Deliverable D10.20: UMAN -

Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties

Work Package 10 - Uncertainty Management multi-Actor Network (UMAN)

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What is the UMAN project about?

Decisions associated with Radioactive Waste Management (RWM) programmes are made in the presence of irreducible and reducible uncertainties. Responsibilities and role of each stakeholder, the nature of the RW disposal programme and the stage of its implementation influence the preferences of each category of actors in approaching uncertainty management. EURAD WP UMAN carries out a strategic study about the management of these uncertainties. This study is based on extended exchanges of the experience accumulated in the national RWM programmes by a broad range of stakeholders representing WMOs, TSOs, REs and civil society, as well as on a review of knowledge generated by past and on-going R&D projects, and findings of international organisations (such as IAEA, NEA, etc.).

UMAN discusses the classification schemes and approaches as applied to the management of uncertainties and identifies possible actions to be considered in their treatment. Their relevance for safety associated with waste inventory, spent fuel, near-field, site and geosphere, and human aspects as perceived by each type of the above stakeholders, and the approaches used by these stakeholders to manage these uncertainties were explored via questionnaires, workshops and seminars, with the aim to reach either a common understanding on how uncertainties relate to risk and safety and how to deal with them along the RWM programme implementation, or, when agreement is not achieved, a mutual understanding of each individual view. As result of these activities, UMAN identifies uncertainties assessed as highly significant for safety and associated R&D issues that should be further investigated.

This Work Package (WP) of EURAD includes the following tasks, organised as shown in Figure 1:

- Task 1 - Coordination, interactions with Knowledge Management (KM) WP & integration
- Task 2 - Strategies, approaches, and tools
- Task 3 - Characterisation and significance of uncertainties for different categories of actors
- Task 4 - Uncertainty management options and preferences of different actors across the various programme phases
- Task 5 - Interactions between all categories of actors including Civil Society

Interactions between the different tasks and types of actors including civil society are central to this WP. These interactions took place notably through workshops (Task 4) and seminars (Task 5) where the significance of identified uncertainties (Task 3), possible strategies and options to manage them (Tasks 2 and 4) were discussed.

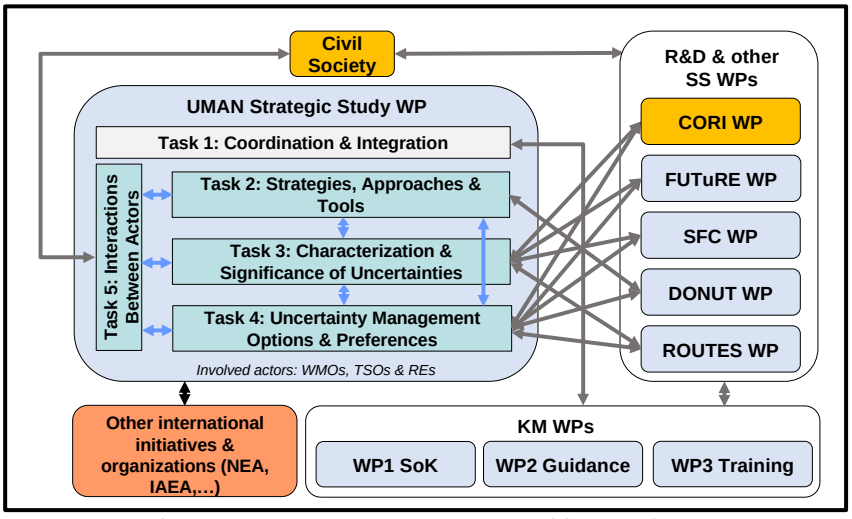

Figure 1 - UMAN WP structure and interactions.

Executive Summary

This report provides information about the work carried out in UMAN Task n°5 - *Interactions between all categories of actors, including Civil Society* in the frame of the extension of Subtask 5.1 – *Preparation, support and reporting of pluralistic analyses*. Existing Task 5 have been extended to test with a broader stakeholder group including civil society the methods identified by UMAN Task 5 (and more especially during UMAN Seminar 4[1]) for a pluralistic assessment of uncertainties and their management, using near-field uncertainties as case study.

The central instrument for testing these pluralistic methodologies was a seminar held on 6-7 December 2023, *"UMAN seminar 5. "Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties*". The seminar provided the opportunity to test and discuss the identified methodologies to explore the uncertainties in a pluralistic way – and especially the PEP game – and to discuss the previous UMAN results from the near-field uncertainties perspective.

The report provides a description and interpretation of this last seminar – UMAN task 5 seminar 5.

Regarding the first objective of the seminar 5 (exploring near-field uncertainties in a pluralistic way), each actor presented its views for discussion. Following the same conceptual framework and template allowed better identification of the differences and similarities of concern. The pluralism of the discussions helped identify transversal key issues regarding the near-field uncertainties, such as the safety significance, the methods to reduce models' uncertainty, or the importance of trust.

The second objective was also reached: the creation of a specific PEP game for the near-field uncertainties allowed to plurally discuss its complex linked issues. The discussions that occurred during and after the PEP game session were highly interesting and led to more global than specific discussions. On how to tackle uncertainty linked to waste, models, monitoring, or engineered barriers.

Both the new PEP game and the discussions stemming from its use in this seminar can be considered as important results. However, some discussions about how to improve this tool for better pluralistic dialog suggested that this topic might be too technical for everyone to easily apprehend it.

[1] See Dewoghelaere J. (2024): UMAN - How to manage uncertainties in a pluralistic way and in a long-term perspective? Final version as of 05.2024 of deliverable D10.16 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

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Acronyms

CS	Civil Society
EURAD	European Joint Programme on Radioactive Waste management
NTW	Nuclear Transparency Watch
PEP	Pathway Evaluation Process
RE	Research Entity
RWM	Radioactive Waste Management
TSO	Technical Safety Organisation
UMAN	Uncertainty Management multi-Actor Network
WMO	Waste Management Organisation
WP	Work Package

1. Introduction

1.1 Objective of Task 5, definition of uncertainty and main hypothesis in UMAN

Management of uncertainties is a cross-cutting issue within the different research themes identified in the work programme of EURAD. It is why a project such as UMAN was implemented. The UMAN project started its work on uncertainties from the basic definition: *"An uncertainty is a situation in which something is not known, or something that is not known or certain"* (Cambridge dictionary). An uncertainty can be **« epistemic »** i.e., relating to knowledge or to the degree of its validation (e.g., lack of knowledge about site characteristics). In this case, it can be reduced (reducible uncertainties). Or it can be **« aleatory »,** i.e., related to random variability (e.g., uncertainty over the time of occurrence – long term uncertainty or magnitude of rare events). In this case, it cannot be reduced (irreducible uncertainties).

Uncertainty is different from risk, that can be defined as "*a quantity expressing hazard, danger or chance of harmful or injurious consequences associated with exposures or potential exposures* (definition from IAEA Safety Glossary 2022[2]). Risk is related to a scenario or sequence of events and can be interpreted as the measure of significance of an uncertainty. **The significance of uncertainties needs to be assessed.**

On this basis, the following assumptions guided the work carried out in UMAN and especially in UMAN Task 5:

- The involvement of stakeholders is essential at all stages of a radioactive waste management (RWM) programme.
- Decisions related to radioactive waste management and geological disposal facility (GDF) have to be made in the presence of uncertainties.
- Even in the post-closure phase, some uncertainties will inevitably remain, but it should be demonstrated that these uncertainties are managed in a way that they do not undermine safety arguments.
- Dealing with uncertainties associated to disposal facilities is particularly challenging due to the long timescales.

Based on these assumptions, Task 5 addressed the following objectives:

1 - Develop a **common understanding** or at least share different viewpoints among the different categories of actors on uncertainty management[3] and on how it relates to risk & safety, whether and why a safety case is robust vis-à-vis uncertainties.

2 - Share knowledge and **discuss challenging issues on uncertainty management among a broader group of actors.**

3 - Identify **methods for organizing a regular and pluralistic[4] dialogue** on uncertainties during the development and review of the safety case.

4 – Provide **recommendations for future EURAD activities.**

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, IAEA Safety Glossary: 2022 Edition, Non-serial Publications, IAEA, Vienna (2022)

[3] In the UMAN perspective, uncertainty management is a key element of the safety case. It is an iterative process associated with the stepwise implementation of the disposal programme. As some uncertainties have the potential to jeopardize safety, they need to be identified and assessed; several options might be available to reduce, avoid or mitigate these uncertainties. The strategies defined to do so are called uncertainty management.

[4] In the context of UMAN Task 5, Pluralistic means diversity of actors and an interdisciplinary perspective (embedding technical and socio-technical issues)

1.2 Methodology of Task 5

To fulfil these objectives, Task 5 implemented a methodology based on the organisation and animation of a set of pluralistic seminars. The aim was to discuss UMAN (interim) results with a broader range of actors including civil society (CS) actors (CS experts[5] (Dewoghelaere J. et al, 2020) and members of CS larger group[6]), representatives of regulators[7] and international organisations (IGSC[8], FSC[9]). The set of seminars was elaborated as an integrative process, each seminar constituting one step of the pluralistic analysis of UMAN results. The final goal was to identify methodologies enabling to organize a regular dialogue around uncertainties between experts and civil society all along the geological disposal implementation (including pre-disposal phase and post-closure phase). The topics of the different seminars were:

- **Seminar 1: What does uncertainty management mean for different types of actors? How is it related to risk, safety, and the safety case?** (October 2020) Seminar 1 addressed the meaning for different actors of uncertainty management and its relationships with risk, safety, and the safety case. It discussed the results of the different UMAN tasks (Task 2.1 and Task 3.1). The results are available in D10.13 (Röhlig K.-J., 2021)
- **Seminar 2**: **Focused on site and geosphere: Preferences of actors, evolutions of uncertainties throughout different phases and how interactions with civil society could contribute to manage these types of uncertainties?** (October 2021) Following seminar 1 which provided a global perspective on uncertainties and their management, seminar 2 examined the aspect of uncertainties on site and geosphere. The aim was to identify and discuss the views of different types of actors on the following topics based on concrete cases: preferences regarding possible uncertainty management options, possible evolutions of uncertainties throughout different phases of a disposal programme and how the interactions with civil society could contribute to manage these uncertainties. The results are available in deliverable D10.14 (Rocher M., 2023).
- **Seminar 3: Focused on uncertainties related to human aspects: Preferences of actors, evolutions of uncertainties throughout different phases and how could interactions with civil society contribute to manage these types of uncertainties?** (June 2022) seminar 3 focused on the uncertainties related to human aspects. Human uncertainties are defined on a very large basis, i.e., the uncertainties related to human activities during the different phases of a geological disposal programme. The topic was considered too large to enable fruitful discussions, it was therefore necessary to select key topics to be further analysed. The aim of

[5] The CS experts are experts with technical and socio-technical background or/and experience on the involvement of CS in scientific and technical issues. They are involved in EURAD activities through NTW (international association), translating scientific/technical results for exchanging with a larger group of CS representatives (NGOs, representatives of local communities)

[6] The composition of the CS larger group is detailed in EURAD deliverable D1.13 (Dewoghélaëre et al., 2020a): https://www.ejp-eurad.eu/sites/default/files/2020-11/EURAD%20-%20D1.13_ListofCSgroupmembers_EURAD.pdf

[7] The representatives of regulatory authorities are part of the UMAN end user group: FANC from Belgium, Environment Agency from United Kingdom, Safety of Nuclear Waste Management (BASE) from Germany, State Office of Nuclear Safety from Czech Republic

[8] The Integration Group for the Safety Case (IGSC) is the main technical advisory body to the Radioactive Waste Management Committee (RWMC) on the deep geological disposal, particularly for long-lived and high-level radioactive waste. It was established in 2000 in recognition of the need to foster full integration of all aspects of the safety case. https://www.oecd-nea.org/jcms/pl_29043/integration-group-for-the-safety-case-igsc

[9] The Forum on Stakeholder Confidence (FSC) was established by the NEA Radioactive Waste Management Committee (RWMC) in 2000 and serves as a platform for understanding stakeholder dialogue and discussing methods to develop shared confidence, informed consent and approval of radioactive waste (RW) management solutions: https://www.oecd-nea.org/jcms/pl_26865/forum-on-stakeholder-confidence-fsc

seminar 3 was to discuss the views of different types of actors on the following topics based on concrete cases: public acceptance, schedule to be considered for implementing the different phases of the disposal programme, the management of new knowledge emerging during the implementation of the GDF, and the adequacy of safety related activities for the implementation of safety provisions (with a focus on the construction phase). The results are available in deliverable D10.15 (Dumont J.-N., 2022).

- **Seminar 4**: **Methods that can be used for discussing and organising pluralistic assessments of uncertainties throughout a disposal programme** (December 2022) Seminar 4 focused on methods enabling fruitful interactions between institutional/technical experts and civil society in the long term. Seminar 4 gave the opportunity to discuss the lessons learnt during the 3 previous seminars and Task 4 workshops on how to manage uncertainties in a pluralistic way and in a long-term perspective. One of the objectives was to assess the methods to organise pluralistic discussions on uncertainty management in RWM that were identified during the process implemented by UMAN Task 5. The second objective was to identify potential strategic research needs on methods to achieve the goal of enabling a pluralistic assessment of uncertainty management related to RWM in the long term. The results are available in deliverable D10.16 (Dewoghelaere J., 2024).
- **Seminar 5**: **Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties**. In the frame of the EURAD second wave, an extension of the UMAN project was decided. It was the opportunity for Task 5 to test the pluralistic methodology on the topic of near-field uncertainties during a fifth seminar. Seminar 5 was held in Brussels in 06-07 December 2023. During this seminar, representatives of the different colleges (3+1) presented their views on near field uncertainties and a PEP game session was held, with a specific PEP created for this event.

This document presents the preparation of this fifth seminar, its content, and its results.

2. Conception and preparation of the seminar

This fifth UMAN task 5 seminar was not initially planned but was integrated in the extension of the UMAN project decided during the second wave of UMA. It was decided to add an additional seminar to test the identified methodologies for exploring uncertainties in a pluralistic way. The near-field uncertainties were identified as a key topic and an interesting one to test these methodologies.

This seminar was designed with some available material:

- The results of the previous UMAN seminars and related deliverables (D10.13 (Röhlig K.-J., 2021), D10.14 (Rocher M., 2023), D10.15 (Dumont J.-N., 2022), D10.16 (Dewoghelaere J., 2024));
- The analysis of the UMAN results by the CS experts involved in UMAN gathered in deliverable D10.17 (Dewoghelaere J. et al, 2024a);
- The inputs of the UMAN task 3.6 on identification, characterization and potential significance of uncertainties on the near field gathered in deliverable D10.18 (Pfingsten W., 2024);
- The results of the task 4 workshop on the management options and preferences of actors related to near-field uncertainties gathered in deliverable D10.19 (Becker D.-A et al., 2024).

All the detailed references of the deliverables are available on references section of the report.

Task 3.6 provided a preliminary list of uncertainties that have been proposed by the expert group as input for the task 4.2. These uncertainties were linked to three main themes:

- Uncertainties associated with the processes governing or altering radionuclide migration and the performance of disposal system components.
- Uncertainties to be taken into consideration when conceptualizing waste packages, technical barriers and adjacent EDZ of natural barriers.
- Uncertainties associated with THMCBR processes dominating at different time scales as well as with gas migration in near-field systems.

Based on this preliminary list, participants of Task 4 workshop were asked to evaluate the significance of each uncertainty through the lens of their own experience. This qualitative evaluation then helped selecting one source of uncertainty for each theme for seminar 5.

The three uncertainties selected for this seminar were:

- The hydraulic properties of the bentonite.
- Metallic material behavior in different barriers.
- Modeling of radionuclide transport.

The uncertainty related to the hydraulic properties of the bentonite was considered too specific because not all repository concepts include bentonite. Therefore, and it was agreed to extend this issue to a more general one regarding the choice of whether or not to use bentonite in the design and the methods of using it having in mind the hydraulic properties of the system.

It was agreed that these three uncertainties should be explored both in normal and exceptional conditions and for all phases of the repository.

CS experts involved in UMAN reviewed the work performed by UMAN partners in Tasks 3.6 and 4.3. They addressed the results of their analysis to CS larger group during the UMAN of ICS Workshop n°4 (May 2023) and ICS Workshop n°5 (October 2023), and updated their analysis based on the results of

these discussions. They also used the results of their analysis of the whole pluralistic process implemented in task 5 (Dewoghelaere J. et al, 2024).

It was decided during the preparatory meetings that the seminar would both present the different actors' views on near-field uncertainties and let the participants testing the PEP game as a tool for dialogue, based on a board and cards specially designed for this seminar.

The pluralistic team organizing the seminar 5 proposed that the presentations of the different actors would focus on significance and available options for managing the main uncertainties related to the three topics related to near-field uncertainties based on:

- The work performed in UMAN, notably:
    - Views of WMOs, TSOs and REs on the identification, characterization, and potential significance of near-field uncertainties (Task 3.6),
    - The results of the Workshop (17 May, 17&29 June 2023) on management options and preferences regarding near-field uncertainties. (Task 4.3),
    - The work carried out by the CS experts involved in UMAN (Task 5.2).
- Other relevant references (IAEA, national programmes, etc.).

The PEP material was designed by a pluralistic team. Based on the existing material and following the proposed main uncertainties and linked concrete examples, the CS experts and members of the TSO college designed the new cards and board on near-field uncertainties. Several meetings were held with the UMAN task 5 members to discuss and improve the work-in-progress PEP material.

The PEP event cards were designed following the 3 main themes. An additional transversal theme was added for cross-cutting issues. The criteria cards were designed based on three general categories: Management of uncertainties and risk, Governance, Public participation & Ethics.

The new PEP material can be found in Appendix D. The details on the PEP are given in the next section.

3. UMAN seminar 5

3.1 First session of the seminar: views of each type of EURAD actors on near-field uncertainties

This session presented and discussed views of each type of EURAD actors (WMO, TSO, RE, CS) on near-field uncertainties based on UMAN results.

3.1.1 Introductory session

Task 5 leader presented the objectives, the framework, the context of this seminar and how it was prepared (see above). He then presented a few definitions of near-field uncertainties, to be sure all participants have a common understanding of this concept for the rest of the seminar.

3.1.2 WMO keynote presentation

Ondraf representative presented WMOs' views on the management of near-field uncertainties. His presentation focused on main points:

- The issue of safety significance and its link to the safety concept.
- The need for a common understanding of the safety concept to address any issue.
- The dynamics aspect of a repository, meaning that uncertainty management depends on the project phase.
- The necessity to characterize better EBS materials and safety-relevant processes, to provide an adequate defense in depth, and to ensure a correct quality assurance and associated controls.
- The need for a process to envisage better the impact of the uncertainties linked to models of safety.

He then proposed some topics for discussion:

- How to explain the differences between actors' perceptions on the safety significance of uncertainties? Is it due to the methods of assessment or its basis on which it relies? Does the scope of the assessment (integrative or more focused) impact the assessment?
- How to prove the models used for the safety assessment are correct, especially regarding the expectations of the different stakeholders?
- How to reach a common understanding of model purposes and the meaning/significance of modelling results regarding safety? How to deal with the choice between conservative assessment and system understanding, or between simple and complex models?

The following discussion started with clarification questions on the extent of the "near-field" and its link to the operational phase. Some questions about the processes of model validation and their link to data were raised. A remark concerning the "significance" was raised: it is difficult to argue on the significance without a more precise definition (what parameter, what number). Finaly the question of post-closure monitoring was addressed, considering however that the different options should be based on sensitivity analysis to better know what to do in each case.

3.1.3 TSO keynote presentation

Bel-V representative presented the TSO views on near-field uncertainties. At the end of his presentation, he raised some issues to discuss:

- The safety significance of the near-field uncertainties and its dependence on the choice of the host-rock and especially the containment safety function.
- The reduction of the near-field uncertainties with the progress in the disposal programme
- The responsibility of the WMO to choose the management option regarding the prevailing circumstances
- The role of the TSO in influencing these prevailing circumstances through regulatory framework or the state of the knowledge and in challenging the programmatic activities leading to the choice of a management options by the WMO.

After this presentation, the discussion was about the role of TSO in challenging the WMO concepts and tools (even complex models). There was also a discussion about the UMAN iterative strategy (illustrated in Figure 2) – that was suggested as a powerful and fruitful framework to envisage the dynamics of the assessment and the reduction of uncertainties – and how to improve it.

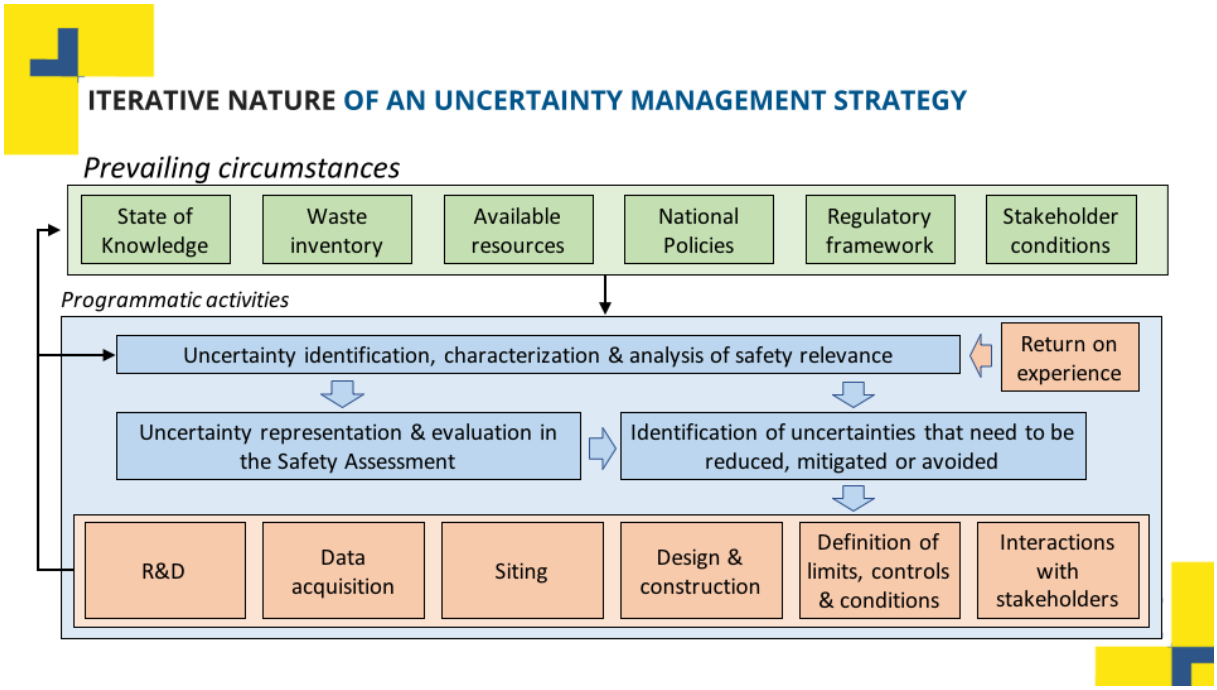


Figure 2 – UMAN iterative strategy.

3.1.4 RE keynote presentation

PSI representative presented the RE views on near-field uncertainties. The main messages of this presentation were:

- The importance of the uncertainties' safety significance evolution and analysed parameters over the phases of the DGR programme (uncertainties are of high significance in the phases after the site characterization)
- The role of modelling and experimentation in investigation of the complex THMCBR processes and accessing parameter uncertainty. REs propose solutions but do not drive the uncertainty management strategy
- A flexible near-field design helps reduce parameter uncertainty and optimize safety and costs
- The need to have more research on global parameter uncertainty analysis and optimisation in future EURAD activities.

3.1.5 CS keynote presentation

NTW representative presented the CS views on near-field uncertainties. The main messages were:

- The fact that some of the CS concerns regarding near-field uncertainties are global because they focus on the decision-making process (pluralistic assessments help keep in mind the global picture)
- However, CS also has specific concerns on near-field uncertainties: bentonite and conditions for closure, compromise between new knowledge and safety, models and measurement issues
- The need for shared values as a basis for establishing and keeping a strong shared culture for safety and security: independence of expertise, mediative tools, etc.
- The issues about opacity or transparency of models and measurements and conditions to build trust
- The need for more transparency and participation in all steps of RWM
- The necessity to develop a shared vision for dealing with RWM in the long-term
- The role of civil society to help broadening the scope of research or to keep a global view.

After this presentation, several questions were raised, notably about the representativity of the civil society in question.

3.1.6 General discussion

The general discussion after these presentations was quite short, as time was running out and a more global discussion was envisaged for the day after. However, some questions and remarks were raised, especially about the possibility of post-closure or long-term (over 100 years) monitoring and the link to safety, and the representativeness of the different types of public that constitute the civil society, and the model used in EURAD (double-wing model).

3.2 Second session of the seminar: PEP game

After a brief presentation of the PEP by Task 5 leader, the PEP game session was held in three small pluralistic groups of 7-8 persons (see in Appendix B). Each group discussed concrete situations elaborated by participants based on PEP material (see in Appendix C). Each situation is associated with two questions to guide the discussion in the working groups.

The method of discussion is the following: two successive rounds of discussion where the participants are asked to give their opinions without being interrupted during the first round. At the end of the first round, the participant who have suggested the situation presents a summary of what has been said by the others and the facilitator launches a second round of discussion. During this second round, participants are invited to provide additional information or to clarify their thoughts based on what was said by other participants during the first round of discussion.

After having discussed different situations proposed by all the participants (at least one scenario per participant of the working group), a final round of discussion is organized to collect the strong points and recommendations of the participants at the end of the exchanges.

A concrete situation of PEP is based on one event card associated with 2 evaluation criteria cards (Figure 4), located on the board (Figure 3) to specify the phase of the program in which the events occur.

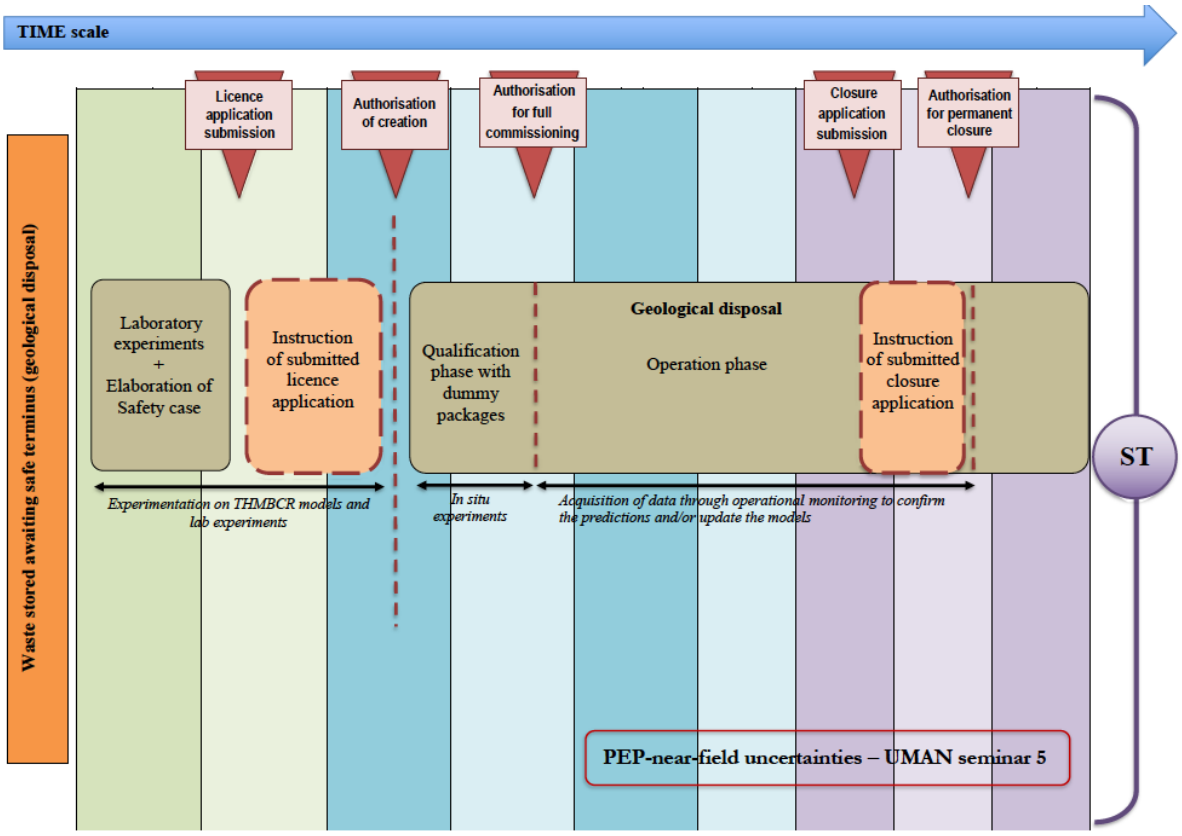


Figure 3 – Board used in this PEP game.

Figure 4 – Example of a scenario: one event card associated with two criteria cards.

The exhaustive list of the evaluation criteria cards, the event cards and the board can be found in Appendix C.

3.3 Third session of the seminar: Restitution and conclusion

3.3.1 Restitution of the PEP game

The facilitator of each group presented the results of their PEP game session.

The first group discussed various topics, such as:

- the questioning about models' parameters and the pluralistic assessment of uncertainties,
- the case of an operating accident and the uncertainty management,
- the uncertainties about packages corrosion, the link to the safety case and the risk of repository abandonment,
- the uncertainties about monitoring, the adaptability of the system, and the transparency and access to information,
- the discrepancy between data and models.

The second group discussed three scenarios on uncertainties of waste characterization:

- one linked with the uncertainty management after authorization and reversibility,
- another linked with the conditions for closure and the intergenerational governance,
- the last one linked with the uncertainties in the safety case, the democratic processes and the social trust.

The third group discussed four cases:

- one on the discrepancy between measurements and models, linked with the questions of adaptability and the risk of abandonment,
- another one on the change of classification of the waste, linked with the issues of continuous safety and security, and of adaptability,
- another one on the performance of seals linked with the uncertainty management after authorization and the intergenerational governance,
- the last one on technological innovation and the questions of adaptability and knowledge management.

All the details of the scenarios played can be found in Appendix D.

After the presentation of the results of each group, a more general discussion on the PEP game was held.

One of the main remarks about this PEP is that it was hard to focus on the near-field uncertainties. Indeed, near-field uncertainties are linked to very technical issues, and it is difficult for non-experts to know if scenarios are credible or not, or the significance of such scenarios, or even to understand the difference between near and far-field. These difficulties could explain why the discussions were mainly about global scenarios and issues, and not specific near-field topics. It might be interesting to rather have a generic PEP with some items about near-field uncertainties. To have a more specific discussion on near-field, it was suggested to have a driven scenario. Indeed, the PEP is designed to let participants freely discuss what they have in mind, but if a precise topic is expected, it could be better to drive the participants to the wanted discussion. The discussion also depends on the type of public and leaders, for a TSO-driven PEP could be more technical and less global than a regulator-driven one. However, it has been said that what matters most in a PEP game is not solving uncertainty management problems or monitoring problems, but rather creating a common understanding among all actors brought about by discussions about the meanings of the events being discussed.

3.3.2 Generic discussion on potential needs for future research

The generic discussion started with the presentation by a CS expert of a concept of a new visualisation tool to help understand the evolution of the safety envelope of a GDR through time (Figure 5).

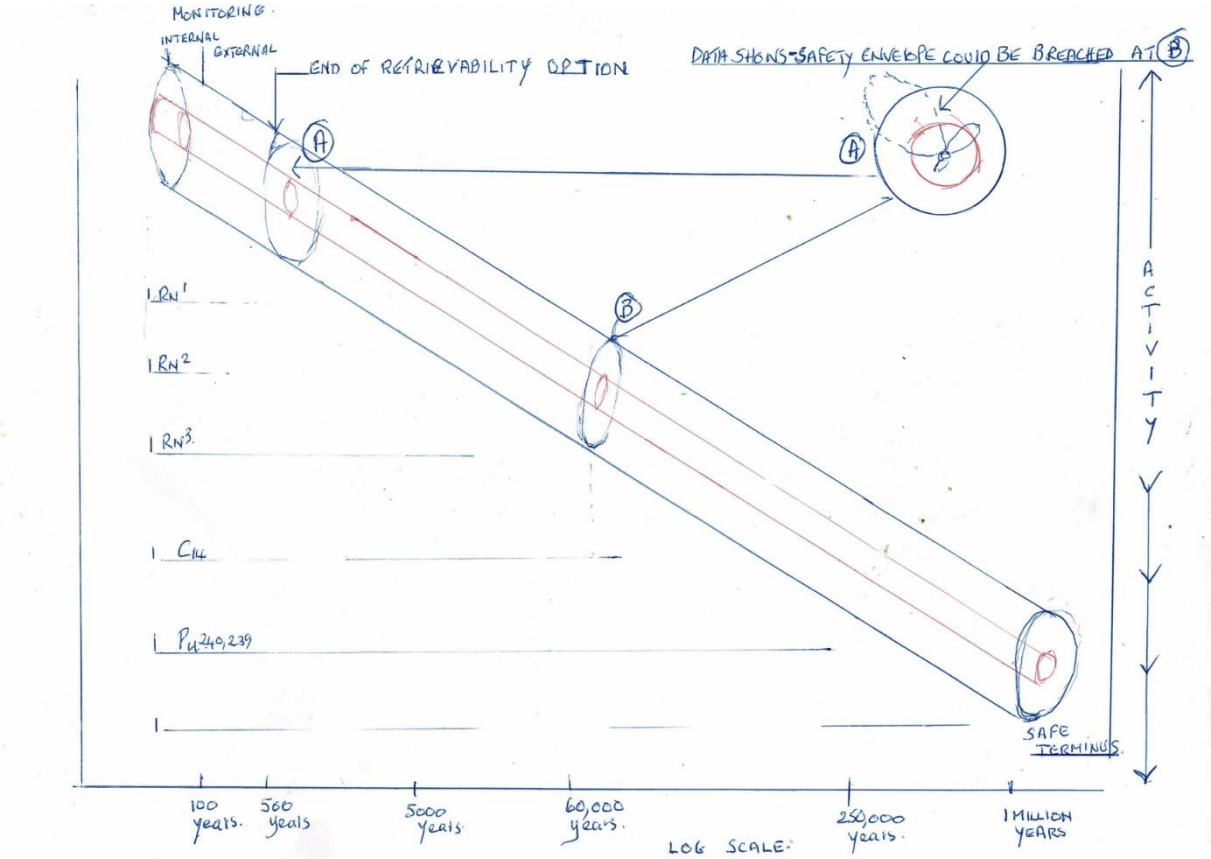


Figure 5 - Proposition of a visualisation tool for the dynamics of uncertainties.

This tool represents a dynamic vision of the evolution of uncertainty regarding the safety envelop and what is envisaged in the safety case through the years.

In this draft figure, the inner red circle would represent the safety case time boundary (or the regulatory envelope) and the outer blue one the safety envelope. Within these circles is displayed a small, closed ellipse which represents an expected repository evolution process which falls within the regulatory time envelope. The dotted elliptic lines represent the idea that monitored data could inform at (A) that a breach of the safety envelop which breaches the regulatory envelope is possible and has the potential to breach the safety specifications.

The discussion about this tool started with the fact that it is crucial for a community concerned by a repository to have the best knowledge possible about it, and that such tools could help better understand what is at stake, notably the evolution of the safety envelope. It was said that such tool is a work in progress but however could be very useful to enable dialogue, to grasp the complexity of a repository, to discuss the uncertainties and to show the main issues at stake. Such tool could be complementary to the PEP to create a pluralistic dialogue.

The final discussion was about the possibility to include artificial intelligence in the process of a repository. It was said that AI promised a lot in a large range of fields, but the question of its relevance to manage uncertainties in RWM was raised. Three main points were raised:

- The fact that AI is already used in radioactive waste management. Machine learning is currently used and it is expected to develop predictive tools based on large amounts of data and neural networks to replace physics-based models when needed. There are current experimentations on core sample analysis through AI. Artificial intelligence and neural network-based tools are also currently being studied for sensitivity analysis of radionuclide transport models.
- Some of the main issues with the development of AI: it was said that it is crucial to discuss now the potential problems and threats that AI can bring and not wait for the actual deployment of such tools. One on the main problem in the discussion is that AI is very diverse and that it is important first to precise what is discussed. The necessity of a robust database was raised, since the results of the current AI tools (GPT for example) mostly depend on the quality of the data used. Also, AI meets the tension in RWM between the welcoming such new technologies and keeping a low-tech repository. Moreover, the question of transparency related to the status of such tools was raised, since nowadays the most powerful AI tools belong to big corporations whose products falls under the industrial property/secrecy.
- The perspectives of AI in EURAD. It was proposed to used AI for knowledge management, creating a GPT-like tool that could be used to access all the knowledge produced in EURAD, that should be first put in a container.

4. Synthesis and conclusion of Seminar 5

The objectives of this seminar were:

- To discuss the UMAN results related to near-field uncertainties,
- To test the identified methodologies to explore uncertainties in a pluralistic way and especially the PEP game.

Concerning the first objective, each actor presented its views to discuss them. Following the same conceptual framework and template allowed to better envisage the differences and similarities of concern. The pluralism of the discussions helped identify transversal key issues regarding the near-field uncertainties, such as the safety significance, the methods to reduce models' uncertainty, or the importance of trust.

The second objective was also reached: the creation of a specific PEP game for the near-field uncertainties allowed to plurally discuss its complex linked issues. The discussions that occurred during and after the PEP game session were highly interesting and led to more global than specific discussions on how to tackle uncertainty associated with waste, models, monitoring, or engineered barriers.

Both the new PEP game and the discussions that resulted from its use in this seminar can be considered as important results. However, some discussions about how to improve this tool for a better pluralistic dialog suggested that this topic might be too technical for everyone to easily apprehend it.

Appendix A. Agenda

WP 10-UMAN
UMAN task 5, seminar 5
Agenda
6 - 7 December 2023
Bel-V, Brussels, Belgium

The main objectives of the seminar n°5 are:
- To discuss the UMAN results related to the near-field uncertainties.
- To test the identified methodologies to explore uncertainties in a pluralistic way and especially the PEP game.

6 December 2023

Introductory session – 14:00-14:30

Objectives and setting the frame of the seminar, definition of near-field uncertainties – Julien Dewoghélaëre, NTW – UMAN Task 5 leader

First session – 14:30-18:00

This session will present and discuss views of each type of EURAD actors (WMO, TSO, RE, CS) on near-field uncertainties based on UMAN results.

14:30 **WMO Keynote presentation –** Agniezska Strusinska-Correia, BGE

15:10 **TSO Keynote presentation –** Representative of Bel-V

15:50 *Break*

16:20 **RE Keynote presentation –** Wilfried Pfingsten, PSI

17:00 **CS Keynote presentation –** Gauthier Fontaine, NTW

17:40 **General discussion**

18:00 **End of the first day**

19:00 **Social dinner**

7 December 2023

Second session – 09:00-12:30

This session will enable participants to test the PEP game based on cards dedicated to near-field

uncertainties. The participants will be invited to create their own scenarios and to discuss it in small groups composed of different types of actors.

09:00 **PEP presentation: objectives and mechanisms of the game –** Julien Dewoghélaëre, NTW – UMAN Task 5 leader

09:30-12:30 **PEP session in small groups**

12:30-14:00 *Lunch break*

Third Session – 14:00-17:00

14:00-15:30 **Restitution Session** – animated by Julien Dewoghélaëre, NTW – UMAN Task 5 Leader

This session will be organised as a generic discussion involving all participants. We will try to collectively answer the following questions:
- What did you learn about the issues related to the near-field uncertainties through the PEP game?
- What do you think about the ability of this tool to enable pluralistic assessment of uncertainties?
- How could it be improved?

15:30 *Break*

16:00-17:00 **Generic discussion on potential needs for future research –** animated by Julien Dewoghélaëre and Gauthier Fontaine, NTW

This generic discussion will try to collectively identify the potential needs for future research around this field and especially about the issues of ignorance models.

17:00 **End of the second day**

Appendix B. List of participants and PEP Game groups

WMO
TSO
RE
CS representative
Regulatory body

In bold: Facilitator

In red: Online participant

PEP group 1

Fontaine	**Gauthier**	**NTW**
de Butler	Malcolm	NTW
Ikonen	Ari	EnviroCase
Pfingsten	Wilfried	PSI
Soloviov	Oleksandr	SSTC NRS
Wales	Colin	NTW/Cumbria Trust
Zeleznik	Nadja	EIMV

PEP group 2

Geisler-Roblin	**Alexis**	**NTW**
Ivanov	Ivan	TU-Sofia-R&DS
Kecek	David	SURO v.v.i.
Lemy	Frank	Ondraf/niraf
Li	Xiaoshuo	Nagra
Matthews	Philip	Nuleaf
Surkova	Maryna	FANC

PEP group 3

Dewoghelaere	**Julien**	**NTW**
Coelho	Daniel	Andra
Detilleux	Valery	Bel-V
Diaconu	Daniela	RATEN
Hooge	Niels Henrik	NTW/NOAH
Ilett	Doug	Environment Agency
Konopásková	Soňa	SÚRO
Tatomir	Alexandru	BGE

Appendix C. PEP game material

List of Events cards for the PEP near-field

UNCERTAINTIES LINKED TO PROCESSES GOVERNING RADIONUCLIDE MIGRATION

- E1: **Defects in manufactured barrier properties**: Additional control reveals defects in the manufacture of canisters or waste packages. These defects could threaten the barrier function, depending on the number of affected components. (*E.g.: default in the metal of the canister leading to preferential migration path; Falsification of quality control of defective disposal packages*)
- E2: **Uncertainties about the performance of seals:** Uncertainties remain about the sealing option for disposal (*E.g.: Uncertainty about the long-term durability of sealing materials; uncertainty on the mechanical behaviour of bentonite*)
- E3: **Lack of data related to transport properties of RN:** Some key parameters related to processes governing radionuclide migration in the near field are insufficiently documented. There is a need for in-situ data. *(E.g.: accessible porosity and solubility limit values are extrapolated from lab measurements for very few elements and are extrapolated for the other elements*)
- E4: **Lack of data related to host rock properties**: Some assumptions associated with the conceptual model of Kd deserve to be verified in-situ. (*E.g.: need for in-situ data to specify Kd values*)
- E5: **Uncertainties linked to evolution through time of transport properties**: Uncertainties remain about the evolution through time of transport properties. *(E.g.: Reactions caused by the diffusion of reactants from different sources can alter rock diffusivity)*

UNCERTAINTIES LINKED TO WASTE PACKAGES, TECHNICAL BARRIERS AND EDZ

- E6: **Defective demonstrator:** The prototype submitted for authorization does not confirm initial expectations related to the performance of disposal system components (*Example: Properties related to hydraulic gradient below expectations; Release of higher amounts of CO2 and organic acids during heating than predicted*)
- E7: **Uncertainties about package corrosion:** Significant uncertainties remain about the corrosion of the materials surrounding the packages (*Example: Shape of containers leading to the possibility of premature piercing by corrosion*)
- E8**: Uncertainties on waste characterisation**: Uncertainties remain on some type of waste's characterisation. *(E.g.: Modification of the waste inventory including new category of waste; Difficulty to characterize legacy waste)*
- E9: **Impact of the excavation on the host rock:** Uncertainty remains on the impact of excavation on the surrounding rock properties due to stress changes. *(E.g.: Difficulty to characterize the impact on the permeability of the host rock; Uncertainty on the extent of the EDZ)*
- E10: **Waste conditioning problem**: Premature decay of some waste packages calls for unprepared repackaging. (*Example: Unexpected cladding corrosion leads to urgent retrieval of ILW, new package must be designed and implemented.; An accident during storage causes damage to some of the waste, reconditioning is challenging*.)

UNCERTAINTIES LINKED TO THMCBR MODELS

- E11: **Controversy on models used for GD**: The publication of new scientific data drastically challenges the assumptions on which relies the models used for the safety case (*E.g.: Emergence*

of alternative conceptual models; *Contrary to initial hypotheses, the dynamics of bentonite resaturation cannot be neglected)*

- E12: **Serious questioning on models' parameters**: Some phenomena taken into account in THMBCR models have been underestimated (*Example: Hydraulic gradient larger than expected, higher impact of chemical reactions due to organic matter*)
- E13: **Uncertainties about natural hazard:** New scientific knowledge leads to an upward re-evaluation of natural events (*Example: Climate change is destabilizing the Earth's crust, increased risk of flooding*)
- E14: **Trust in models challenged:** The representativeness of the models used is not sufficiently satisfying for some actors. *E.g.: request for monitored data from civil society to complement models; Some coupled effects are not sufficiently demonstrated for the authorities in charge of the safety case's assessment)*
- E15: **Uncertainties linked to coupled effects:** Modelers encounter difficulties in predicting and assessing the effects resulting from the coupling of processes that have been modelled separately *(E.g.: a. Changes in porosity and other transport and chemical parameters caused by mineral precipitation/dissolution reactions*
- E16: **Discrepancy between measurement and models:** Physics-based models and monitored data do not present same results on some key elements. (*E.g.: the resaturation is not supposed to happen within hundred of years but sensors detect high humidity in the host rock)*
- E17: **Complex modelling of long-term issues:** Modelers encounter difficulties in describing the heterogeneity of processes that will influence each other in a long-time scale. *(E.g.: Domination of different processes at different time scale: temperature in the first 1000 years, resaturation up to 10000 years, etc.)*

CROSS-CUTTING ISSUES LINKED TO NEAR-FIELD UNCERTAINTIES

- E18: **Operating Accident:** An operating accident reveals a major safety deficiency on one or more installations (*Examples: A controlled fire during the handling of a package reveals an undersizing of the extinguishing systems; A leak in a nuclear ventilation well is detected*)
- E19: **Uncertainties about monitoring**: Uncertainties remain about the ability to monitor the evolution of some parameters of the disposal (*Example: Uncertainties remain about the ability of sensors to be measure key parameter (porosity, solubility limit) for radionuclide migration*
- E20: **Technological Innovation**: New techniques are being developed enabling to drastically reduce certain categories of uncertainty (*Example: Development of materials with better performance*)
- E21**: Impeding knowledge breakthrough**: Scientific investigations reveal unforeseen technological weaknesses (*Examples.: New phenomena regarding faster dispersion of some radionuclides are found; Projected long term geological conditions are strongly challenged by new discoveries.)*
- E22: **Change of external conditions:** Significant change of the social or environmental situation makes it necessary to reconsider the terms of the impact assessment. (*E.g.: Water hydric shortage changes the concern for nearby groundwater as a resource.; New valuable natural resources are found in the neighbourhood*.)

List of Criteria cards for the PEP near-field

MANAGEMENT OF UNCERTAINTIES AND RISK

- Q1- Uncertainty management over time: Does the pathway draw together all the conditions allowing a good management of uncertainties? Does it ensure the effective implementation of the three main strategies (avoid, reduce, mitigate)?
- Q2- Assessment of the uncertainties in the safety case: How does the pathway deal with uncertainties in the safety case (insignificant uncertainty, need for R&D or revision of the concept)? How does the pathway manage to deal with the remaining uncertainties?
- Q3- Uncertainty management after authorisation: Does the pathway governance system allow managing certain uncertainties that cannot be addressed when examining the storage authorisation request?
- Q4- Conditions for closure: What level of certainty is requested to close the facility? How and by who is it decided? What would be the conditions for reaching a safe terminus, entailing a switch from active to passive safety in the pathway?
- Q5- Continuous safety and security: Does the pathway maintain an adequate level of requirements over time to ensure the safety and security of RWM all along the decision-making process?
- Q6- Risk of abandonment: Is the pathway vulnerable to possible abandonment in uncontrolled conditions, before reaching a Safe Terminus?
- Q7- Undue transfer of risks: Does the pathway open the gate for potential undue transfer of risks?
- Q8- Pluralistic assessment of the uncertainties: How does the pathway allow a continuous involvement of a diversity of expertise, knowledge, and sensitivities?

GOVERNANCE

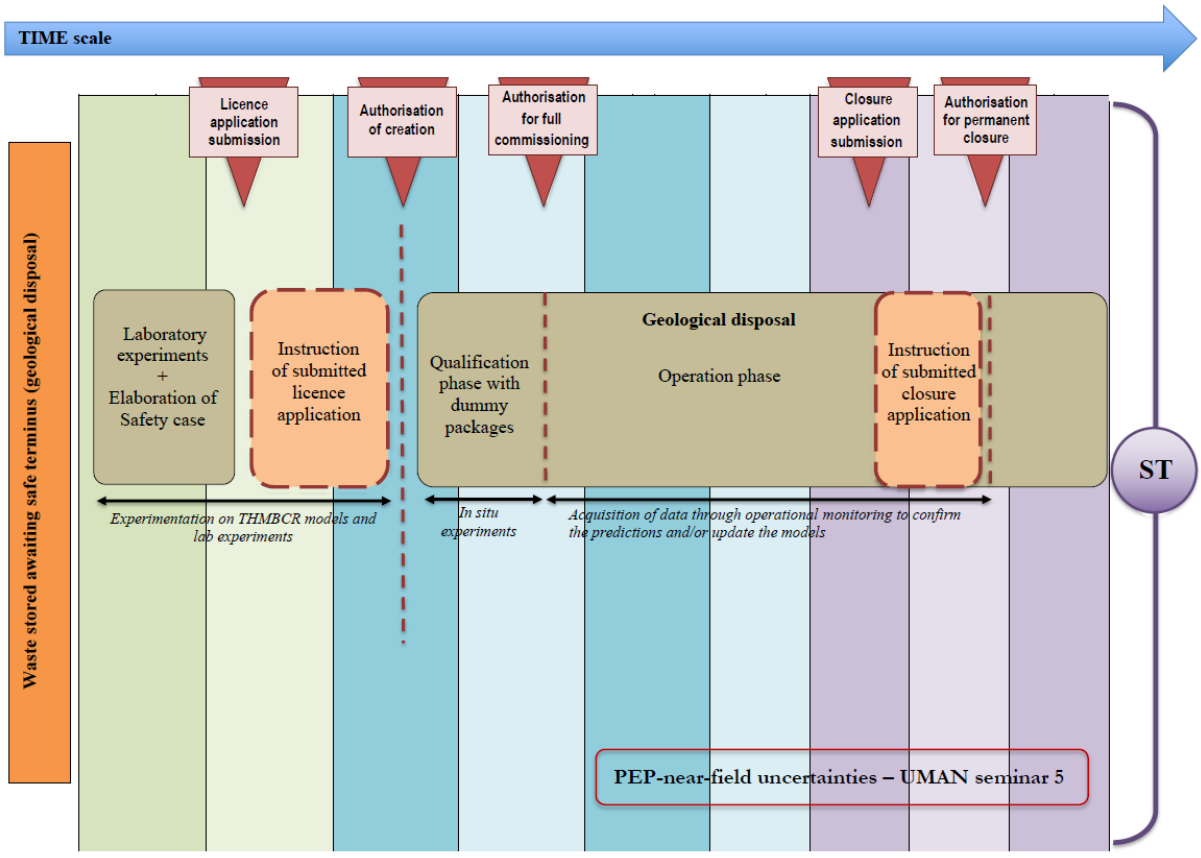
- Q9- Robustness of the pathway to disruptive events: Can the pathway manage difficulties encountered over time? Can the monitoring pathway undergo disruptive and unexpected events (major discovery, financial crisis, armed conflict, etc.) without being blocked?
- Q10- Adaptability of the pathway: Can the pathway be flexible and adaptative to the evolution of scientific context (new knowledge, technological breakthrough)? Is the pathway sensitive to external social, financial economic, political constraints (loss of skills, financial crisis, evolution of political and societal requests, etc.)? Are there actual alternatives (B plan) at each stage?
- Q11- Maintaining reversibility: Does the pathway ensure that reversibility is maintained over time?
- Q12- Intergenerational governance: What room for manoeuvre does the pathway give to future generations?
- Q13- Maintaining preservation of knowledge over time: Is the pathway able to maintain knowledge and keep (active or passive) memory all along the stages of the DGR, including post-closure?
- Q14- Time allowed for the evaluation of the safety case: Does the pathway allow the regulator the time necessary to assess the proposed option without short-term pressure or urgent constraints related to waste management?

PUBLIC PARTICIPATION & ETHICS

- Q15- Maintaining social trust: Does the pathway generate/maintain trust of the different types of concerned stakeholders over time?

- Q16- Democratic process: Does the pathway allow encountered difficulties to be addressed democratically? Does it allow a pluralistic set of actors (including society) to anticipate and participate in important choices all along the DGR implementation?
- Q17- Monitoring: What would be the key stakes of monitoring activities in the pathway? How does it deal with the balance between the use of the precautionary principle and the need to proceed with some action?
- Q18- Transparency and access to information: Does the governance of the pathway ensure transparency regarding events all along the DGR phases? What level of access to information (and to whom) is planned by the pathway?
- Q19- Transfer of risks to future generations: Does the pathway open the door to potential transfers of undue risks to future generations? What room for manoeuvre does the scheme give to future generations?

Board of the PEP near-field



Appendix D. Results of the PEP game session

Group 1

Facilitator : Gauthier Fontaine

	Type of actors	Events card	Criteria cards	Time occurrence of the event	Description of the event
Case 01	CS	E12: Serious questioning on models' parameter	Q8: Pluralistic assessment of the uncertainties	Before the license submission	What does "serious questioning" mean -> problem of "significance" of the problem How to explain coupling to people?
Case 02	RE	E18: Operating Accident	Q8: Pluralistic assessment of the uncertainties Q1: Uncertainty management over time	Operational phase.	There is an accident in the ventilation system that was not foreseen. What to do? Accidents are very likely to happen, and procedures are needed notably to keep trust Root cause analysis and safety culture at international level
Case 03	TSO	E7: Uncertainties about package corrosion	Q6: Risk of abandonment Q2: Assessment of the uncertainties in the safety case	Operational phase	Uncertainties about package corrosion. And risk of abandonment. Depends on the type of corrosion. Importance of the role of the regulator Safety relevance
Case 04	WMO	E19: Uncertainties about monitoring	Q10: Adaptability of the pathway Q18: Transparency and access to information	Application phase – early operational phase	Uncertainties about monitoring. New knowledge is needed through new data. How adaptable is the monitoring system? ➔ Flexibility is the key
Case 05	TSO	E16: Discrepancy between measurement and models			General questions about discrepancy between data and models. Discussion about the reasons to have difference between physics-based models and data.

					Should we trust better data or models?

Group 2

Facilitator: Alexis Geisler-Roblin

	Type of actors	Events card	Criteria cards	Time occurrence of the event	Description of the event
Case 01	NRA	Uncertainties on waste characterization.	Uncertainty management after authorization. Maintaining reversibility.	During instruction, before and after.	**Uncertainties regarding credibility of input inventory.** The original inventory might be adjusted : uncertainties on waste characterization. In the case the construction has been authorized. Acceptance criteria are evolving, as optimization process is working. Where should we put a tension ?
Case 02	WMO	Uncertainties on waste characterization.	Conditions for closure. Intergenerational governance.	End of operation phase.	**New waste streams appearing, even exotic waste streams.** More at the end of operation phase. Evaluation : conditions for closure ? We don't know if our repository is ready for hosting this waste. At some point you need to close the repository. And coming back to the near-field, when you design an underground facility, you have a certain lifetime of underground building, because of oxidation. In the same time, will it be interesting for society to wait ? Postponement of a new facility, but waiting with this waste ?

Case 03	CS	Uncertainties on waste characterization.	Q2, Q16, Q15 : Assessment of uncertainties in safety case. Maintaining social trust. Democratic process.	Before and after instruction.	**Near surface repository with LLW.** Because of waste hierarchy, very big reduction of this waste, 80% by compaction and other. So room available. Question open regarding ILW that was planned for GDF but that is suitable for near-surface disposal. Safety case issue, and community and social issues. Importance of community consent process. Problem of location of the facility, not the best, and vulnerable to climate change.

Group 3

Facilitator: Julien Dewoghélaëre

	Type of actors	**Events card**	**Criteria cards**	**Time occurrence of the event**	**Description of the event**
Case 01	WMO	E16: Discrepancy between measurement and models	Q10: Adaptability of the pathway Q06: Risk of abandonment	Operation phase	Should we change the concept? Should we stop the GD? Should we close the tunnel? Policy point of view? Monitoring will not be precise. Objectives of monitoring (define range and connected decisions), intergenerational governance, pluralistic structure to answer the questions raised by monitoring results.
Case 02	CS	New card: change of the classification of the waste	Q5: Continuous safety and security Q10: 1daptability of the pathway	Before the site selection, before the license application, during the construction of the subsurface	National classification => International classification change the LL waste initially planned for subsurface and now have to go into the GD, balance between safety and economics (case in Denmark, and also in France - Center Manche)

					Changes in the reglementation difficult to handle This situation will occur in the 100year operation phase also (change in institution will occur)
Case 03	TSO	E2: Uncertainties about the performance of seals	Q3: Uncertainty management after authorisation Q12: Intergenerational governance	After the license application but before the authorisation of full commissioning	License was given in the conditions to have some elements precise for the uncertainties on seals. Level is not reach at the time of the authorisation for full commissioning. Conditions: reversibility to be ensured, resources for maintenance of knowledge for letting the next generation decide, also other option: extension of the qualification phase by doing R&D, using alterated scenarios (to ensure the safety envelope), impact on safety for the delays. Concept should not rely only on seal performance (robustness should rely on several elements in order to avoid consequences of risk of abandonment and consider this risk as probable)
Case 04	RE	E20: Technological innovation	Q10: Adaptability of the pathway Q13: Management of knowledge overt time	Middle of Operation phase	Innovation related to the waste package (more resistant to corrosion). Should we apply the technology to the rest of the waste? And for the already stored waste? How to ensure the future generations will be able to do the assessment of this new technology? Progressive packaging (review every 10 years), stepwise approach, transparency on the new technology, cross-efficiency and proportionality, question of equilibrium between safety and economic issue (political perspective),

					importance of maintenance of knowledge

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