EURADSCIENCE Position Paper responding to the EURAD SRA Update Note

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Decades of EURATOM research has provided a profound scientific basis for radioactive waste management which contributed to the successful implementation of nuclear waste repositories in some countries, starting their operation in this decade - a success story for the respective WMOs but also for the scientific community. Nevertheless, continuous RD&D in this context is indispensable and will help in the future (1) to further validate and develop the existing safety cases until the respective first repositories will be closed in several decades, (2) to support many EU member states, who will need much longer for the implementation of their repositories, (3) to enable future optimization steps and (4) to be prepared for new developments, adapt to new findings and allow for innovations (e.g. new waste forms, new materials, progressing state of science and technology, societal changes etc.).

The goal of this position paper is two-fold. On the one hand, it responds to the questions raised in the Bureau Note to the Colleges about the updated EURAD Strategic Research and Knowledge Management Agenda (referred to hereafter as the SRA). On the other hand, it highlights important viewpoints and strategic directions a future EURAD can take in order to sustainably support the whole community and the different Member States (and their associated National Programmes) in driving innovation in research and technology, training new experts and ensuring transfer of knowledge. This position paper is accompanied by a more detailed EURAD SRA where we elaborate on the previous (updated) SRA providing inputs and adding on specific topics.

Action 2: Do you have any suggestions to change how the 2019 SRA activities are structured according to the roadmap goals breakdown structure?

We agree that the overall structure covers the key topics of interest and were able to fit all of our additional suggestions for further work within the themes and domains listed.

We agree that no prioritisation of topics should be included in the SRA.

Some topics which are cross-cutting now seem to be placed somewhat out-of-place regarding their position within the roadmap goals breakdown structure. As an example, THMC understanding and modelling, as well as reactive transport models are now cited under Theme 7 ("Safety Case") – Domain "7.3 Safety assessment and tools", while in reality these topics are more cross-cutting between Themes 3 ("EBS") and 4 ("Geoscience"). Other cross-cutting topics that could be added include digitalisation, including digital twins and data management.

Consolidated track changes and more detailed comments are included in a marked-up version of the SRA V1.1, provided separately.

Action 3: Do you have any suggestions to consolidate groupings of activities?

Individual topics within the SRA could be described in more general terms to highlight the remaining issues that need to be addressed. Initially, they should define fields of research within which our community could progress to achieve technical/scientific innovations.

More detailed descriptions of SRA activities could then be presented in the form of a hierarchy, as intended within the Roadmap (firstly the main headlines, and then the detailed description of actions, which could be presented in an annex). This detail would then be available in order to stimulate discussions within the EURAD community and to support the development of work packages.

Suggestions regarding consolidation of specific activities within the roadmap are included in a marked-up version of the SRA V1.1.

Action 4: Review the initial driver assignments made in the SRA V1.1 (right hand column in the tables) and provide improvements or changes.

We agree with most of the proposed EURAD SRA drivers and note the following:

- We suggest that one "primary" driver is defined for each topic in the SRA, and –if applicable- complemented with "secondary" drivers. The main driver needs to drive and should highlight "why" the work is needed. The total number of drivers could be limited to max 3 per topic so that the focus remains on why the work is needed and which party would benefit the most with an action being undertaken on the topic. It is understood that the (number of) drivers are not an instrument for selecting and prioritizing topics. However, the community would benefit to have a more clear view how drivers will be used in this future selection.
- Implementation Safety – Ultimately, the goal of our community is to come to safe long-term management of radioactive waste. Therefore, it might be evident that all topics qualified for the EURAD programme are somehow linked to this driver. However, we interpret this driver as responding to somewhat urgent needs necessary to the next step in the implementation of a waste management strategy (including disposal). Showing how the different topics are supporting the safety case and demonstrating safety should be more central in the future EURAD programme, and we propose a specific action targeted at the integration of results in view of overall safety and system performance. We have to make it explicit, not only implicitly assume that this will be taken up by National Programmes.
- Scientific excellence – Here we understand the remarks made by some colleagues and Colleges in the past in the sense that scientific excellence "as such" is related more to how we do things (and therefore serves as a quality criterion and KPI) and is linked to the programme as a whole as stated in the EURAD Vision (and which is very important for the RE College). If the semantic discussion continues, the driver's name could be changed to highlight the importance of improving scientific insight (solving unknowns, going a step further in the understanding of the system and its components, exploratory research, going beyond currently used standard approaches and concepts, questioning established views, making sure to reach and/or maintain a high scientific quality and competence on certain topics) as a driver for new research.
- Societal engagement is cited only once as a reference driver, for 4.2.1 (Perturbations) in relation to improved understanding of the role of colloids. An effort should be made to identify other activities that could be linked to societal engagement, especially in themes 5-6-7, and maybe

also in a few more R&D-related activities. Monitoring and safety case activities could be linked to societal engagement as well. Given the lack of use, maybe it is not a primary driver? Also, it is remarked that societal engagement involves "divulgation", where members of EURADSCIENCE could play a role.

Action 5: Highlight any other relevant ongoing or pipeline projects external to EURAD that we should be aware of.

We note the following projects not included within EURAD:

- HARPERS project will produce position papers and/or guidelines focusing on harmonization of practices and regulations. The priority topics within this domain that will be handled within HARPERS will only be available by February 2023 (more or less). We should be aware of these topics before making decisions on (mostly) guidance/KM initiatives within EURAD-2.
- EN-TRAP consortium which deals with waste characterization and is currently undertaking RD&D efforts in the minimization of total uncertainty in radiological inventory by using Bayesian approaches.
- INGSM (International Nuclear Graphite Specialist's Meeting) is more a community of specialists working on different topics related to nuclear graphite

Suggestions regarding specific projects to be linked to certain topics within the roadmap are included in a marked-up version of the SRA V1.1.

Action 6: Are there any activities in the SRA that you consider no longer suitable for inclusion because they have been sufficiently addressed elsewhere or are expected to be addressed by existing EURAD WPs?

Here, we want to reflect on the closing of topics, and issuing statements that sufficient evidence and arguments are available (See also last EURAD General Assembly with the comment made by the External Advisory Board: "statement that DG is safe"). From a research perspective, it is self-explaining that it is always possible to take scientific insight a step further (referring to the "scientific excellence" driver), but in some areas it is definitely correct to state that knowledge is sufficiently advanced in order to proceed to the next step within a certain contextual framework (e.g., in the implementation of a specific national programme). However, we want to avoid that statements are made which lead to the false conclusion that there is no longer any funding needed to support research going beyond the current state of the art in these fields.

Indeed, even if subjects are "closed", it is of paramount importance to keep knowledge and expertise, at least on a European scale, sufficiently alive and accessible so that the community can react when new data or publications appear that might contradict or challenge known truths. This can only be done by ensuring that sufficient competence (people) and capability (infrastructure) remain available. Therefore, we invite the other Colleges to join reflections on how to organize this within a future EURAD. Actions evolving from these reflections might be defined under the Knowledge Management driver.

Specific suggestions are included in a marked-up version of the SRA V1.1.

Action 7: Highlight new needs to be considered and evaluated by the EURAD Bureau for inclusion in this SRA update.

The RE College opinion is that the Strategic Research Agenda also reflects the higher-level strategy of the whole community, and is not "merely" the sum of different topics from which a future EURAD-2 can then identify some (cherry picking) and make a consistent and coherent programme.

From the viewpoint of the RE College, EURAD programme should really position itself as 1) the most important international player driving research and technology development with the goal of implementation (including public acceptance) through innovation, safety, and robust knowledge management as the combined goals of the different Colleges; 2) the go-to place to structure and organize radioactive waste management competence, knowhow and capabilities on a European scale, which includes the school for radioactive waste management as a European knowledge management (KM) platform and for training new young experts, a network of state-of-the-art research infrastructures (hot labs, URLs, etc.), acting as a think tank and writing position papers on important/emerging topics, with a high visibility (nationally and internationally). KM should therefore more focus on competence development, and less on document production/management, making KM a more active state-of-mind (compared to a more passive "library collection of knowledge") within a future EURAD that could lead the way to a real step-change for the community in this field.

For the latter goal, the KM programme could benefit from the consideration of new and innovative initiatives in order to structurally establish EURAD:

- Training and education of young PhDs could be organized within an international context by offering (access to) state-of-the-art laboratory environment. A EURAD PhD label could be awarded to the PhD students following this programme, and each WP could select 1 or 2 PhD topics in which students travel between different organisations (like Marie Curie ITN) in order to be trained by best experts and get flavor of different research institutions + combined with specialized training
- An imperative prerequisite is the efficient transfer of knowledge to the next generation experts via direct interaction with experienced scientists and by means of appropriate documentation applying (and developing) state-of-the-art knowledge management tools.
- Providing/keeping/developing dedicated research infrastructures
    - for experimental work on radioactive waste materials.
    - for geophysical/mechanical experiments up to high pressure/temperatures
    - for simulating disposal relevant systems in virtual and visualization laboratories
  and opening those infrastructures to scientists within international cooperations (like the previous TALISMAN/ACTINET projects, and connecting to the new OFFERR project).
- How do we make sure that people do not repeat things without knowing that things have already been done before and think they invent new stuff while they are actually re-inventing the wheel? Filter should also come thru KM.
- Within the KM work package also strategic studies could be performed to gain insights how sustainable informatics systems for knowledge management can be developed that span 50

years or more, and which tacit knowledge transfer methodologies could be applied on the time scale of several decades (ensuring inter-generational transfer)

- Divulgation to a wider public should be a matter of concern that will, undoubtedly, be positive for societal engagement.
- Link to IAEA and NEA should be firmly established, as well as to existing national structures, in order to avoid competition and duplication
- Data management (see later)

Additionally, some cross-cutting topics should be put on the agenda for reflection how to incorporate these in a EURAD-2 programme:

1. It is important that in a future EURAD, topics are linked to safety and the safety case, allowing involved researchers to learn and look at integration of results in view of overall safety and system performance. This will generate an understanding of purpose to newcomer scientists and will guide the identification and development of future research needs.
2. Data gathered within EURAD should be accessible for the community, now and in the future, making sure these can be used in a productive way. This will not be a simple exercise, and requires more efforts than devoted now, as all data are different and one always needs to know the boundary conditions under which data have been gathered. Metadata and quality qualifiers (ensuring future researchers are pointed to certain key experiments) could be added to allow for such use.
3. Digitalization can run horizontally through the programme (e.g., in safety case work package to integrate results from different WPs in a large scale digital representation of a generic repository, in data management to allow artificial intelligence and machine learning algorithms to be applied), but also specific actions could be defined in specific work packages (which could go in different directions like AI or surrogate modelling , up to development of digital twins for specific experiments), both in RD&D but also in KM/training (Virtual Reality/Augmented Reality applications). Here, a digital twin means a process based digital representation of a nuclear waste repository sub systems comprising all relevant THMC/B processes.
4. The programme could also benefit from long-term experiments spanning a timeframe of several programmes: many spent fuel corrosion, for instance, studies take many years from obtaining suitable sample material, setting up the actual experiment, verifying correct condition, taking solution samples, recovering the corroded sample material, analyzing the material. Similar time scales apply to URL experiments on e.g. geophysical, geochemical and radionuclide migration issues. EURAD-2 and beyond should enable a mechanism to work on a long term experiment over more than 1 joint programme.
5. Again we stress the use of current state-of-the-art research infrastructure (URLs, laboratories, advanced equipments distributed among large or specific research institutes/universities).

General topics of high interest to the RE College for development in the next EURAD programme (besides the detailed ones as can be found in the marked-up version of the SRA V1.1) include (in no particular order of importance):

1. RD&D on spent nuclear fuel, including the effect of long-term interim storage and damaged fuel on performance under repository conditions, and the behavior and insights into more special fuels (MOX, doped fuels, new fuel types) throughout the whole back-end.

2. Studying the long-term (dissolution) behavior of other waste forms (HLW, LILW) under repository conditions to better understand and constrain and limit uncertainties on the containment and retardation safety functions that could be associated with these waste forms.
3. Digital tools and applications, accompanied with specific experimental programs to provide systemic understanding on complex coupled processes of repository subsystems and to deliver relevant quantitative parameters and data.
4. Waste characterization with a focus on new non-destructive techniques to allow gaining more insight into the physico-chemical as well as radiological inventory of high density and/or historical/legacy wasteforms.
5. Improved pre-disposal techniques for radioactive waste treatment, decontamination, immobilization, etc. We refer here to the PREDIS SRA currently under development.
6. Waste management from new Small Modular Reactors (SMRs, both light water based and advanced reactor types) considered for deployment in Europe, including fuel cycles considered for SMRs. A strategic study should be performed as a first step to identify if topics emerge which deserve further research. More in general, EURAD should aim for a structural link with the FISA community (and its SRA) to pick up topics which (might) impact (current) waste management (strategies and concepts).
7. Geosciences including the study of natural analogues and heterogeneities and their past evolution to capture FEPs which can bring insights into the long-term evolution of host rocks currently considered for a DGR.
8. Behaviour and uncertainty management associated with materials for buffers and engineered barriers including material mixtures (bentonite/rock/aggregate/sand) to help optimization, also at higher temperatures as well as for surface disposal.

The updated EURAD SRA will serve as a basis for the next European Joint Program on Radioactive Waste Management. It will define a kind of an umbrella for future R&D activities. However, it would be essential to develop specific project ideas in a suited EURAD exchange forum allowing for interpersonal exchange between the different Colleges (IGD-TP exchange forum as a blueprint), and with a wider community compared to the current EURAD Bureau. We consider a future EURAD-2 exchange forum as a key element for the development of new project ideas, which will ensure an adequate scientific exchange between research entities, WMOs and TSOs. New proposals should also be set up in a transparent and inclusive way (→ already many topics are circulating now, not necessarily in an open way, in pre-defined circles). One could think here of showing new project ideas by means of a system like the one used by SNE-TP.