Managing Uncertainties Associated with Radioactive Waste Disposal: Task Group 4 of the IAEA PRISM Project - 11190

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ABSTRACT

It is widely recognised that the results of safety assessment calculations provide an important contribution to the safety arguments for a disposal facility, but cannot in themselves adequately demonstrate the safety of the disposal system. The safety assessment and a broader range of arguments and activities need to be considered holistically to allow demonstration of the safety of radioactive waste disposal at any particular site. Many programs are therefore moving towards the production of what has become known as a Safety Case, which includes all of the different activities that are conducted to demonstrate the safety of a disposal concept. Recognizing the growing interest in the concept of a Safety Case, the International Atomic Energy Agency (IAEA) is undertaking an intercomparison and harmonization project called PRISM (Practical Illustration and use of the Safety Case Concept in the Management of Near-surface Disposal). The PRISM project is organized into four Task Groups that address key aspects of the Safety Case concept:

- Task Group 1 - Understanding the Safety Case.
- Task Group 2 - Disposal facility design.
- Task Group 3 - Managing waste acceptance.
- Task Group 4 - Managing uncertainty.

This paper addresses the work of Task Group 4, which is investigating approaches for managing the uncertainties associated with near-surface disposal of radioactive waste and their consideration in the context of the Safety Case. Emphasis is placed on identifying a wide variety of approaches that can and have been used to manage different types of uncertainties, especially non-quantitative approaches. This paper includes discussions of the current results of work on the task on managing uncertainty, including: the different circumstances being considered, the

sources/types of uncertainties being addressed and some initial proposals for approaches that can be used to manage different types of uncertainties.

INTRODUCTION

Safety assessment for a near-surface radioactive waste disposal facility involves consideration of the performance of engineered and natural features over long times and assessment of exposures to humans far in the future. An important aspect of developing a Safety Case for waste disposal is how uncertainties associated with natural and engineered systems and unknowns associated with long time scales are managed. Modeling uncertainties arise for example as a result of measurement errors, the effects of spatial variability associated with natural or engineered materials, and uncertainties regarding conceptual models or future human behaviour. In the context of the Safety Case, non-quantitative uncertainties in regulatory and other stakeholder positions and public perception also need to be considered (e.g., potential changes in regulations or the legal framework, political changes, etc. that can affect implementation of a disposal facility).

There are many different approaches that have been used to classify and manage uncertainties in addition to the use of quantitative uncertainty analyses (e.g., directed research at laboratories or universities, monitoring, operational controls, stakeholder dialogue processes). The strategy adopted to manage these uncertainties will depend on the specific situation within a given country, regulatory requirements, the type of waste and disposal facility, as well as on the decision to be taken within the lifecycle of the disposal facility. The recognition of the "give-and-take" between realism and conservative-bias in assessments, and the importance of demonstrating sufficient understanding of the behaviour of the disposal system are fundamental considerations for the development of any strategy for managing uncertainty. It is also important to document assumptions and biases relevant to the Safety Case.

Uncertainties pose challenges to decision makers. How these uncertainties are managed and presented are critical aspects of the strategy for development of a Safety Case that will evolve as the design, operations, and closure processes move forward. There is a need to share experiences regarding different approaches that have been used and are available to manage the uncertainties in the context of decisions that must be made throughout the lifecycle of a disposal facility.

MANAGING UNCERTAINTIES

Managing uncertainties, whether it is uncertainties related to the operators, regulators or public, is closely linked to building confidence in the Safety Case and to assist the decision-making process. It is important to establish a strategy that provides sufficient confidence in the decision to be made recognizing the inherent uncertainties associated with long-term models. The probability of making an appropriate decision and the confidence in that decision can be significantly improved by investing the time and effort to effectively identify and manage the uncertainties. From the technical perspective, it has long been realized that what is important is not just the individual uncertainties, but the need to identify and manage uncertainties that can adversely affect the decision on regulatory compliance of the disposal system [e.g., 1, 2]. There are consequently differences in the objectives of a strict numerical uncertainty analysis as practised in many branches of science and engineering, and approaches that are used to manage uncertainties analysis in the assessment of near-surface radioactive waste disposal sites.

Uncertainty management for radioactive waste disposal typically involves a variety of different confidence building measures, which may or may not include formal uncertainty analyses.

Management of uncertainties can be viewed with four main components (after [3]):

- **Awareness:** Uncertainties cannot be managed if they are not known. A Safety Case and safety assessment need to identify all major potential sources of uncertainty.
- **Importance:** Some uncertainties have significant effects on the Safety Case, while many others are unimportant. Before attempting to reduce uncertainties it is first necessary to determine whether the uncertainty has a significant effect on the overall outcome and conclusions of the safety assessment. This can involve the use of scoping calculations and sensitivity analysis.
- **Reduction:** Having ascertained the importance of particular uncertainties, measures can then be undertaken to reduce them. This is the focus of the approaches to manage uncertainties discussed later in this paper.
- **Quantification**: The effect of uncertainties on the final safety assessment needs to be addressed as part of the documentation. Some uncertainties are more difficult to quantify than others, but it is helpful to have some quantitative consideration of key uncertainties (sensitivity and/or uncertainty analysis).

As with other aspects of the safety assessment approach, it is important to ensure that a level of effort is given to the management of uncertainties that is appropriate to the circumstances (i.e., graded approach). Furthermore, a strategy for uncertainty management should include consideration of building confidence for a variety of specific stakeholders, including technical reviewers, regulators, and the general public.

OBJECTIVES AND SCOPE

The PRISM project is focused on exchanging experience and communicating good practice for developing an effective basis for near-surface disposal of radioactive waste and the role of a Safety Case to support the decision for disposal. The expectation is that the participants will provide experience of facilities with a wide range of designs, waste characteristics and regulatory frameworks, and which are at different stages of development. The changing nature and use of the Safety Case over the lifecycle of a near-surface disposal facility is a key consideration. The project will consider the applicability of different approaches in these different circumstances.

A critical objective for the project is to gain insights that encompass the situation in a wide variety of circumstances in Member States. The context of the regulatory situation and disposal needs of developing countries and countries with specific disposal needs (e.g., Disused Sealed Radioactive Sources (DSRS) using borehole disposal, large volume waste) will be a major consideration and those views are an important aspect of the task.

The objective of the document being prepared for this task is to share and exchange information and communicate:

- Good practice on how to manage uncertainties as part of the strategy for development of the Safety Case, and.

- How the approach to managing uncertainties affects decision making over the lifecycle of a disposal facility.

To meet these objectives, the Uncertainty Management Task is investigating different strategies that have been used to manage uncertainty in the context of a Safety Case. These strategies can include a wide variety of targeted activities often prioritized using sensitivity and uncertainty analysis as part of a graded and iterative safety assessment approach.

A variety of sources are used to obtain existing information regarding management of uncertainty including:

- Previous IAEA activities that have addressed safety assessment concepts;
- Specific examples from activities within national programmes; and
- Other International and national research programmes.

The intent is for the information to stand alone on the subject of uncertainty management, but specific aspects can also be directly applied to information prepared for the other tasks in the PRISM project.

The task on managing uncertainties is one of four major tasks that comprise the PRISM project (see Fig. 1):

- Task 1 - Understanding the Safety Case.
- Task 2 - Disposal facility design.
- Task 3 - Managing waste acceptance.
- Task 4 - Managing uncertainty.

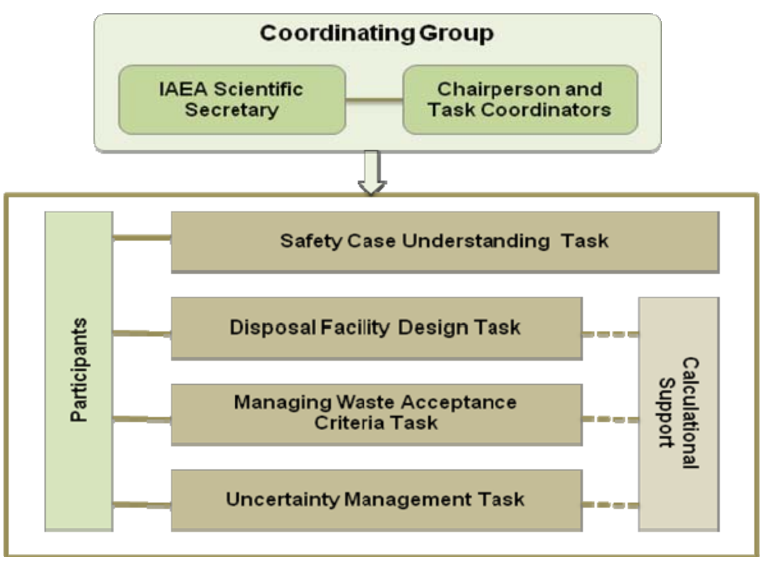

Fig. 1. PRISM working groups and project structure (Courtesy: IAEA).

Task 1 is a high-level task that will provide a broad context for the more detailed activities associated with Task 2 (Disposal Facility Design), Task 3 (Waste Acceptance), and Task 4. Tasks 2 through 4 provide examples and suggestions in more detail that can be used as input to support the higher-level discussions in Task 1. Task 4 will also provide information that is of interest for discussions in Tasks 2 and 3. The examples and input for Task 4 are developed in a format that is directly transferable to the structure of information being developed for Task 1.

As illustrated in Fig. 1, the project structure makes provision for a Calculation Support Function. It is expected that there may be a need for relatively simple calculations to illustrate the role of safety assessment as a tool to investigate specific aspects of the Safety Case. If such calculations are desired, they will be proposed by each task group with oversight from the Coordinating Group.

CIRCUMSTANCES CONSIDERED

The types of uncertainties and approaches to manage uncertainties can be different depending on the specific circumstances. In the context of implementation of the Safety Case concept for the PRISM project, it is important to recognize the variety of circumstances that need to be considered to provide a global view of situations in different countries and to place the discussions of different approaches for managing uncertainties in the context of those circumstances. To date, in the PRISM project, several categories of circumstances have been identified for consideration. These include:

- Stage in the lifecycle for a facility (see Fig. 2);
- Type of waste to be managed (operational low-level waste, sources, medical or institutional wastes, etc.);
- Types of facilities (engineered trenches, vaults, surface impoundments, etc.);
- Regulator or operator perspective;
- Level of maturity of the waste management program in a country; and
- Past practice or a new facility.

Experience has shown that the types of uncertainties to be managed and approaches that are used to manage uncertainties varies depending on the stage in the life-cycle of a facility and the general circumstances in a given country or program. In order for the results of PRISM to be the most useful for a broad spectrum of Member States, addressing each of these different perspectives and discussing differences is an important objective.

Participants in Task 4 represent a variety of different situations, including: developing countries without nuclear power, countries pursuing nuclear power programs and developing disposal facilities, and countries with well developed nuclear power and waste disposal programs; regulators and operators; and different disposal concepts. The diversity of the group has resulted in a variety of different examples representing the different perspectives.

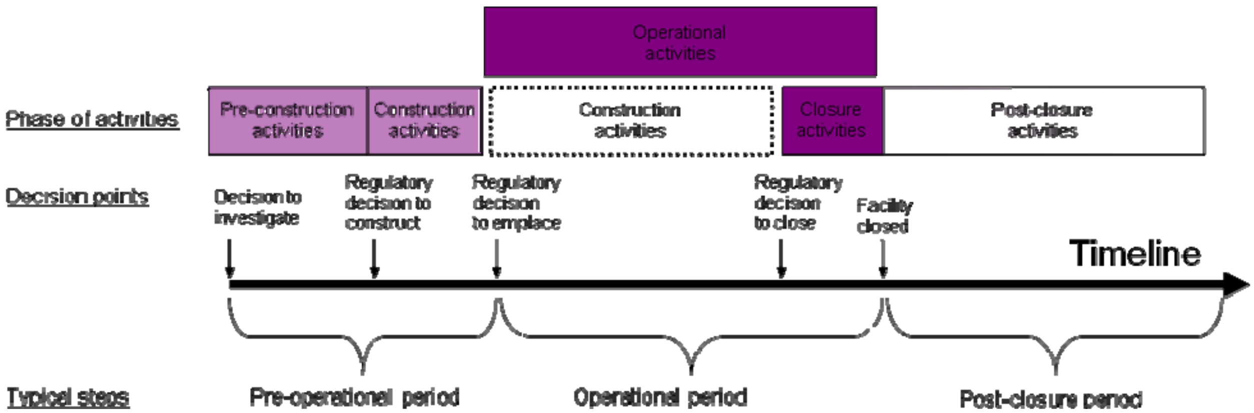

Fig. 2. Example of activities during lifecycle for a disposal facility (Courtesy: IAEA).

SOURCES OF UNCERTAINTY

For the purposes of the task, sources of uncertainty are categorized into the following four groups:

- Data and parameter uncertainty, in terms of inputs, spatial and temporal variability;
- Model uncertainty, in terms of conceptual and mathematical model development;
- Scenario uncertainty (future uncertainty), in terms of the near-field geosphere and biosphere; and
- External uncertainties.

Historically, especially in the context of a safety assessment, it is only the first three categories of uncertainty that are normally considered. For example, Fig. 3 illustrates a general structure for treatment of scenarios, their associated conceptual model uncertainties, and their parameter uncertainties.

In the broader context of a Safety Case, external uncertainties are an important consideration, and in the case of waste disposal, can often be a major factor in decision-making. External uncertainties relate to conditions and factors outside the assessment framework, but that might have an influence on the broader context of the Safety Case. Examples of this type of uncertainties include the following:

- Uncertainties related to the definition of regulations and standards and the variations and interpretation of these regulations and standards,
- Uncertainties related to financial and technical resources, managerial changes, stakeholder involvement and security,
- Uncertainties related to the scope of the nuclear program, and
- Uncertainties related to stakeholder involvement.

Subjective uncertainty is often added as a separate category of uncertainty. However, subjective uncertainty can be seen as inherent within each of the categories of uncertainty and arises from the need to rely on professional judgment and expert elicitation due to lack of data, lack of knowledge concerning future conditions, conceptual models and parameter values (and distributions), or any aspects of the system under study that are not currently well understood [4]. Thus, for this report, subjective uncertainty is addressed within the four categories identified in the above list.

APPROACHES TO MANAGE UNCERTAINTY

A variety of approaches for building confidence have been discussed that also provide the context to identify specific approaches to address uncertainties. Table I includes a list of potential confidence-building approaches in the first column and the tentative list of potential approaches to manage uncertainties developed for the task group in the right column. Listing the confidence-building approaches helped to emphasize the variety of potential non-quantitative (in the context of a safety assessment) approaches that are available to provide additional support to manage uncertainties. Note that many of the items in the lists would be conducted outside of the actual safety assessment calculations.

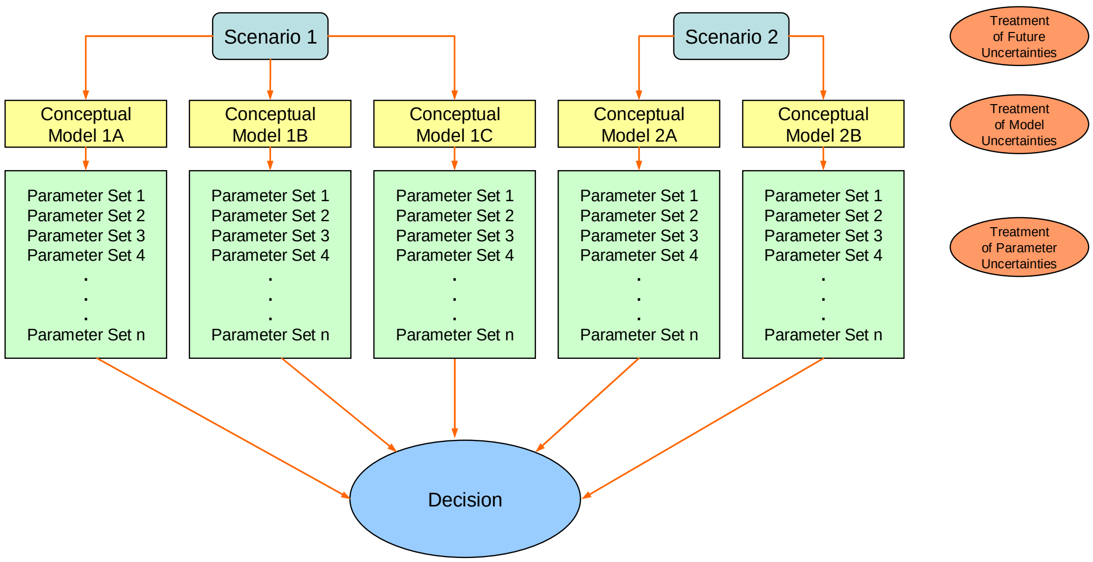

Fig. 3. Structure of the uncertainty analysis, showing the relationship of scenario (future), conceptual model, and parameter uncertainty (after [5]).

TABLE I. Confidence-Building Methods and Example Approaches to Manage Uncertainties.

Confidence-Building Methods	Example Approaches to Manage Uncertainties
• Use of Management Systems • Stakeholder Involvement • Discussion of Options • Passive Safety • Defence in Depth • Robustness • Scientific and Technical / Engineering Principles • Understanding the Disposal System • Monitoring • Independent Peer Review • Completeness of the Safety Case • Traceability and Transparency • Complementary Safety Indicators • Multiple Lines of Reasoning • Plans for Addressing Significant Unresolved Issues.	• Sensitivity Analysis • Uncertainty Analysis • Quality assurance/Quality control • Communication of confidence building • Site Characterization • Expert judgment/elicitation • Verification/Validation of Models • Plume matching/assimilation • Decision analysis (multi criteria and multi attribute, cost benefit) • Waste acceptance criteria • Laboratory experiments • Reality check – simple calculation • Demonstration analogues • Alternative conceptual models • Data estimation – inverse methods • Alternative designs • Balancing realism and conservativism • Monitoring and surveillance

CURRENT ACTIVITIES

Current efforts on Task 4 are focused on documenting examples that illustrate the application of different approaches to manage specific types of uncertainties. To date, 25 examples have been developed. Each example includes a summary of the example, links to specific circumstances for the example (e.g., operation time frame, vault disposal concept, country with well developed regulatory structure and widespread use of nuclear power), types of uncertainties that are addressed, as well as links to other tasks in the PRISM project. The links are provided with the anticipation that there will be a means to sort examples into specific categories.

The first level of sorting has resulted in development of a draft reference table that illustrates links between specific examples and types of uncertainties and approaches for managing them. Fig. 4 is a current draft of the table. The numbers within the table are references to specific examples that will be included in the final report.

	Approach to Manage Uncertainties	AA	BB	CC	DD
A	Sensitivity Analysis	1,3,4,5,10,14,15	1,3,4,5,10	1,3	1,3,10
B	Quality assurance/ Quality control	4,16,17,20	4,16,20	16,21	12,21
C	Stakeholder Communication	9,15,16	9,16	21	3,6,7,8,9,12,16,21
D	Characterization	18,22	18,22		
E	Expert judgment/elicitation	1,15,16,18	1,16	1,16	1,6
F	Verification/Validation of Models	2,19,20	2,20	2	
G	Plume matching/assimilation	18			
H	Decision analysis (multi criteria and multi attribute, cost benefit)				12
I	Waste acceptance criteria	17			
J	Laboratory/Field experiments	2,8,19,22	2,8,22	2,8	5,8
K	Reality check – simple calculation	20	20		
L	Demonstration analogues	2	2	2	
M	Alternative conceptual models	1,8,15,18,20	1,8,18,20	1,8	1,8
N	Data estimation – inverse methods	18,22	18,22		
O	Alternative design	6,13	6	6	6,11
P	Realism and conservative	20	20		
Q	Monitoring and Surveillance	8	8	8	8

	Sources of Uncertainties
AA	Data and parameter uncertainty
BB	Model uncertainty
CC	Future uncertainty (scenario uncertainty)
DD	External uncertainties

Fig. 4. Example reference table illustrating the relationship between the sources of uncertainty and approaches for management of uncertainties. (The numbers in the table are links to specific numbered examples that have been developed for the formal report)

FUTURE ACTIVITIES

The third plenary meeting for the PRISM project is scheduled for 31 October – 4 November, 2011. The plan for that meeting is to have a complete draft of the report documenting the efforts of the working group available for that meeting. The PRISM project is expected to conclude in Fall 2012 with publications of reports documenting the efforts of all of the working groups as well as an informational brochure on the concept of a Safety Case. Current efforts for Task 4 are focused on developing and refining examples of how uncertainties have been managed under a variety of different circumstances and completion of the draft report.

SUMMARY

Many near-surface disposal programs are moving towards the production of what has become known as a Safety Case, which includes all of the different activities that are conducted to demonstrate the safety of a disposal concept. Recognizing the growing interest in the concept of a Safety Case, the IAEA is undertaking an intercomparison and harmonization project called PRISM. The PRISM project is organized into four Task Groups.

This paper focused on the work of Task Group 4, which is investigating approaches for managing the uncertainties associated with near-surface disposal of radioactive waste and their consideration in the context of the Safety Case. Efforts to date have placed an emphasis on identifying a wide variety of approaches that can and have been used to manage different types of uncertainties, especially non-quantitative approaches that have not received as much attention in previous IAEA projects.

The working group has prepared a draft report with examples of approaches that have been used to manage uncertainties for a variety of different circumstances. The examples are being categorized by specific types of uncertainties and approaches for managing uncertainties that have been identified by the working group. Current activities include further development of examples and completion of the draft report which will be reviewed and discussed at a PRISM Plenary meeting to be held 31 October – 4 November, 2011.

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