Deliverable D10.16: UMAN -

How to manage uncertainties in a pluralistic way and in a long-term perspective?

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

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 847593.

Document information

Project Acronym	**EURAD**
Project Title	**European Joint Programme on Radioactive Waste Management**
Project Type	**European Joint Programme (EJP)**
EC grant agreement No.	**847593**
Project starting / end date	**1st June 2019 – 30 May 2024**
Work Package No.	**10**
Work Package Title	**Uncertainty Management multi-Actor Network**
Work Package Acronym	**UMAN**
Deliverable No.	**10.16**
Deliverable Title	**UMAN - How to manage uncertainties in a pluralistic way and in a long-term perspective?**
Lead Beneficiary	**IRSN**
Contractual Delivery Date	**Month 48**
Actual Delivery Date	**31/05/2024**
Type	**REPORT**
Dissemination level	**PU**
Authors	**Julien Dewoghelaere (NTW)**

To be cited as:

Dewoghelaere J. (2024): UMAN - **How to manage uncertainties in a pluralistic way and in a long-term perspective?** Final version as of 21.05.2024 of deliverable D10.16 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Disclaimer

Acknowledgement

This document is a deliverable of the European Joint Programme on Radioactive Waste Management (EURAD). EURAD has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 847593.

Status of deliverable		
	By	Date
Delivered (Lead Beneficiary)	Julien Dewoghelaere (IRSN (NTW))	14 May 2024
Review	Nadja Zeleznik (EIMV)	20 May 2024
Verified (WP Leader)	Daniela Diaconu (RATEN)	21 May 2024
Approved (PMO)	Elisabeth SALAT (IRSN)	30 May 2024
Submitted to EC	Andra (Coordinator)	31 May 2024

What is 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 (CS), 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 applied to the uncertainties management and identifies possible actions to be considered in the treatment of uncertainties. The relevance for safety of the uncertainties associated with site and geosphere, human aspects, spent fuel, waste inventory, spent fuel and near-field, as perceived by each type of the above mentioned stakeholders, and approaches used by these stakeholders to manage these uncertainties are 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:

- Task 1 - Coordination, interactions with Knowledge Management (KM) WP & integration
- Task 2 - Strategies, approaches, and tools
- Task 3 - Characterization 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 take place notably through workshops (Task 4) and seminars (Task 5) where the significance of identified uncertainties (Task 3) as well as possible strategies and options to manage them (Tasks 2 and 4) are discussed.

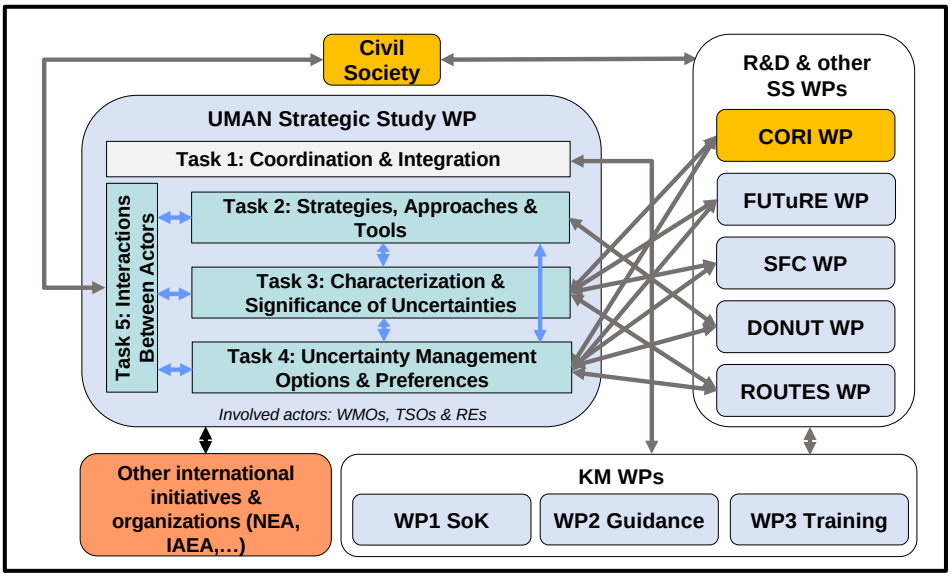


Figure 1 – UMAN WP structure and interactions

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 Subtask 5. 1 – *Preparation, support and reporting of pluralistic analyses,* topic 4: Methods that can be used for discussing and organizing pluralistic assessments of uncertainties with civil society stakeholders throughout a disposal programme. Various inputs were used for topic 4, but the central instrument was a seminar held on 14-15 December 2022 ("UMAN seminar 4. How to manage uncertainties in a pluralistic way and in a long-term perspective?"). This report provides a description and interpretation of the seminar.

Seminar 4 aimed at gathering all the thoughts and ideas that have been raised during the previous seminars regarding pluralistic management of uncertainties in the long-term. The goal was to perform a synthesis and identify recommendations for implementing meaningful processes enabling multi-actors and multi-disciplinary management of uncertainties in the frame of geological disposal.

Discussions were engaged on meaningful pluralistic methods for managing uncertainties throughout the implementation of geological disposal (including pre-disposal phase, operational phase, and post-closure phase). A first session presented views of the different types of actors involved in EURAD that have been gathered in the frame of UMAN. A working groups session continued the discussion following the "Pathway Evaluation Process" approach, a methodology of dialogue enabling different types of actors to discuss on the same footing on issues related to Radioactive Waste Management. The discussion was focused on concrete cases elaborated by Task 5 and illustrating situations where pluralistic uncertainty management was needed, and issues related to implementation of multi-actors' process. The goal was to evaluate the relevance of the pluralistic methodologies identified by Task 5 to solve these challenging situations.

The results of the fourth UMAN seminar are divided in two parts: the key elements extracted from the presentations of actors' views based on UMAN results and results coming from working groups discussion and restitution of these discussions.

Two presentations have been made based on UMAN results: a presentation gathering the EURAD researchers (WMOs, TSOs and REs) views and a presentation synthetizing the CS analysis of UMAN results. The two presentations were focused on two main aspects: What should be the role of the different actors all along the phases of a GDF programme? What are the key elements for ensuring a pluralistic management of uncertainty in a long-term perspective?

To summarize the UMAN results regarding the roles and functions of different actors at different GD phases, a broad range of actors' categories were identified, covering those from international regulations. The types and number of the identified actors varies among the respondents, reflecting the different approaches employed in the national RWM programmes, the different national frameworks (political and administrational systems) and the current implementation phase. At the end, this small UMAN survey presents some interesting results, but the analysis is burdened with certain biases. Regarding the pluralistic management of uncertainties, it was underlined that uncertainty management strategy should meet regulatory requirements/laws: participative and transparent process, application of defense in depth approach, demonstration of robustness of a disposal system, definition of specific criteria for site selection, implementation of reversibility including waste retrievability, recovery and others. To be able to meet all these requirements, a strong regulatory body is needed. It was mentioned that a common generic uncertainty management strategy is needed that must be based on a stepwise, iterative, and flexible approach that is safety-oriented and that implies a regular, continuous communication and dialog with stakeholders all along the programme phases. A regular, continuous communication and dialog with stakeholders should be implemented. It is notably important to consider different views of actors in different aspects of GD implementation). It implies suitable communication strategies with key aspects. It should be science and solid knowledge based and using "simple" models to visualize certain aspects (e.g., impact of remaining uncertainty). It is important that public involvement covers different aspects from communication to active involvement and CS taking some ownership

through a process that looks for public consensus. An important question was raised related to this pluralistic management of uncertainty: When to stop the interactions on uncertainty to take decisions? The main answer was at the lowest justifiable level. Optimisation should be kept reasonable.

To summarize the CS views, the specific perspective of uncertainty management enables the highlighting of several transversal topics of utmost importance to civil society:

- Transparency and public participation (T&PP), as it is uncertain if there will be effective and good quality T&PP in RWM including GDF development.
- Safety culture, as CS involvement in a shared safety culture increases efficiency of decision-making in RWM; management of uncertainties has to become a part of the safety culture.
- Nuclear security, as there is an increased relevance due to war, terrorist attacks, intrusions, etc.; uncertainties related to security issues need to be managed.
- Precautionary principle and other guiding principles, as one of the main pillars in environmental ethics and law, should be one basis for uncertainty management.
- Pluralistic management of uncertainties, by enabling effective public participation in all steps including research (e.g., double-wing model), and by using cases and scenarios to promote pluralistic dialogue (PEP game, cases developed in UMAN…).

All these conceptual elements will lead to a serious contribution to a long-term management of uncertainties, relying on two key elements: reversibility, retrievability and recoverability, as it is uncertain if plans will work out as foreseen, long-term Stewardship (LTS)/Rolling Stewardship, as a method to deal with uncertainties in the long-term.

Some relevant recommendations for seminar's discussion were also extracted from the CS work in UMAN:

- Promote inclusion of information on and debates about uncertainties and their management in public participation procedures, i.e., by developing guidelines in EURAD,
- Enlarge the CS larger group with appropriate resources for recruitment of members and time engaged in the follow-up of activities,
- Continue and develop the uses of concrete cases and PEP methodology in research but also in participative processes.
- Based on its pros and cons, recognize that LTS/RS is not a controversial or "alternative" notion and integrate research on LTS/RS in the EURAD project.

The seminar provided the opportunity to validate the different identified pluralistic methodologies for managing uncertainties at different stages of GDF's implementation. Based on the discussions on different concrete situations, it is possible to summarize key messages. It is important to be well prepared. Some tools are already existing (Safety Case, altered scenarios to assess the robustness of the safety case, emergency plan, monitoring plan, periodic safety review, etc.) but the implementation of tools for regular pluralistic exchanges is also required. A stepwise approach, additional RD&D all along the GD, and a flexible process are necessary to be able to deal with difficult situations, including the management of unexpected ones. Rolling stewardship should be implemented to ensure transparency of information and ensuring trust will not be lost in case of problematic situations. Shared safety culture should be included in the involvement of rolling stewardship because rolling stewardship focuses on safety at all costs (sharing is caring). Ensuring a memory keeping, knowledge transmission with the justification of the initial implementation plan and of all decisions taken all along the phases is necessary to maintain conditions of trust and let the possibility for future generations to decide with all the information.

Table of content

List of figures

Acronyms

Andra	Agence nationale pour la gestion des déchets radioactifs
BAT	"Biologischer Arbeitsstoff-Toleranz-Wert": biological tolerance value for occupational exposures
BC	Boundary Conditions
BGE	"Bundesgesellschaft für Endlagerung", federal agency for radioactive waste disposal in Germany
CS	Civil Society
DM	Decision Making
EURAD	European Joint Programme on Radioactive Waste Management
FSC	Forum of Stakeholder Confidence of NEA
GD	Geological Disposal
GDF	Geological Disposal Facility
ICS	Interaction with civil society
IGSC	Integration Group for the Safety Case (IGSC) of NEA
IPPC	Integrated Pollution Protection and Control (European directive 2008/1/EC)
IRSN	"Institut de Radioprotection et de Sûreté Nucléaire", public expertise body in France in charge of radioprotection and nuclear safety
LTS/RS	Long-Term Stewardship/Rolling Stewardship
NGO	Non-governmental organisation(s)
NTW	Nuclear Transparency Watch
PEP	Pathway Evaluation Process
RD&D	Research, Development and Demonstration
RE	Research Entity
RW	Radioactive Waste
RWM	Radioactive Waste Management
RWMC	NEA Radioactive Waste Management Committee
SA	Safety Assessment
SC	Safety Case
T&PP	Transparency and Public Participation
TSO	Technical Safety Organisation
UMAN	Uncertainty Management multi-Actor Network
WMO	Waste Management Organisation
WG	Working Group in UMAN Seminar 4
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 a 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* (Source: IAEA Safety Glossary 2022). 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 developed the following objectives:

1 - Develop a **common understanding** or at least to share different viewpoints among the different categories of actors on uncertainty management[1] and 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[2] dialogue** on uncertainties during the development and review of the safety case.

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

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 scope of

[1] 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.

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

actors including civil society (CS) actors (CS experts[3] and members of CS larger group[4]), representatives of regulators[5] and international organisations (IGSC[6], FSC[7]). 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).
- **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 addressed in UMAN, namely "Site and Geosphere related uncertainties". 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?
- **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 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, Management of new knowledge emerging during the implementation of the GDF and Adequacy of safety related activities for the implementation of safety provisions (with a focus on the construction phase).
- **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 to enable fruitful interactions between institutional/technical

[3] The CS experts are experts with technical and socio-technical background or/and experience on the involvement of CS in scientific and technical issues related to RWM. 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)

[4] 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

[5] 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

[6] 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

[7] 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

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 the potential needs for strategic research on methods to achieve this goal of enabling a pluralistic assessment of uncertainty management related to RWM in the long term.

The report presents the detailed results of this seminar 4.

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 December 2023. The results were obviously not discussed during seminar 4 but can be find in D10.20[8].

[8] Dewoghelaere J., Fontaine G. (2024): Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties. Final version of deliverable D10.20 as of May 2024 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593

2. Conception and preparation of the seminar 4

2.1 Structuration of the seminar's sessions

As for the previous seminars, seminar 4 was prepared by a pluralistic team involving representatives of each EURAD college: Waste Management Organisations (WMOs), Technical Support Organisations (TSOs), Research Entities (REs) and civil society (CS) experts involved in UMAN. The team prepared presentations:

- On the work performed in UMAN (views of WMOs, TSOs and REs on the identification, characterisation, potential significance, and management of uncertainties). The main elements of these views were constituted based on UMAN Task 4 workshops. When appropriate, elements coming from other sources (IAEA, national programmes, etc.) were added to feed into the discussions. For the seminar 4, the views of WMOs, TSOs and REs were gathered in a unique presentation that was presented by UMAN Task 4 leader coming from Bundesgesellschaft für Endlagerung" (BGE), federal agency for radioactive waste disposal in Germany
- On the CS views and analysis. The analysis was performed by the CS experts involved in UMAN based on their review of the UMAN work (results of the discussions coming from the previous UMAN Task 5 seminars and Task 4 workshops) and on the comments from the CS larger group[9]. The presentation of the CS views was made by two members of the UMAN CS experts' team and Nuclear Transparency Watch[10] (NTW) coming respectively from Austria and Denmark.

These presentations constituted the basis for starting the discussion during the first session of seminar 4. For framing this discussion, it was needed to define two core concepts:

- Pluralistic processes: In the context of UMAN Task 5, pluralistic means diversity of actors and an interdisciplinary perspective (embedding technical and socio-technical issues)
- Long-term perspective: In the frame of seminar 4 discussion, it was decided to define "long-term" as a relatively long period of time. In the perspective of interaction between experts and civil society, it implies the perspective of at least several generations (operational phase) and the institutional control phase (period after closure).

To deepen the discussions, a working groups (WGs) session was organised. Participants were divided in four groups and invited to discuss concrete cases (see section 2.2) by using the Pathway Evaluation Process (PEP) approach[11]. The aim of this WG discussions was to see how (and on what conditions) the pluralistic methods identified by Task 5 can contribute to reinforcing safety or achieving a common understanding by different actors throughout the implementation of geological disposal (including pre-disposal phase, operational phase, and post-closure phase[12]).

After the WGs session, a final session was dedicated to reporting and identification of potential needs of research. The agenda of the seminar is available on Appendix A.

[9] The comments from the CS larger group were collected during the annual ICS workshop n°3. During the UMAN session of this workshops, the UMAN results were presented and discussed. The UMAN session of ICS workshop n°3 was held online on 16 March 2022.

[10] NTW is a European network created in 2013, gathering around 50 members (individuals and organisations) from twenty European countries and aiming at organising a citizen vigilance on safety and transparency around nuclear issues at European level and in the different national contexts. In EURAD, NTW is organising the Interaction with civil society (ICS) activities. See the website: https://www.nuclear-transparency-watch.eu/

[11] The PEP is a tool of dialogue (designed as a serious game) developed under the frame of the SITEX-II project and SITEX.network that enable multi-actors' discussions in the field of radioactive waste management. EURAD Lunch and Learn Session on PEP methodology: https://www.ejp-eurad.eu/news/recording-ll-pluralistic-tool-dialogue-rwm-pathway-evaluation-process-pep. The PEP methodology is presented in more detail in section 2.2 of the report as one of the identified pluralistic methods by Task 5.

[12] Recognising that safety must be demonstrated for very long periods during post-closure (e.g., hundreds of thousands of years).

2.2 Elaboration of concrete cases

The preparation of the seminars notably consisted in elaboration of concrete cases. The concrete cases are a way to illustrate the issues linked to the uncertainties under discussion, enabling all actors to enter the discussion on the same footing. The concrete cases presented during seminar 4 illustrated more specifically challenging situations where pluralistic management of uncertainties on the long term are needed or where issues related to implementation of multi-actors' process are encountered. The concrete cases were elaborated to have examples of situations occurring at different phases of the GDF's implementation. The goal was to check the relevance of the pluralistic methodologies identified by Task 5 (see section 2.3) to solve these challenging situations. How and on what conditions the identified pluralistic methods can contribute to achieving a common understanding by different actors and reinforcing safety?

The concrete cases presented concrete issues and were an opportunity to assess the added value of these pluralistic methods for managing challenging situations (linked to uncertainties). Below is the description of the four concrete cases that were discussed:

Concrete case 1: Degree of acceptable remaining uncertainties - uncertainties about the performance of seals

At the time of submission by the operator of the application for the construction of the geological disposal, the efficiency of the global concept has been proven but some uncertainties remain about the sealing option. More precisely, the regulatory authorities have questions about the long-term durability of sealing materials (In a generic URL facility, an experiment has been conducted. The measures of permeability were higher than expected). The operator indicates that additional experimentations will be conducted during the operational phase in order to reduce the remaining uncertainties regarding these materials.

The public opinion is informed about the situation. A debate starts. *Should the authorization for construction be prohibited until there remain no more uncertainties? Should we engage more research on the topic before the authorization is given?*

On the contrary, *if authorization is given, what arrangements will be put in place to allow monitoring of this issue during the operational phase? Who should be involved in this monitoring?*

More generally, this concrete case raises the question of the degree of acceptable remaining uncertainties: *how to deal with remaining uncertainties before launching the construction?* The same question is also relevant in the perspective of long term.

Figure 2 – Concrete case 1 discussed during WG session

Concrete case 2: Integration of new knowledge - new results on radionuclides transport modelling

At the very beginning of the operational phase (during the qualification phase of the facility, no nuclear waste in the facility underground, pilot emplacement and sealing tests), a scientific controversy starts. Researchers from a national university publish an article with conclusions that criticize the transport modelling used for the geological disposal safety case. According to the authors, some phenomena considered in the modeling of the transport of radionuclides have been underestimated. They claim that radionuclides are being sorbed by fast-moving colloids rather than by the rock matrix. Thus, nuclides would migrate much faster than estimated in the models used by the operator and agreed by the regulator when authorizing the construction.

It raises question about the integration of new research's results during the implementation of the disposal. *Should the conclusions of this article be considered by the operator? How? More generally, how to include new results (and coming from different sources) all along the disposal implementation?*

Figure 3 – Concrete case 2 discussed during WG session

Concrete case 3 - Operational monitoring data deviating from expectation – monitoring uncertainties and need for waste retrieval

The operational phase has been on-going for 50 years. At this time, the data collected from a monitored waste package in the disposal area indicate that a leakage has occurred. The data of the other monitored waste packages do not indicate problematic results. So, it might be an isolated issue or even a measurement error. It is important to check the problematic cell (to ensure it is an isolated issue and to solve the issue), but the gallery has already been backfilled and is not easily accessible. The intervention could generate safety issue, notably for the workers.

The public is informed about the situation and the operation is stopped while a decision is made on how to proceed. *What decision should be made? Who should be involved in the decision and in the follow-up of the situation?*

This concrete case raises the question of the interpretation of monitoring data and how to take a decision based on monitoring data. In addition, it challenges the concrete implementation of waste retrievability.

Figure 4 – Concrete case 3 discussed during WG session

Concrete case 4 - Role of Institutional control and site memory – abandonment by government of the initially planned institutional control[13] after closure

After closure of the disposal facility, institutional control* of the site has been planned for 150 years. Just before closure, this form of oversight is no longer seen as a priority by the government of the day due to the cost and it is envisioned not to implement it. Regulators indicate that they do not regard a prolonged period of institutional control of the surface site as a necessity to meet national safety criterion as long as the facility is operated and closed as specified.

This late stage change in the agreed approach raises questions in society around trust and also around the role institutional control plays in post-closure safety and public acceptance. *What other changes may be made if the project proceeds?*

The debate also reactivates a debate related to the memory of the disposal facility and the potential consequences associated with the loss of the memory of the site. *Although institutional control is a relatively short-term means of preserving site memory, does the change indicate a lack of long-term commitment to preserving memory of the site - which may in turn indicate a future failure to maintain archives, markers, or other memory techniques?*

The question has to be solved in order to close the disposal facility. How should this uncertainty related to site memory be dealt with? What methods should be used to ensure site memory?

Figure 5 – Concrete case 4 discussed during WG session

2.3 Identification of pluralistic methodologies

The preparatory team of UMAN seminar 4 extracted from the previous seminars results (including work performed by civil society experts involved in Task 5.2) different pluralistic methodologies that were the

[13] IAEA Definition of institutional control: Control of a radioactive waste site by an authority or institution designated under the laws of a State. This control may be active (monitoring, surveillance, remedial work) or passive (land use control) and may be a factor in the design of a facility (e.g., a near surface disposal facility)

basis of the WG discussions. Methodology is understood here as a system of methods and principles for doing something. It encapsulates a large set of elements from concepts to concrete tools. These methodologies are presented below, divided in two categories: the generic methodologies or core concepts for facilitating pluralistic management of uncertainties that were identified during discussions on one hand, and applied methodologies that have been tested in the frame of EURAD research on the other hand.

2.3.1 Identified generic methodologies

The first generic methodology that emerged from the discussion and that was further refined by CS experts' team is **the promotion, the development, the consolidation of a shared culture for safety and security and its intergenerational transmission**. The concept was initially developed in the frame of the SITEX II project[14] under the format of "shared safety culture". It is an extension of the "culture for safety" concept developed by IAEA[15]. It refers to sharing elements of corporate safety culture and societal safety culture (see figure 6 below). This concept can also be called an "enlarged safety culture".

Figure 6 - An enlarged safety culture (SITEX II)[16].

During the seminar's discussions and notably during the discussion related to human uncertainties (seminar 3), it was considered as interesting to add the security aspects to the safety aspects. The main idea behind the concept is to promote a mutual understanding on what are the constituting elements for ensuring a safe and secured management of uncertainty, between institutional experts in charge of ensuring safety of nuclear facilities and civil society concerned by safety and security issues. Enabling

[14] See Bernier F., Dewoghelaere J., Heriard-Dubreuil G., Mannaerts K., Surkova M., Swahn J., Wouters J-P., Zeleznik N. (2018): Conditions and means for developing interactions with civil society, http://sitexproject.eu/index_2.html#deliverables_wp4

[15] See INSAG_4 document (1991) and on-line leaflet: https://www.iaea.org/sites/default/files/culture_for_safety_leaflet.pdf

[16] The EU project SITEX II (task leader: FANC) was dedicated to an enlarged safety culture to support very long-term interactions with society (Hériard-Dubreuil, 2022).

a pluralistic process necessitates for the involved actors to speak a common language and to have an agreement on safety and security components. Promoting a shared culture for safety and security is a way to reinforce existing safety and security systems. It also necessitates tools for ensuring the transmission of this culture from one generation to another. More elements related to shared culture of safety and security are available in the D10.17 - Synthesis report of WP UMAN outcomes from a civil society point of view[17], presenting the views of CS experts involved in UMAN. This concept was also discussed during the second EURAD annual event in Fontenay-aux-Roses on March 2022, during a session dedicated to the ICS-CORI-UMAN process, aiming at creating interactions between the UMAN and the CORI work packages including civil society perspectives[18].

The second identified methodology for enabling pluralistic management of uncertainties is the **implementation of a stepwise approach,** including notably an intergenerational safety case review (a periodic safety review that is maintained all along the phases of the GD programme), a real implementation of the reversibility/retrievability/recoverability principles (that are mandatory by law in several national contexts, e.g., France and Germany) and a continuous knowledge management (ensuring the maintenance of necessary competencies and the transmission of knowledge from one generation to another). The stepwise approach is a way to facilitate the inclusion of pluralistic assessment of the uncertainties at different key stages of the GDF implementation and the exchanges of information among all the involved stakeholders during the occurrence of unexpected events (e.g., operational accidents or unexpected data coming from monitoring). It necessitates to pluralistically define and discuss the key steps and the involvement process of the different actors at the beginning of the programme. It requires also to keep in mind alternative solutions that are achievable in case of problems occurrence. The stepwise approach was mentioned several times during the discussion of the UMAN seminars.

The third generic pluralistic methodology identified by UMAN Task 5 is the implementation of a **rolling stewardship culture:** it implies notably intergenerational transmission of information, empowerment of communities, cultural heritage, e.g., regular celebration around waste like Dutch case. Broadly speaking, it signifies an intergenerational management concept requiring monitoring and maintenance of the radioactive waste (RW) with responsibility being passed on from one generation to the next, preserving the possibility of retrieval, recharacterisation and repackaging of the waste. It also requires a mechanism for reinstructing the next generation, which provides detailed information on the nature of the wastes and the associated hazards, ensures the next generation is fully aware of the need to spend time and money on the RW and if necessary, to see that corrective action is taken in a timely way. This process could last until a final safe solution is found which would no longer require constant care and memory. More specifically, rolling stewardship provides a framework for a chain of management decisions that can be changed over time, empowering each generation with greater information on stewardship tools and practices. Instead of focusing on an infinite, unpredictable future, it touches on practical problems that can be solved in the short term with some guarantee of success. Moreover, it includes institutional control mechanisms that are meant to address among others legal, technical, financial, administrative, and R&D issues. This concept has been discussed during the UMAN seminars[19] and in the frame of ROUTES ICS activities[20].

[17] Dewoghelaere J., Fontaine G., Hooge N. H., Mraz G., Wales C. (2024): Synthesis report of WP UMAN outcomes from a civil society point of view. Final version of deliverable D10.17 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593

[18] A description of the ICS-CORI-UMAN process is available in D3.5 od EURAD, Altmayer M. and alii (2024): CORI - Final Report integrating the RD&D performed in CORI, including application to the Safety Case. Final version as of 04.08.2023 of deliverable D10.14 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

[19] See D10.17 opcit.

[20] See Zeleznik N., Swahn J., Daniska M., Haverkamp J., Hooge N.H., de Butler M, Wales C., (2024): Implementation of ROUTES action plan third phase. Final version of deliverable D9.18 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593

The reinforcement of an appropriate legal framework enabling pluralistic interactions was identified as the fourth and last generic pluralistic methodology. The legal framework concerns RD&D activities and decision-making processes. It implies the concrete implementation in the different national contexts of elements coming from international legislation and recommendations ensuring transparency of the RD&D results and decisions and public participation. Task 5 identifies a set of documentation constituting a basis for elaborating an appropriate legal framework. It includes:

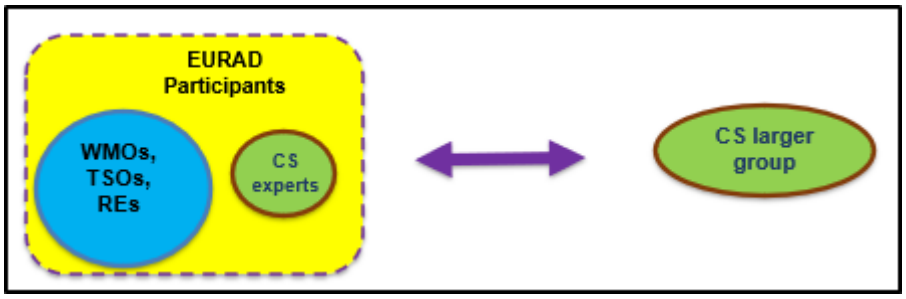
- the Aarhus Convention and its three pillars (access to information, effective public participation including report on ways public consultations are duly taken into consideration, access to justice if the two other pillars are denied[21]),
- the BEPPER[22] report prescribing a fourth pillar that is the access to resources for enabling effective public participation, prescriptive EU directives (e.g., Article 10 Transparency of RWM directive[23], promotion, and enhancement of public participation),
- the international recommendations and guidance (e.g., recommendations coming from IGSC like the results of the workshop in 2022 on building confidence in the face of uncertainty[24] and recommendations coming from FSC like the results of the workshop held in October 2023 on Stakeholder engagement in decommissioning, radioactive waste, and legacy management[25]).

The existence of such international legal framework constitutes a guarantee for ensuring the implementation of good practices in terms of public participation in national programmes or at least are a way for contesting bad practices and the decisions aiming at lowering the standards of public involvement and transparency.

2.3.2 Applied methodologies tested in the frame of EURAD research

In addition to the four generic methodology, UMAN Task 5 identified two applied methodologies that were tested in the frame of EURAD. These applied methodologies aimed at enabling fruitful dialogue between researchers and members of civil society involved in the discussion related to the results of the EURAD research.

The first applied methodology is the **double wing model**. Such original model includes a small number of CSOs or NGOs as members of an EU project (“CS experts”) calling for, in some activities, a larger panel of members of the CS gathered in a mirror group (“CS larger group”).



[21] The text of the Aarhus convention is available here: https://unece.org/environment-policy/public-participation/aarhus-convention/text

[22] See BEPPER report: Swahn J., Kearney P., Zeleznik N., Liston V., Heriard-Dubreuil G., Haverkamp J. Lorenz P. (2015): A first report from Nuclear Transparency Watch (NTW) BEPPER project – Transparency in Radioactive Waste Management. The report is available online: https://www.nuclear-transparency-watch.eu/wp-content/uploads/2016/04/NTW_Transparency_in_RWM_BEPPER_report_December_2015.pdf

[23] The legal text of Radioactive Waste Directive (2011/70/Euratom) is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32011L0070

[24] See https://www.oecd-nea.org/jcms/pl_84206/building-confidence-in-the-face-of-uncertainty

[25] See https://www.oecd-nea.org/jcms/pl_88383/stakeholder-engagement-in-decommissioning-radioactive-waste-and-legacy-management

Figure 7 - Double wing model for inclusion of Civil Society in the EURAD project

The group of CS experts works together with the other EURAD colleges on a regular basis. The larger group of CS members gives input and feedback at several points in time (ICS-workshops, questionnaires etc.). This model aims at representing as much as possible the large variety of profiles that are behind the syntagm “civil society”, i.e., from non-institutional independent experts to citizens that have no specific knowledge in the field. It helps for translating technical knowledge to enable a larger public to understand it and make up their own minds on the topic and for problematizing socio-technical issues (integrating a societal perspective in technical results). The double wing model and the composition of the two CS groups are detailed in D10.13 of EURAD **List of members of the Civil Society group**[26]. One of the questions for seminar 4 was to assess the possibility to extend the double wing model to other situations than research? (e.g., follow-up of Geological Disposal implementation for instance) On what conditions?

The second methodology applied in the frame of EURAD was **the “Pathway Evaluation Process” (PEP) approach.** The PEP methodology has been developed within the SITEX II project (2015-2017). It is based on a “serious game[27]” enabling a multi-stakeholder's discussion on radioactive waste management issues[28]. The main goal of the PEP is not to identify one solution as better than another. The objective is to facilitate discussions between different types of stakeholders to grasp the complexity of the issues involved in the management of radioactive waste in the short, medium and long term. It is also to better understand the views positions of the different categories of actors. The PEP objective is to identify and discuss issues, that are important to the various stakeholders (including civil society), in the context of the investigated RWM “Pathways” over a timescale of several generations. RWM is considered including waste already produced and potentially waste to be produced. The PEP methodology invites the participants to frame the discussion by building their own practical cases (using one event card and two criteria cards). The discussion around a practical case is structured in two rounds of discussions. After the first round, the participant that suggested the practical case synthetised what he/she heard from the others. A second round of discussion is organised to let the possibility to all the participants to add additional comments and react to what they heard from the other participants. During the two rounds of discussions, every participant are invited to speak, one after the other, without being interrupted. The facilitator ensures an equal speaking time for each participant the facilitator also helps to reformulate views and opinions in order to make them clear for all the participants (without interfering with the opinion expressed). In the frame of EURAD and UMAN seminars, the PEP approach has been used to organised discussion on concrete cases (see sections 2.2 and 2.4) but PEP tools have also been developed in the frame of ICS activities. In the frame of MODATS, a PEP dedicated to monitoring issues have been developed[29]. In the frame of UMAN, a PEP dedicated to near-field uncertainties has been created and tested[30].

[26] Dewoghélaëre J., Rey H., Hériard-Dubreuil G. (2020): List of members of the Civil Society group, Final version as of 09.03.2020 of deliverable D1.13 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

[27] A serious game or applied game is a game designed for a primary purpose other than pure entertainment. Serious games are a subgenre of serious storytelling, where storytelling is applied "outside the context of entertainment, where the narration progresses as a sequence of patterns impressive in quality ... and is part of a thoughtful progress". See, https://en.wikipedia.org/wiki/Serious_game

[28] A video introducing the PEP principles have been elaborated by SITEX.network: https://drive.google.com/file/d/1e5-WBGezWmwj6IxPRtKbRKDrzzv8QsPF/view. A lunch & learn session of EURAD have been dedicated to the presentation of the PEP tool. You can find the records of this session here: https://www.youtube.com/watch?v=c00AGwEZVPA&list=PLahXOQn-bremN911IEn0w8yAzQyuUR3ky&index=17

[29] See Debayle C., Dewoghelaere J., Fontaine G., Geisler-Roblin A. (2024): Enhanced system understanding, multi-party dialogue**.** Final version as of May 2024 deliverable D17.5 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

[30] Dewoghelaere J., Fontaine G. (2024): opcit.

2.4 Organisation of the Working Groups session

In addition to the elaboration of the concrete cases, the preparatory team of seminar 4 has to define the elements of framework for the WGs session. It was decided that discussions would be organised around a specific board of a PEP game dedicated to the phase of "Authorization and qualification" of the geological disposal (see figure below).

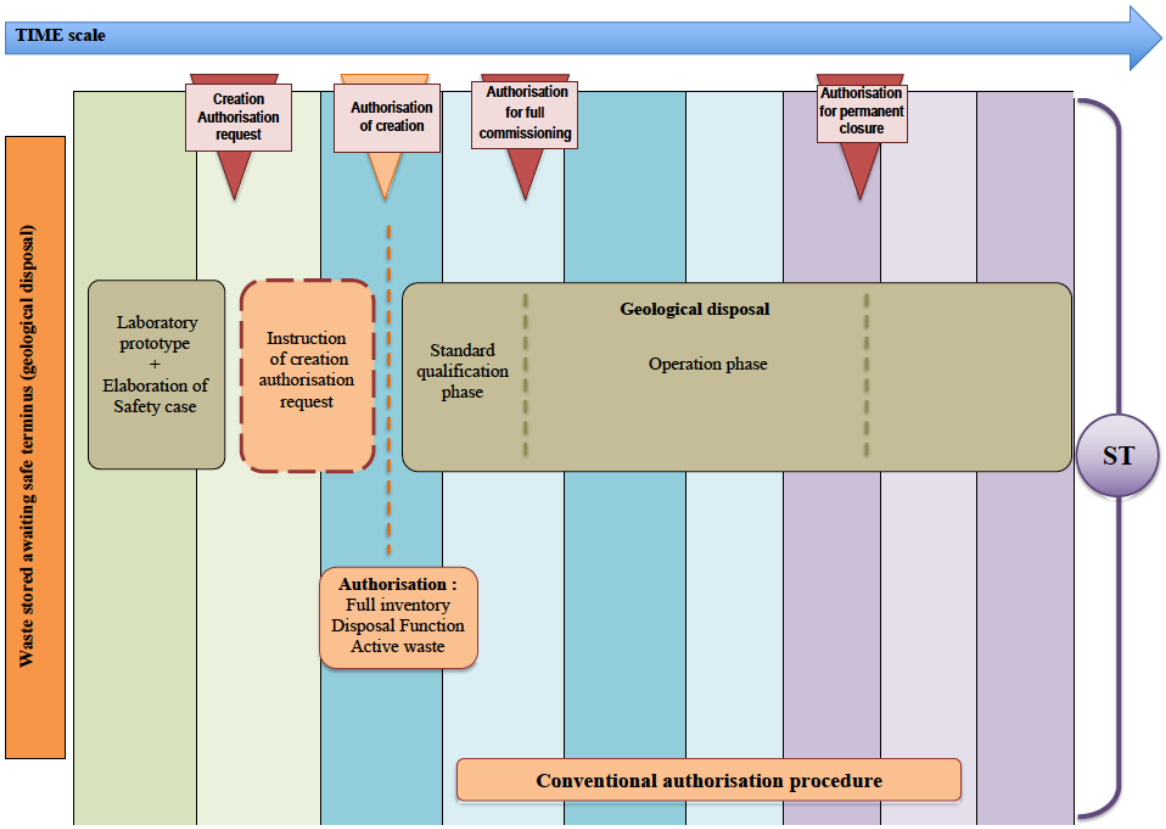


Figure 8 – PEP board as basis for WG discussions in seminar 4

The board presents a "conventional authorization procedure" that includes basic governance elements of a geological disposal implementation. ST in the board means "safe terminus" (meaning a situation that does not implies an active human contribution for the management of radioactive waste). The preparatory team divided the registered participants into 3 Working Groups trying to have a pluralistic composition (representatives of each type of stakeholders in each group) and designated a moderator and a rapporteur (NTW team and IRSN) for each group.

Regarding the methodology of the facilitation, it was decided that each WG would discuss the 4 "concrete cases" illustrating challenging situations where multiple actors are engaged into a dialogue and/or where pluralistic methodologies could help managing uncertainties and ensuring safety. For each concrete case, the WG had to answer the same following set of questions:

- Among the methodologies identified, do you see one (or more) that can be used to manage the situation? If so, which ones and how can they contribute to managing the situation?
- Do you see other methods for managing the situation?
- What are the conditions for the successful implementation of these methods?
- In your opinion, how do these methods contribute to the safety of waste management or to the development of mutual understanding between all stakeholders?

2.5 Composition of the seminar's audience

Similar to Seminar 1, a participation of around 40-50 people was envisioned, gathering various kinds of actors, i.e., those participating in UMAN (half UMAN partners of Task 5, half coming from Tasks 2, 3 and 4), namely WMOs, REs, TSOs as well as CS representatives including some members of the CS larger group, but also people invited from and outside of EURAD consortium, notably some representatives of the regulatory authorities. An equilibrium between the different types of actors was researched. The seminar was held under a hybrid format, allowing online participation for participants that could not attend physically. At the end, 31 participants attended the seminars (see Appendix C).

3. Results of UMAN seminar 4

The results of the fourth UMAN seminar are divided in two parts: the key elements extracted from the presentations of actors' views based on UMAN results (see 3.1) and results coming from working groups discussion and restitution of these discussions (see 3.2).

3.1 UMAN key elements on pluralistic management of uncertainties in a long-term perspective

This session aimed at presenting the differences and communalities of views between the types of actors involved in EURAD. Two presentations have been made based on UMAN results: a presentation gathering the EURAD researchers (WMOs, TSOs and REs) views and a presentation synthetizing the CS analysis of UMAN results. The two presentations were focused on two main aspects:

- What should be the role of the different actors all along the phases of a GDF programme?
- What are the key elements for ensuring a pluralistic management of uncertainty in a long-term perspective?

3.1.1 EURAD colleges views

Leader of UMAN task 4 was responsible for the presentation gathering the views of the different EURAD colleges. The presentation started by listing the sources of the results:

- the results of the questionnaire prepared and administrated by UMAN subtask 4.1[31] aiming at identifying the key actors (their roles, responsibilities, and interest) at different phases of a GDF programme,
- the results of UMAN workshops n° 1 and 2 organised by Task 4 on uncertainties related to site and geosphere and to human aspects[32]. Task 4 leader extracted from these results the elements related to a pluralistic management of uncertainties and explained that the results on the other fields of uncertainties tackled by UMAN were not considered in the presentation as they were not discussed in UMAN seminars ("spent nuclear fuel", "waste inventory") or planned for future discussion ("near-field").

The results are presented below in three parts: the identified key actors and their roles, the key elements related to pluralistic management of uncertainties, the key elements related to long-term perspective.

3.1.1.1 The identified key actors, their roles, responsibilities, and interest in a GD programme

The presentation first detailed the elements of the Task 4 questionnaire methodology, starting by the questionnaire structure and the questions to be answered by the respondents:

- What are the functions/roles of your organisation?
- What are the other actors involved (if identified)? Name and roles?
- What are the interest and potential impact on safety and uncertainties of identified actors?

[31] The questionnaire and detailed results are available in D10.10: Göbel A., Wengler W., Strusińska-Correia A., Müller-Hoeppe N., Mikšová J., Vojtechová H. (2020): Analysis and description of groups of different actors. Final version as of 2024 of deliverable D10.10 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

[32] The detailed results of the all the workshops organised by Task 4 are available in D10.12: Haverkate B., van Gemert M., Strusińska-Correia A., Göbel A., Mertens J., Detilleux V., de Gregorio y Robledo S., Grigaliūnienė D. (2024): UMAN – Preferences of different actors on uncertainty management. Final version as of 2024 of deliverable D10.12 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

It was added that it was possible to provide phase-specific or generic answers, that the functions of organisations were pre-defined (in a EURAD perspective). All the answers given were phase-specific answers (except those for Phase 5) and were further divided into 7 specific themes according to EURAD Roadmap.

The composition of the respondents coming from UMAN, and ROUTES WPs was also detailed**:**

- 11 Waste Management Organisations (WMOs), 8 Technical Support Organisations (TSOs), 11 Research Entities (REs)
- The respondents were representing different EU national programmes (different implementation stages, waste types, disposal solutions, host rocks)

Below are different figures presenting the results of the UMAN questionnaire related to the roles of actors:

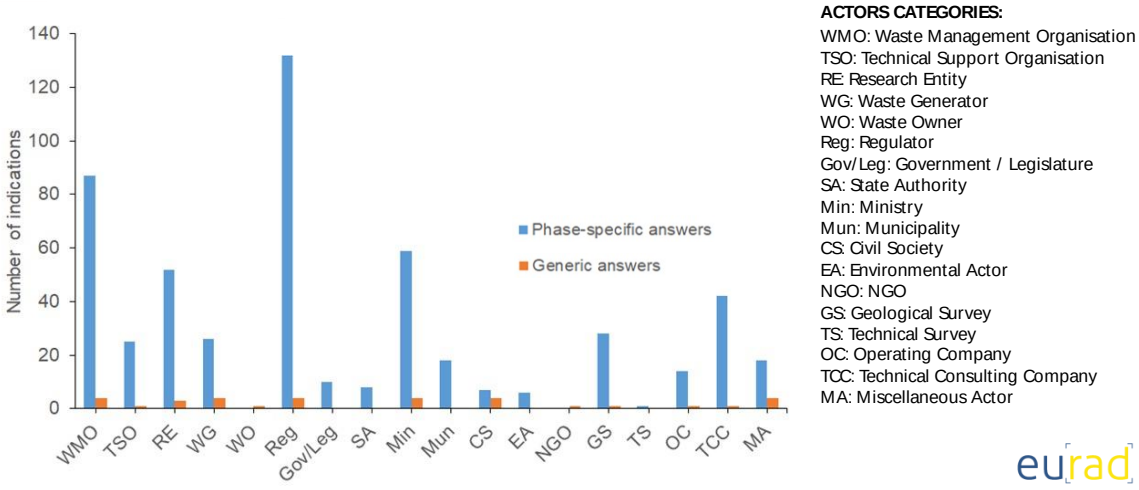
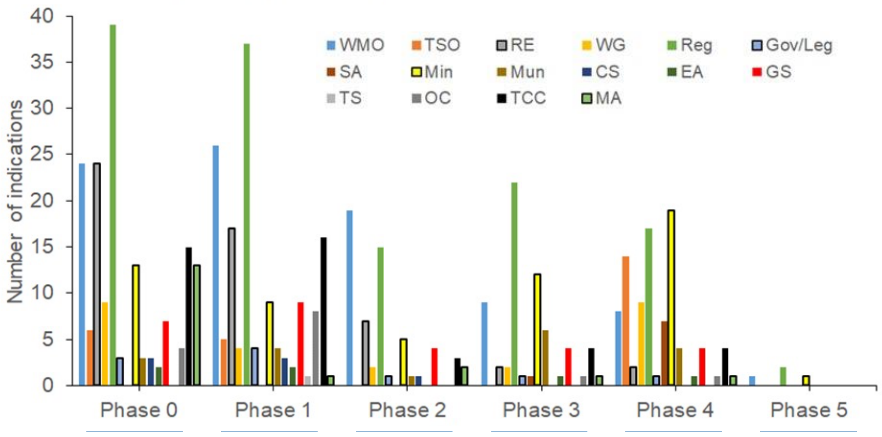


Figure 9 – Identified actors in a GD programme

18 actors' categories have been identified by the questionnaire respondents (i.e., WMOs, TSOs, REs and 1 Technical Consulting Company). The actors involved in EURAD (i.e., WMOs, TSOs, REs and CS) are well recognized. In red on the figure 9 above are indicated the actors invited to seminars organised by UMAN Task 5. At the same time, regulators are identified as an important actor. Surprisingly, there are a low number of indications for civil society, environmental actors, and non-governmental organisations (NGOs).

A focus was then made on the questionnaire results related to the importance of identified actors according to the different phases of a GD programme defined as follow: phase 0: policy framework and programme establishment, phase 1: site evaluation and selection, phase 2: site characterisation, phase 3: repository facility construction, phase 4: repository facility operation and closure, phase 5: post-closure. The results are synthetized in figure 10 below:



WMO: Waste Management Organisation
TSO: Technical Support Organisation
RE: Research Entity
WG: Waste Generator
WO: Waste Owner
Reg: Regulator
Gov/Leg: Government / Legislature
SA: State Authority
Min: Ministry
Mun: Municipality
CS: Civil Society
EA: Environmental Actor
NGO: NGO
GS: Geological Survey
TS: Technical Survey
OC: Operating Company
TCC: Technical Consulting Company
MA: Miscellaneous Actor

Figure 10 – Identified actors in a GD programme

Waste Owners and NGOs are not shown in the figure since they were indicated using the option "generic answers" (meaning present at all phases).

The results were detailed according to the type of respondents focusing on WMOs and REs responses (see figure 11 below):

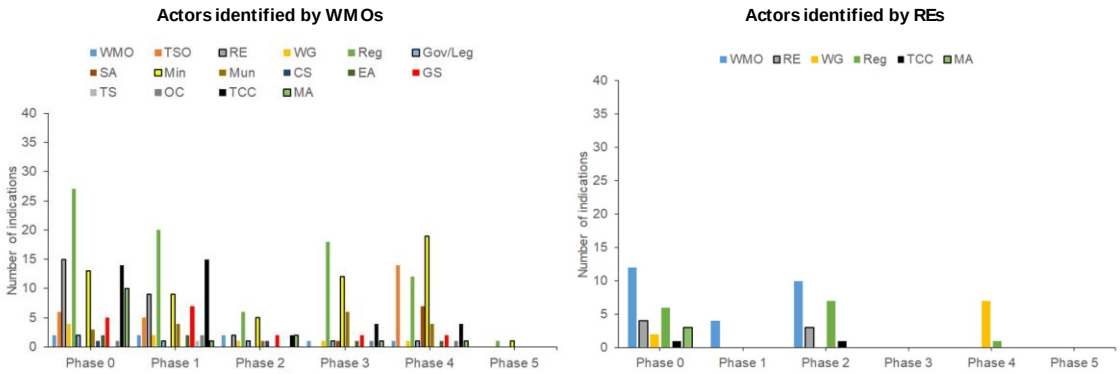


Figure 11 – Identified actors in GD programme by WMOs and REs

WMOs provided the widest spectrum of actors. On the left-hand side of the figure, Waste Owners and NGOs are not shown since they were indicated using the option generic answers. On the right-hand side of the figure, TSOs, waste owners, governmental institutions, state authorities, ministries municipalities, civil society, environmental actors, NGOs, geological surveys, technical surveys and operating compagnies are not shown since they were indicated using the option generic answers.

After the identification of the key actors, the answers related to the actors' functions were presented. What are the roles and responsibilities of the different actors during the different phases? The presentation focused on the three EURAD colleges: WMOs, TSOs, REs. The main identified functions are initiation/planning, execution/implementation, funding, research, safety assessment, organizing civil society participation, regulatory oversight.

The figure 12 below details the functions identified by the respondents for the WMOs:

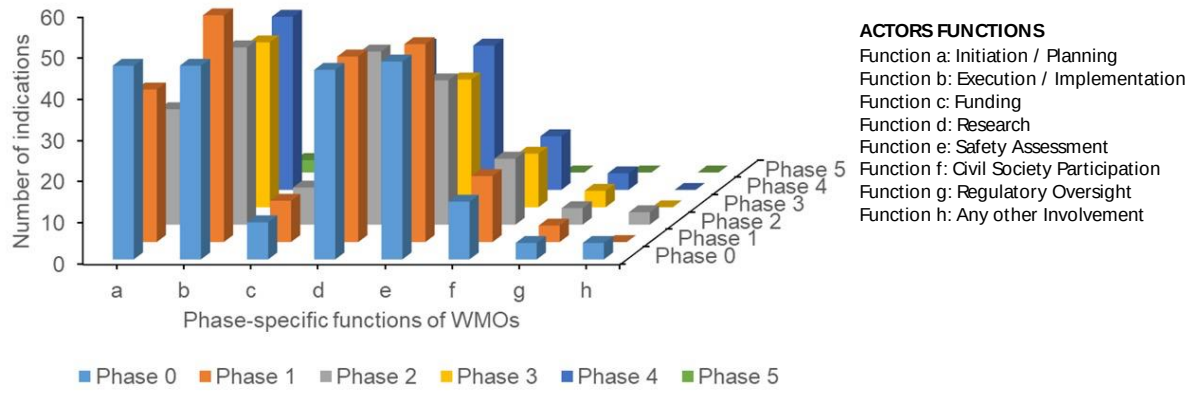


Figure 12 – Identified functions for WMOs

The figure 13 below presents the functions identified by the respondents for the TSOs:

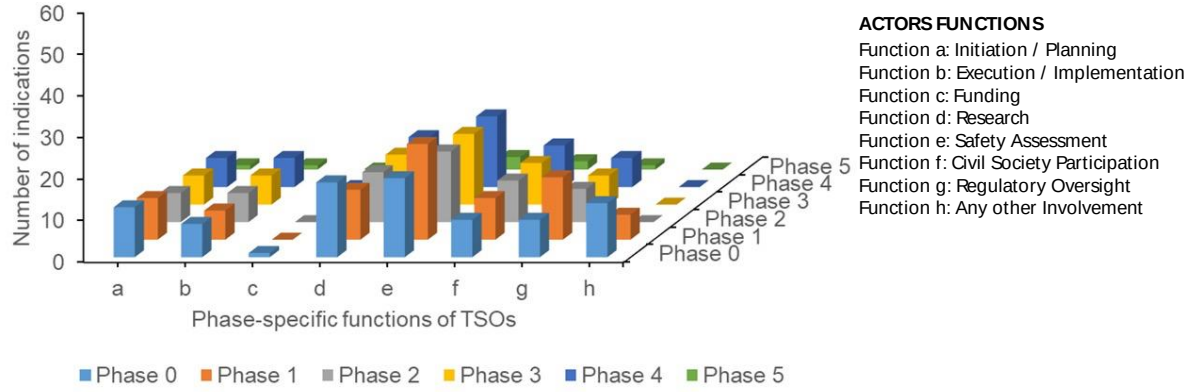


Figure 13 – Identified functions for TSOs

The figure 14 below details the functions identified by the respondents for the REs:

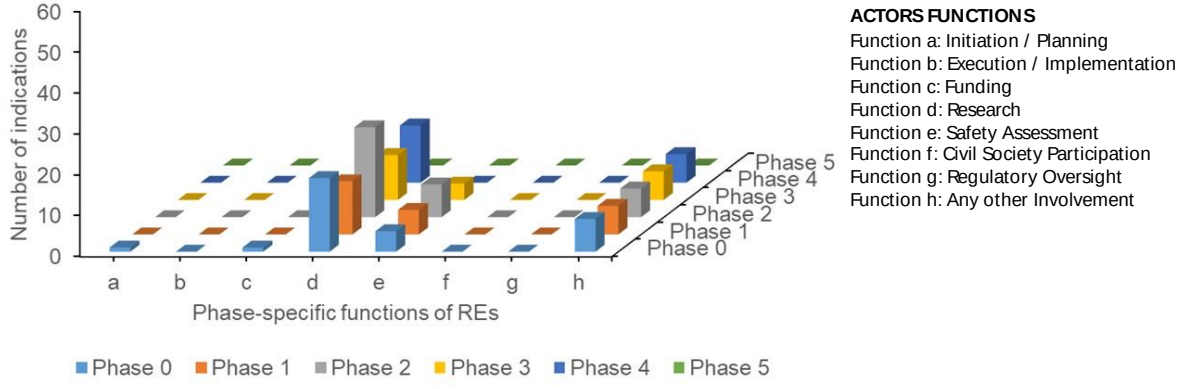


Figure 14 – Identified functions for REs

Regarding the REs views on their own functions, a set of interesting elements were given by REs respondents:

- "*Uncertainty management is safety driven for all actors, but REs can provide sound scientific arguments and a good knowledge basis in assessing safety significance*".

- *"Safety relevance is too narrow definition for the investigation areas of REs. REs put efforts also for investigations of processes that are not safety relevant (e.g., mobility of actinides), but such research creates the background for arguments regarding significance"*. As examples, other important investigation fields were identified by REs respondents:
  - Mechanistic understanding of the processes. Uncertainties reduction is not limited to acquiring more data and their processing.
  - Coupled view of processes (coupled uncertainties). It is important to consider not only the significance of the processes, but also their interactions (e.g. two phase flow); identification of dominant parameters/processes in non-linearly coupled processes is a challenge.
  - Understanding of actual situation and processes as well as future global evolution (climate, tectonics)
- As a final statement, one RE respondent stated that REs have a dual role in order to open/identify the uncertainties and then to characterize them and help to find a solution to reduce/mitigate/avoid them.

To summarize the UMAN results regarding the roles and functions of different actors at different GD phases, a broad range of actors' categories were identified, covering those from international regulations. It is also important to keep in mind that the presented results are a self-assessment of functions/responsibilities by the questionnaire respondents. The types and number of the identified actors varies among the respondents, reflecting the different approaches employed in the national RWM programmes, the different national frameworks (political and administrational systems) and the current implementation phase. Grouping of the identified actors were challenging due to the specificities of the national RWM programmes. Functions of some individual actors seem to be intertwined and a strict division of their roles is very difficult: actor functions are not always clearly assigned in early implementation phase. In case of historical programmes/facilities (licensed under different political systems), the questionnaire results do not fully correspond to the responsibilities defined by the current international standards. It is also interesting to underline that the actors involved in policy-making process, establishment of international standards/requirements and research at international level (IAEA, OECD/NEA, etc.) were not quoted by the respondents. At the end, this small UMAN survey presents some interesting results, but the analysis is burdened with certain biases.

3.1.1.2 Key elements related to a pluralistic management of uncertainties

Regarding the second topic of the presentation, Task 4 leader started by detailing some methodological aspects of the UMAN Task workshops n°1 and 2 that were the main sources of the presented results. The objectives of the workshops were to discuss and identify actors' preferences on uncertainty management options and to understand the rationale behind these preferences. The participants of the workshops were asked to answer the following questions:

- What is the safety significance of this uncertainty in the view of your organization? How do you expect the safety significance to evolve over disposal programme phases?
- What are the preferred management strategy and options?

As it was not possible to address all the uncertainties in the frame of UMAN workshops, it was necessary to select some key uncertainties to be discussed. Regarding the workshop n°1 on site and geosphere uncertainties, the discussions focused on (1) Hydraulic conductivity of the host rock, (2) Sorption capacity of the host rock, (3) Homogeneities of the host rock, (4) Fault locations, detection and reactivation, (5) Climatic evolution (focused on permafrost) Regarding workshop n°2 on uncertainties related to human aspects, the discussions focused on (1) Public acceptance of the repository at potentially suitable or projected locations, (2) Schedule to be considered for implementing the different phases of the disposal programme, (3) Adequacy of safety-related activities during construction for the

implementation of safety provisions, (4) Management of emergence of "New" knowledge. The workshops participants were asked to answer a questionnaire in advance and then to discuss during the workshop in three participating actor groups: one group composed of WMOs representatives, one group composed of TSOs representatives, and one group composed of REs representatives. It was the opportunity to collect views of the different colleges and to identify communalities and differences between the different groups of actors as well as within them.

Before to present the results extracted from the discussions, the framework for uncertainty management elaborated in UMAN was reminded (see figure 15 below) as it was an important basis for these discussions:

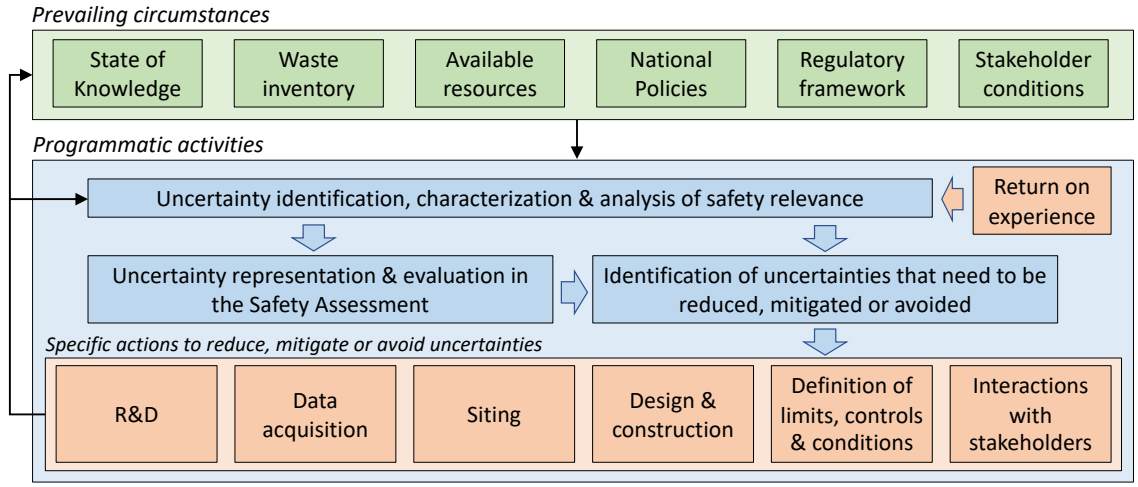


Figure 15 – Framework of uncertainty management elaborated by UMAN

As it is shown by the figure, an iterative approach is required to manage uncertainties in the performance of a disposal facility as the disposal programme progresses through each phase of its development. This includes an iterative approach to research and data acquisition activities aimed at reducing or mitigating uncertainties. At each stage in such a process, results from a safety assessment can be used to understand the parameters to which performance measures are most sensitive and therefore guide subsequent data acquisition activities and thus reduction of associated uncertainty in a meaningful way.

The presentation then detailed UMAN task 4 results related to pluralistic uncertainty management trying a synthesis of the different colleges views:

First, it was underlined that uncertainty management strategy should meet regulatory requirements/laws: participative and transparent process, application of defense in depth approach, demonstration of robustness of a disposal system, definition of specific criteria for site selection, implementation of reversibility including waste retrievability, recovery… To be able to meet all these requirements, a strong regulatory body is needed.

Second, it was mentioned that a common generic uncertainty management strategy is needed that must be based on a stepwise, iterative, and flexible approach (e.g., regular, periodic safety review; self-questioning, learning from previous stages and from similar construction activities), that is safety-oriented (e.g., strong safety culture incl. QA; inspections) and that implies a regular, continuous communication and dialog with stakeholders all along the programme phases.

Third, a regular, continuous communication and dialog with stakeholders should be implemented. It is notably important to consider different views of actors in different aspects of GD implementation (e.g., aspects of monitoring; waste retrievability / recovery) It implies suitable communication strategies with key aspects such as: acknowledgement of uncertainties, multifaceted communication (multiple channels and multiple stakeholders). It should be science and solid knowledge based and using "simple" models to visualize certain aspects (e.g., impact of remaining uncertainty). To be able to implement such a dialog, it requires popularization of science and educational measures and a focus on future generations

and building trust is the key issue and not more R&D/communication. It is important that public involvement covers different aspects from communication to active involvement and CS taking some ownership through a process that looks for public consensus. Strong actors' interaction aiming at uncertainty reduction should imply increasing knowledge, research and development measures, transdisciplinary research to capture socio-technical and ethical aspects, citizen science, international collaboration (e.g., comparison of the climate development results among neighboring countries particularly at their common borders)

An important question was raised related to this pluralistic management of uncertainty: When to stop the interactions on uncertainty to take decisions? The main answer was at the lowest justifiable level. Optimisation should be kept reasonable. Other interesting issues were raised related to this topic: how to organize fruitful international exchange of knowledge, experience, etc.? How to organize and maintain knowledge management over time? How to deal with the different "risk appetite" among the various stakeholders involved in the process.

3.1.1.3 Key elements related to long-term perspective of uncertainty management

Finally, a synthesis of elements related to the long-term perspective of uncertainty management needed for GDF programme were presented. These elements were also extracted from the UMAN workshops n°1 and 2 discussions.

It was stated that a stepwise, iterative, and flexible approach along the programme phases with experience feedback programme (considering the experience from construction and operation of other/similar facilities, international and industrial experience) was needed to deal with the long-term issues. As it was mentioned above, it implies a regular, continuous (over all phases) communication and dialog with stakeholders, a knowledge management including management of "new knowledge", the implementation of reversibility incl. retrievability and recoverability principles. The approach should ensure enough time for testing, notably testing of methodologies /tools /approaches before their application. The importance of the implementation of an industrial pilot phase to get feedback before starting the "real" project was reminded. The approach should also include the implementation of an appropriate monitoring system and a Long-term RD&D programme.

Some other issues were also raised during the workshops that could rely on the long-term perspective. How to manage uncertainties possibly emerging during the implementation of GD:

- e.g., during facility construction and operation due to disturbances of the host rock, creation of EDZ from waste packages and engineered barrier materials,
- during post-closure phase due to temperature increase, desaturation, hydrogen gas and chemical perturbations from backfilling materials & waste

The workshops participants also raised the question of how to deal with transgenerational aspects (views and concerns of future generations, possible future societal changes, etc.)

3.1.2 EURAD CS perspectives

Two members of the CS experts team involved in UMAN were responsible for the presentation gathering the views of CS groups involved in EURAD. The aim of this presentation was to make visible topics of importance for the CS experts in UMAN. The addressed topics are here presented under the following headlines: Introduction to CS views (3.1.2.1), role of the actors (3.1.2.2), methods supporting fruitful interaction in the perspective of the long-term and in an uncertain environment (3.1.2.3), how, where and when to integrate pluralistic discussions in a safety case review and other procedures linked to GD (3.1.2.4), how to manage uncertainties in this pluralistic and long-term perspectives (3.1.2.5),

recommendations (3.1.2.6). A detailed and comprehensive analysis of CS views related to uncertainty management and UMAN results is available in EURAD D10.17[33].

3.1.2.1 Introduction to CS views

Why are uncertainties the focus of CS? It appears that this specific perspective enables the highlighting of several transversal topics of utmost importance to civil society.

- Transparency and public participation (T&PP), as it is uncertain if there will be effective and good quality T&PP in RWM incl. GDF development; therefore, management of uncertainties in GDF development must be part of the T&PP.
- Safety culture, as CS involvement in a shared safety culture increases efficiency of decision-making in RWM; management of uncertainties must become a part of the safety culture.
- Nuclear security, as there is an increased relevance due to war, terrorist attacks, intrusions, etc.; uncertainties related to security issues need to be managed.
- Precautionary principle and other guiding principles, as one of the main pillars in environmental ethics and law; should be one basis for uncertainty management.

In addition to this, CS members want to underline the benefits of pluralistic management of uncertainties, by enabling effective public participation in all steps including research (e.g., double-wing model), and by using cases and scenarios to promote pluralistic dialogue (PEP game, cases developed in UMAN…).

All these conceptual elements will lead to a serious contribution to a long-term management of uncertainties, relying on two key elements:

- Reversibility, retrievability and recoverability, as it is uncertain if plans will work out as foreseen.
- Long-term Stewardship (LTS)/Rolling Stewardship, as a method to deal with uncertainties in the long-term.

3.1.2.2 Role of actors

Regarding the definition of Civil Society actors in RWM and in EURAD, it needs to be said that Civil Societies are highly heterogeneous and diverse, several definitions exist. However, in the frame of EURAD, all the interactions with civil society rely on the definition of the public in the Aarhus Convention, Article 2, 2(4-5):

"*One or more natural or legal persons, and, in accordance with national legislation or practice, their associations, organizations or groups*."

In further details, the terms of concerned public can be used, as

"*The public affected or likely to be affected by, or having an interest in, the environmental decision-making; for the purposes of this definition, NGOs promoting environmental protection and meeting any requirements under national law shall be deemed to have an interest*."

In fact, CS actors engaging in environmental topics relate to several forms of diversity of concerned publics. They have different degrees of knowledge of RWM and nuclear topics in general, different political standpoints on nuclear, they are working on local, regional, national, European and/or global

[33] See D10.17 opcit.

level, they may be organizations and private persons, and they have different amounts of resources for their work.

For the case of EURAD, CS experts have an expertise in nuclear topics including nuclear waste, they are partly paid, and partly rely on voluntary engagement.

What can be the roles of Civil Society actors in uncertainty management? CS members participate in SEA, EIA and other participation procedures enshrined by law (Aarhus Convention, ESPOO Convention, EU law, national law) and increase the quality of policy and licensing procedures. CS members are a part of a shared safety culture, by having a watchdog function and enabling more efficient and better-quality decision-making in RWM. CS experts take part in research (not necessarily by being researchers themselves) giving input on topics of interest for CS and contributing to better feasibility of results. CS experts introduce Long-term Stewardship/Rolling Stewardship models in the RWM debates.

CS experts contribute to apply shared safety culture in the context of EURAD, they open-up for dialogue and cooperate with CS in good faith, they promote transparency in communication and provide understandable information. There is still a need for access to second opinion, with an independence of expertise. All these elements enable CS' capacity building, and thus rightfully contribute to the reality of the Aarhus convention.

3.1.2.3 Methods supporting fruitful interaction and pluralistic methods in RWM uncertainty management

CS members involved in UMAN want to put under the spotlight that a certain framework of pluralistic methodology in RWM can enable fruitful interactions.

Behind this statement, several elements needed to be detailed: fruitful interactions, pluralistic and multi-actors' methodologies and pluralistic uncertainty management methodologies such as the examples of the double wing model and PEP interactive tool.

First, a certain definition of "fruitful Interactions" has been developed by PMO Task 8.3, and the core idea is that fruitful interactions can be revealed thanks to the non-exhaustive compliance of nine conditions: legitimacy, methodology, postural changes, personal unity, expertise function, meaning of the repository, territory, shared complexity, addressing the long term.

Respectively to these nine conditions, this stipulates that fruitful interactions necessitate legitimate processes in which all actors can dialog on the same footing; fruitful interactions require that a community is able to conduct a variety of inquiries (scientific, moral, social); fruitful interactions depend on the capacity of all actors to encompass others' views and to enlarge their initial perspective; fruitful interactions require from an actor that he or she takes into account the different dimensions of him/herself; fruitful interactions require a pluralistic expertise that therefore cannot be reduced to a sole scientific process; fruitful interactions include exchanges on the meaning of the existence of repository in the concrete life of people; fruitful interactions must take into account the deep impact of a geological disposal on the meaning people give to their life in a territory; fruitful interactions necessitate to address the complexity of the issues (technical and non-technical) linked with geological disposal; fruitful interactions cannot be meaningfully achieved without an intergenerational perspective, given the extreme timescales.

These conditions rely on a methodology of co-evaluation coming up from interviews of a selected panel of the different categories of EURAD participants together with an open workshop held in 2021. The presentation of those nine conditions is reflecting the inspirations and horizons of the co-evaluators.

Further details can be found in EURAD Deliverable D1.14: Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society[34].

Then, the terms of "pluralistic" and "multi-actor" can be detailed in the following proposed frames of definition.

- The multi-actor approach, grounding on a definition based on in EU Horizon 2020 Programme on agriculture, states that projects must focus on real problems for which end-user need a solution; partners with complementary types of knowledge – scientific, practical and other – must join forces in the project activities from beginning to end; solutions should be developed which are ready to be applied in practice and cover real needs; and those benefiting directly from the results of the projects will be more motivated to use them, because they were involved in generating them.
- Pluralistic, multi-actor approaches in RWM research, imply the co-creation and sharing of knowledge among different types of actors with complementary expertise; the establishment of collaborative processes involving a diversity of actors to address complex problems together throughout the whole process; methods supporting inclusion (of actors and topics) and that are open for inclusion of future actors and topics.

Why is it necessary to develop pluralistic methods? To enable different actors to enter fruitful interactions in all phases of RWM; to fulfil legal requirements of the Aarhus Convention and other important legal requirements; and finally, because fruitful pluralistic interactions between different actors are a tool of effective participation and therefore can contribute to effective decision-making in RWM.

However, pluralistic interactions are no substitute for participation or decision-making. The advanced objective would then be the following: making uncertainty management part of the transparency and public participation regimes. In this perspective, effective transparency & public participation needs to be established in all steps and phases of RWM, also in the post-closure phase:

- In environmental licensing procedures: EIA, SEA
- In the safety case and licensing procedures for siting, construction, and operation
- In periodic safety reviews and in decommissioning licensing
- In the long-term, intergenerational stewardship.
- In crisis situations, establish ways to quickly enable participation in crisis situations

A framework for good practice in T&PP can be found NTW's BEPPER report[35] from 2015. It sets four pillars for effective transparency: (i) effective access to information and communication, (ii) effective access to public participation and consultation, (iii) effective access to justice and decision-making, and (iv) effective access to resources.

It needs to be underlined that it is crucial that uncertainties and their management are part of the T&PP regimes: is obligatory according to Espoo and Aarhus Convention and EU EIA and SEA Directives, but information on uncertainty (management) is very sparse or missing at all in recent EIA or SEA procedures. Guidelines would improve reporting and discussion of uncertainty topics in participation procedures.

Two further examples of pluralistic methodologies applied in the context of EURAD will be detailed in this sub part: The double wing model and PEP interactive tool.

[34] See for more detailed description D1.14: Geisler-Roblin A., Lavelle S. (2022): Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society. Final version as of 28.04.2022 of deliverable D1.14 of the HORIZON 2020 project EURAD. EC Grant agreement no:847593.

[35] Swahn J and alii., opcit.

The double wing model is a model previously tested throughout SITEX II[36] and JOPRAD[37] European projects, and is built on some important basis:

- Give opportunity for CS representatives to collect information of the EURAD outputs that will impact (directly or indirectly) decision-making processes in RWM at national level.
- Elaborate and test innovative ways of collaborative work to foster the mutual understanding of key processes of RWM on the basis of R&D outcomes and uncertainty management.
- Bring comprehensive documentation of Civil Society participants on scientific and technical dimensions of the issues at stake in EURAD so that they can form their own views on the R&D performed.

Concretely speaking, the model relies on two articulated bodies of CS:

- CS experts with technical and socio-technical background or/and experience on the involvement of CS in scientific and technical issues, involved in EURAD activities through NTW (international association, thus CS experts are Austria, Denmark, Finland, France, Hungary, Netherland, Slovakia, Slovenia, Sweden, United Kingdom), translating scientific/technical results for exchanging with
- A larger group of CS representatives (CSOs, representatives of local communities, individual experts), organized as a mirror group. This group is coming from a certain selection process, that ensured a well-balanced group of 22 members : Equilibrium between Western and Eastern countries; Quite well-balanced gender representativity (9 Women and 13 Men); Good repartition between the categories of involved stakeholders (12 individual or/and local stakeholders and 10 national or/and European associations); 15 countries are represented in the CS larger group: Belgium, France, Germany, Italy, Norway, Sweden, United Kingdom, Bosnia and Herzegovina, Bulgaria, Czech Republic, Hungary, Poland, Slovakia, Slovenia, Ukraine

The methodology allowed to create conditions for building mutual trust (between research actors and civil society representatives). It allowed the results to be enriched (UMAN and ROUTES, ICS-CORI-UMAN process). There is still a question of erosion of participation (difficulties for maintaining 5 years of commitment without any resources for time engaged in the follow-up of the technical activities), and a question of renewal of members, and a question of enlargement of the mirror group: Having representatives coming from all Europe countries should be recommended in the future.

The Pathway Evaluation Process (PEP) methodology is a methodology tested and experimented many times in the context of EURAD. Its objectives are to put into discussion different strategies allowing to reach a safe situation for the long term, to identify issues that would really matter for different categories of actors, which have not the same vision of what should be the safe situation of radioactive waste for the long term. It is not a predictive tool or a tool to select the “best” technical option, but rather a tool to create the conditions of a fair dialogue on RWM among a plurality of stakeholders: providing them with equitable opportunities to contribute to the framing of the purpose and content of the exchanges on the way to secure safety of humans and the natural environment through different strategies that have all advantages and disadvantages.

The PEP methodology invites the participants to frame the discussion by building their own practical cases (using one event card and two criteria cards). The discussion around a practical case is structured in two rounds of discussions. After the first round, the participant that suggested the practical case synthesized what he/she heard from the others. A second round of discussion is organised to give the possibility to all the participants to add additional comments and react to what they heard from the other participants. During the two rounds of discussions, every participant is invited to speak, one after the other, without being interrupted. The facilitator ensures an equal speaking time for each participant. The

[36] SITEX II project website: http://sitexproject.eu/index_2.html

[37] JOPRAD project website: http://www.joprad.eu/

facilitator also helps to reformulate views and opinions to make them clear for all the participants (without interfering with the opinion expressed).

Such a methodology underlines the very useful dimension of the uses of Concrete Cases in uncertainty management. Indeed, PEP methodology can be adapted in different ways: originally, it is designed as a serious game (enabling freedom of speeches), but it can be adapted for Working Groups discussions (as it is in UMAN) with the same organisation of turns of discussion with concrete cases as basis for discussion.

So, in the context of pluralistic uncertainty management, why using concrete cases:

- To create a link between scientific issues and concrete situation facilitate the pluralistic discussion including persons who are not experts of the scientific field
- The use of concrete cases could be envisioned also as a way to organise discussion in the follow-up of GD implementation by civil society or in other participatory processes.
- However, the identified risk is the link with decision-making process could reduce the capacity of the methodology to create a “safe space”, thus a possible polarisation of the discussion due to the decision at stake.

3.1.2.4. How, where, and when to integrate pluralistic discussions in a safety case review and other procedures linked to GD (licensing process, etc.)?

This question will be answered by the articulation of two elements to take into account: the guiding principles of RWM and the safety culture as a cornerstone.

First, regarding the guiding principles, it needs to be said that arguably, the responsibility principle is the most important guiding principle in safety culture. To be responsible presupposes that one possesses the causal capability to carry out an act. First and foremost, the sense of responsibility is based on a will to act unselfishly in regard to a valuable object and this responsibility is not reciprocal. The responsibility principle is supplemented by the precautionary principle, which says that if there is strong suspicion that an activity may have harmful consequences, it is better to act before it is too late than wait until full scientific evidence is available that unequivocally demonstrates a causal connection between the activity in question and its possible impacts. The precautionary principle is a sub-category of the prevention principle, which says that is easier to respond to harmful activities before rather than after they occur, by preventing them

Then, regarding safety culture, it can be said that the role of CS in RWM, which also has consequences for the safety culture, has long been recognised in international, European, and national law and it should have a role in Long-Term Stewardship/Rolling Stewardship (LTS/RS). A European framework already exists relevant to LTS/RS, mainly the Aarhus Convention and the Radioactive Waste Directive’s (2011/70/Euratom) Article 10 on transparency. It also establishes a level system for evaluation of efficient transparency. Amongst others, it could include citizen science as independent citizens’ input, including citizens measurement networks, citizens’ sampling, but also access to, for instance, laboratories for second opinions. Citizen laboratories should be recognized as important players, and whistle-blower protection, as a necessary precondition for transparency and access to relevant information.

It can also be added that common licensing standards exist as part of safety culture: particularly on common licensing standards. RWM is excluded from the Integrated Pollution Prevention and Control Directive[38]. Instead, the legal basis of licensing is found in the Spent Fuel and Radioactive Waste

[38] The text of the directive is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0075

Directive[39]. It provides that each Member State must have a licensing system for RWM and/or facilities and ensure that the RW license holders maintain adequate resources to fulfil their obligations for safety of RWM. The exclusion from the Integrated Pollution Protection and Control (IPPC) Directive[40] (2008/1/EC) means that there is no mandatory integrated approach in the licensing procedure (e.g. impact is considered in regard to the environment as a whole; no significant pollution allowed; waste production is avoided in accordance with the Waste Framework Directive[41] – which also is not applied to nuclear installations; emissions limit values are based on BAT ("Biologischer Arbeitsstoff-Toleranz-Wert": biological tolerance value for occupational exposures); necessary measures are taken upon definitive cessation of activities to avoid any pollution risk, etc.). T&PP is also granted in the licensing procedure in the Waste Framework Directive.

3.1.2.5 How to manage uncertainties in this pluralistic and long-term perspectives?

What is Long-term Stewardship/Rolling Stewardship (LTS/RS)? Broadly speaking, it signifies an intergenerational management concept requiring monitoring and maintenance of the RW for an in principle an indefinite period, with responsibility being passed on from one generation to the next, preserving the possibility of retrieval, recharacterization and repackaging of the RW. It also requires a mechanism for re-instructing the next generation, providing detailed information on the RW and the associated hazards, and ensures that the next generation is fully aware of the need to spend time and money on the RW and if necessary, to see that corrective action is taken in a timely fashion. This process could last until a final safe solution is found which would no longer require constant care and memory.

The pillars of LTS/RS are the following:

- Despite the long time-horizon, continuous knowledge management, including memory keeping.
- Unbroken possibility of reversibility of all crucial decisions in RWM in all phases of the disposal process, including post-closure of GDR in the strong version of RS.
- Unbroken possibility of retrievability and recoverability of the radioactive waste, including during post-closure of GDR in the disposal process in the strong version of RS.
- Continuous access to resources for the rolling stewardship, including for all stakeholders and CS.
- Both long-term partnership between all stakeholders and long-term public participation must start early and be kept also in the post-closure phase
- Assignment of long-term and final responsibility

LTS/RS can be understood as an important Management method in a pluralistic long-term perspective.

In fact, the main argument for LTS/RS is a strong emphasis on safety (and security) under all conditions as the primary goal of RWM and final disposal of RW, which should not be diminished, offset, or compromised. Hence, LTS/RS is the best manifestation of the precautionary principle. As an intergenerational management concept dealing with uncertainty, LTS/RS sets out to define an "intergenerational common good" to address the uncertainties triggered by the extremely long time-horizons of the issues that it deals with. It represents a strong manifestation of both the responsibility principle and intergenerational justice.

[39] The text of the directive is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0070&qid=1397211079180

[40] The text of the directive is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0001

[41] The text of the directive is available here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098

The main argument against LTS/RS is its perceived lack of practicality because it is doubtful whether it can be sustained for tens or hundreds of thousands of years. Due to its high economic costs, it could also be argued that it puts undue and disproportional burdens on future generations, thus violating the polluter pays principle. Rolling stewardship also raises some fundamental questions regarding the long-standing discussion on whether obligations to future generations exist and if so, how far they go, whether a comparative, egalitarian or absolute standard should be applied, and how risks and uncertainties should be dealt with.

3.1.2.6 Recommendations

Finally, the presentation described some relevant recommendations for seminar's discussion that were extracted from the D10.17:

- **Recommendation 1:** Promote inclusion of information on and debates about uncertainties and their management in public participation procedures, i.e., by developing guidelines in EURAD.
- **Recommendation 2**: Enlarge the CS larger group with appropriate resources for recruitment of members and time engaged in the follow-up of activities.
- **Recommendation 3:** Continue and develop the uses of concrete cases and PEP methodology in research but also in participative processes.
- **Recommendation 4:** Based on its pros and cons, recognize that LTS/RS is not a controversial or "alternative" notion and integrate research on LTS/RS in the EURAD project.

More recommendations can be found in D10.17[42].

[42] See D10.17, opcit.

3.2 Restitution of WG discussions

As described above in section 2 of the report, the discussions in working groups were based on 4 concrete cases. Here are presented the results of the discussions for each concrete case. The description of the concrete cases is available in section 2.2 of the report. For each concrete case, the results are presented working group per working group. The composition of the working groups is available in Annex C.

3.2.1 Discussion on concrete case 1 **– Degree of acceptable remaining uncertainties - uncertainties about the performance of seals**

3.2.1.1 Discussion results of Working Group 1

Key points from the discussion:

- *Importance of preparation of the situation (emergency plan, monitoring plan, PEP game to be prepared, robust safety case).*
- *Importance of exchanges with public (differences of opinions in the group regarding how to communicate).*
- *Importance of stepwise approach and additional RD&D.*

First it is important to check what is the influence of uncertainty, what are the limit. Normally you would have large safety margins and it would not bring a problem. For enabling discussions with public, PEP could be applied so public would have an idea about the subject issues, not necessarily when the issue occurred but in previous phases. For solving the monitoring issue, it is not clear how to perform for such big plugs, and it could not be very successful (heterogeneous saturation).

Participation of the public and provision of information by official institutions like regulator, WMO, or the special advisory forum are also very important in such a situation. It would be good to inform in parallel to solve the issue. Best management would be that the information would remain at the same level all along the phases to maintain trust among the actors. T&PP procedure as established for construction phase could be used for discussions. If not, information will be provided through the media, and it could generate problems. Structured discussion should be used.

One participant expressed doubts regarding the scenario: who perform the experiments? The results should be used for the Safety Case (SC) and it should be assessed before (as part of the SC). It opens the question of quality of WMO. It is important to perform testing to ensure the systems are performing well. In this perspective, the stepwise approach is a suitable management option, coupled with communication and transparency.

Another participant considered that every facility should have monitoring plan and prepared procedures to react if such situation happened. It is important to envision and work in some critical scenarios. It could be a question of good implementation of stepwise approaches. Also, closer integration and exchanges with regulatory body should be organized. Concerning public and transparency, this participant considered that information should be released after having well established what happened, what are the impacts for safety and what could be the solution. Such decisions and communication processes should be designed in an emergency plan with a strong role of the regulatory body.

An implementer participant gave some information about implementation of industrial projects: what has been design is different with implementation and reality. It is normal that there are remaining uncertainties. Further regarding differences between foreseen and measured data, it is important that

there is explanation of the differences: variability of data, or something with understanding of processes. This is this consideration that should lead the approach: if there are no big differences, it is not a big deal, it would not impact safety (it has to be assessed). If there is a process misunderstanding, it is more important, and some additional RD&D should be performed. This situation should be assessed also from a safety Analyses' perspective. Regarding the modeling, we might have the differences that come more due to device itself and not due to real problem. What to do in such cases, it has to be planned in advance.

Another participant underlined the necessity of regular monitoring after issuing of authorization. The extent of remaining uncertainty should be assessed. Double wing model could be applied to ensure information towards Civil Society, but the experts should take the main role in decision-making. The PEP approach would not be useful in this case.

3.2.1.2 Discussion results of Working Group 2

Key points from the discussion:

- *Important to understand the significance of an uncertainty before a decision is made.*
- *Necessity of second opinions by independent expert or control groups.*
- *What independent / neutral means? Importance of composition of such pluralistic groups.*

Regarding the methodologies to be applied regarding the sealing systems, the question was asked, whether it really mattered and if the uncertainties were enough to cause delays or even a reaction. At least it was not enough to change the program. On the other hand, it was also important to maintain trust from the public, possibly in a multi-stakeholder regime. The reliability of the sealing system must be guaranteed. A sensitivity analysis should be made to test the system. It would not stop authorization for construction, but it would make sense to see the passive safety clearly demonstrated. It is acceptable to have uncertainties – the question is how you deal with them.

Thus, the sealing problem could also be seen as a process issue. The question here is not least whether the uncertainties are enough to warrant an independent expert opinion. It is also a situation, where the precautionary principle could be applied. An independent review could happen in multiple steps by e.g. expert groups from the industry and in this context the question of "what is independent?" came up.

It was noted that second expert opinions organized by the government are built into the Swiss RWM system regarding a final RW repository and that there are also expert groups following the Finnish RWM process. But if they are paid by the government, are they really independent? It was mentioned that in France, all the university experts are selected by the government, so the same question could be asked here? In France there is a system for the situation described in the scenario that does not address the failure before all uncertainties are clarified.

There was also an attempt to define independent expertise: Free from outside influence and neutral. However, the whole surrounding environment is important, and an independency culture should be in place.

It could be argued that all or most of the methodologies can be applied but not necessarily to their full extent. PEP could be used as a general tool for public enlightment and together with the double wing model, it could facilitate the transfer of technical knowledge. Also, a legal framework could be in place to favor the presence of independent/neutral groups.

3.2.1.3 Discussion results of Working Group 3

Key points from the discussion:

- *Importance of monitoring and iterative process.*
- *Necessity to have altered scenarios to assess the robustness of the safety case.*
- *Possibility to postpone decision if it is not possible to demonstrate the seals will evolve as expected.*
- *Stepwise approach: having an agreement on what is expected at each programme phase.*

A generic comment was made on the concrete case itself: seal permeability higher than expected in and Underground Research Laboratory, it's rather a question of initial state than of long-term evolution! Data is coming from a lab., it's still a generic case. Would it be the same in the real disposal?

It is extremely important to be able to measure data and associated interval of accuracy and simulate this with super-computers. It should be an iterative process: measure the data and sensitivity of measurement device, model it, improve knowledge, etc. It will be done all along the operational phase. The modelling's process is a sort of general exercise gathering data, representing all the processes etc.

It is also important to have a continuous R&D process as it would ensure trust for all the actors, including the CS. It's important to show what can happen, make more experiences. To deal with the situation, it's necessary to have much data, include all the processes in the demonstration (FEPs database). It is necessary to define several altered scenarios. In such a complex process of seal behavior and evolution, it's better to gather different specialties, different intelligences, different safety cultures, so as be sure have all the possible interpretations (including the good one!)

To the regulatory point of view, the authorisation would not be given if the implementer cannot demonstrate that the seals will evolve as expected ("demonstration principles"). So, it would lead to postpone the decision. The target for construction and acceptable range of values at closure (GEOSAF) should be initially defined. It is important for each decision step to have an agreement on what is expected. Defining a common reference for the review by all stakeholders will reduce risk of disagreement after. In such a situation, the legal framework will really matter.

In addition, if the target values cannot be reached, resources must be allocated to solve the problem during operation. Regarding multistakeholder dialog methods, the management option should be the stepwise approach: at each step, the objectives initially fixed should be reached, otherwise the step is not "validated". The consequences of this situation depend on the concept and on existing safety margins… Several scenarios considering several degraded situations should have been developed. If the facility is very robust regarding the degraded situation, it is possible to continue. If not, it can be necessary to completely change the concept and the license application should be postponed to improve knowledge or change concepts.

3.2.2 Discussion on concrete case 2 - **Integration of new knowledge – new results on radionuclides transport modelling**

3.2.2.1 Discussion results of Working Group 1

Key points from the discussion:

- *Need to have a transparent information of how the results of new knowledge are considered in the GDF implementation.*
- *International peer reviews should be used to assess the validity of the new results and the way to integrate them in the current models.*
- *PEP exercise could be used to stimulate discussion among experts (and with public) on the way to reassess the current models through the perspective of new results.*
- *Good system of actors and interaction should be developed from the beginning (like double-wing model, advisory forum).*

According to the participants, the first step in such a situation is to check if the publication is sound (from a research's perspective). Transfer of isotopes is fundamental and there should no doubt left regarding the conceptual modeling of such system. In case the results are valid, the implementer would lose the public's and authority's trust. The methodological work of implementer would be in question as the understanding of the whole system would be under question. It is a need to provide the information to the public transparently, but there should be consensus in expert community. There should be communication, but double wing might be too slow (if it is started only at the moment of the problem occurs).

To trust the new results, we need them to be repeated by independent source, to reassess the situation and think about more precise models, use of sensitivity analyses. It would be useful to inform society and use PEP and double wing model to collect some good ideas from public, or even use it for stimulation of discussion among experts.

This can be example of uncertainty model; it is hard in such case to argue against. One has to analyze in more details what could happen (difference, at more precise steps). Finally, we should prepare an answer to the paper: no or yes and provide the plan. How to organize exchange with CS – to use double wing model, or some other methodology. It is hard to assess which would function well and would depend on cultural context (safety culture method).

It is important to assess the quality of the paper (the journal, the team, the peer review process, …). If there are strong elements for selection of the conceptual model used, there should be explanation and also the reasons why to stay with. The communication with stakeholders should start before the submission of the SC with explanation of the conceptual models, including scientific community. Good system of actors and interaction should be developed from the beginning. Keeping them in power and involved.

Interact with the researchers and discuss with them the use of new model and reasons for it. It is needed to know the properties of host rock and to perform sensitivity analysis. Then to decide if it is important message or if it is not. If yes, design must be modified, if not it should be used as lessons learnt. Also, it could be relevant to discuss with CS experts, who could be also knowledgeable in the area. There are many international peer reviews for disposal establishment and could support such situation.

Regarding a new research's paper, first the implementer must react and show if the situation is transferable to disposal. If this is the case, then the implementer must have prepared solution and worst-case calculation should be available. If no, then some improved barriers should be used (e.g., copper canister use as additional barrier). Such situation should be prepared. How to communicate: it is difficult, sometimes Q&A are available on websites (regulators, implementers, …) and given some information for worst case scenarios. On the other hand, codes can be used under different boundary conditions and such answers should be prepared.

Advisory forum could be solution for such scientific debate, and in the modified double wing method translate the situation and inform the public. Maybe also PEP could be applied to organize technical debate in innovative way.

We need to be humble and would acknowledge that some uncertainties have been missed, could also checked the scenario if we collect all situations. Such papers could be used to have iteration of safety issues and impacts, and to look at all possible scenarios even those with low probability.

3.2.2.2 Discussion results of Working Group 2

Key points from the discussion:

- Importance of reversibility of the RWM process / periodic reassessment plus stepwise approach and practical visits.
- Facilitation of public understanding and necessity of independent expertise (double wing model / PEP).

Regarding this scenario, it was argued that a regulatory requirement should be in place to reassess the safety case every 15 years and that a safety demonstration should clear up the uncertainties. Additional studies and more experiments, e.g., physical modelling in real conditions, are required. A similar case occurred in Sweden some years ago and recently in IRSN, where it was necessary to explain what the ramifications were. In such situations, reversibility of the RWM decision-making in a stepwise approach must be a possibility. The question was also asked, why was the inventory not correctly mapped out? The inventory must be absolutely known.

It was also mentioned that the situation is like the first scenario, i.e., not least a question of process, and possibly second expert opinion(s) and implementation of the precautionary principle.

The double wing model and PEP could be helpful tools in a scenario like this, where new knowledge must be transferred.

3.2.2.3 Discussion results of Working Group 3

Key points from the discussion:

- *R&D process should continue during the GDF implementation.*
- *Review of the research's results should be performed and assessment of the safety significance of the new results (impact for the safety case).*
- *Use of very conservative values for models could be a way to avoid such a situation.*
- *Organizing a regular dialog with civil society (rolling stewardship) is necessary to be able to discuss in good conditions (i.e., without losing trust) potential safety issues resulting from the emergence of new knowledge.*

This is technically a complex topic (RN migration & colloids) that still requires R&D. Many factors can participate in the RN migration, it's very difficult to model. Experiments can be different to the real life, but it should be reviewed, to see if it's really a safety issue. The case is not surprising. It is important to verify if the new result is relevant (it's just 1 publication from 1 team of researchers). Then if it's really a safety issue, i.e., regarding the safety case. In this perspective, it's better to use and compare very different models.

If it's a safety issue, decision whether to continue disposal or to retrieve waste should be taken through stakeholder's dialog. Such dialog should occur regularly, each X year →it requires to maintain a rolling stewardship. Such situation can also be avoided by using very conservative values. Through a multistakeholder dialog, it's important that at the end, the process is understood by all and potentially interpreted the same; It is important also to share the safety case elements by linking the different parts: knowledge and uncertainties, a whole set of scenarios, uncertainties treated through sensitivity analyses…

New knowledge can also sometimes be « good news »! Ideally, it is a progress in knowledge (it could sometimes be a potential regression, due to remaining large uncertainties). It should be imagined before as much as possible (licensing phase)

3.2.3 Discussion on concrete case 3 - **Operational monitoring data deviating from expectation – monitoring uncertainties and need for waste retrieval**

3.2.3.1 Discussion results of Working Group 1

Key points from the discussion:

- *Importance of involving all relevant actors including public for discussing problematic monitoring data but raw data is not easy to understand for non-specialists' persons.*
- *GDF's safety should not rely on monitoring only.*
- *The implementation of an advisory Board (with CS experts in it) could be a way to manage the monitoring uncertainty. It could invite additional experts to give opinion on the issue.*
- *Importance to exchange at international level: the issues could be relevant for other national cases.*
- *Implementation of Digital Twin could help to manage monitoring uncertainty.*

First, it is necessary to perform analyses for such data's occurrence – this is important to decide on the measures to perform. We should theoretically analyze what could happened. There is probability of measurement 's error, as it happens after 50 years of good data. To investigate what could happened, it would not be a problem to wait for 1 - 2 years. Public discussion is important, all relevant actors should be involved. The approach what to do should be taken after the analyses.

Such situation could really happen. It is important to look if some event occurred before (earthquake, seismic event, etc.), to assess what is extent of the monitoring results (larger or limited to local), to investigate the reason for leakage, evaluation of sensors functionality (power for sensor), WMO would be responsible, to investigate how safety can be impacted. If there is really indication of strong leakage, what can be the radiological impact (for people and environment). If it is something urgent, emergency plans could be implemented. Consultation should be made with regulators and some experts. How to inform the inhabitants: it should be established in emergency plans (as part of country EP&R).

This example shows the limits of monitoring and could lead to emergency. The implementer would check with other data if this could be really a leakage. There is high probability that it is just error. Question if implementer can prove that there is no problem to the public and would need to retreat it at the end. It is important to have good research and implementation as monitoring could be not reliable. The safety should be not relied on monitoring only. It is complementary, but not to rely so much on monitoring.

More as gaining trust, but also limitation should be realized. As example: community ask to be informed about all raw data of monitoring, it was agreed to put on-line, also raw data (with all errors, like noise, variability, ….). And later community decided to have access to only clean data.

CS will make pressure to break up the backfill and open the waste package to research it.

It might be a design problem of the canister and affect repositories in other countries using the same type of canisters.

Safety of workers must be guaranteed, but costs should not be as important as safety, there will be high pressure to go for cheaper options to fix it.

Every actor should be involved in the decision-making. The Advisory Board (with CS experts in it) might want to invite additional experts to give opinion on this; there will be high pressure to go for cheaper options to fix it.

Upfront it will be helpful if public is informed what will be done if such monitoring results occur.

How will this event and its handling be implemented in the knowledge management? It should be preserved for future generations. Problems with the waste package might also have consequences for other countries repositories – how will this be communicated to other countries?

You should have digital twins by then. If you see values that indicate a leakage, you can check with the digital twin - the canister might be destroyed, so you can reach a conclusion i.e., if it is a sensor failure. Can you calculate when the next sensor will show higher levels? This might also indicate that it was a sensor failure. Sensor failures are much more likely than canister failures.

But if the canister failed, there would cost-intensive measures have to be taken. This might to happen again; the operation needs to be stopped.

MODATS is also researching how we can rely on sensor data. It is a difficult topic.

Communication: raw data is difficult to handle by unexperienced people, you must explain. It is Terabyte by day, who would be able to have a look at it?

3.2.3.2 Discussion results of Working Group 2

Key points from the discussion:

- *PEP could be seen as a management option.*
- *Rolling stewardship is important to keep the CS involved in technical topics. In this regard, to make it possible, an efficient legal framework is need.*
- *The double-wing model could be used for mutual understanding.*

It was argued that LTS/RS might be appropriate here because there could be an organisational problem, although the definition of RS is still in its initial phase. However, why LTS/RS is not part of shared safety culture is difficult to understand. An example was mentioned from CSM (Cherbourg), where legacy waste must be retrieved under very difficult conditions and the risk for workers related induced by the leakage had to be assessed.

Retrievability of the RW would be the main issue here and the public must be involved at an early stage to understand the gravity of the problem and that it probably can be solved by optimisation of the protection. The case is full of uncertainties that need to be investigated. Results from the monitoring system might not be enough. A performance assessment system must be in place. The OODA (Observe, Orientate, Decide, Act) Loop could be appropriate. Under all circumstances, this is a very

complicated situation that could be difficult to explain to the public, where it could cause widespread panic. PEP as well as the double wing model could be part of the solution.

3.2.3.3 Discussion results of Working Group 3

Key points from the discussion:

- *Problems of monitoring must be investigated upstream, at licensing: where/when to monitor, what actions in each situation.*
- *The lifetime of the sensors is a key issue.*
- *Several points of view are needed to be sure the situation is well understood. Sharing key data from monitoring during operation (and beyond) with CS is an important management option.*
- *Knowledge management and transmission by each actor is needed to well interpret data over time.*

From a regulator's perspective, monitoring is a confirmation everything goes as expected! To be credible, problems of monitoring must be investigated upstream, at licensing: where/when to monitor, what actions in each situation. The decision process must be defined, including operation procedure to follow: no decision to take, everything should be pre-defined! It's not a question of date: whenever such situation arrives, it's too late to discuss on how to proceed. Thus, regulatory framework should be clear.

For some participants, message that we will be able to measure everything for such a long time, it's science fiction. It is important not to do too much monitoring (monitoring should not impact safety), but we should put in place dummy galleries (with real waste or not in it, it remains an open question.) One important question is how long the sensor can perform. It is better to use complementary sensor technics for a same parameter. First, it is necessary to evaluate all the potential consequences (contamination of workers when retrieving vs. LT impact of the leakage), retrieve waste as a last option depending on the impacts

Operator should take its responsibility: stop operation and try to explain, propose additional measurements to remove the doubt. Use modeling, artificial intelligence… Operator should identify the situation to find the solution.

Several points of view are needed to be sure the situation is well understood, to have the pros and the cons of each decision. Therefore, consulting the public is important. Sharing key data from monitoring during operation (and beyond) with CS is an important management option. Important to agree before on what data should be communicated: quantity, regularity, from which level of deviation from expectations…

During 100 years of operational phase, knowledge transmission by each actor is needed to be able to well interpret data over time.

3.2.4 Discussion on concrete case 4 - **Role of Institutional control and site memory – abandonment by government of the initially planned institutional control after closure**

3.2.4.1 Discussion results of Working Group 1

Key points from the discussion:

- *It is important to ask government for the maintenance of the institutional control after closure as it was planned or to organize democratic procedure (voting) to change the plan.*
- *International research and legal framework could help managing the situation (abandonment of initially planned institutional control after closure).*
- *It is important not to rely only on one measure to guarantee GDF memory. Having a weel-established rolling stewardship process could help.* Other organizations can take over the memory keeping from the Government (or *organisation of several processes in parallel to ensure memory keeping).*
- Importance to ensure funding for memory keeping to avoid such a situation.

Such a decision damages trust with public, especially for municipalities. It is also change of legal aspects. It is not clear if this would also be true for borehole disposal. It is a serious problem. How to manage it? Public should be against this decision, so it is important to ask government for this institutional control. Questions of funding for institutional control, depends on the economic situation of the country. It is important to make a funding to prevent the situation. For some RE participant, it is a difficult case, a bit outside of possibilities of uncertainty management of a RE.

Regulator might not have arguments to influence the government. See also legacies (waste dropped into Sea – no control). Also, operator can only convince the Government to change this decision based on trust, not on safety arguments. We must also check the legal framework: the operator might not be longer responsible after closure. To manage the situation, some participants indicated that we should rely on NEA activities: Memory and record keeping project – there should be international markers, should be clear to everyone. Recommendations from international agencies have more power to push Governments to avoid such decisions.

What could be the effect of such a decision on site memory? Different measures can be taken to make sure that the memory is guaranteed. One should not rely on one measure like institutional control. For some participants, the concept of a GDF is passive safety. Future generations should not have any harm, loss of memory should be no problem. Such a decision could be possible due to public voting and direct democracy if it is in accordance with the national framework. For other participants, this situation is a no-go. This is most probably a breach of the original concept which will be enshrined by law. Trust will be lost. Members of CS will go to court and challenge this. They will do monitoring of their own and engage experts they trust for doing it. Uncertainties of public acceptance and uncertainties according to political decisions must be considered in uncertainty management.

Participative institutions like an Advisory board might no longer exist (because if no budget is available for institutional phase, then no budget will be available for advisory board) – which would be a pity in such a situation. It is not easy to keep memory for the very long-terms. If a Rolling Stewardship system has been established before, this will be helpful because other organizations can take over the memory keeping from the Government.

3.2.4.2 Discussion results of Working Group 2

Key points from the discussion:

- *LTS/RS including memory-keeping is relevant.*
- *Principles and values at all stages of the RWM process are important.*

- *Shared safety culture should be included in the involvement of rolling stewardship.*
- *Could original functions of the involved actors be modified when applying rolling stewardship? There is a possibility of overlap of functions while preserving independence of national institutions.*
- *Legal framework should secure the application of pillars of the Aarhus convention and access to resources.*

By some, it was asserted that this was the most political and general scenario of all the scenarios, because it relates to the general perception of the RWM system and the confidence one has in it. The scenario could result in the lack of trust by the public and furthermore, the question is how you perceive the role of the actors in all phases of RWM, including post-closure. Principles and values are important at every stage and future generations should be able to have a say. The question was also raised, who assesses how the safety is demonstrated.

And some final reflections on the implementation of methodologies in this scenario have been made:

Shared safety culture should be included in the involvement of rolling stewardship. There is a necessity to develop a shared safety culture and permits its intergenerational transmission

Two important questions have been raised on rolling stewardship: Should conditions for successful implementation be the same for institutional organisation and civil society? Could original functions of the involved actors be modified when applying rolling stewardship? There is a possibility of overlap of functions while preserving independence of national institutions.

Legal framework should secure the application of pillars of the Aarhus convention and access to resources.

3.2.4.3 Discussion results of Working Group 3

Key points from the discussion:

- *Importance to organize multi-party dialogue in such a situation to find an optimal solution.*
- *Resources should be available to avoid such abandonment of initial plan. Costs should not lead to such political decisions.*
- *All levels of decisions (local and national) should be involved in the decision.*
- *Ensuring a memory keeping of the justification of the initial governance plan to let the possibility for future generations to decide with all the information.*
- *International framework should be a management option.*

It is necessary to find optimal solution and to share with CS: ask CS what do you expect as consequences of such a decision, what could be negative? In regards of some participants, there will be not so much negative safety aspects associated with such decision. It will question the trust to the government. A practical example occurred in United Kingdom; government broke a consent with the CS. Resources should be available to avoid such a situation.

Some participants indicated potential consequences on the memory keeping: risk of other (economic/political) interest for the site. Maintaining institutional control is important, but it should be the choice of the future generations. Who decides? Local community or the whole nation? It is important that the government is representative of the whole opinion, including locals.

What were the reasons for having chosen 150 years, why changing it? The cost should not be a reason! The reasons why 150 years of institutional control has been decided (agreement with CS, safety reasons, helps keeping memory...) These reasons should be written, so that the future generations are able to decide if they prefer to change. To prevent the instability of decision, the local communities should empower. With regards to security, surveillance by IAEA forever could also be considered as an option!

4. Synthesis and conclusion of the Seminar 4

4.1 Synthesis of the seminar's findings

The seminar provided the opportunity to validate the different identified pluralistic methodologies for managing uncertainties at different stages of GDF's implementation. Based on the discussions on different concrete situations, it is possible to summarize key messages:

- It is important to be well prepared. Some tools are already existing (Safety Case, altered scenarios to assess the robustness of the safety case, emergency plan, monitoring plan, periodic safety review, etc.) but the implementation of tools for regular pluralistic exchanges is also required. It should be done as early as possible and should start during R&D projects (i.e., double wing model). Other tools could help to be prepared like the PEP game that is considered as an appropriate tool for involving all the stakeholders and reinforce mutual understanding. The robust international legal framework ensuring exchanges with the public is needed to support implementation of pluralistic dialog in national cases. Legal framework should secure the application of pillars of the Aarhus convention and access to resources.
- A stepwise approach, additional RD&D all along the GD, and a flexible process are necessary to be able to deal with difficult situations, including the management of unexpected ones. The possibility should remain to postpone decision until second opinions is given by independent expert or control group when problematic situations occur. It is important to have an agreement on what is expected at each programme phase and to ensure a real reversibility of RWM process.
- Rolling stewardship should be implemented to ensure transparency of information and ensuring trust will not be lost in case of problematic situations. It should imply different levels (international peer review, advisory forums at national level, involvement of local stakeholders). Knowledge management and transmission by each actor is needed to well interpret data over time.
- Shared safety culture should be included in the involvement of rolling stewardship because rolling stewardship focuses on safety at all costs (sharing is caring). Ensuring a memory keeping, knowledge transmission with the justification of the initial implementation plan and of all decisions taken all along the phases is necessary to maintain conditions of trust and let the possibility for future generations to decide with all the information.

4.2 Conclusions of the seminar

Interactions between experts and civil society aim at improving mutual understanding on uncertainty, contribute to the development of a shared safety culture and therefore contribute to improve R&D results and safety (at the end of the process). There is a strong interest to maintain independence of expertise, to reinforce research on uncertainties related to "unknown unknowns", governance issues (including reversibility, transparency, and post-closure) and non-technical uncertainties in general. Issues like the continuity of institutions and availability of sufficient financial provisions to deal with unexpected situations are important concerns.

Methodologies and processes can be implemented to enable multi-actors and multi-disciplinary management of uncertainties in the frame of geological disposal. The implementation of an enlarged safety culture appears to be a precondition for ensuring continuity of safety related activities and for supporting an intergenerational, multi-actors' management of uncertainties related to GD Implementation of a Long-Term/Rolling Stewardship culture could be a management strategy for ensuring intergenerational transmission of information, empowerment of communities, cultural heritage. Reinforcement of an appropriate legal framework is necessary to enabling pluralistic management of uncertainty. Double Wing Model in the frame of research is a way for translating technical knowledge in order to enable a larger public to understand technical results and make up their own minds on the

research topic. Development of dialogue tools (e.g., under the format of serious game) could facilitate the development of pluralistic management of uncertainties. A stepwise, transparent & flexible decision-making « process » is needed to manage uncertainties in a way which is satisfactory to all stakeholders. However, the question of the conditions to make it sufficiently transparent and flexible remains. The Safety Assessment & Safety Case have a role to play. Some roles of CS in this process were defined or discussed: oversight of the overseers, challenge experts and measures foreseen to manage uncertainties (e.g., completeness check of the FEP list & scenarios), developing scenarios (e.g., stylized approaches), identification & selection of possible options («Optimisation principle»).

References

Bernier F., Dewoghelaere J., Heriard-Dubreuil G., Mannaerts K., Surkova M., Swahn J., Wouters J-P., Zeleznik N. (2018): Conditions and means for developing interactions with civil society. Final version as of 23.05.2018 of deliverable D4.1 of the HORIZON 2020 project SITEX II. EC Grant agreement no: 662152

Dewoghelaere J., Fontaine G., Hooge N. H., Mraz G., Wales C. (2024): Synthesis report of WP UMAN outcomes from a civil society point of view. Final version of deliverable D10.17 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593

Dewoghelaere J., Fontaine G. (2024): Application of the methods for a pluralistic assessment of uncertainties and their management to near-field uncertainties. Final version of deliverable D10.20 as of May 2024 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593

Dewoghélaëre J., Rey H., Hériard-Dubreuil G. (2020): List of members of the Civil Society group, Final version as of 09.03.2020 of deliverable D1.13 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Dumont J.-N. (2022): UMAN - Pluralistic analysis of uncertainty related to human aspects. Final version as of 11.07.2023 of deliverable D10.15 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Geisler-Roblin A., Lavelle S. (2022): Mid-term evaluation of the ICS activities and experimental model of interaction between EURAD participants and Civil Society. Final version as of 28.04.2022 of deliverable D1.14 of the HORIZON 2020 project EURAD. EC Grant agreement no:847593.

Göbel A., Wengler W., Strusińska-Correia A., Müller-Hoeppe N., Mikšová J., Vojtechová H. (2020): Analysis and description of groups of different actors. Final version as of 2024 of deliverable D10.10 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Haverkate B., van Gemert M., Strusińska-Correia A., Göbel A., Mertens J., Detilleux V., de Gregorio y Robledo S., Grigaliūnienė D. (2024): UMAN – Preferences of different actors on uncertainty management. Final version as of 2024 of deliverable D10.12 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Hériard-Dubreuil G. (2022): Power Point Presentation, UMAN Seminar #3: Key Uncertainties Related to Human aspects from UMAN draft deliverable 10.8 from Subtask 3.4 (J-N. Dumont, Andra) The Civil Society contribution, prepared by the UMAN Task 5.2 together with the CS group (March 16th 2022), Mutadis.

IAEA (1991): Safety Culture, A report by the International Nuclear Safety Advisory Group, Safety Series No. 75-INSAG-4, Vienna. Pub882_web.pdf (iaea.org)

Rocher M. (2023): UMAN - Pluralistic analysis of site and geosphere uncertainty. Final version as of 04.08.2023 of deliverable D10.14 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Röhlig K.-J. (2021): UMAN - Understanding of uncertainty management by the various stakeholders. Final version as of 28.06.2023 of deliverable D10.13 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Swahn J., Kearney P., Zeleznik N., Liston V., Heriard-Dubreuil G., Haverkamp J. Lorenz P. (2015): A first report from Nuclear Transparency Watch (NTW) BEPPER project – Transparency in Radioactive Waste Management.

Zeleznik N., Swahn J., Daniska M., Haverkamp J., Hooge N.H., de Butler M, Wales C., (2024): Implementation of ROUTES action plan third phase. Final version of deliverable D9.18 of the HORIZON 2020 project EURAD. EC Grant agreement no: 847593.

Appendix A. Agenda

WP 10-UMAN

UMAN seminar 4

How to manage uncertainties in a pluralistic way and in a long-term perspective?

Agenda

14-15 December 2022

Hybrid meeting: IRSN premises and ZOOM - https://us02web.zoom.us/j/8384914149

This Seminar is organized by NTW with the support of an expert's team from task 5 of the UMAN project.

After seminar 1 offering a global picture and seminars 2 and 3 digging two domains of uncertainties respectively "Site and Geosphere Characteristics" and "uncertainties related to the human aspects", Seminar 4 will focus on methods to enable fruitful interactions between institutional/technical experts and civil society in the long term.

Seminar 4 will give 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 will also be to identify the potential needs for strategic research on methods to achieve this goal.

First Day - 14 December 2022

Introduction

9:30 **UMAN pluralistic seminars: objectives and methodology of seminar 4** – Julien Dewoghelaere (UMAN Task 5 leader), NTW, France

Session 1 – Views of actors on how to manage uncertainties in a pluralistic way and in a long-term perspective? (hybrid)

This session aims at presenting an integrated vision of different views of UMAN research actors (Waste Management Organisations, Technical Support Organisations, Research Organisations) based on Task 4 workshops results regarding the question: how to manage uncertainties in a pluralistic way and in a long-term perspective? The team of civil society experts working in UMAN will also present their views on this question, based on their work carried out in UMAN Task 5 for preparing the previous seminars. The two presentations will launch the discussions with the participants on the conditions, methodology and tools that could ensure a pluralistic management of uncertainties on the long term.

9:45 **Views on UMAN research actors on how to manage uncertainties in a pluralistic way and in a long-term perspective** – Agnieszka Strusinska-Correia (UMAN Task 4 leader), BGE, Germany

10:25 Questions and answers (elements of clarification)

10:30 **Views on UMAN civil society team on how to manage uncertainties in a pluralistic way and in a long-term perspective** – Gabriele Mraz and Niels Henrik Hooge, UMAN CS experts' team, Austria and Denmark

11:10 Questions and answers (elements of clarification)

11:15 Coffee break

11:30 **Plenary Discussion – what are the conditions, methodology and tools that could ensure a pluralistic management of uncertainties on the long term?**

12:30 End of the session 1

12:30 – 14:00 Lunch

Session 2- Working Groups session (hybrid)

During this session, the participants will be split in Working Groups in order to continue the discussion held in plenary during session 1. The discussion in working groups will be based on the PEP methodology (tool of pluralistic dialogue developed by the SITEX.network) and concrete cases will illustrate issues related to pluralistic management of uncertainties on the long term.

14:00 **Description of the working groups' session and presentation of the concrete situations** – Julien Dewoghelaere (UMAN task 5 leader), NTW, France

14:20-17:30 **Working groups session**

17:30 End of the first day

Second Day - 15 December 2022

Session 3 - Restitution session (hybrid)

9:30 **Introduction of the session**, Julien Dewoghélaëre (UMAN Task 5 leader), NTW, France

9:40 **Working groups results presentations**

The rapporteurs of the working groups will present a synthesis of the results of the discussions to be held during the working groups sessions.

10:40 10 minutes coffee break

10:50 **Synthesis Discussion - how to manage uncertainties in a pluralistic way and in a long-term perspective?**

All the participants will have the opportunity to comment and discuss the results of the working group discussions and also to bring elements regarding the potential needs for strategic research on methods to manage uncertainties in a pluralistic way and in a long-term perspective.

11:45 **Conclusive remarks** – Julien Dewoghélaëre (UMAN Task 5 leader), NTW, France

12:00 End of the Seminar 4

Appendix B. UMAN Seminar 2 Terms of Reference

European Joint Programme on Radioactive Waste Management

Terms of reference
UMAN Seminars

In order to ensure fruitful discussions in mutual respect, it was suggested to elaborate terms of reference that will be agreed by all the participants in the UMAN Task 5 seminars. These terms of reference establish a set of prerequisites to attend the seminar, notably based on elements of the procedure for establishing the group of CS representatives involved in EURAD that have been validated by the EURAD PMO and Bureau.

1- The participants in the UMAN seminar will have to support the EURAD vision hereunder and commit to contribute constructively to the exchanges that will take place in EURAD, respecting the goals of EURAD described hereunder:

EURAD vision:

"A step change in European collaboration towards safe radioactive waste management (RWM), including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports timely implementation of RWM activities and serves to foster mutual understanding and trust between Joint Programme participants"

EURAD goals:

- "Support Member-States in developing and implementing their national RD&D programmes for the safe long-term management of their full range of different types of radioactive waste through participation in the RWM Joint Programme;
- Develop and consolidate existing knowledge for the safe start of operation of the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste, and supporting optimization linked with the stepwise implementation of geological disposal;
- Enhance knowledge management and transfer between organisations, Member States and generations."

2- The participants in the UMAN seminar recognize that the objective of the seminar is to foster a common understanding or understanding of the different viewpoints among the different categories of actors on the management of uncertainties associated with the management of radioactive waste and how it relates to safety.

3- It is not intended to reach a consensus. Rather, the discussions during the seminar will seek to allow for a nuanced understanding of the issues at stake and a better understanding of the arguments of the various participants, without prejudice to their position with regard to a particular option.

4- The seminar will promote the clarification of the implicit elements leading each actor to establish his choices and preferences, while creating a climate of mutual listening and respect for the views of each participant. The discussion will be based on a freedom of expression of views. The plurality of categories of participants, or at least a plurality of views, experiences and professional profiles, is therefore desirable to foster an in-depth discussion that takes into account a wide range of issues.

5- The animation of the seminar will require pluralistic and transparent governance, i.e the organisation of the seminar and the facilitation of the discussions will be done by a pluralistic team gathering representatives of different categories of actors (WMO, TSO, RE and CS).

Appendix C. List of participants to the working groups (14 December)

Legend

	Civil society (CS) representative
	RE (Research Entity) representative
	Regulatory body and international organisations
	Technical Support Organisation (TSO) representative
	WMO (Waste Management Organisation) representative

Working Group 1

Dewoghelaere	**Julien**	**NTW**	**France**	**Physically**
Zeleznik	**Nadja**	**EIMV**	**Slovenia**	**Physically**
Becker	Dirk	Tu Clausthal	Germany	Remotely
Capouet	Manuel	IGSC	/	Remotely
Georgieva	Rayna	TU Sofia	Bulgaria	Remotely
Ikonen	Ari	Envirocase	Finland	Physically
Mikšová	Jitka	Suro	Czech Republic	Remotely
Mraz	Gabriele	NTW	Austria	Physically
Pfingsten	Wilfried	PSI	Switzerland	Physically
Tatomir	Alexandru	BGE	Germany	remotely

Working Group 2

Marsal	**François**	**IRSN**	**France**	**Physically**
Henrik-Hooge	**Niels**	**NTW**	**Denmark**	**Physicially**
De Butler	Malcolm	NTW	France	Physically
Diaconu	Daniela	RATEN	Romania	Remotely
Holt	Erika	IGSC/VTT	Finland	remotely
Ivanov	Ivan	TU Sofia	Bulgaria	Physically
Li	Xiaoshuo	Nagra	Switzerland	Physically
Mattews	Philip	CS larger group	United Kingdom	Remotely
Soloviov	Oleksandr	SSTC	Ukraine	remotely
Strusinska-correia	Agnieszka	BGE	Germany	remotely
Surkova	Maryna	FANC	Belgium	physically

Working Group 3

Geisler	**Alexis**	**NTW**	**France**	**Physically**
Rocher	**Muriel**	**IRSN**	**France**	**Physically**
Bernier	Frédéric	FANC	Belgium	Physically

Dimov	Ivan	TU Sofia	Bulgaria	Remotely
Grambow	Bernd	CNRS	France	Remotely
Grigaliūnienė	Dalia	LEI	Lithuania	Remotely
Lahodová	Zdena	SURAO	Czech Republic	Remotely
Mauro	Christiana	CS larger group	Italia	Remotely
Vojtěchová	Hana	Suro	Czech Republic	remotely
Wales	Colin	NTW	United Kingdom	Physically