicates of actively involving the PhD students in major EURAD events.

DAY 2 – BREAKOUT SESSIONS

Session 1 on Innovation

This session dedicated to Innovation (How can science, technology, knowledge management, civil society, contribute to innovate in radioactive waste management?) was organized around three main topics:

- Technical innovation and safety,
- Innovative forms of interactions with civil society
- Is the digital twin an innovation, a myth or a reality?

Around 90 people actively participated in this session.

The work on the first topic was organized as a World Café creativity workshop around 3 questions. The participants split spontaneously into 3 groups and discussed around these 3 questions. The main outcomes of these exchanges concern the place of innovation in a long-term industrial activity (as GD) for which safety is a driving factor, the consequences of development of new reactors (eg. SMR) on waste disposal design and future operation, the interactions in EURAD needed to support technical innovation in RWM (ICS, knowledge transfers, positions papers, etc.).

The second and third topics were treated through discussions with all the participants after a short presentation to introduce the subject.

Concerning the innovative forms of ICS, the main discussion was about the representativeness of the CS members involved in EURAD: limited number of CS larger group members in EURAD, the necessity to reinforce regional representatives and to ensure the presence of all countries. It was also highlighted that the work of CS experts in research brings fruitful inputs for all partners.

Finally, the discussions about digital twins highlighted the fact that digital twins offer the possibility to share data with non-decision maker more easily, allow having more information due to the better visualization and easy access to information about the data (metada) and could facilitate KM transfer towards less advanced program countries.

Session 2 on Improving Cross-border cooperation

This session was focussed on discussing the question: How can more advanced and early-stage programmes work together towards a common goal? Introductory talks were used to set the scene on existing cross-border cooperation mechanisms within radioactive waste management. This included a detailed introduction by the EURAD Chief Scientific Officer (Piet Zuidema) who offered perspectives on the potential mechanisms that are (and could be) used within EURAD or a future Joint Programme. The Commission, both DG-RTD (Seif Ben Hadj-Hassine) and DG -ENER (Jolanta Svedkauskaite provided an overview of known challenges, priorities and perspectives based on Member States national reporting to Council Directive 2011/70/Euratom. This talk and subsequent discussions reinforced the role of EURAD to support Member States to demonstrate compliance and progress with the Directive.

Finally, there was a presentation via video link from IAEA (Stefan Mayer and Rebecca Robbins) on cross border cooperation mechanisms external to EURAD. Thereafter the floor was opened to all participants to share their needs and/or their experiences and ideas on future improvements. Highlights from the discussion included:

- The use of generalists to integrate and translate science;
- That efforts should focus on the knowledge ‘at large’;
- The importance of networking and agile strategic studies;
- The potential role of shared solutions and to cooperate on non-R&D or non-technical issues;
- The use and complementary nature of existing commercial services, and mobility and secondment opportunities;
- The need to respect human resources in small inventory member states;
- The role of requirements management to guide and provide context and orientation;
- The need to leverage existing infrastructure (URFs and hotlabs);
- The benefit of position papers and establishing common views on key issues; and
- Awareness and the ability to react and cooperate on issues that are triggered outside of EURAD.

The conclusion from the session was that beyond generation of the long list of ideas and existing cooperation mechanisms, the platform of EURAD has a strong role to play in coordinating, focussing and enabling the linkages between the different options and pathways. Many actors in the session showed a strong interest (including IAEA) to develop the EURAD approach as a new way of cross border collaboration in Europe, including but not limited to issues related to compliance with the Directive, Knowledge Management and the other activities listed above.

Around 30 people actively participated in this session. In addition to the named presenters, the following attendees shared their experiences and perspectives: Posiva (Johanna Hansen), COVRA (Marja Vuorio), DEKOM (Ole Kastbjerg Nielsen), BGE and Core Group and Bureau Member (Astrid Göbel); EURAD EAB – (Hans Wanner) Research Entity College and Large Infrastructure Representative (Marcus Altmaier).

Session 3 on Building competencies

External speakers from different institutions and projects were invited to share their knowledge, ideas and needs for building competencies and how to take these competencies in the future with about 20 to 30 participants online and on site:

- Bo Strömberg (SSM) - Regulatory review of the Swedish geological repository programme for spent nuclear fuel: developing and maintaining competence
- Csilla Pesznyak (ENEN) - ENEN+ and competence building
- Antonio Puertas Gallardo and Mario Ceresa (JRC-ISPRA), online - Artificial Intelligence
- Gunnar Hoefer (BGE), online - Building competencies – Address generational gap and knowledge management - View of the German WMO (BGE)
- Vincent Maugis (Andra), online - Competence building in Andra

The main goals of building competencies are to develop and maintain specific competencies, capacities and new ideas despite changes (retirement, job change, etc.), to facilitate processes, prepare new generations, adapt to generational changes and modern technologies and to close the generational gap. The solutions to these challenges provided by the speakers are first to attract younger generations (e.g., ENEN+, job fares, network between stakeholders and research centres) and to retain the talents. It is also important to establish and support a well organised on-/offboarding procedure and self-study process. To enhance the dialogue of internal and external experts e.g., through review processes, programmes such as the Knowledge Café (BGE) or defined Communities of Practice providing tools to share knowledge more efficiently (Andra) is an additional way of gaining and retaining knowledge. Further strategies are the creation of a strategic knowledge map identifying critical knowledge, the initiation of research projects (SSM) and the use of modern technologies like Large Language Models (JRC-ISPRA).

DAY 2 AND 3 – TOPICAL SESSIONS (TECHNICAL RESULTS)

Session 1 on Waste Acceptance Criteria (ROUTES and PREDIS)

The Waste Acceptance Criteria (WAC) session was chaired by Erika Holt (VTT) with presentations of results from ROUTES (Liz Harvey, Galson Sciences Ltd and Chris de Bock, ONDRAF/NIRAS) and PREDIS (Lumir Nachmilner, CV REZ). Some end-users (Marja Vuorio, COVRA and Anastasia Savidou, NCSRD) also provided their feedback on the question, "How is industry benefiting from collaborative activities on WAC?". The audience was then asked to provide feedback on the four following questions:

- How is the work of ROUTES and PREDIS influencing national waste management programmes?
- Which challenges in developing or modifying WAC will the project outcomes have the most impact on?
- What challenges need to be further addressed? What do you consider to be critical priorities and why? Do the presented recommendations adequately capture these challenges?
- Are the needs of less mature radioactive waste management programmes being addressed? If not, what is missing?

The discussions focused in particular on the current capacity of guidance to answer efficiently some specific problems and how they could be improved by including practical issues and not only generic solutions. Other topics discussed were the interest to develop a forum for member states to explore waste management case studies, the importance of projects such as PREDIS or ROUTES for a better understanding of WAC, the interest of benchmarking to enhance knowledge transfer and how WAC could be used to support technical dialogue on safety issues with civil society.

Session 2 on Data (MODATS and DONUT)

The aim of the session was twofold. The first part of the session was built to learn what is done outside the EURAD community on the data management and decision-making, while the second part was dedicated to the last cutting-edge development made in MODATS and DONUT. Therefore, in the first part of the session, two talks entitled "From data and models to decision making in risks management", and "Monitoring, modelling and data : AI applications for air quality issues" have been given respectively by Gilles Grandjean BRGM and Laurence Rouil, INERIS. In the second part, the use of monitor data gathered in running in situ experiment either in the Meuse Haute Marne or the Mont Terri Underground Research Laboratory to build either THMC models or digital twin prototype have been discussed.

Session 3 on Migration (CORI and FUTURE)

A session organized by CORI and FUTURE was focusing on radionuclide migration processes. These projects are focusing on specific aspects of radionuclide retention in clay and crystalline host rocks as well as cementitious environments.

A technical overview presentation from FUTURE was given by N. Maes (SCK-CEN, BE) regarding radionuclide mobility in clays. Main conclusions presented were that bottom-up schemes are able to provide a mechanistic description of ion transport for well

characterized systems. Particularly important in this context is the closing of knowledge gaps for specific nuclides and mineral phases that feed into sorption models. The mechanistic understanding of anion exclusion and surface diffusion has been advanced. Further mechanistic understanding of sorption and transport processes is supported by data from advances in spectroscopic characterizations and atomistic modelling.

The second technical presentation was given by N. Macé (CEA, FR) of CORI and focused on the effect of organics onto radionuclide migration in cementitious media. Studies on solubility and speciation were discussed. An example of Ni(II) solubility at high pH, looking at the impact of phthalate complexation (leading to no substantial solubility enhancement), and EDTA (leading to a solubility increase), was discussed. A short overview on retention/diffusion experiments ongoing in CORI was likewise presented, highlighting that organic and radionuclide/organic diffusion processes in the investigated systems are extremely slow.

The technical presentations from CORI and FUTURE were followed by panel-like discussion, with S. Churakov (FUTURE, PSI,CH), M. Altmaier (CORI, KIT,GE), B. Grambow (PMO, FR), P. Henocq (CORI, ANDRA,FR), R. Daehn (FUTURE, PSI, CH). Discussion was supported by two moderators, S. Britz (GRS, DE), D. García (Amphos21, ES), and focused to a large extend on the selection of systems investigated in the projects and the expected impact from the work performed. The substantial progress made in both FUTURE and CORI, giving a better scientific basis for the understanding and modeling of the investigated processes, was strongly acknowledged by the community. There was likewise a consensus that the overall topic of radionuclide migration has reached a rather high level of maturity for many systems. At the same time, however, several open questions, for instance pertaining to the treatment of perturbances, were identified which need further in-depth scientific investigation.

Session 4 on Uncertainties (UMAN and DONUT)

The goal of this session was to give an integrated view on uncertainties classification based on the work carried out within UMAN. Then, a focus has been made on the uncertainties associated to radionuclide sorption.

To introduce the participants to the main topic of the session, Daniela Diaconu (RATEN Romania) presented an overview of the role of uncertainty management in the RWM program and their approach in WP UMAN. This introduction was followed by the presentation of the uncertainty classification method proposed by UMAN, which consists of a multi-level scheme that integrates the views of the main actors involved in a radioactive waste management program (WMOS, TSO and RE). This scheme covers all phases of the program and disposal types, and has been discussed and agreed with the CSOs. Particular attention was given to site and geosphere uncertainties, with a particular emphasis on the views of the three categories of actors regarding the safety significance of uncertainties related to the transport of radionuclides. A second presentation by Wilfried Pfingsten, (PSI, Switzerland) provided insights into the uncertainties associated with radionuclide sorption as they resulted in UMAN investigations. Participants were asked to react to the UMAN findings, identifying missing categories or uncertainties not yet captured by this strategic study.

The session continued with an analysis on how the numerical models developed in DONUT approach the problem of radionuclide migration. Among others, the use of Neural Network Metamodels for either sensitivity analysis of radionuclide transport models or calculation speed up have been discussed. Novel coupled modelling approach to represent uncertainty using probabilistic simulation have also been emphasized. To conclude this session a

debate was engaged to question about the use of model as a good tool to discuss uncertainty with civil society.

Session 5 on Repository evolution due to radionuclides, heat and gas (GAS,HITEC and SFC)

The purpose of the session was to present and discuss the links and interfaces between the gas and temperatures in particularly finals disposal (although there are topics also in the rest of the back-end), including the behaviour of the spent fuel itself.

The session began by a common presentation highlighting the links and between gas, temperatures and the spent fuel in the back-end of the nuclear fuel cycle, created by all the three work packages and presented by Anders Sjöland. Important features of a geological repository, such as temperature was presented. The role of the gas issue particularly in sedimentary rock concepts was introduced, and also the importance of gas for the long-term dissolution behaviour of spent nuclear fuel (without cladding).

Next the work of the Spent Fuel Characterization WP was presented by Anders Sjöland. The importance of temperature and the decay power of the fuel was presented and not least he importance for economic optimization and cost reducing was highlighted. Results showing for example the uncertainties resulting only from uncertainties in nuclear data was presented, were several common European fuels without experiment verification of its decay power have significant high uncertainties (e.g. VVER and MOX). Others were work on the calorimetric measurement at Swedish Clab, as well as work on the extensive dat set SKB-50 (based on characterized fuels form Clab). Further, mechanical investigations of the integrity of various fuels were demonstrated. The status of Work Package 4, potential accident scenarios, was shown.

Then the GAS WP continued with two presentations of results by Elke Jacops, SCK CEN, Belgium, and Michael Pitz from BGR, Germany. Here laboratory and modelling studies of gas behaviour in various clays, not least sedimentary host rock clays, were presented. One important background for these studies is the importance of gas for the sedimentary host rock repository concept. The complexity of understanding gas in clays was emphasized.

The final two presentations were on HITEC, describing the work, in terms of laboratory and modelling work by Dragan Grgric, University of Lorraine, CNRS, GeoRessources, France, and Jiří Svoboda, CTU in Prague, Centre of Experimental Geotechnics, Czech Republic. Here laboratory and modelling studies of bentonite and other clays up to and beyond 100 C were presented. These studies have the aim to try to establish a new higher temperature threshold requirement than the present 100 C.

The session ended with a fairly intensive discussion. The participants raised a number of important questions, some examples: How will the different repository concepts work with the thermal issue in the operational phase? The plans were described for some of the concepts.

How representative are the laboratory work done on high temperatures in bentonite and clay material for application at repository depth of 4-500 m, where the boiling point of water is higher than 100 C due to the high pressure?

To what extent were models and knowledge applied to the gas work? Should and could the approach be simple or complicated?

Session 6 on Chemistry and microbio (ACED, ConCorD and MAGIC)

As part of the parallel technical sessions, the WP leaders of ACED, CONCORD and MAGIC proposed a focus on the chemo-microbiological impact on the EBS, especially on concretes and steels exposed to relevant disturbances representative of geological disposal environment. The microbial impact is considered as a perturbation likely to modify or accelerate the main reactive pathways in the materials composing EBS. Generally, this influence is not physically considered in RT modelling. The objective of this meeting was to launch discussions across the EURAD community about the coupling between chemistry and microbiology activities and to propose a way to include the coupled impact in the reactive transport modelling.

A set of 6 presentations were carried out to support discussions. First of all, WP leaders during 10 minutes each summarized the activities of the WP by focusing on the topic proposed in the session. In a second time we received respectively three technical presentations from Nikitas Diomidis (NAGRA) about the corrosion of disposal canister materials with and without microbes, Jonathan Lloyd (U. Manchester) about the assessment of microbial processes on cement structures during geological disposal and Nicolas Seigneur (Mines Paris Tech) about an example of Reactive Transport Modelling of microbial activity with the HYTEC code: applications for bioremediation and steel-clay interactions. Close to 60 participants were present physically or online. Fruitful discussions were conducted to initiate the topic and will reclaim additional exchanges in the future.

Session 7 on Knowledge Management (SoK, Guidance and Training and Mobility)

In the Knowledge Management (KM) session, the three KM WPs presented the current status, lessons learnt during the 4 years of the programme and an outlook for EURAD KM.

The key achievements of WP11 presented in the session are the publication of the first SoK document and that 45 out of 79 Domain Insight (DI) documents are in production or were published. Additionally, the feedback mechanism (D11.10) for the KM document producers and end-users was developed in order to optimize the knowledge capturing process and to improve the end-user oriented documents. Also, a web-based KM system, i.e., platform-KMS (D11.9 and MS242), was specified with the aim of providing all EURAD knowledge at one access point, including a forum for exchange of experts. The lessons learnt in the resource-intensive, time-consuming work of capturing the SoK are the importance of communication in the creation a culture of trust, the recognition of the efforts of knowledge providers (e.g., 100% reimbursement) and the good framework to structure the knowledge and to identify knowledge gaps provided by the EURAD Roadmap.

WP12 produced a pilot guide for the cost assessment and financing schemes of RWM Programmes (D12.4), mapped existing guidance documents on geological disposal (D12.7) and started the guide production of requirement management in RWM with an updated production approach after the identification of the prioritized topics for future documents (D12.5). The main lessons learnt in the challenging process of guidance production are to meet the different levels of end-user knowledge, the importance of networking and the time needed to identify the real end-users and their needs.

WP13 reported on the achievements in the EURAD School of Radioactive Waste Management including its pillars courses/webinars, mobility, panorama and PhDs to involve the young generation. Seven training courses and 21 webinars were organised, 31 mobility programmes out of 43 applications were approved and 19 have already been

completed. In addition, more than 90 Master and PhD students as well as postdocs are involved in and supported by the community, e.g, by three student events.

DAY 3 – CUTTING-EDGE SCIENCE SESSION

Seven different presentations were planned to share some cutting-edge science from across EURAD work packages.

- Overview of issues related to challenging wastes
- Mechanistic understanding of gas transport in porous clay materials from molecular scale and mesoscale points of view–
- On the estimation of nuclide inventory and decay heat: a review from the EURAD WP8 SFC
- Core shell materials for the sealing of ceramics canisters by microwave processing
- Retention of redox sensitive radionuclides Tc and Se on Fe-bearing lay minerals
- Characterization of thermo-hydro-mechanical properties of Wyoming sodium bentonite using X-ray imaging
- A coupled chemo-mechanical approach to model the appearance and propagation of cracks during the carbonation of cementitious materials

The various exchanges with the participants show the large interest in sharing results from across EURAD work packages.

The presentations are available on the EURATOM4U application, used during the event.