Considerations Related to Human Intrusion in the Context of Disposal of Radioactive Waste – The IAEA HIDRA Project - 14101

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ABSTRACT

The principal approaches for management of radioactive waste are commonly termed ‘delay and decay’, ‘concentrate and contain’ and ‘dilute and disperse’. Containing the waste and isolating it from the human environment, by burying it, is considered to increase safety and is generally accepted as the preferred approach for managing radioactive waste. However, this approach results in concentrated sources of radioactive waste contained in one location, which can pose hazards should the facility be disrupted by human action in the future. The International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA), and Organization for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) agree that some form of inadvertent human intrusion (HI) needs to be considered to address the potential consequences in the case of loss of institutional control and loss of memory of the disposal facility.

Requirements are reflected in national regulations governing radioactive waste disposal. However, in practice, these requirements are often different from country to country, which is then reflected in the actual implementation of HI as part of a safety case. The IAEA project on HI in the context of Disposal of RadioActive waste (HIDRA) has been started to identify potential areas for improved consistency in consideration of HI. The expected outcome is to provide recommendations on how to address human actions in the safety case in the future, and how the safety case may be used to demonstrate robustness and optimize siting, design and waste acceptance criteria within the context of a safety case.

INTRODUCTION

In order to develop a position and a general approach regarding representation of potential inadvertent HI in a safety assessment, it is first important to recognize the concentrate and contain philosophy applied to disposal of radioactive waste and how that needs to be a consideration when determining the scope of potential scenarios that are appropriate for the purpose. It is also important to understand existing requirements, recommendations and guidance from the IAEA, ICRP, and OECD/NEA related to consideration of future human actions. This section provides a summary of key points, including international recommendations that helps define the basis and expectations for the consideration of potential HI. Communication of these principles with interested parties needs to be a priority throughout the lifecycle of a disposal facility.

The underlying principles include:

- Adoption of the concentrate and contain philosophy for radioactive waste results in potentially greater hazards should someone unknowingly disrupt the disposal system, but it is believed to be the best approach for management of radioactive waste.

- Consideration of future human actions that will disrupt the repository barriers is somewhat unique to radioactive waste disposal (e.g., typically not considered for hazardous chemical waste disposal) and can be viewed in context of additional defense-in-depth and confidence building.

- IAEA [1], ICRP [2] and OECD/NEA [3] agree that some form of inadvertent intrusion (future human actions) needs to be considered to address consequences in the case of a loss of institutional control (notably, there is also agreement that advertent intrusion, knowingly disrupting a disposal facility, is not considered).

- Consequences from inadvertent intrusion are considered in the context of optimization rather than being compared with the dose constraint (the intent is to enhance the robustness of the disposal system and to consider opportunities to reduce the likelihood and potential consequences of inadvertent intrusion, it is not a “yes or no” result that could, on its own, disqualify the viability of the disposal facility).

- One or more stylized scenarios based on current practices and technology near the disposal site should be used rather than speculating about future human behaviour. Protective measures can then be used to reduce or mitigate the likelihood and/or potential consequences.

In September 2012, the IAEA established the HIDRA project to address the consideration of HI as part of the safety case. The objectives of the project are to:

- Share experience and practical considerations for development and regulatory oversight of assessments of impacts of future human actions, primarily HI, in the context of the safety case during the lifecycle for a disposal facility
- Provide specific information regarding technical, societal and design considerations to support development of a structured process or methodology for identifying and selecting protective measures and/or scenarios that are applicable for site-specific application
- Describe the role of assessments of future human actions for siting, design and development of waste acceptance criteria in the context of the safety case
- Provide suggestions for communication strategies to describe the rationale for assessments of future human actions and for interpretation of the results of those assessments for the public
- Provide recommendations for the IAEA, as appropriate, for clarification of existing IAEA requirements and guidance relevant to the assessment of future human actions and HI.

HUMAN INTRUSION AS PART OF A SAFETY CASE FOR DISPOSAL

The IAEA Safety Guide (SSG-23) addressing the safety case and safety assessment [4] provides guidance on implementation of the safety case approach for disposal of radioactive waste, including specific guidance for consideration of HI. Emphasis is also placed on the relative role of HI as part of the overall safety case for a disposal facility. Namely, HI is considered in the context of robustness and providing additional defense-in-depth rather than in the context of compliance with a dose constraint. From this perspective, considerations related to HI are generally used in an optimization context (e.g., to identify potential improvements to the design and/or waste acceptance criteria).

IAEA SSG-23 places emphasis on the differences for considerations related to HI for near-surface and geologic disposal facilities, respectively, "HI is particularly relevant for disposal facilities at or near the surface." It is emphasized that most human activities (e.g. construction operations, farming, etc.) that could lead to inadvertent HI into a waste disposal facility take place at limited depths of up to tens of metres (potentially as deep as 30 to 50 m below the surface for some activities). Human activities that reach depths greater than 30 m are much less likely, but include drilling (e.g. for water, oil or gas), exploration and mining activities, geothermal heat extraction or the storage of oil, gas or carbon dioxide. Thus, the specific development of scenarios to be considered in a quantitative framework is more targeted towards near surface disposal.

IAEA SSG-23 is specific about the role of human actions that do not result in a direct disturbance of the disposal facility:

> *"only those human actions that result in direct disturbance of the disposal facility (i.e. the waste, the contaminated near field or the engineered barriers) are considered human intrusion. Human actions resulting in the disturbance of the host environment beyond the disposal facility and its immediate proximity are not categorized as human intrusion, since they do not result in direct intrusion into the disposal facility. Such actions should be considered within the scenarios used for the assessment of long term risks."*

This implies that human actions beyond direct impacts on the facility are addressed as part of the normal evolution scenarios.

IAEA SSG-23 emphasized that inadvertent HI should be assumed to occur at some time following the loss of knowledge about the site and its hazardous contents. This implies that an individual or group of individuals intruding into the disposal facility (the intruders) will, at least for a short period, be directly exposed to radiation while being unaware of the associated potential hazard. Intrusion may also lead to increased release of radioactive material and increased long term exposure of individuals or groups around the disposal facility.

Consistent with ICRP recommendations [2,5] and the IAEA Safety Requirements (SSR-5) for disposal of radioactive waste [1], if HI cannot be excluded for a certain disposal facility, the consequences of one or more plausible intrusion scenarios should be assessed. However, the probability of intrusion is uncertain and per ICRP Publication 60 [6], safety assessment should seek to evaluate the doses associated with HI that may occur, but should not attempt to use a risk based concept that uses as a basis for assessment the product of the probability of intrusion and the dose arising from the intrusion. Although specific probabilities can be difficult to justify, this does not preclude the need to communicate the relative likelihood of intrusion to demonstrate robustness as part of the safety case.

Although details of the approach taken to assess HI may be specific to the types of waste and the disposal facility in question, the general approach can be adopted within the construct of the approach provided in SSG-23. The HIDRA project has proposed a flow chart for consideration of HI based on the safety case approach described in SSG-23 (see Fig. 1). This chart provides the structure for the concepts and approaches being considered in the HIDRA project. Note that the chart emphasizes the iterative nature of the process, recognizing that the safety case will evolve over the lifecycle of the facility. The role of HI in decision-making over the lifecycle of a facility is a key consideration.

In Fig. 1, the safety case context includes considerations such as the national system, regulatory context and the safety objectives and criteria. The safety strategy includes the approach for isolation and containment, role of passive systems and considerations related to robustness, defence-in-depth and demonstrability. The system description includes the definition of the conceptual model and identification of the characteristics of the natural and engineered systems as well as safety functions for different components in the system and any design options being considered. The safety assessment block is discussed separately later in this paper. The blocks for limits, controls and conditions and system optimisation are core components where measures taken to reduce the potential for and/or the consequences of intrusion are considered and implemented. The final block addresses the integration of considerations related to HI with the overall safety case.

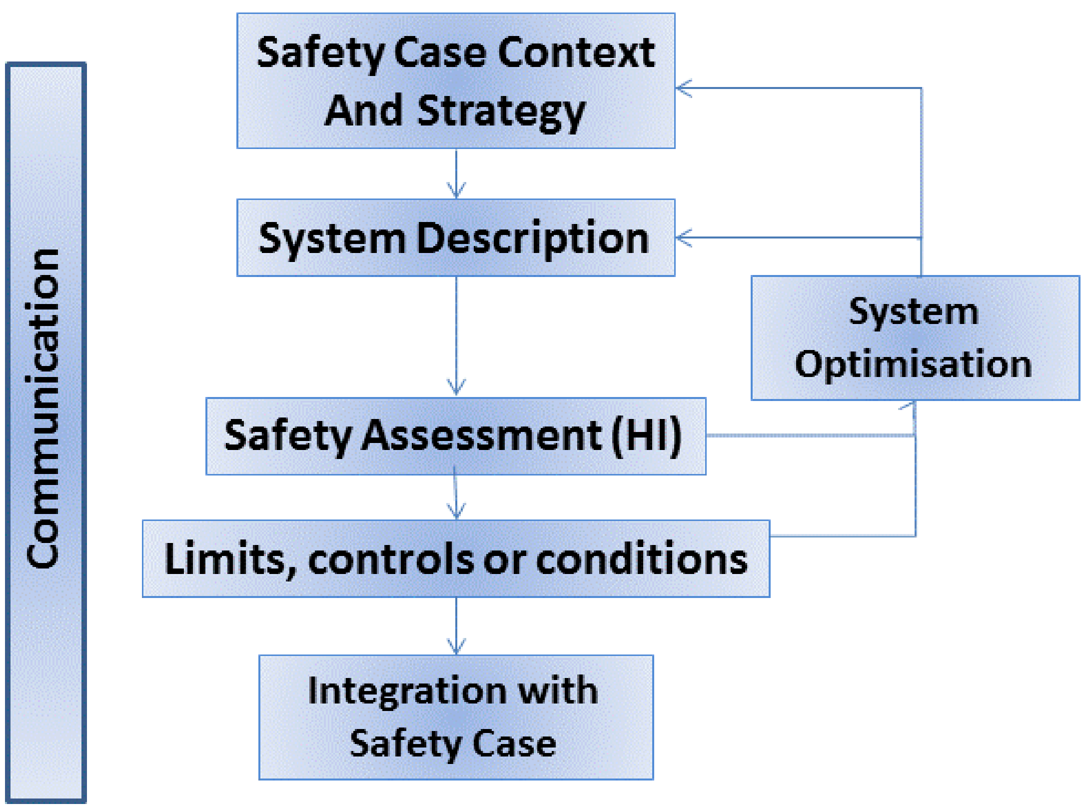

Fig. 1. Safety Case context with considerations for human intrusion.

ROLE OF HUMAN INTRUSION FOR DECISION-MAKING DURING THE LIFECYCLE FOR A DISPOSAL FACILITY

The development of a radioactive waste disposal facility involves a number of key decisions, typically taken when moving from one stage of the facility life cycle to the next. These decisions are generally supported by the production and examination of a safety case. At each decision stage all factors relevant to the safe development of a disposal facility need to be considered. The approaches discussed for this project are being integrated with the framework for decision-making that was developed in the IAEA PRISM project. Fig. 2, from the IAEA PRISM project (e.g., [7]), illustrates the evolution of the safety case over the facility life cycle.

The role of intrusion for decision-making is being developed and refined in more detail at this time. In general, HI considerations can be important during siting of a disposal facility for the consideration of local features that could increase the likelihood or severity of intrusion (e.g., significant natural resources, large populations, etc.). During the design phase, intrusion considerations may influence the selection of waste forms/containers, the layout of a disposal facility, or plans for the distribution or specific placement of selected waste streams. A key influence for the operational phase is the role of intrusion in the development and any updates to the waste acceptance criteria for the facility. After closure, intrusion considerations can have a significant role in the determination of active and passive institutional controls that would be established for the facility.

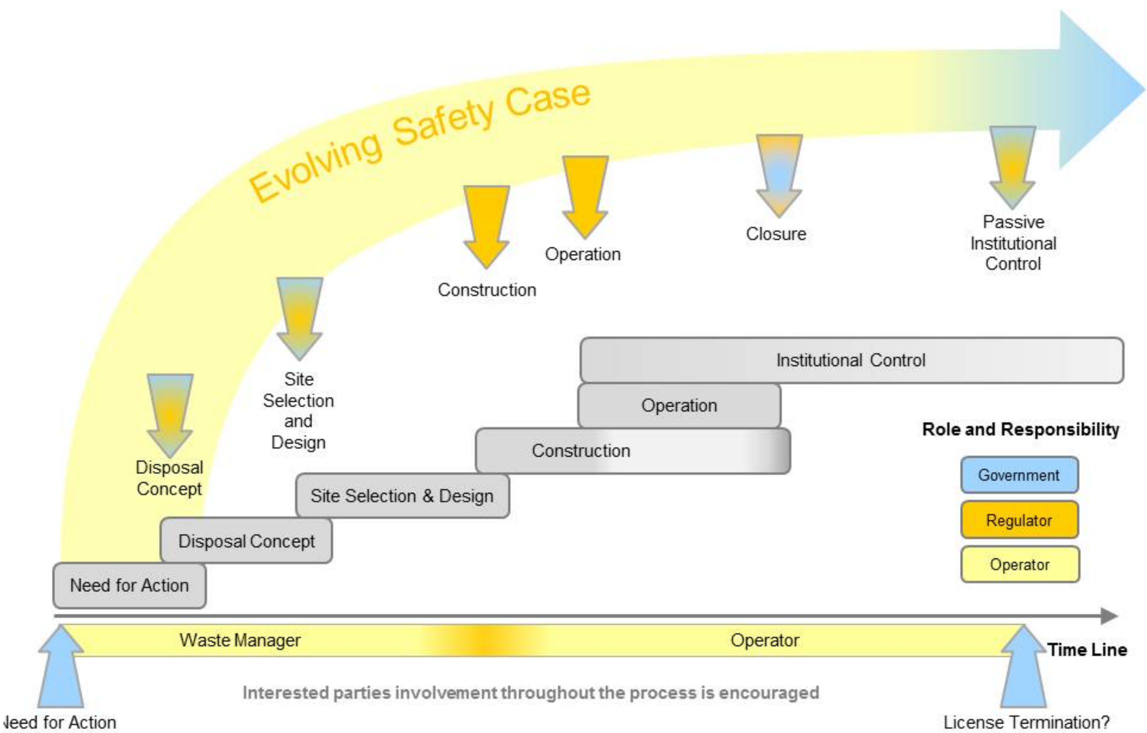

Fig. 2. Illustration of the evolution of the safety case over the lifecycle of a disposal facility.

HIDRA is also considering the information needs related to intrusion to support decision making at each step in the lifecycle. A critical consideration is the role of communication with interested parties throughout the process. Intrusion is a unique concept for radioactive waste disposal and its role in increasing the robustness of the safety case can help build confidence.

CONSIDERATION OF THE LIKELIHOOD OF HUMAN INTRUSION DURING DIFFERENT STAGES OF THE LIFECYCLE

It can be helpful when discussing the timing of the need to consider future human actions in the context of the safety case to think of the life-cycle of a radioactive waste disposal facility as a storyline, divided into a number of phases with distinct features relating to the likelihood of future human actions. As already discussed, in the context of future human action scenarios for the safety case, it is generally accepted that it is only necessary to consider scenarios where any actions that disrupt the safety functions of the facility are undertaken without knowledge of the hazard presented by the disposal facility. We refer to such actions as being “inadvertent”. By definition, inadvertent human actions cannot occur whilst there is general knowledge of the whereabouts of the facility and the nature of its contents. Thus the level of knowledge of the facility is the key factor in defining the different phases of the safety case storyline. Examples of considerations regarding the likelihood of intrusion to be included for the timeline are provided in the following sections.

The active period of development and operation includes construction, waste emplacement and the processes of backfilling, sealing and closing the facility. During this period there is human action at the facility, but it is planned and intentional and suitable protection will be in place for workers, who will be aware of the hazardous nature of the materials with which they are working. By definition, *future* human actions are excluded from this phase of the disposal facility life-cycle.

The active institutional control period begins with the closure and sealing of the facility and continues until institutional control of the facility and site is relinquished. During this phase, it is anticipated that the facility will be monitored and that there will be security in place at the site, preventing any unauthorised access. There will therefore be no possibility for any inadvertent human actions that could damage the safety functions of the facility.

At the end of active institutional controls, there can be a period of passive controls that persists for as long as there is public knowledge of the site and the hazard it presents. It is anticipated that records will be maintained for any radioactive waste disposal facility at the local, national and international levels for many decades and even centuries (such timescales may be justified, for example, by considering the UK Doomsday Book created in the 11^{th} century, documenting land use and locations of towns and villages, populations and livestock throughout England, which survives today). Whilst such records are in place it can be considered that there can be no authorised inadvertent intrusion. It is perhaps possible that there could be minor, unauthorised inadvertent intrusion, for example small-scale digging without any consent, but no major construction or excavation activity that would require any form of planning consent or authorisation.

It is assumed that at some time in the future, there will no longer be any public knowledge of the hazardous nature of the contents of the disposal facility. It may be possible that there is some knowledge of a feature at the disposal facility location, for example it may present a detectable signature on surface mapping techniques, but there is no knowledge of the potential hazard the facility presents. In this phase there is the potential for inadvertent HI into the disposal facility, or other human actions that could disrupt the safety functions of the disposal facility. Such activities could include drilling into the facility, mining or excavating to the depth of the wastes.

IMPLEMENTATION OF HUMAN INTRUSION IN A SAFETY ASSESSMENT

As described previously, HI is not addressed in the context of a dose constraint, it is considered in the context of optimization to improve the robustness of the safety case for disposal. The optimization of the disposal system refers in principle to the need to take measures to:

- Reduce the possibilities or likelihood of HI, and
- Reduce the consequences of HI (i.e. radiological impacts and impacts to safety functions).

The *likelihood* of such actions will be determined by a number of factors including, the depth of the facility and the regional conditions. For example, it is reasonable to assume there is less potential for intrusion into a deep geological facility than into a near-surface facility. In the case of near-surface disposal, siting of the disposal facility in remote areas away from potential natural resources, such as water or minerals, and population centers may also reduce the potential for a facility to be disturbed via inadvertent intrusion.

The *consequence* of such actions will depend on the:

- nature of the waste, its level of radiotoxicity;
- timing of the intrusion event, noting that the further into the future the intrusion occurs, the greater the radioactive decay of the radionuclides in the wastes (although for certain radionuclides, such as Ra-226, there will be ingrowth from the decay of long-lived parent radionuclides that will lead to an increase in the radiotoxicity);
- amount of waste that is brought into the biosphere;
- nature of the intrusion scenario, i.e. how people come into contact with the waste and for how long, whether radionuclides are ingested and/or inhaled and levels of exposure to external radiation.

An area of focus for the project is to support development of the approach to be used to address HI in a safety assessment. This is linked to block (“D”) in Fig. 1. The HIDRA project has divided safety assessment into a few key elements (see Fig. 3): development of a generic set of human actions, identification and selection of scenarios and/or measures, and the actual evaluation of the selected measures and scenarios. The identification of the scenarios and/or measures may include some qualitative screening to eliminate duplicative scenarios or lower consequence scenarios may be subsumed into a higher consequence scenario. The outcome of the selection process would be the disposal system specific scenarios and/or measures that would be evaluated for the HI aspects of the safety assessment. The evaluation can be quantitative or qualitative depending on the country-specific regulations.

A set of generic human actions are being developed that would form the general basis for development of representative scenarios for HI. At this time, the proposed generic actions include:

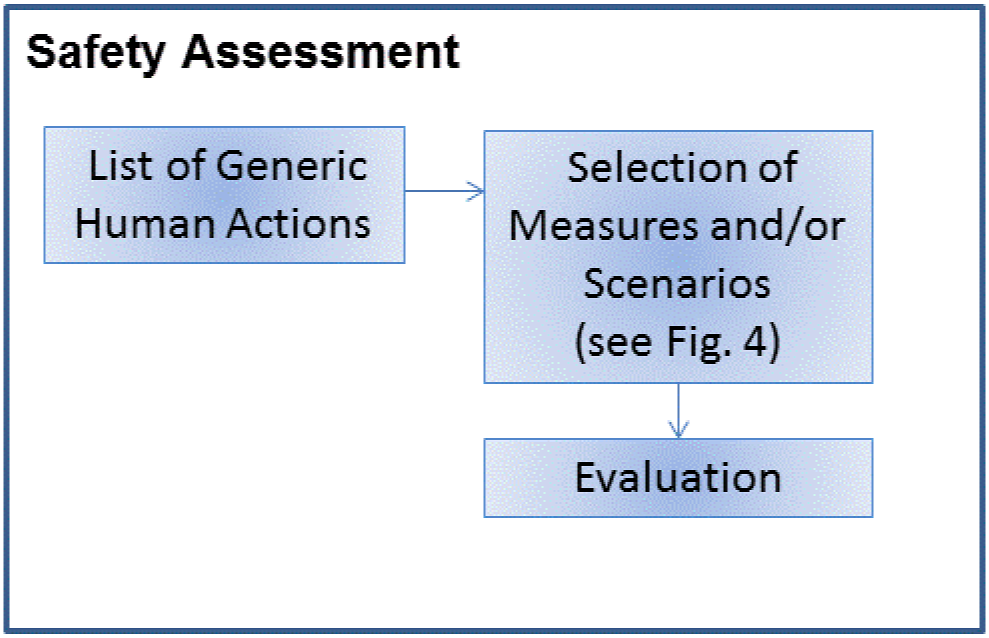

Fig. 3. Safety assessment components (detail for “safety assessment” block in Fig. 1.)

Near surface disposal

- Drilling, Residential Excavation, and Roadway Excavation

Geologic disposal

- Drilling, conventional and unconventional mining.

GENERAL APPROACH FOR SELECTION OF SCENARIOS/MEASURES TO BE CONSIDERED

A well-defined approach that can be applied to establish site-and design-specific considerations for the assessment of future human actions will be a useful tool to support regulators and implementers in Member States and provide a roadmap to address IAEA requirements in a more consistent and structured manner. This approach would be used at each step of the lifecycle of a disposal facility as introduced above. Flexibility in the approach to consider different disposal concepts, site conditions, regional habits, and level of development will be important to serve a broad range of Member State needs.

The HIDRA project has developed an initial concept for the selection of scenarios and measures to be considered in a safety assessment. This concept is illustrated in Fig. 4.The details about implementation of the approach are being developed as part of the project. This is being conducted using three working groups, which are highlighted in the figure. The working groups have started development of detailed input for the final report. The objectives for each of the working groups are summarized below.

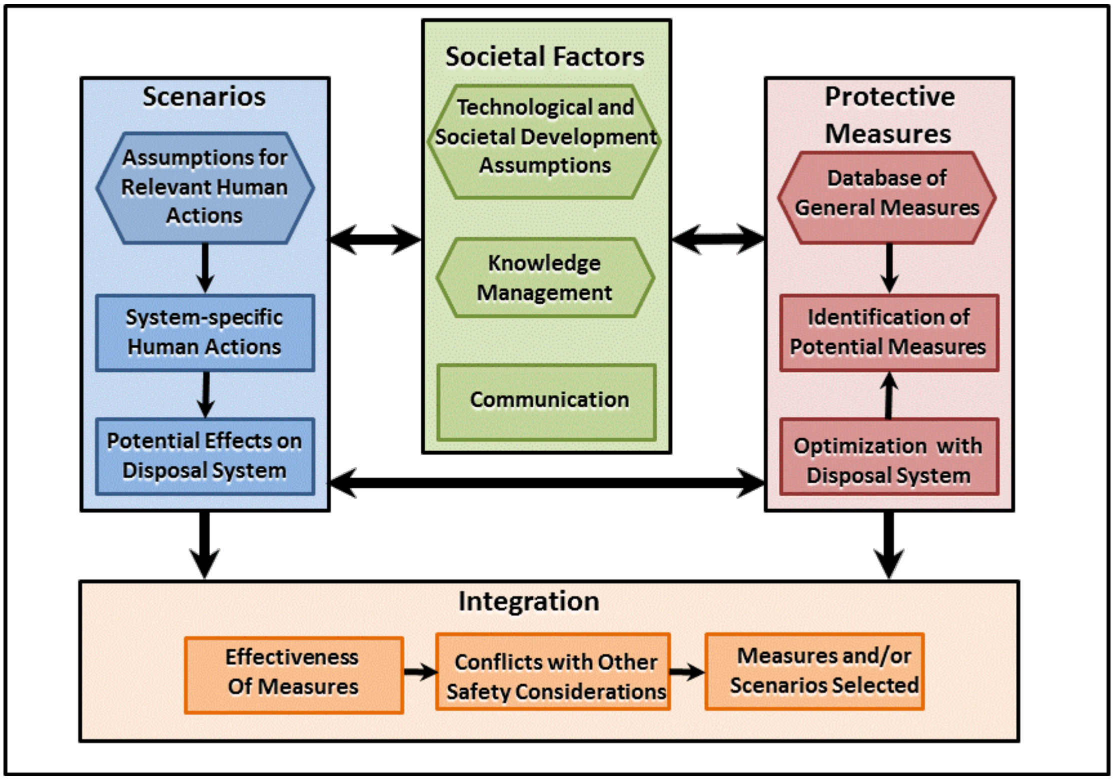

Fig. 4. Considerations for Selection of Scenarios and/or Measures for the Safety Case.

Scenarios Working Group

The objective of scenarios working group is to provide HI scenario development information in a consolidated form that allows for a quick reference to provide high-level insights into this process. These insights may provide a starting point for developing future HI analyses. The specific scope includes:

- Provide an overview of the role of HI scenarios
- Provide a set of primary HI scenarios, including both near-surface and geologic disposal
- Provide a list of considerations to be used to assist in modifying the primary HI scenarios to capture site-specific details

The scope of this section limits the number of potential HI scenarios to that which could provide a reasonable range. The considerations provide an overview of topics that may need to be addressed to develop a site-specific HI scenario. However, these should not be construed as all encompassing.

Societal Factors Working Group

The objectives of this working group are to share, exchange information, and communicate good practices on:

- How societal aspects can be used in selection of scenarios, i.e. what societal aspects should be considered in generating HI scenarios and what is a good practice regarding these aspects,
- How to preserve knowledge throughout the life cycle of the radioactive disposal facility,
- Effective communication of how HI scenarios are used to build confidence in the safety of a radioactive disposal facility.

One aspect of the future that is particularly uncertain, over the timescales considered for radioactive waste disposal facilities (for deep, near surface and land disposal), is how human society will evolve and what human activities may take place at the location of the radioactive waste disposal facility. Therefore, safety cases need to consider the possibility that future knowledge of the site is lost and future HI may affect the radioactive waste disposal facility.

However, there is no common understanding how to incorporate HI scenarios into the safety case as there are questions related to the description of such scenarios, the interpretation of the results and how to communicate these results to stakeholders. Therefore, in order to build methodologies for the derivation of HI scenarios, it is crucial to look at how to incorporate societal context. The relevance of such scenarios depends on the understanding of the societal context for future human actions.

Protective Measures Working Group

There is a general consensus, that any taken measures against HI do not have to compromise the safety performance of the disposal system. Therefore, appropriate measures have to be derived or identified. Those measures can be of different nature and origin. The spectrum might comprise active and passive measures with different characteristics like warning, informing, preventing, delaying, impeding and controlling. In this context several main categories for measures were already identified whereby each category in turn can contain a number of measures. Furthermore, these measures shall contribute to the optimization of the disposal system against HI. The optimization is of particular concern regarding the underlying methodology of the HIDRA project.

The objectives of this working group are:

- Compilation of information necessary for identification of measures (types of disposal facilities, disposal concept, site and design, human activities);
- Description of different categories of measures (monitoring/surveillance/oversight, knowledge management, siting, design and engineered barriers);
- Compilation of potential optimization measures (database of potential measures, description of structure of the database, additional supporting tools);
- Role of waste acceptance criteria and time frames;
- Identification of potential optimization measures.

CONCLUSIONS

The IAEA has established a project to provide guidance regarding the consideration of HI as part of the safety case for a disposal facility. International recommendations have been summarized to provide a general background for the project. The project is placing emphasis on the role of HI in the context of decision making through the lifecycle of a disposal facility and, in that respect, is being integrated with work taking place in the IAEA PRISM and GEOSAF projects which address the safety case for near-surface and geologic disposal, respectively. A primary focus of the project is development of a framework for the selection of HI scenarios and protective measures against intrusion that would be considered as part of a safety assessment for a disposal facility. Three working groups have been established to address key parts of that framework: scenarios, societal factors, and protective measures. Each of the working groups has been developing input to be used for the approach that will then be integrated into a description of an overall framework for the final report.

Note: The NRC staff views expressed herein are preliminary and do not constitute a final judgment or determination of the matters addressed or of the acceptability of any license application or for any existing or future licensing activities.

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