European Joint Programme on Radioactive Waste Management

Deliverable D10.5: Uncertainties relevant to the safety case

Visions of Research Entities (REs), Technical Support Organisations (TSOs) and Waste Management Organisations (WMOs)

Work Package WP10

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Executive Summary

The goal of subtask 3.1 of UMAN is to assess the views of different actors, principally of waste management organisations (WMO), technical safety organisations (TSO) and research entities (RE) on the uncertainties in a safety analysis and in a safety case for geological disposal of radioactive waste and how the uncertainties may evolve over time. According to the spirit of EURAD, the generic nature of these views and not the country specific aspects is searched for, even though these visions are often forged by the national context and reflect the stage of advancement of the national waste management programme. The goal of this report is to provide a high-level integrated picture of the various types of uncertainties that the waste management organisations (WMO), technical safety organisations (TSO) and research entities (RE) consider potentially relevant for the safety case. 1st UMAN Questionnaire has been addressed to participants of the EURAD strategic studies, the Work Packages (WP) UMAN and ROUTES to assess the views of the various actors on high level uncertainties and the safety case and the answers collected address all phases identified in the EURAD roadmap from programme establishment over site evaluation & selection; site characterisation; Facility construction; facility operation to closure. This collection of views shall serve as a starting point for the activities carried out in UMAN by defining the different types of uncertainties and temporal aspects considered by other tasks and subtasks.

Representatives of 9 REs, 8 TSOs and 11 WMOs have responded to this questionnaire. The answers are presented in a generic way in this report, separately for each group of actors. While being heterogenic, the answers were essentially all complementary rather than contradictory. No principal differences were observed comparing the point of views of TSOs, WMOs and REs both on key uncertainties and on their evolution along the various phases of the radioactive waste management program. In the same way, actors from less advanced and more advanced national programmes share rather similar views on the uncertainties of the safety case. Coherent and complementary views were as well observed when interpreting the discrepancy between the rather promising results of quantitative safety analyses and the sentiment of uncertainty prevailing in the civil society.

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List of Abbreviations

FEP	Features, events and processes considered in scenario development for safety analyses
IAEA	International Atomic Energy Agency
OECD/NEA	Nuclear Energy Agency of the Organisation for Economic Cooperation and Development
RE	Research entities (Universities, national research centers)
ROUTES	EURAD Strategic Study WP - Waste management routes in Europe from cradle to grave
Safety case	A collection of arguments and evidence in support of the safety of a radioactive waste disposal concept
TSO	Technical safety Organisation (typically working for regulators)
UMAN	EURAD Strategic Study WP – Uncertainty Management multi-Actor Network
WMO	Waste Management Organisation

1. Introduction

The EURAD WP10 ´Uncertainty Management multi-Actor Network (UMAN)´ is dedicated to the management of uncertainties potentially relevant to the safety of different radioactive waste management stages and programmes. It includes various activities such as exchanges on views, practices and uncertainty management options and the review of existing strategies, approaches and tools. It may also be referred to as 'think-tank' or networking activities to enable experts of WMO, TSO and RE to network on methodological/strategical issues and advance significant challenges in the management of safety relevant uncertainties that are common to various national programmes, generating a common understanding among categories of various actors involved in EURAD. This work package addresses as well emerging issues associated with uncertainty management that could be addressed in the future.

As mentioned in the EURAD Strategic Research Agenda from 2023, in radioactive waste management (RWM) programmes, decisions are made in the presence of a wide variety of irreducible and reducible uncertainties. But how does each category of actors involved in the programme (WMOs, TSOs, REs) assess the significance for safety of uncertainties and what is the approach used in uncertainty management? And how does Civil Society perceive the problem of uncertainty in the decision-making process? The UMAN work package of EURAD addressed these questions with the threefold aim of reaching a common (or at least a mutual) understanding of the uncertainty management and how it relates to risk and/or safety, of assessing the contribution of the past and ongoing research to uncertainty management and of identifying associated remaining and emerging issues and needs.

The present work addresses both generic safety case related uncertainties as well as uncertainties valid in specific phases of a given disposal program, distinguishing between

- Phase 0: Policy Framework and Programme Establishment,
- Phase 1: Site Evaluation and Selection,
- Phase 2: Site Characterisation,
- Phase 3: Facility Construction,
- Phase 4: Facility Operation and Closure,
- Phase 5: Post Closure.

While some uncertainties might decrease in certain phases as new information become available, new uncertainties may be encountered with the advancement if the implementation of each phase of the repository programme. Dealing with uncertainties of radioactive waste disposal facilities is inevitably confronted with unprecedented long timescales over which the radioactive waste remains dangerous

The mission of subtask 3.1 of UMAN is to assess the views of the different actors, what types of uncertainties need to be addressed in a safety analysis and in a safety case. The goal is to provide a high-level integrated picture of the various types of uncertainties that are potentially relevant for safety. This picture served as a framework for the activities carried out in the WP UMAN by defining the different types of uncertainties and temporal aspects to be considered by other tasks and subtasks.

This present report provides input to the UMAN Task 2 on strategies, approaches and tools in uncertainty management, to Task 4 on uncertainty management options and preferences, on Task 5 on interactions between actors and other subtasks of Task 3.2-3.5 on the compilation review and synthesis of more specific view on areas of uncertainty like uncertainties on waste inventory and on the impact of predisposal steps, the site and geosphere related uncertainties, the uncertainties related to human aspects and as well spent fuel related uncertainties. The report provides a detailed assessment of the views of different actors on the various types of uncertainties that need to be addressed in a safety analysis and in a safety case as well as how these uncertainties may evolve throughout the different phases of a disposal programme as identified in the EURAD roadmap.

2. The safety case in radioactive waste management and disposal

According to OECD/NEA (2013a) a safety case is a formal compilation of evidences, analyses and arguments that quantify and substantiate a claim that the repository will be safe. The IAEA SAFETY STANDARDS SERIES No. SSG-23 (2012) defines the safety case as follows:

"*The safety case is the collection of scientific, technical, administrative and managerial arguments and evidence in support of the safety of a disposal facility, covering the suitability of the site and the design, construction and operation of the facility, the assessment of radiation risks and assurance of the adequacy and quality of all of the safety related work associated with the disposal facility. Safety assessment, an integral part of the safety case, is driven by a systematic assessment of radiation hazards and is an important component of the safety case. The latter involves quantification of radiation dose and radiation risks that may arise from the disposal facility for comparison with dose and risk criteria, and provides an understanding of the behaviour of the disposal facility under normal conditions and disturbing events, considering the time frames over which the radioactive waste remains hazardous. The safety case and supporting safety assessment provide the basis for demonstration of safety and for licensing. They will evolve with the development of the disposal facility, and will assist and guide decisions on siting, design and operations. The safety case will also be the main basis on which dialogue with interested parties will be conducted and on which confidence in the safety of the disposal facility will be developed*".

Not all national programmes use the term "safety case" to describe the broader range of arguments and evidence of which safety assessment forms one part; they may alternatively call such products a "safety report", "safety dossier" or "license application", for example.

According to the IAEA (2012), the safety case shall include the context; the safety strategy; the facility description; safety assessment; limits, controls and conditions; iteration and design optimization; uncertainty management; and integration of safety arguments. It integrates the current understanding of the operational phase and the behaviour and performance of the disposal system after closure and identifies the associated uncertainties, their significance and identifies approaches for the management of significant uncertainties. A key output from safety assessment and safety case compilation is the identification of uncertainties that have the potential to undermine the understanding of the degree of safety the system offers (OECD/NEA 2013a). Typically, the uncertainties considered in safety assessment are classified into scenario uncertainties, model uncertainties, and data and parameter uncertainties. The safety case shall specify how uncertainties will be identified, how they will be characterized and what the approach will be to their management. Guidance and recommendations are provided on the management of uncertainties within the radiological impact assessment (IAEA 2012).

The safety case and supporting safety assessment will evolve with time following the evolution of the national disposal project and shall be reviewed and updated prior to each major decision point and periodically as necessary to reflect actual experience and increasing knowledge (e.g. knowledge gained from scientific research or site characterization, more advanced project stages), with account taken of relevant operational aspects. For example, early safety cases (e.g. safety cases used to assist early site characterization efforts) might rely on rather generic assumptions about the properties of a host rock and the layout of a repository, whereas the safety case for authorization of construction of the repository would need sufficient factual basis and detail to provide the necessary confidence for the regulator to determine that the repository would be safe (OECD/NEA 2013a).

The safety concept is developed by describing the roles of the natural and engineered barriers and the safety functions that these are expected to provide in different time frames. This forms the basis for evaluation of the implication of uncertainties in the fulfilment of the safety functions over time, leading to the formulation of scenarios for the evolution of the repository over time and the derivation of related assessment cases. The results of the analyses of scenarios are complemented with arguments, for example, for the quality of the site and design (low impact of detrimental phenomena) and for the validity of model assumptions and boundary conditions from the assessment basis. They are also supplemented with any available independent supporting evidence for safety to place these results into context (OECD/NEA 2012).

The uncertainties in safety assessment and the interpretation of results also complicate the communication of safety assessment results. Mutual understanding and confidence in the overall outcome and processes can be improved through ongoing dialogue between the implementer, regulator and other stakeholders, especially representatives of potential host communities or municipalities. Through this dialogue, regulators and other stakeholders can influence the decisions and final outcomes, as well as ensuring the safety case contains the information for their needs. The concerns of each stakeholder need to be taken into account so that joint understanding is established and expectations converge (OECD/NEA 2013b).

3. Assessment of the views of different actors on uncertainties in the safety case

The various actors involved in radioactive waste management often and to various degrees have different views on safety strategy and on safety assessment, on the characteristics of a potential or selected disposal site, on the optimization of repository architecture and barrier performance; on uncertainty management and safety arguments like e.g. natural analogues, natural tracer profiles, etc…; on the acceptability of evidence and on safety indicators others than radiological dose. The question is as well, how these actors imagine how these uncertainties could evolve throughout the different phases of a disposal programme that have been identified in the EURAD road map.

The goal of UMAN task 3.1 is to develop a high level picture on safety case uncertainties (i.e. uncertainties needing to be addressed in a safety case) as viewed by different actors considering well established knowledge on uncertainties and on barrier performance but including uncertainties beyond the area where a rigorous uncertainty analyses can be made.

A questionnaire has been prepared jointly by representatives of the 3 colleges (1st WP Questionnaire) and addressed to participants of EURAD Work Packages UMAN and ROUTES to

1) identify and characterize the different actors across the entire radioactive waste management process (Task 4.1)
2) compile, review and compare uncertainty management strategies and approaches that can be used in a radioactive waste disposal programme (Subtask 2.1);
3) identifiy the views of different actors on the types of uncertainties relevant to the safety assessment and the safety case and on their possible evolutions throughout the different programme phases (subtask 3.1).

Representatives of 9 REs, 8 TSOs and 11 WMOs responded to each question.

The present document focusses on the views of individual views of actors expressed in their answers on point 3 of the questionnaire considering safety case relevant uncertainties and does not include a synthesis of the main types of uncertainties that are potentially relevant to safety. Questions and answers are summarized in the following for each phase of the repository program and for each category of actors. The results of this synthesis have been discussed in the UMAN 1st Seminar “What does uncertainty management means for different types of actors and how it is related to risk, safety and the safety case?” with representatives of WMOs, TSOs, REs and civil society experts, organized by Task 5 as WEB conference the 26-27 October 2020.

3.1 Summary of answers of REs, TSOs and WMOs

The questions addressed and the given answers are summarized in the following separately for REs, WMOs and TSOs. Both generic answers are provided as well as answers valid only for a given phase of a national disposal programme.

3.1.1 What do you/your organization consider as key uncertainties in the appreciation of safety in the various phases of a disposal programme for radioactive wastes? Explain briefly why these uncertainties are considered as safety relevant.

The answers to this question address uncertainties for each of the phases, which have been identified in the EURAD roadmap, covering the impact on the safety case of the various roadmap themes from programme management over pre-disposal and engineered barrier system, geoscience, design and implementation to siting and licensing. Some differences between the responses by the groups of actors became evident. For example, WMOs identify uncertainties regarding the facility layout as particularly important for the construction phase whereas it is clear for TSOs (typically supporting regulators) that these uncertainties need to be addressed before starting the construction.

Some of the answers include as well viewpoints on how to manage the identified uncertainties. For completeness and outreach, these answers were kept in the present document, even though, this is not the focus of the present work, as they are treated in UMAN task 4.

REs responses

Responses on this question are diverse among REs probably due to the very different experiences, but since answers were in most cases complementary and not contradictory, they are presented all together in this presentation in a concise way. No attempt for completeness in the answers is made.

TSOs responses

The answers reflect the diversity, which appears consistent with the diversity of waste management programmes in the respective EU countries, ranging from programmes in the setup phase to advanced programmes with strong research background, which are being implemented in practice and licensed. It also appears that the answers are in principle similar and to some extent complementary.

WMOs responses

Responses on this question are quite different in terms of level of details. Only a few WMOs developed nuances for each of the disposal phases presented. No obvious contradiction is pointed out and the answers are quite complementary. It therefore is possible to formulate, to some extent, a common view.

3.1.1.1 General high level uncertainties, valid for all phases

REs responses

The views of the various REs are complementary, not contradictory. Considering the uncertainties relevant to safety assessment of the nuclear facility, namely scenario uncertainties, model uncertainties as well as parameter uncertainties, a key high level uncertainty is the ability to provide reliable information. Particular concerns are insufficient knowledge on disposal system configuration, on impact of the extended dry storage on the integrity of the spent fuel (SF) packages, on input data of system description in geochemical evolution of waste packages, barriers and host rock including the source term and speciation. It is not always possible to reduce certain uncertainties in particular in geology and geochemistry as this may require over-proportional efforts, as experiments on large scales in time and space are practically impossible. In particular in such cases information can only be considered reliable if the remaining uncertainties are clearly specified.

The complete picture from beginning to end is subdivided into a certain amount of individual parts that each requires a high level of knowledge and experience. Overall understanding of this very complex repository system is at hand only for very few experts if any. It is difficult probably not only for REs to have specialists that are still able to get a full overview. Understanding of subsystems is often very high, however, only few experts are available with strong understanding of the connections between these specialized parts, including the problems for scaling up and for coupling different time scales. Failure to meet the deadlines for the implementation of a new radioactive waste repository project may result in a change in plans. The teams' existing competences might be lost; the data collected so far might become outdated, etc. The availability of experts in overall systems understanding is a high level uncertainty.

Appreciation of safety is based on realistic and detailed quantitative knowledge on some features and processes and their couplings and upscaling. Sometimes, in the absence of such knowledge, worst case bounding hypotheses are made. The different lines of reasoning are often not clearly distinguished. This situation may lead to a reduction of credibility in the results of safety assessment to stakeholders not directly involved in the analyses.

TSOs responses

TSOs identify the following categories of uncertainties that need to be addressed in the safety case:

- Uncertainties associated with the national radioactive waste disposal programme and other « prevailing circumstances »: waste to be disposed of, stakeholder conditions, available sites, regulatory framework, available financial resources, R&D needs, available skills and experience, scope of the safety case, …
- Uncertainties associated with the quality of input data related to:
    - the initial characteristics of the waste, site, host rock and engineered components;
    - natural events and complex processes that may affect these characteristics (e.g. during the transient phase);
    - hazards that may occur during construction and operation;
- Uncertainties on the future evolution of the disposal system considering these events, processes and hazards (normal evolution, and more of concern, disruptive events and alternative evolutions);
- Uncertainties associated with the completeness of the features, events and processes (FEPs) considered in the safety assessment (SA);
- Uncertainties associated with the quality of the SA including those related to the tools and methods used in the SA.

Some of these uncertainties can be embedded in the formulation of scenarios. These uncertainties are reported by all TSOs. However, it should be noted that the two last categories identified here above are not considered by all TSOs.

One TSO mentions that all these categories need to be considered from the beginning of the programme. However, the approach to manage them and the level of effort needed differ from one phase to another, depending on the decision associated with the programme phase.

WMOs responses

Some WMOs point to the societal and political uncertainties as major uncertainties to which are related the decisions (national policies), the siting and the financing. Regarding the siting, one respondent raised the specific issue about the construction and operation of disposal facilities in sites previously used for mines. Others mention uncertainties on the barriers and their related safety functions with regard to all possible FEPs as well as the models and parameters values difficult to validate due to the long timeframes at stake. Such timescales seem to undermine the credibility and the reliability of predictions. For instance, how can human influence be included into the safety assessments since human behaviour is difficult to predict over such a long period. In addition to the barriers and the relevant compartments (including geosphere, biosphere), the uncertainties regarding the nuclear inventory, the legacy (historic) waste and most generally the waste characterisation were also pointed out. The uncertainties regarding the hazards caused by the non-radioactive substances associated with radioactive waste are also of interest. Finally, these uncertainties should be reduced ahead of important decisions/phases whereas some aspects/phases can influence each other (e.g. impact of the operational phase on the long-term safety).

3.1.1.2 Uncertainties addressed at Phase 0 (Policy, framework and program establishment)

REs responses

The inclusion of key stakeholders early in the programme is not always assured. In some countries, distribution of responsibilities among actors is not always clear. Very often in national programmes, REs are only involved in developing of process understanding while process coupling in the overall analysis of a repository site and in scenario development is left to engineers of WMOs or TSOs. A stronger inclusion of REs in scenario development and safety analysis would allow to identify overlooked interdependencies and other shortcomings. This requires of course that REs are willing to commit in long-term engagement.

There are important uncertainties in various countries in the national energy policy and in the national views on spent fuel management and the associated governmental decision on long-term waste management. This leads to uncertainties in the inventory data provided by the waste producers as well as in uncertainties related to the planning assumptions. Uncertainties are increased if decisions become affected by political and/or personal preferences of decision makers. The resulting delays in programme implementation could lead to outdating of policies, frameworks, programmes and data that could lead in the long-term to a loss of competences, teams, and human resources.

TSOs responses

All the uncertainties identified in Section 3.1.1.1 are relevant at this stage. The most important uncertainties identified by TSOs are those associated with:

- The demonstration that the key factors important for safety have been identified;
- The characteristics of the components of the disposal system (potential host rocks and sites, waste, engineered components) important for safety (considering that no host rock or site has been selected at this stage);
- The national policy and programme (i.e. will a repository be built? When, where and what will be built?);
- The prognosis and availability of required financial and human resources;
- Waste classification and inventory, i.e. uncertainties on the adequacy of general waste acceptance criteria, on the types, volume and characteristics of the waste to be disposed of (in particular in some countries, the question whether SNF is considered as waste or not);
- The establishment, interpretation and implementation of safety requirements;
- The R&D programme preceding the choice of the site and/or rock.

WMOs responses

The respondents point out the uncertainties and deficiencies in the regulatory framework and/ or the national policies regarding the principle of geological disposal itself or aspects of the waste management programme such as the retrievability. The siting uncertainties are one of the major concerns with sometimes an open issue regarding a potential multinational shared repository. Without a site yet chosen, there is a lack of data for modelling which is thus of a generic nature. The public acceptance of a repository is of course an issue, part of the “general feasibility” and potentially even more acute in countries with a high-density of population. To mention that for one of the respondents, new regulations will not necessarily make the disposal facility safer (especially if introduced due to public pressure) which can be nuanced by another answer pointing out the fact that more generally, the political understanding of the waste management programme can influence safety on the long-term. Political changes leading to changes in the framework as well as, in some cases, the interpretation of the emerging regulatory basis create uncertainties that challenge the confidence in the disposal programme.

3.1.1.3 Uncertainties addressed at Phase 1: Site evaluation and site selection

REs responses

Site suitability is too often viewed only based on technical/scientific criteria, while social acceptance is important, too. Social opposition is a large source of uncertainty including disagreement with communities and local governments and uncertainty is increased in case of underestimating the importance of cooperation with the local communities. On the other hand one needs to base the decisions in site evaluation on the technical evidence on site suitability before addressing socio-economic and political aspects: a technically unsuitable site will not become suitable by having high acceptability by local stakeholders. For geological disposal: key uncertainties are in the long term scenarios and in model uncertainties on the Engineered Barrier System (EBS), the site characteristics and the geosphere, while for near surface disposal models on climate change (infiltration rate being one of the most sensitive parameter) are more important. Some REs put more the social acceptance in the foreground, others (the majority) the technical criteria.

Site evaluation depends on the availability of adequate geological host formation. It is often done using well established criteria, but shall allow for flexibility for example for compensating shortcomings in some site characteristics or in national geology by an appropriated engineered barrier system. If for example the low frequency of earthquakes is a reasonable criterion, such a criterion is meaningless in Japan (except in relative terms). It can be that a site not fulfilling a given set of criteria would become suitable with a good engineered barrier concept, and a site fulfilling all criteria may turn out not suitable after detailed site characterization. Very often the illusion is produced that we are able to select the very best site. This is simply not possible and a good site is always only good if it is combined with a good engineered barrier system.

TSOs responses

At this phase, TSOs consider that the most relevant uncertainties are those on the parameters associated with the site or host rock selection criteria and thus on site characteristics and its future evolution. TSOs also underline the importance of uncertainties on waste volume, properties (thermal, chemical, gas production…), acceptance criteria and on radionuclide inventory.

The investigations and R&D programme related to site evaluation and characterization typically address the following uncertainties: the retention properties of the host rock, its hydrodynamic properties as well as the ones of aquifers, the potential external perturbations caused by human activities or by natural phenomena and the potential internal perturbations (interactions between the disposal components) and how the host rock withstands these perturbations. Uncertainties on the scope of these investigations are also identified.

Thus, the technical uncertainties seems to be of higher importance at this stage. However, the uncertainties related to the interpretation of legal requirements and to changes in the legal framework as well as to the public opinion are also mentioned.

WMOs responses

At this stage, the key uncertainties are related to the performances of the suitable geological formations as a natural barrier. Different host rocks can be assessed despite sometimes different levels of knowledge on their characterisation (e.g. heterogeneous amount and quality of parameters for the rocks under consideration; heterogeneous amount and quality of data from underground research facilities, etc.). The preliminary safety analyses rely on generic/conceptual modelling that still needs to be confirmed at a later stage. The site selection stage involves public acceptance and is a socio-political and technical process. The uncertainties related to the site characteristics can affect the robustness of the siting decisions.

3.1.1.4 Uncertainties addressed at Phase 2: Site characterization

REs responses

The responses of the REs address the following key uncertainties: the time and budget allocated to site characterization, the ability to collect information in sufficient extent and quality, allowing for a similar level of data extent and quality for comparing different sites to limit possible “surprises“.

Another important uncertainty mentioned by some REs is that certain aspects of the environment, affecting safety, could be omitted in site characterization, e.g. underground watercourses, changes in terrain formation over time, etc.

TSOs responses

At this phase, key uncertainties are those relevant to the application for licensing the construction of the disposal facility. Thus, those uncertainties associated with the facility construction, operation (including reversibility when relevant) and closure are given an increasing role, in addition to those associated with the site and the components of the disposal system (their characteristics and their potential perturbations - FEPs). Any safety-relevant residual uncertainty should be known to a relatively good level (information in sufficient extent and quality) to be accounted for explicitly in the safety case, even if some of them are expected to decrease during construction phase.

Uncertainties associated with the following aspects are also identified:

- spatial heterogeneities in the site, including for example heterogeneities in chemical, hydrogeological and mechanical parameters;

- costs of R&D investigations and availability of R&D funds;

- the ability to collect information in sufficient extent and quality;

- the FEP list to be considered;

- the identification of waste acceptance criteria and the waste inventory;

- changes in the regulatory framework.

WMOs responses

At this phase, the uncertainties related to the geological barrier, identified in the previous phase, should be progressively reduced as more information become available, confirming that the site meets the requirements. However, as mentioned by one respondent, the representativeness of some local characterisation can be questioned in some cases. Ongoing research is still needed in order to assess the uncertainties related to FEPs that might affect the engineered part of the system; the design depending on specific factors like geochemical conditions, hydrogeology, etc. However, results generated through research and exploration can raise new uncertainties. At this stage, all the collected data can provide an input for detailing the design of the facility.

3.1.1.5 Uncertainties addressed at Phase 3: Facility construction

REs responses

Uncertainties arise in some countries from the fact that facility construction continues to occur in parallel to site operation.

Advanced engineering technology will /shall be used for not perturbing long term safety by repository construction. In this context QA/QC issues are important, allowing for compliance with construction design and standards and ensuring that irregularities and non-avoidable disturbances are properly managed. For example, host rock disturbances due to the repository construction will occur in all geological formations. In granite this is the impact on the existing fractures; in clay the creation of an excavation disturbed zone and the changes in the pore water chemistry. Micro-organisms may become an important source of disturbance, especially those brought in with the construction equipment, which are not site-specific, and in particular considering the often hydrogen filled void spaces created.

Uncertainties relate as well to costing (contingencies), to correct settlement of tenders for environmental research and in particular to construction works, correct selection of technology, investment and quality assurance by implementers. Timely execution of design and construction works shall not compromise quality of facility construction. Facility construction may take tens of years. Construction workers need to be educated to follow closely the instructions. Only a minimum of staff of subcontractors shall be used. Workers need to get well trained with frequent repetitions to assure that this first-of-a-kind construction meets quality assurance criteria. Experienced experts and advisors, as well as contractors and the chain of supervisors of tasks can be the guarantors of safe operation of the repository and a minimum impact on long term safety.

TSOs responses

At this stage, key uncertainties are those relevant to the application for licensing the operation of the disposal facility and of the potential surface facilities.

New knowledge will become available as key uncertainties should be reduced by the activities of excavation and construction of the underground works (including the fabrication and emplacement of some engineered components) and of demonstration tests, as well as monitoring and inspections during these activities. As a result, the facility will likely be constructed differently as originally planned.

In particular, uncertainties related to the following topics are identified by TSOs:

- impact of excavation methods and chosen ground support on the host rock and engineered components;
- impact of possible deviations from the design specifications ("as-built" facility) resulting from inproper quality of the construction (e.g. quality of engineered barriers, possible impact of construction activities on site characteristics);
- impact of design changes considering increasing knowledge of the site (e.g. unexpected features of the rock formation), waste, construction and emplacement techniques or new regulations;
- control of operational hazards; management of accidental and post-accidental situations;
- ageing of waste packages and disposal cells as well as their monitoring;
- determination of operating limits and conditions for the facility;
- performance of closure works.

WMOs responses

Even if some uncertainties previously identified (geological barrier) should be strongly reduced at this stage, some others can have a strong influence on the repository layout such as provisions regarding reversibility and retrievability. Moreover, the balance between operational safety and long-term safety has to be found and has an impact on the number of shafts, the doubling of access galleries, the ventilation system, etc. The safety case is translated from what it is planned to what is built. Construction plans are updated/confirmed and their related uncertainties are reduced. There are uncertainties related to the technological readiness of the required equipment and the engineered barriers. The correct functioning of methods and tools is challenged and the question of the correction of potential deviations arises. Uncertainties related to the focus and the sustainability of the monitoring programme start to emerge. Finally, the construction making the disposal more concrete, also leads to (new) socio-economic uncertainties. Changes in the political framework are still possible and can lead to required amendments in this stage of the programme.

3.1.1.6 Uncertainties addressed at Phase 4: Facility operation and closure

REs responses

The multigenerational character of this phase is not always taken into account as source of uncertainty. Considering that repository closure has to be assured by decisions of the next 2-5 generations, which were not involved in repository conceptualization and construction, it is not sure that future decisions will really be taken in the way we are conceptualizing today, and we cannot be sure that the repository will be closed in due time. The consequences of such a scenario of poor closure or non-closure or even repository abandonment on repository performance and radiological long term risks have not been always assessed.

The state of the art best practice in nuclear facilities necessary needs to be implemented, ensuring incorporation of QM principles in routine operations, recording performed activities, mapping waste emplacement and assure the true application of waste acceptance measures. In this respect one needs to learn from the accident in the WIPP facility, caused by the non-respect of a large national laboratory of WIPPs waste acceptance criteria. Research work needs to be done for developing better non-destructive monitoring techniques of delivered waste inventories.

Uncertainties arise as well from possible damages to system components due to the operator errors (incorrect operation during waste packages emplacement), from fire, inadequate shielding of waste and contamination; from inadequate backfilling and sealing. Considering the long time periods for repository operation of many tens of years, the probability of such operator errors is expected to be close to 100%.

Another uncertainty in this phase is the lack of quick response to any irregularities in the operation of the repository. Also release of radionuclides into the environment may occur as it was observed in the WIPP accident in the USA. Considering the multigenerational character of repository operation, uncertainties are linked to the lack of reaction to scientific and technical innovations, which will definitively occur over the time of facility operation. Modernized IT systems will make some of the early equipment's outdated. No response to any abnormalities, careless monitoring need to be avoided.

Even if societal acceptance has made repository construction possible, it is not sure that this acceptance is granted forever. Disregarding cooperation with the local community can cause loss of confidence, in particular in case of accidents associated with radionuclide release. Continuous monitoring of the repository's surroundings, well trained working staff and constant supervision by the regulator will guarantee safety. Constant honest dialogue and cooperation with the community at the repository's location is necessary. Such dialogue shall show that a maximum of effort is taken to avoid any accident, but the message shall as well be given that some accidents will occur over such long time and that measures are taken to limit to a maximum the impact to the local population and the workers.

TSOs responses

At this stage, key uncertainties are those relevant for ensuring safe construction and operation as well as for licensing the closure of the disposal facility, considering the rather long duration of construction, operation and closure, during which new knowledge and regulations may become available. This could lead to changes in the waste inventory, design and operation.

Hence, key uncertainties are those associated with possible deviations from or changes in:

- the design and operation that may result from new knowledge gained through experience feedback, accidental situations, monitoring and inspection programmes or from improper quality management;
- closure works (for example changes in plugs following tests carried out during operation, or changes in the whole design resulting from societal/economical decisions…);
- waste characteristics (deviations w.r.t. foreseen waste acceptance measures);
- the behaviour of the disposal system owing to the relatively long period during which the excavations will remain open and possible consequences on long-term performance;
- site-related hazards to be considered.

WMOs responses

At this stage, most of the respondents agree on the predominant role of the monitoring. Uncertainties regarding monitoring may be of different kinds: its funding, its role in the decisional process w.r.t the disposal phases (operation and closure) as well as reversibility and retrievability, the general functioning of the equipment, etc. Uncertainties regarding seals, plugs and backfill procedures should be reduced.

The interface between conventional safety and nuclear safety is of particular interest at this stage. Insufficient resources during this period is also a matter of concern. Changes in the safety case would be expected to confirm the initial choices and performances. The inventory should be firmly known even if another respondent mentions remaining uncertainties regarding the waste characteristics in general. It might be understood from the latter that the radiological inventory is known even if some general characteristics (e.g. chemical behaviour, behaviour of related non-radioactive substances) may contain (to some extent) some residual uncertainties.

3.1.1.7 Uncertainties addressed at Phase 5: Post closure

REs responses

Generally shared positions of REs on uncertainties in the post closure phase are the memory loss, the maintenance during institutional control (if it occurs beyond closure), human intrusion, and geodynamic processes. Well characterized system reduce post closure uncertainty. Monitoring during operation should confirm assumptions, but it would be important if properly designed and managed monitoring system (specifically for understanding hydrogeochemical evolution of the underground geological structure) are installed which remain operative after repository closure.

Uncertainties concern changes of the environment in the far future (both natural causes and human activities).

TSOs responses

After closure, some uncertainties will remain. This concerns in particular those associated with human actions as well as phenomenological uncertainties (transient processes, natural events and future evolution of these processes, climate changes), which must have been characterised, taken into account in the design and covered by post-closure scenarios (documented in the safety case associated with the application for licensing the closure of the disposal facility).

Uncertainties that may still have to be addressed after closure are those on the effective duration of institutional control, the time when the knowledge about the repository will be lost and monitoring results.

WMOs responses

The safety case should be updated thanks to monitoring outcomes (if any) that should reduce the residual uncertainties. The system becomes fully passive and raises the question of the maintenance of monitoring activities (with potential lack of resources) as well as the transfer of knowledge. The implementation of the institutional control phase is a matter of concern. The compliance of the as-built properties of the closed repository can also be a key issue raising uncertainties. The issue of human and non-human intrusion is at stake and more generally, the question of the evolution of human society. Some security issues may arise after the institutional control (e.g. the proliferation of plutonium).

3.1.2 Some uncertainties will decrease as new information becomes available (e.g. “as-built” properties, monitoring data, RD&D results,…) whereas activities associated with the programme (process modelling, safety assessment,…) can also lead to new viewpoints and sometimes new uncertainties.

3.1.2.1 How do you think the different types of uncertainties that you have identified in your answer to the previous question could evolve throughout the different programme phases?

REs responses

It is expected that contextual uncertainties will probably not decrease over time. In general, while the number of uncertainties may tend to increase, their relative significance for the Safety Case will decrease (as more detailed information will improve the quality of inputs for modelling and decision making). Well characterized systems and process understanding should limit surprises or needs for additional research.

The direct reduction of all uncertainties is too costly or in certain cases impossible. Uncertainties and estimates (in a broad sense) are unavoidable, but uncertainties in these estimates need to be clearly quantified.

Important uncertainties are decreasing as the programme implementation progresses, in particular those related to the knowledge on disposal system configuration, the impact of the dry extended storage on the integrity of the spent fuel packages, as well as those related to the waste inventory. The parameter uncertainties are also decreasing as more investigation on the system are performed and the new techniques are developed and implemented.

On the other hand, the uncertainties related to the climate change will remain on the same magnitude but it is important to address these in "what if" type scenarios.

Considering innovation in technology, especially at the stage of repository operation and in the post-closure phase, it can significantly affect safety, but also here, uncertainties will decrease as new information becomes available.

An individual position, not necessarily shared by other REs, was that stated to be not entirely convinced that additional research will always reduce remaining uncertainties: Already in 1982 people were convinced that a repository can be built with few additional research works. New research shows as well additional dependencies, which were not considered previously and which in consequence were not included in the uncertainty analyses. At the same time as the scientific understanding rises, so does the complexity of the problem. Increased knowledge does not always reduce uncertainties and it is not clear how to judge the adequacy of knowledge in a system, which complexity rises with the time of analyses.

TSOs responses

Uncertainties associated with the programme and other prevailing circumstances are expected to evolve over the lifetime of a disposal programme. The ‘when, where and what’ uncertainties will reduce. However, for several of them associated with social, economic and political factors, it is very difficult to foresee how they might evolve due to the relatively long duration of a disposal programme.

Uncertainties associated with the initial state and evolution of the disposal system are expected to decrease as the programme progresses (in particular several uncertainties associated with site characteristics, waste inventory and the behaviour of engineered barriers). However, some uncertainties will always remain and new sources of uncertainties (perhaps more practical) could be found in the course of programme implementation.

Uncertainties with the completeness of the FEPs considered in the safety assessment need to be minimized from the very beginning of the programme. However, as it cannot be excluded that new potentially relevant characteristics, processes, events and contingencies linked to construction might arise in the course of programme implementation (e.g. processes associated with interactions between disposal components), measures need to be taken to deal with such situations.

Uncertainties associated with the quality of the safety assessment (SA), including those related to the tools and methods used in the SA, need to be minimized during the whole duration of the programme.

These possible evolutions of uncertainties call for an uncertainty management approach that needs to be implemented throughout the different phases of the disposal programme.

WMOs responses

Although some uncertainties may always arise and others can be considered as irreducible (political decisions, veto right of locals, intrinsic variability of the host rock,…), the overall uncertainty is expected to decrease over time, except for rare events, which likelihood is difficult to assess. In particular, the design concept, the performance of the natural barriers (depending on the site characterisation) and the engineered barriers become progressively better known. Uncertainties regarding the construction and its funding should also decrease over time as well as those related to closure measures when in situ testing is performed. The attention is drawn by a respondent on the fact that even after 30 years of experience in a disposal facility, some uncertainties regarding the radionuclides and the nuclear material may remain.

3.1.2.2 Do you identify measures that can be taken to deal with these possible evolutions? If yes, please explain briefly what these measures are.

REs responses

REs suggested that the uncertainties could be minimized by systematically implementing QMS principles (allocating responsibilities, defining processes, documentation, and control/supervision) and -assessing the uncertainty at each stage and adequately addressing them in the safety case. However, secured long term funding, long term political consensus and knowledge management remain an important issue. One needs for the overall project duration a qualified staff tracking all news and available literature on the subject. International industry and science cooperation needs to continue over time. Adequate financing needs to be provided to enable rapid implementation of new control and measurement systems as well as new characterization techniques. After all, retrievability of the waste remains important.

A specific position is given by one respondent: “Strategies to overcome such problems are very diverse. They stretch from a “Do nothing” option (ignore the respective process as it may hopefully not be essential and the harm of ignoring may be smaller than using some estimates not really defensible) over the famous “Expert guess” which can be anything between pure assumptions and the application of well-established informal rules, further on to “Estimates” stemming from pure correlations in the sense of empirical fits, over chemical analogues, the usage of structure-based incremental systems, linear free energy relationships, or quantum chemical approximations (to name just the most prominent examples), to the “Re-computation” of parameters from other (hopefully similar) models (e.g. going from the Pitzer-approach to SIT parameters and vice versa – this direction being the more challenging one), the “Re-fitting” of a pool of already existing raw data and – finally – the hard way of setting up an experimental programme to derive the parameters in the lab.”

TSOs responses

Different types of measures are identified by TSOs to deal with the evolution of uncertainties and the possible occurrence of new uncertainties. The measures that can be adopted depend on the type of uncertainty being considered.

The measure consists in the implementation of a stepwise and flexible decision-making process, where the validity of assumptions made at one phase is verified during subsequent phases through RD&D, characterisation, monitoring and inspection activities.

Another measure consists in the implementation of an experience feedback programme based on construction and operational feedback as well as international experience.

The systematic implementation of quality management system principles (allocating responsibilities, defining processes, documentation and control/supervision) should allow minimising several types of uncertainties. This includes the verification and validation of computer models.

The implementation of the defence in depth principle is also seen as an important way to deal with possible new uncertainties. This may include:

- measures to prevent deviations from normal operation and the failure of items important to safety. This can be done by using safety margins and reducing or avoiding as far as reasonably achievable sources of uncertainty having the potential to jeopardize safety (e.g. by modifying the location or design of the disposal facility, preserving the knowledge about the repository). Control measures and procedures are also needed to prevent defects and damages to the disposal;

- measures to maintain as much as reasonably achievable (by host rock/site selection, design and the use of safety margins) the performance of system components when they are subjected to disturbances;
- the implementation of a multi-barrier system approach providing the disposal system with independent and complementary safety functions and components so as to maintain a sufficient level of safety following the occurrence of an uncertain disturbing event or process;
- detecting deviations from normal operation, defects or damage to the disposal system so as to take corrective measures where needed;
- preventing the progress of, and mitigating the consequences of, accidents that would result from failure of previous measures;

Finally, risks linked to uncertainties associated with prevailing circumstances could also be managed. The goal is to identify measures to reduce and mitigate these risks during the different programme phases. For instance, uncertainties on the waste to be disposed of can be handled to some extent through a careful and methodical analysis of the operations performed by waste producers.

WMOs responses

R&D programmes can be carried out in order to close open knowledge gaps. In terms of the quantitative part of the safety case, the evolution of some specific uncertainties should be managed mathematically in the light of new information. For qualitative uncertainties, a register of their evolution from one iteration of the safety case to the other can be maintained and updated. In parallel, opposite exercise can be performed, trying to find the most generic properties a system may have in order to capture the invariants that will be encountered in each case such as general design principles. A stepwise approach with appropriate level of detail at each decision point is recommended in order to keep options open (flexible approach) and to accommodate the not-yet defined uncertainties or their unexpected evolution. Regarding the societal uncertainties, the WMO can be at the origin of some initiatives to influence the decisional process. To have a network of citizen experts with whom it is possible to develop a steady dialogue might provide an added value in terms of communication. Each time a safety assessment is performed, an assessment of the uncertainties should be carried out as well.

3.1.3 If you/your organization is questioning the current safety demonstration of a radioactive waste disposal concept or facility, please answer to the following questions:

3.1.3.1 What are the key uncertainties underlying your interrogations and which uncertainties do you think would need to be further addressed or managed (analysed, avoided, reduced,…) to improve the safety case?

REs responses

While there is generally confidence in current safety demonstration, a more detailed judgement is impossible as without a global sensitivity analysis this would just be a guess. Host rock and barrier material investigation/characterisation and interpretation of gained results will be provided by WMO (& its subcontractors) while TSO access to the metadata will be limited and, thus, ability to independently interpret the gained outputs will remain limited as well. This concerns as well

- nonlinear processes which are covered by WMOs by "conservative" estimates;
- coupled description of near field evolution and radionuclide transport - which are separately dealt with in nearly all programmes;
- multiphase flow and transport, which defines long term safety (waste isolation).

A specific remark for surface disposal was given by one RE: "No, we don't question the safety demonstration for conform waste, but see an enormous challenge for reconciliation of existing non-conform waste with acceptance in disposal facility".

TSOs responses

The TSOs address mostly technical uncertainties here, including the engineered safety barriers, monitoring strategy in the operational phase, possible disturbing events in the operational phase, layout of the disposal facility and inventory of waste and site characteristics. Some non-technological uncertainties have been mentioned, including assessment context, political, societal and governance uncertainties.

WMOs responses

Generally speaking, WMOs identified the following categories of uncertainties:

- Uncertainties in the Natural Barrier System;
- Uncertainties in the Engineered Barrier System;
- Uncertainties in the Surrounding rock formations.

More particularly, respondents pointed out:

- Container lifetime determination;
- Corrosion of the Engineered Barrier System under specific (aggressive) conditions;
- Gas production and removal from repository;
- Radionuclide and material inventory;
- Radionuclide behaviour in geosphere and biosphere.

One respondent proposes to reformulate the question in the following way: what would be necessary to make the safety demonstration more convincing? What does demonstration really mean?

3.1.3.2 What would be necessary to improve the robustness of the safety case w.r.t. these uncertainties?

REs responses

One still needs better process understanding and related data availability. After estimating these uncertainties, one should start a sensitivity analyses to check if they are critical at all. If so, they could be refined using a tiered approach including tailored conformity criteria and safety analysis.

A better organization in the design phase is also important to improve the robustness of the safety case, including, beyond WMO-TSO-Regulator exchange, also better cooperation/interaction among stakeholders involved, better information flow, and constant cooperation with communities.

A reasonable extent of parallel investigations shall be conducted independently from WMO to confirm the isolation capabilities of the disposal system in near field and far field by substitutable safety functions of engineered and/or geological barriers.

TSOs responses

The mentioned ways to improve the robustness of the safety case include in-situ demonstration, site investigation, long-term oversight, management of uncertainties while adopting conservative approaches, independent technical review(s), updates of national strategies, development of a thorough monitoring programme and optimisation of the layout of the facility. Focussed R&D and detailed studies on the waste to be disposed of as well as on incidental and accidental scenarios during the operational phase were also identified.

WMOs responses

Only a few answers to this questionare provided by WMOs. The following suggestions were made in order to improve the robustness of the safety case:

- Conceptual perspective for long term safety and scenario analysis;
- Sensitivity analyses should be performed if detailed knowledge is lacking;
- R&D roadmaps to clearly show how these uncertainties will be addressed in the future of the programme;

- Generic approach should be carried out to demonstrate safety with a minimum of knowledge in order to be applied to more specific cases afterwards
- Description of the uncertainties in a measurable way in order to allow stakeholders to understand what we do not know and why some of these unknowns can be nevertheless assessed as not relevant for safety;
- Showing that the technologies used are already safe and approved, while being still adaptable to new development may enhance public confidence.

3.1.4 Safety assessments of geological disposal concepts and associated uncertainty management by WMO have shown consistently in several countries that the disposal would provide safety for hundreds of thousands of years and that no release is usually expected for the first thousands of years. Still many people have fear from radioactive waste disposal.

REs responses

While in most cases largely complementary and coherent views are presented by REs when responding the other questions, large discrepancies were identified in responses to these last ones.

TSOs responses

A large diversity in answers is also noted for TSOs in this part. Therefore, the answers are simply cited in the following section.

WMOs responses

A great diversity in the answers of WMOs is observed, too. However, all of them complement each other. An inclusive consolidation is tempted in the following section.

3.1.4.1 What do you think are the reasons for this situation?

REs responses

Some REs consider that the results of safety assessments are not largely known or shared by a wider community beyond WMO and TSO. Assessments for 100,000 years are considered by many as not credible because they are understood as quantitative predictions, which are impossible. They recall that there is a lack of confidence in the scenarios and models capability to predict the system evolution on such a very long term. The strong weight given by WMO and TSO in their communication to the 100,000-year time frame as opposed to the safety for the next thousands of years enforces this interpretation. Instead it is proposed to focus more on the first thousands to ten-thousands year time scale, even though almost all analyses have shown that during this period, the radiological risk beyond human intrusion is close to zero. One shall make clear that these are not a prediction but a consequence analysis for the expected evolution scenario, considering known processes, assessment of barrier performance and the state of site investigation. One shall not argue for a time cut-off in safety assessment but shall acknowledge that for a communication with stakeholders the thousand to ten-thousand year time scale is closer to the capacity of the imagination and this is the same for our co-citizens.

It is recalled that since people are thinking in intervals of tens of years, thousands of years is mostly beyond their horizon of understanding, considering as well that their experience with chemical pollution is negative. They can thus hardly be persuaded that radioactive waste management would be different.

Other REs stresses that the key point for lack of confidence is the bad information for example by media coverage and bad cooperation with the media. Missing or wrong communication strategy in the past and insufficient communication skills and strategy of WMOs are addressed, considering the knowledge presentation in a language or a style, which is often not understandable by the public. There are also errors in the politics (e.g. hiding of problems or of information in general, a lack of transparency of activities, pressure on opponents, financing the research may create bias, ...). One respondent recalls that all this is a very complex issue of low social trust, where social science is now very active.

A number of REs address as well the bad level of education already from primary school level. Physics education is weak for many people. In many such cases technical/scientific explanations are not the best strategy to approach civil society. It is mentioned that some people still believe that the Earth is flat. Even more people do not believe in the theory of evolution.

TSOs responses

The main concerns are typically related to disruptive alternative evolution scenarios. Not all scenarios might be taken into account.

In addition to these remaining uncertainties, several other explanations were provided c:

- Reliable research data to prove the technical option might not be available.
- Lack of open, transparent and inclusive governance.
- Radiation / nuclear industry have a terrible reputation. Many countries have botched the stakeholder communication. However, Finland has been successful in this.
- The first reason is rather societal and political: we can observe a general lack of confidence in institutions, although the members of such institutions may be perceived as good « experts » or « scientists ». Such public perceptions may not be limited only to the nuclear, but also to other high-tech fields. Notably, the fact that safety demonstration relies on numerical simulation is not well perceived.
- The current status of existing geological disposal facilities in operation throughout the world is not helping the confidence in safety. Several accidents and incidents that may have serious impacts on the environment have occurred. WIPP (USA), Asse (Germany) and StocaMine (conventional waste in France) accidents can be mentioned.
- Surprisingly inconsistently with this lack of confidence with “science”, the rapid development of technologies (laser, drones and robotics, electronic equipment computer sciences…) in the few last decades makes it look paradoxical to rely on a system for thousands of years whereas another solution, maybe more effective, might be developed in a few years. People are thinking in intervals of tens of years, thousands of years is mostly beyond their horizon of understanding; their experience with chemical pollution is negative, thus, they can hardly be persuaded that RWM would be different.
- Lack of information about disposal.
- Lack of knowledge needed to understand the explanations.
- Lack of confidence in state authorities and institutions, as well as in waste management operators (but at the same time much better confidence in universities, research centres and science).
- Lack of interactions between state authorities, WMO and civil society.

WMOs responses

Many people have fear of radioactive waste disposal because they are asked to believe in the safety of a system over such long timescales, far beyond the human time. People also understand that geological time is commensurate with the time of radioactive decay but at the same time, keep on thinking that we rely on geology because we do not have something better to propose. A geological repository is very often perceived as a hole in the ground, no more than that.

Scientists explain to people that even if there are still some uncertainties, they are bounded, ruled out by design or addressed by conservatism. These concepts are not straightforward. Besides, when the concept of “environment protection” comes into play, it can be difficult to associate the very abstract 'reference biospheres' to the complexity of life and environmental processes - this may create some scepticism. People do not accept any release at all from a final repository.

Another issue also lies in the misinterpretation of the notion of “uncertainty” as 'no knowledge' when it is really 'incomplete knowledge'. It is also difficult to communicate that there is no need to know everything precisely in order to make a safety case. For lay people, it is difficult to understand that scientists can bound their “ignorance” in a safe way and especially on the ultra-long-term. Moreover, people give sometimes undue weight to some uncertainties because they relate to scenarios with added fear factor (risk perception), whereas most of the uncertainties can be shown not to be significant.

As experts, WMOs also try to explain to the civil society that the expert knowledge is not a prediction but an envelope of possible evolutions, even though for most of people it is understood as a prediction by WMO. People understand however that all the answers regarding the future cannot be provided by the models or analogues but this is precisely what can create some fear. There is always a difficulty to convincingly communicate in understandable fashion: in the public’s mind, all the questions and concerns have more or less the same timeframe; besides to understand probabilities is challenging. More generally, there is lack of transparency and traceability in the overall process (even though people often agree understanding details need expertise, the big picture of what has been done and on which grounds is seldom made clear to all audiences).

People cannot smell or see radioactivity and that makes scary. In addition, most nuclear facilities are very secretive which reduce the trust of people. Why so secretive when it is not dangerous? This is the problem. The concept of passive safety does not help the understanding because radioactive waste will not be "visible" anymore. Human beings would like to believe in a possibility of control, a possibility to see what can be wrong (surveillance) and to be able to react. However, fear might be less related to radioactive waste disposal than to radioactivity in general (e.g., linking it to war, nuclear accidents, etc.). It should be noticed that opponents play with this fear in order to undermine long-term safety creating some confusion with the operational short-term issues (e.g. risk of explosion). This emotional driver is also often used by media, which negatively present radioactive waste disposal.

Furthermore, people have lost trust in science and experts and perhaps especially the ones that work for a WMO (not seen as independent). More generally, the involved organizations do not always benefit from a large credibility. There have already been large failures in both nuclear and conventional facilities that required retrieval of waste, which do not help to build confidence.

3.1.4.2 If this is a result of a lack of credibility of the safety assessment or of overlooked uncertainties, which uncertainties according to you are driving their reluctance?

REs responses

Some REs do not think that this is a result of credibility of safety assessments. REs often do not understand in which way their data fit the overall picture of assuring safety. Since only rarely they have an overall understanding of the barrier system and of expected boundary conditions, there is the tendency of over-interpreting the importance of the processes, which one knows best. A better integration of REs in the development of the safety strategy of WMO and TSO is necessary to increase shared understanding.

While some REs believe that this is a result of uncertainties related to the evolution of the relevant processes considered in the safety assessment, others put more emphasis on the fact that any fear (= emotion) cannot be suppressed by technical evidence. One RE concluded that we must find 'emotional' interpretation of our investigations to persuade them. In line with this is the question about confidence and trust in general. Very often “conservative estimates” are given, which are then not conservative when looking at coupled processes, like for example very low permeability of barriers, which is good for radionuclide isolation but not for gas pressure build-up, which can generate new migration paths, fully saturated initial conditions, but less head transfer for unsaturated conditions, etc. One RE responded that the problem is due to the lack of cooperation with society from the initial phase as well as the lack of transparency of decisions taken.

TSOs responses

The following answers have been provided by TSOs:

- General audience could not tell the difference between a good and a bad safety case. This may be rather a communication issue.
- Disruptive alternative evolution scenarios may be hypothetical, speculative and/or real dangers. For non-involved parties it is difficult to distinguish between these.
- Good research, scaling up to built solutions, proper modelling, involvement of stakeholders and transparency.
- The concept of safety case and associated safety assessment is a very difficult approach for civil society. Tackling the question of uncertainties through those associated to the models or scenarios, as it is classically defined in the main international guidance (IAEA SSG-23, NEA MeSA initiative…), may be too complex for them. A more concrete definition of uncertainties e.g. based on their nature and not on the way they are treated in the safety case (see §3.1.1.1) could be more appropriate (even if elaborating a list of FEPs is burdensome…).
- Behaviour of the disposal system during the operational phase and in the post-closure period.
- This is not a question of uncertainties, any fear (= emotion) cannot be suppressed by technical evidence, we must find 'emotional' interpretation of our investigations to persuade them...

WMOs responses

The long timescales are identified as the major issue. However, the perception of such an issue can vary from one WMO to another. Timescale can be a general issue regarding credibility and therefore, public acceptance. Timescale can also be seen as the risk regarding the lack of stable policies or national waste programmes and may affect the plausibility of such a long process.

The release of radionuclides is an issue to the general credibility irrespective of the timeframe at stake. The migration of radionuclides itself is perceived as a contamination even if spread in time and space.

The lack of acknowledging the differences between technical and safety criteria and the social acceptance criteria is a fundamental problem.

Other issues were identified as well such as:

- Lack of strategies to manage uncertainties;
- Completeness of FEPs;
- Previous failures being explained by a less adverse attitude to risk;
- The communication regarding the safety assessment and its associated uncertainties. It should be performed in a consistent way and presented honestly which means, for instance, to stop pretending that all uncertainties will be reduced over time, some will remain forever and it has to be accepted.

3.2 Visions from the 1st UMAN Seminar of subtask 5.1

The first UMAN Seminar of Task 5 addressed the vision on uncertainties of the different categories of actors, building as well on the answers to the 1st UMAN questionnaire addressed to WMO, TSO and RE presented above. Here only the high level uncertainties relevant to the safety case are addressed:

According to WMOs, TSOs and REs, epistemic uncertainties and their consequences are major ones which will steer R&D programmes. Further, they claim that it is not worth to address non-reducible uncertainties like political ones in the safety case. Particularly important are uncertainties related to geology and site. All actors distinguished between uncertainty and risk. There is no idea of reducing all uncertainties but to manage them. The uncertainty management process is driven by sensitivity to safety assessment.

While there is the general view that uncertainties decrease with time, this is in praxis not always the case, as for example with new knowledge on microbial effects one may actually realise that the uncertainty is higher than initially thought without taking the effects of microorganism into account. High-level uncertainties can be categorized in terms of known and unknown unknowns (and even unknown knowns). Only the 1st category can be addressed with statistical approaches and bounding cases, but the others need to be addressed as well.

The increasing complexity of the understanding of the disposal system is associated to new uncertainties, difficult to be captured by the experts. Visualisation of subsystems information enables tracing arguments addressing holistic needs for the safety case, including uncertainty management and avoiding specialization. Different categories of actors should participate in safety case development.

Evolution of programme optimisation and uncertainty management should be organised in an iterative process, with experience feedback program, keeping options open to react on new uncertainties. Regular dialogue between the different stakeholders is needed, including CS, both on the uncertainty evolution, on the understanding of this evolution and the implications for safety, and on how to deal with the remaining and "new" uncertainties. There are also uncertainties on knowledge management and transmission of data over generation, as a part of societal uncertainties.

While there is only little difference in the appreciation of different key uncertainties and their completeness (FEP…) among different categories of actors, actors may have different views about the significance of an uncertainty for the safety case and on its management. There are not sufficient discussions among the actors on possible management strategies, also in the light of increasing mutual confidence. Transparency between all the actors about uncertainty management is very important to mitigate these differences.

4. CONCLUSIONS

This deliverable aimed to assess the views of different categories of actors on relevant safety uncertainties associated with radioactive waste disposal and was based on the 1st UMAN questionnaire addressed to UMAN and ROUTES participants.

The three categories of actors involved in this study were WMOs, TSOs and REs.

This analysis compiles 28 responses received from 11 WMOs, 8 TSOs and 9 REs.

The questionnaire was focused on:

- Key safety-relevant uncertainties specific to each stage of program implementation
- Evolution of safety-related uncertainties throughout the program
- Actors' confidence in current safety demonstration concepts and reasons for people's reluctance to safety assessment

Responses showed a wide diversity of views on safety-significant uncertainties that complement each other, both at actor category level and between categories. The actors' differences of opinion could be related to the progress achieved in programme implementation, type of disposal and host rock, and the actor’s role in the RWM,

This survey enabled the outline of a high-level integrated picture of the significant uncertainties for safety and their classification into five major groups:

- Programme uncertainties
- Uncertainties related to the initial characteristics of the waste, site, host rock and engineered components
- Uncertainties related to the evolution of the disposal system
- Uncertainties related to models, data and tools
- Uncertainties associated with the FEPs completeness

Almost all actors believe that uncertainty decreases as the program progresses through knowledge and experience accumulation as a result of research and development, site characterization, implementation of monitoring programs and technological progress, well acknowledging that new knowledge might reveal that uncertainties are larger than initially thought.

Consistent and complementary views were also observed when interpreting the discrepancy between the rather promising results of quantitative safety analyses and the prevailing sense of uncertainty in the general public.

Management options on key uncertainties discussed include assuring availability of qualified staff conscious on actual understanding of scientific and technical issues, set up of research programmes, registers of safety case uncertainties, dialogue with citizen experts, feedback from international experience, quality management and defence in depth systems as well as stepwise and flexible decision making.

References

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