SITEX

Contract Number: 295 889

DELIVERABLE D2.2

Main key technical issues, expertise and support needed

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Abbreviations used

DGR	: deep geologic repository
DiD	: defence in depth
EA	: environmental assessment
EBS	: engineered barrier system
EC	: European Commission
EPG	: European Pilot Group
FEP's	: features, events and processes
GSR	: general safety requirement
HAZOP	: hazard and operability study
H&S	: health and safety
IAEA	: International Atomic Energy Agency
ICRP	: International Committee of Radiological Protection
IGD-TP	: Implementing Geological Disposal of Radioactive Waste Technology Platform
LT	: long term
NDT	: non-destructive testing
NEA	: Nuclear Energy Agency
NSA	: national safety authority
OLC	: operational limits and conditions
PA	: performance assessment
PIE	: postulated initiating events
QA	: quality assurance
QC	: quality control
R&D	: research and development
R&R	: reversibility and retrievability
RN	: radionuclide
RWM	: radioactive waste management
SA	: safety assessment
SC	: safety case
SEA	: strategic environmental assessment

SITEX : Sustainable network of Independent Technical Expertise for Radioactive Waste Disposal

SRL : safety reference level

SSC : structures, systems and components

SSG : specific safety guide

SSR : specific safety requirement

THM : thermo-hydro-mechanics

TSO : technical safety organisation

URL : underground research laboratory

WAC : waste acceptance criteria

WENRA : Western European Nuclear Regulators Association

WMO : waste management organisation

WP : work package

1 Introduction

According to the Specific Safety Requirements of IAEA for the disposal of radioactive waste [1], the responsibilities of the regulatory body involve carrying out a number of activities such as:

- Development of regulations and guides;
- Approvals and setting conditions for the development, operation and closure of each individual disposal facility;
- Inspection and enforcement as necessary to ensure that the conditions are met;
- Maintaining competent staff;
- Acquiring capabilities for independent assessment.

The importance of the technical capabilities of the regulatory body is also underpinned in Article 8 of the EC Directive 2011/70/Euratom [2], stating that Member States shall ensure that the national framework require *all parties* to make arrangements for education and training for their staff, as well as research and development activities to cover the needs of the national programme for spent fuel and radioactive waste management in order to obtain, maintain and to further develop necessary expertise and skills. This requirement, when applied to the regulatory body, is indeed a prerequisite for ensuring effective independence of the regulatory body, as required by Article 6-2 of the same EC Directive.

Figure 1 illustrates the interactions between the regulatory function, the expertise function fulfilled by or in support of the regulatory body, the implementer and society. The main tasks associated with the regulatory function in the framework of its interactions with the implementer are two-fold:

- To develop the safety requirements and conditions that have to be fulfilled in order to meet the general safety objective of protecting human and the environment against the hazards associated to ionizing radiations ("Regulatory expectations");
- To assess compliance with these requirements and conditions ("Compliance demonstration").

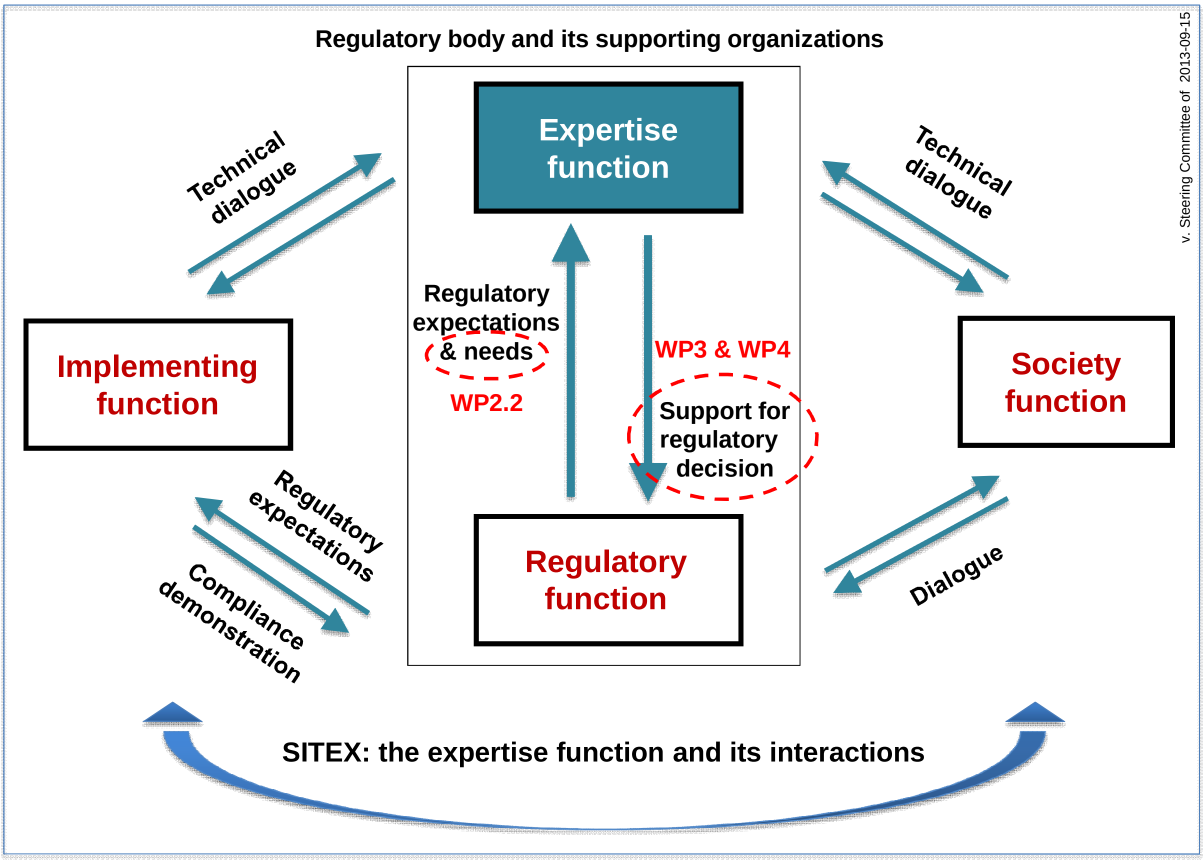

Figure 1: Interactions between the expertise and regulatory functions of the regulatory body, and the functions related to the implementer and the society. The regulatory function is the regulatory body of a country. The expertise function is typically a "Technical Support Organization (TSO) and the implementer is the Waste Management Organization (WMO) – the organization who would be the licence applicant. Depending on the country and on the topic, the regulatory function and expertise function can be within the same organisation.

Assessing compliance with safety requirements requires strong technical support from the expertise function. This includes several activities such as independent R&D (WP3), reviewing of safety demonstration (WP4) and inspections. In order to provide the regulatory function with an adequate decision support, the regulatory needs associated with the evaluation of conformity have to be clearly formulated and communicated to the expertise function. Furthermore, from the beginning of the project, the regulator should define and implement an appropriate organization to ensure allocation of sufficient and adequate resources at all the stages of the development of the geologic repository. In particular, the regulator needs to establish and develop its resources and identify the need for independent R&D to be conducted in support of its expertise and ensure that the results are available in due time [3].

The main objective of the deliverable is to identify the expertise and technical support needed by the regulatory function in order to perform an independent assessment of compliance with safety requirements. Priorities are established considering the agendas of national programmes for implementing a deep geologic repository. The report provides an identification of:

- The main key technical issues that must be assessed by the regulators at the different stages of repository development;
- The types of expertise and technical support needed at each phase of repository development.

2 Methodology

The followed methodology is illustrated in Figure 2. The work was mainly based on the following input:

- The high-level safety requirements identified in deliverable D2.1 [11];
- The regulatory expectations regarding the safety case at the different phases of repository development identified by the European Pilot Group (EPG) [3];
- A questionnaire aimed at identifying the types of technical support needed at each phase of repository development;
- Other relevant documents discussing the technical support and activities performed by the expertise function.

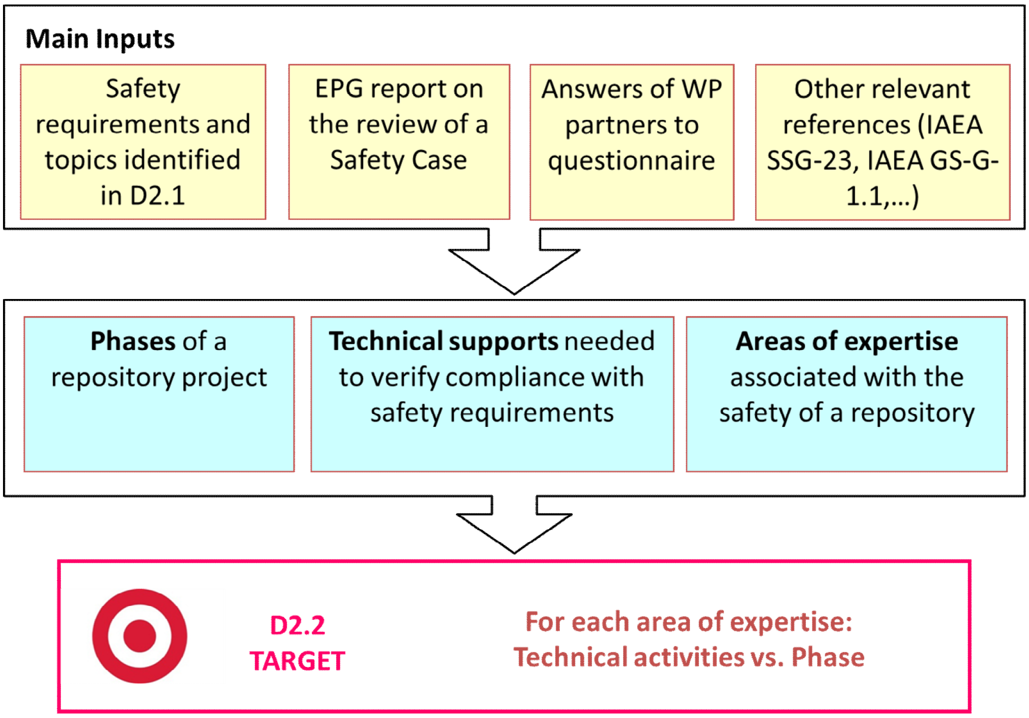

Figure 2: Working methodology.

These inputs were first used to identify:

- The different phases of a geologic repository project and the decisions associated with these phases (section 3);
- The different types of technical supports and activities needed to verify compliance with safety requirements (section 4).
- The areas of expertise associated with the safety of a repository that have to be acquired by or available to the regulator body (section 5).

The specific expertise and the technical activities needed at each phase of the repository project were then identified based principally on the answers to the questionnaire and discussions held during WP meetings. The rationale followed for this identification was also of interest. This includes the identification of the possible outcomes of a particular type of technical support (R&D, review, …) and the approach to identifying the most suitable technical support(s) for a particular safety requirement or a particular decision / programme phase.

In the sections 6 to 11, the technical support activities that might be performed at each phase/stage of the repository development are identified. The relative importance of the identified activities and its evolution throughout the lifetime of the repository is not discussed in the current deliverable. Note that practically, the importance of the identified activities will evolve according notably to the specificities of each national project.

Several outcomes of the study served as input to WP3 (“Identification of scientific issues and prioritization”) and WP4 – Task 2 (“Skills to be developed to perform technical review”).

3 Phases of repository development

The exact definition of the phases and decision-making points that cover the development and implementation of a geological disposal facility, differs among national programmes. In nearly all programmes, regulatory approvals are expected at least from the point of repository construction and, in some countries, regulatory approvals will also be needed in earlier phases e.g. during the conceptualization and siting phases. Decisions by various levels of Government in a country may also be required (i.e., legislative decisions, local referendum) in addition to the regulatory process. In addition, an environmental assessment (EA) may also be required prior to proceeding with licensing.

The EPG report on the Regulatory Review of a Safety Case for Geological Disposal of Radioactive Waste [3] defines six key phases: (1) conceptualization, (2) siting, (3) reference design, (4) construction, (5) operational, and (6) post-closure. These phases described below provide a broad description of the progressive development of a repository and of its safety case. As such, they are used in this document as a generic framework for the identification of the evolution of the needs for expertise and technical support.

1. The **conceptualization phase**, during which an implementer considers potential sites and design options, establishes the safety strategy and carries out preliminary assessments. Regulatory review of the work at this phase should guide the implementer on the likelihood of achieving the necessary demonstration of safety and should help the implementer decide whether to commit resources to move to the next phase of the project.
2. The **siting phase**, during which the implementer identifies potentially suitable sites that are compatible with the concept in terms of the safety strategy adopted and characterizes these sites based on a preliminary safety case to the extent that a decision can be made on the preferred site.

3. The **reference design (and application for construction) phase**, during which the implementer adapts the conceptual design to the site properties, finalises and validates the design of the disposal facility, and develops the safety case, to support the implementer's application to construct, operate and close the facility. This is used by the regulator to decide whether to grant a licence for the implementer to construct the facility and is a crucial milestone in the development of a repository.
4. The **construction (and application for operation) phase**, during which the implementer demonstrates that it is safely constructing the repository and that it has built the facility as planned and in accordance with the terms of the construction licence. Towards the end of this phase the implementer will present its final overall approach for operation and a draft concept for closing the facility. In preparing for operation, the implementer will need to demonstrate safety during operation and radiation protection of workers and members of the public and the environment. The regulator would typically decide whether to grant a separate licence or approval before emplacement of waste in the facility would commence. It should be noted that construction activities are generally expected to be carried on beyond the construction phase (i.e. during the operational phase).
5. The **operational phase**, during which the implementer emplaces waste packages and closes the disposal facility. During this phase, the implementer may build new disposal units, and backfill and possibly seal, either temporarily or permanently, parts of the disposal facility where waste emplacement has been completed. The implementer also develops an application to close (decommission) and seal the facility, and further develops the plan for post-closure institutional controls, monitoring and surveillance. The regulator will decide during this phase whether to grant a licence for the implementer to close (decommission) and seal the facility. When the licence is granted the implementer proceeds to the closure of the facility.
6. The **post-closure phase**, at the start of which the implementer provides evidence to demonstrate that it has closed (decommissioned) the disposal facility in accordance with safety requirements and presents a firm plan for institutional controls and continuing monitoring and surveillance. At this phase the regulatory body will confirm what controls, monitoring and surveillance are required and for how long. The amount of activities carried out during this phase is expected to decrease significantly compared to "pre-closure phases during which post-closure safety has to be thoroughly taken into consideration. The scope of the document is limited to the period during which active institutional controls are performed. The expected duration of these controls is country-specific. Indeed, the discussions in the WP2 have emphasised that the activities that would be performed during the post-closure phase are strongly sensitive to the national specificities. For instance, the nature of the controls that would be performed during this phase and their expected duration may differ from one country to another. The technical support activities that may be needed during the post-closure phase may therefore differ from one country to another.

Figure 3 relates these phases to the pre-licensing, licensing and post-closure periods and to the evolution of the safety case. This illustration shows that the different components of the safety case are progressively developed during the conceptualization, siting and reference design phases. A complete safety case covering all safety-relevant aspects and programme phases and demonstrating that the concept is safe and feasible is expected before entering the construction phase. The safety case is then regularly revised to incorporate operational experience, design changes, as-built properties, monitoring data and new prevailing circumstances into consideration. Moreover, the safety case needs also to be updated to confirm the assumptions that were made in the previous licence stages or phases to demonstrate safety. The plans for closure and post-closure are also expected to be refined and further developed during the operational phase.

The safety requirements associated with specific stages or phases of repository development are identified in Table 3 of Appendix 1.

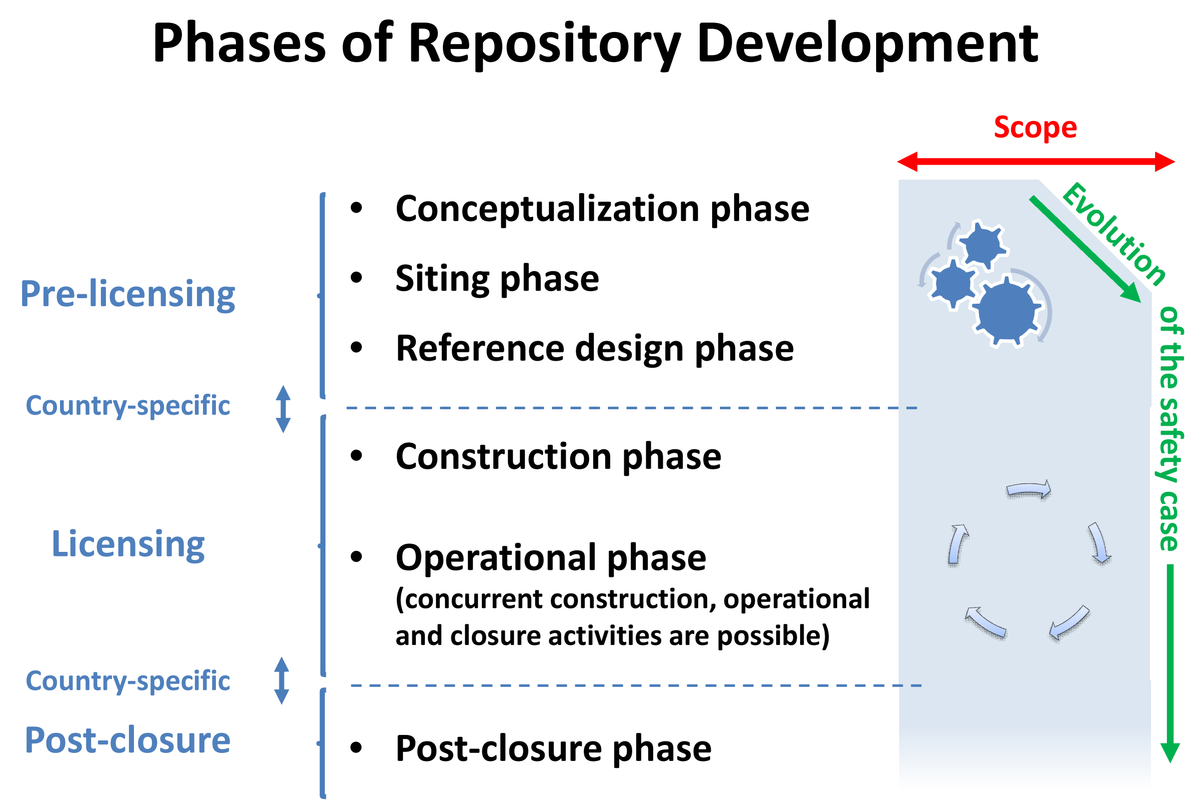

Figure 3: Repository development phases, pre-licensing, licensing and post-closure periods and evolution of the safety case.

4 Types of technical support needed

The principal tasks to be performed by the regulatory body are the development of regulations and guides, review and assessment, authorization and inspection and enforcement. To fulfil its mission, the regulatory body needs technical expertise and support in order to:

- Check adequacy, completeness and justification of technical requirements and guidance;
- Take informed decisions with full knowledge of the facts;
- Justify advices and decisions;
- Develop the capacities to understand and assess the safety case;
- Judge the adequacy of the approaches followed to reach the safety objective and of their implementation;
- Perform efficient inspections.

This section focuses on the types of technical expertise and support needed (i.e. reviews, inspections and R&D activities) to verify compliance with safety requirements. It is also important to note that the expertise needed to conduct reviews, inspections and R&D activities will depend on the stage or phase of the development of the repository.

4.1 REVIEW

The overall goal of regulatory review is to verify that the disposal facility will not cause an unacceptable adverse impact on human health or safety, or on the environment, both now and in the future. To achieve this goal, the regulatory review process will typically have the following objectives [4]:

- To determine whether the safety case has been developed to an acceptable level (in terms of its quality and the detail and depth of understanding displayed) and whether it is fit for purpose;
- To verify that the safety case and the assumptions on which it is based comply with, or are in accordance with, accepted principles for radioactive waste management and regulatory requirements and expectations;
- To determine whether the safety case provides an adequate and appropriate basis to demonstrate that the proposed facility will be constructed, operated and closed safely and provides reasonable assurance of an adequate level of safety in the period after closure;
- To verify that relevant measures for mitigating unlikely potential effects have been identified and addressed, and that adequate follow-up plans for their implementation have been developed;
- To determine whether issues required by the regulatory body to be addressed by the implementer have been clearly identified;
- To identify any unresolved issues and to verify that plans for resolving these issues have been developed.

Reviewing activities considered in the framework of SITEX WP2 encompass the review of the safety case as well as of documents such as programmes and plans (e.g. R&D programmes, monitoring programmes, …).

In order to ensure the quality and success of a regulatory review, the regulatory body should have personnel with expertise and hands-on experience in safety assessment of radioactive waste facilities and should have either in house expertise or should have access to specialists in all the necessary disciplines involved in such assessment. The team of experts in charge of a review typically includes a project manager responsible for overall coordination and for the verification that the safety case and its review process are consistent with regulations as well as senior specialists responsible for peer reviewing, integrating and synthesizing comments from other specialists.

The regulatory review should be also conducted using a level of resources that is commensurate with the level of complexity of the safety case and the potential risks associated with the disposal facility under consideration.

4.2 INSPECTIONS

The principal objectives of regulatory inspection are to provide a high level of assurance that all activities performed by the implementer at all stages of the authorization process and all stages during the lifetime of a nuclear facility have been executed safely and meet the safety objectives and license conditions [5]. Regulatory inspection shall cover all areas of regulatory body' responsibility. If there are areas outside the mandate of the nuclear regulatory body or there is dual jurisdiction, consideration may be given to conducting joint inspections with other regulatory authorities on a case-by-case basis to ensure a harmonized approach. Although formal inspection is possible only if a license exists, specific types of inspections may also be carried out before a license is granted in the pre-licensing phase. Pre-licensing activities should to be outlined in the form of a specific framework or agreement between the regulatory body and the implementer (or future license applicant). In this case, inspections are not associated with legal enforcement activities but generally lead to the formulation of guidance or recommendations to the implementer. When such a specific framework or agreement is initiated for activities occurring in the pre-licensing phase and for what repository development phase a license application has to be submitted are country-specific points.

The regulatory body shall conduct inspections to satisfy itself that the implementer is in compliance with the conditions set out in the authorization (the licence) and regulations. Inspections include independent verifications in such areas as:

- Management system, human performance, operating performance, safety analysis, physical design, radiation protection, conventional health and safety, environmental protection, emergency management and fire protection, waste management, security, safeguards.

Generally speaking different types of inspections are identified:

- Planned inspections (announced or unannounced);
- Reactive inspections.

Enforcement actions shall be applied as necessary by the regulatory body in the event of deviations from, or non-compliance with, conditions and requirements. These actions are intended to modify or correct any aspect of an implementer's procedures and practices or of a facility's SSCs as necessary to ensure safety.

Regulatory inspection differs somewhat from other regulatory functions in that an inspector's principal activity takes place at the facility site, interviewing people, observing and evaluating activities, reviewing records and procedures and, where appropriate, making decisions and recommendations [7]. Inspection results are recorded and are typically sent to the implementer for follow-up actions. All inspectors should be able to evaluate and discuss safety-related issues with the implementer and the implementer's contractors. Appropriate training is therefore essential.

A distinction is made in this document between the following methods of inspections:

- Tests, measurements and direct observations:
  - Continuous or periodic observations and measurements (i.e. monitoring);
  - Specific tests and measurements;
- Interviews with personnel of the implementer and the contractor;
- Examinations of procedures, records and documents.

4.3 R&D ACTIVITIES

An independent R&D programme is essential for the regulator's scientific and technical ability, because it maintains or improves the regulator's competence, it contributes to the regulator's independence and it helps to achieve public confidence in the regulatory system [6]. The development of an independent R&D programme helps to ensure the development of independent capabilities for reviewing the Safety Case and assessing the scientific arguments provided by the implementer (WMOs). Activities in the R&D programme may also support inspections.

The R&D objectives set by the regulatory body differ generally from the R&D objectives set by the implementer. The regulatory body will mostly investigate issues directly related to safety with the objective to verify the adequacy of the approaches followed by the implementer to reach the safety objective. The regulatory body may decide to initiate R&D work where it considers that there is a need for additional studies beyond those undertaken by the implementer [8]. There may also be situations in which the regulatory body requires independent R&D work so that it can apply suitable critical considerations in its review and assessment. Special attention in R&D programmes will be usually given to the detection of possible inadequate choices, hypothesis or assumptions, knowledge gaps, incompleteness, inconsistencies, mistakes (of reasoning or of implementation), … . The R&D carried out by the regulator body is therefore more a "complement to" and "a verification of" than a "duplication of" the R&D activities performed by the implementer.

More specifically, regulatory R&D activities carried out in support of reviews and inspections may contribute to one or several of the following objectives:

- To develop expertise;
- To identify key safety issues;
- To develop specific safety requirements;
- To determine the current level of scientific and technical knowledge, and to make this knowledge available for supervisory tasks;

- To develop own tools for independent review of e.g. assumptions, models and approaches;
- To verify whether a logical and justified path has been followed to optimise protection;
- To verify safety (performance and radiological impact);
- To check technical feasibility;
- To develop inspection strategies and techniques.

Table 1 indicates the objectives of R&D activities related to the different regulatory body tasks and presents the main outcomes expected for each type of task after fulfilling the objectives of R&D activities.

Table 1: Matrix showing the multiple relationships between the objectives of R&D activities and their expected outcomes for the different regulatory body tasks.

Regulatory body tasks	Authorization		Review and assessment	Inspection & enforcement
Expected outcomes of R&D activities → / Objectives of R&D activities ↓	Informed decisions	Justification of advices and decisions	Adequate assessment of Safety Cases & preliminary documents	Efficient inspections
To develop expertise	X	X	X	X
To identify key safety issues			X	X
To develop own tools for independent review			X	X
To verify whether a logical and justified path has been followed to optimise the protection	X	X	X	X
To verify safety	X	X	X	X
To check technical feasibility	X	X	X	
To develop strategies & techniques to control installations				X

The regulatory body's R&D programme may use results from external research conducted by academic or other research institutes [6]. R&D activities such as independent modelling and experiments may also have to be conducted directly by or for the regulatory body in order to investigate some specific issues where alternative methods / analyses are required to support regulatory decision. In addition, the regulatory body may decide to collaborate on R&D internationally with other regulatory bodies and/or technical support organizations. In addition, there may be international R&D projects/working groups that regulatory bodies may participate in.

It is assumed in this report that the R&D activities include:

- **Desk studies** to establish the state-of-the-art and to take benefits from existing R&D;
- **Modelling and calculations** e.g. to:
  - Identify key parameters and uncertainties;
  - Assess the level of conservatism;
  - Verify results;
- **Lab tests and in-situ experiments** in underground laboratories (URL) e.g. to characterize components or to increase knowledge in the phenomenology.

It is important to note that R&D needs and tools evolve with the development phases or stages of the repository. They depend on the objectives of the development phases or stages, associated authorisations and on available resources (human and financial).

5 Areas of expertise

A number of safety-related topics are identified in the SITEX deliverable D2.1 based on existing "high-level" safety requirements developed in the new EC directive [2], WENRA SRLs [9], ICRP recommendations [10] and updated IAEA Safety Requirements (see Appendix 2). These topics, listed in Appendix 1, cover a wide range of disciplines and, hence, require the use of various technical supports throughout the different phases of a repository development. The different types of technical supports that can be a priori needed are discussed in Section 4.

For the purpose of this work, it is proposed to define the following 6 areas of expertise covering most of the safety issues considered in D2.1 [11]:

- Safety strategy and policy
- Management
- Waste
- Site
- Engineering
- Operational safety

The scope of each of these areas and their relationships with the topics identified in Appendix 1 are described in sections 6 to 11. The verification of conformity with the safety requirements associated with post-closure safety and its assessment necessitates a large variety of skills and expertise. For this reason, post-closure safety is addressed through the following areas of expertise: "Safety strategy and policy" (methodological aspects), "Management" (QA aspects, …), "Waste" (waste-related FEPs, source term modelling, …), "Site" (site characteristics and host-rock-related FEPs, modelling of radionuclide transport in the host rock and the environment, …) and "Engineering" (EBS-related FEPs, modelling of radionuclide transport in the EBS, …).

Lists of more specific fields of expertise are also provided in sections 6 to 11. Although not necessarily exhaustive, these lists are aimed at providing a good overview of the different disciplines associated with the main areas of expertise listed above. Furthermore, it should be kept in mind that a multidisciplinary approach is very often needed to deal with interactions between the different fields of expertise and the coupling between various processes. Such a multidisciplinary approach can be implemented in different ways and typically calls for the collaboration of both generalists and specialists.

6 Safety strategy and policy

6.1 INTRODUCTION

The safety strategy and policy are defined as the high-level approach for achieving safe disposal [3]. The safety strategy is intended to define objectives and principles to guide the overall project development. Hence, the safety strategy should address the implementation of the "governing principles" identified in deliverable D2.1 [ref] (see Table 1 of Appendix 1). The safety strategy should also identify the safety functions of the repository (containment and isolation), as well as those allocated to its components. Moreover, the safety strategy should describe all the approaches, processes and methods that will ensure that the repository meets the safety objective.

The main components of the safety strategy are [3]:

- The approaches for selecting a site, developing a concept, implementing practical engineering solutions and monitoring; the main basic design choices, depending on the national context. Wherever applicable, these design choices take into account arrangements to ensure the reversibility of disposal operations and the retrievability of waste packages;
- The approach to optimization leading to achievement of the best level of protection under the prevailing circumstances;
- The safety assessment methodology that describes how safety assessments will be carried out and defines the approach to evaluating evidence, analysing the evolution of the system in the context of defined and substantiated scenarios and the approach to treating uncertainties (i.e. ranking uncertainties and propagating them in the impact assessment);
- The overall approach for managing the various activities related to the repository development and implementation (such as siting and design, safety assessment, site characterization, management of uncertainties, waste form characterization, R&D and long term information management) ensuring that the work focuses on the safety objective, that adequate resources are available and that activities are correctly carried out and co-ordinated.

Constraints may be imposed by the prevailing circumstances (including scientific and technical state of the art, socio-economic situation, national legislation, …). These constraints and their consequences on the safety strategy should be clearly identified. Within the stepwise process, the implementer will have to confirm that the safety strategy is adequate to meet the key objectives.

Fundamental aspects of the strategy are not, in general, expected to change over the course of the project. However, they may be re-interpreted and the implementation priorities and methods may evolve to take into account experience, technical developments, societal inputs, and new national and international standards and guidance.

6.2 NEEDED EXPERTISE

The fields of expertise needed to verify compliance with safety requirements associated with the area of expertise "safety strategy" are as follows:

- Generalist with a good knowledge and understanding of the requirements / recommendations for the safety strategy;
- Support of experts in specific fields to verify that specific approaches (e.g., for host rock selection, concept and design development, reversibility and retrievability, …) are appropriate.

During the pre-licensing process the level of expertise needed throughout the repository programme should be adapted to the issues to be explained and/or demonstrated in the safety case to support the decision to move to the next step.

6.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

"The early development and adoption of a strategy for safety is a key point in the development of the safety case" [4]. Safety strategy is indeed the starting point to develop a repository: It is therefore essential to judge the appropriateness of the safety strategy from the beginning as well as to check its effective implementation.

The review and inspection activities that may have to be carried out at each development phase to verify compliance with safety requirements associated with the area of expertise "safety strategy and policy" are given in the following table.

Table 2: review and inspection activities related to safety strategy and policy.

Safety strategy and policy **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Verification that the safety strategy is, or remains, appropriate to the disposal objectives (i.e. waste types and volume, …) including a review of (SRL 1.1.3 & 4.1.5): • Safety principles • Optimisation / identification of prevailing circumstances • Safety concept • Host rock and site selection approach • Concept development approach • Design approach • Operational safety approach • Measures necessary for the purpose of accounting for and control of nuclear material (SRL 2.1.10) • Reversibility and retrievability (R&R) aspects • Safety assessment methodology including the approaches: - To develop scenarios/ models - To manage uncertainties • Monitoring methodology	X	X	X	X	X	
Verification that safety is not unacceptably affected by measures for any other purpose			X	X	X	
Verification of the effective implementation of the safety strategy (including interviews of people in charge of developing / implementing the safety strategy throughout the facility lifecycle)	X	X	X	X	X	

6.4 NEEDED R&D ACTIVITIES

R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise “safety strategy and policy” are limited to the participation in international working groups on the development and implementation of safety strategies.

7 Management

7.1 INTRODUCTION

The implementer should establish, document, maintain, assess and continuously update a management system during all the activities to be carried out from site characterization to closure of the facility and, as required by the regulatory body, post-closure activities [3]. The objectives of the management system are in particular:

- To ensure that the implementer has set up an appropriate organization (including staffing, skills, experience and knowledge) and processes ensuring a.o. that all requirements associated with safety remain fulfilled throughout the repository programme;
- To ensure that the implementer competently undertakes all relevant activities required to be implemented and to ensure the quality of the deliverables;
- To ensure that R&D programmes are appropriately focussed on safety-relevant issues and adequate for the management of uncertainties;
- To take into account international feedback from similar facilities elsewhere;
- To ensure that knowledge is transferred and that key information, data and their provenance are traceable, recorded and preserved.

The safety case should contain information about the implementation of the management system with particular emphasis on long project timescales (that typically extends over several decades or centuries) considerations and the iterative nature of the project over these timescales. In particular, the implementer will be expected to present activities to be carried out and targets to be reached prior moving to the next step.

As part of quality management, quality audits are needed, for example to provide [5]:

- Assurance that models, codes and data are fit-for-purpose and correctly applied;
- Assurance that scientific understanding within the assessment basis is state-of-the-art;
- Assurance that an approach to managing uncertainties has been implemented;
- Assurance that the facility has been constructed as designed and that any changes have been assessed for their effects on safety and incorporated in the safety case;
- Confidence in the adequacy and quality of the records of the wastes disposed of.

Evidence of quality audits will form part of long-term information management and record-keeping.

The implementer's management system needs progressively to improve and adapt so that it is suitable for each phase when that phase is reached. The implementer should substantiate that the allocation of appropriate resources is being updated and that needs for the next phase will be satisfied. In order to ensure that this is achieved, necessary adaptations need to be formulated in advance. In the early stages the regulator should be satisfied that the implementer will allocate and commit appropriate resources to the project. The long timescale for the process (i.e. several decades or centuries) requires confidence in the stability of the implementing organization such that the safety strategy and safety relevant information will be preserved irrespective of potential future changes in organizations or responsibilities.

Safety requirements associated with the management system are identified in Appendix 1 (Table A2).

7.2 NEEDED EXPERTISE

Expertise in management system and quality assurance (QA) (in general and specificities applying to nuclear facilities) is needed to verify compliance with safety requirements associated with the area of expertise "management".

7.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

The review and inspection activities that may have to be carried out at each development phase to verify compliance with safety requirements associated with the area of expertise "management" are given in the following table.

Table 3: review and inspection activities related to management.

Management **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Review of the management and quality assurance (QA) systems and more specifically: • Verification of implementer commitment to safety throughout all phases of the repository – from construction, operation to closure and the achievement of post-closure safety (SRL 1.1.2) • Verification that the management system is documented (SRL 1.3.5, 1.3.6) and continuously improved to achieve and enhance safety (SRL 1.3.1, 1.3.7) • Verification that an experience feedback programme is conducted and enforced SRL 1.3.7) • Verification that the management system encompasses all activities related to design, construction, operation, decommissioning, closure and after closure (SRL 1.3.3) and that a management process of the	X	X	X	X	X	

Management Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
requirements is in place • Verification that the quality management system covers all relevant properties and elements assumed in the safety case • Verification that the management system covers normal operation conditions, anticipated operational occurrence and possible accidents (SRL 1.3.2) • Verification that implementer's organisation has adequately defined: - Organisational structure (SRL 1.2.1) - Financial guarantees in place for decommissioning and managing any resulting waste - Resources (plans, staff, skills, experience, knowledge, training, …) (SRL 1.1.5, SRL1.2.2, 1.2.3, 1.2.5) - Capability to assess contractors activities (SRL 1.2.5) - Responsibilities of the implementer and delegated contractors - Implementer responsibilities (SRL 1.1.1, 1.1.3, 1.1.4, 1.1.6) - Interfaces between implementer responsibilities and those of the organisations responsible for the waste (SRL 1.1.8) - Processes • Verification that used safety standards are appropriate to the importance of safety of the activities (SRL 1.1.7) • Verification of QA processes to address all relevant requirements including processes to check compliance of the waste with WAC (SRL 1.3.4), and processes to record data and preserve knowledge (especially over long periods of time) (SRL 2.7.1, 2.7.2) • Verification that the management system ensures the transparency, the traceability and the consistency of the whole process						
Inspection of the effective implementation of the management and quality assurance (QA) systems (SRL 1.1.4): • Interview of people in charge of implementing the management and QA systems throughout the repository lifecycle • Examination of the procedures describing how the management and QA systems are implemented • Examination of QA records, workers / personnel's training records,	X	X	X	X	X	

Management Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
work permits, clearance, …						
• Observation of the safety culture						

7.4 NEEDED R&D ACTIVITIES

R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise "management" are limited to the participation in international working groups on the development and implementation of management and quality assurance (QA) systems.

8 Waste

8.1 INTRODUCTION

Expertise in the characterization, processes, phenomenology and modelling associated with the waste to be disposed of is needed to verify compliance with safety requirements related to the following issues (see Appendix 1):

- Design: prevention of the risks of criticality, possible disturbances, ...
- Waste acceptance
- Monitoring
- Characterisation, knowledge and system understanding: waste-related FEPs, …
- Uncertainties: identification of waste-related uncertainties and their management (R&D, ...)
- Scenario development
- Models used in the SA: source term modelling, modelling of interactions between the waste form and other repository components, …

The safety case will be periodically updated to incorporate information gained during the different phases of the project. This will include information about the waste as actually emplaced [3]. Elements such as waste package materials may also evolve. The significance of any changes to safety will need to be identified and assessed.

8.2 NEEDED EXPERTISE

The specific fields of expertise needed to verify compliance with safety requirements associated with the area of expertise “waste” are as follows:

- Waste characteristics (including waste types and streams)
- Waste characterization methods
- Waste processing and conditioning and packaging
- Waste acceptance criteria (WAC)
- Waste form, package and container behaviour (physical, (bio)-chemical, radiolysis) and modelling
- Criticality
- Waste handling

8.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

The review and inspection activities that may have to be carried out at each development phase or stage to verify compliance with safety requirements associated with the area of expertise “waste” are given in the following table.

Table 4: review and inspection activities related to waste.

Waste **Activities (by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Waste characteristics and processes						
Verification of the waste description (radiological and non-radiological characteristics of the waste, container characteristics, waste inventory and its evolution) (SRL 4.1.5, SRL 4.1.14), characterisation and testing including uncertainties (SRL 4.1.9)	X	X	X	X	X	
Verification of waste-related postulated initiating events (PIEs) and features, events and processes (FEPs) considered in the design of the repository (e.g.: heat and gas generation) (SRL 2.3.1-2.3.4, SRL 2.3.9) and in the safety assessment (SRL 4.1.8, SRL 4.2.1-2)	X	X	X	X	X	
Review of the programme (e.g. through R&D, investigations, modelling, testing and monitoring activities) aimed at improving and confirming the understanding of the waste evolution (SRL 2.1.8, SRL 2.4.3, SRL 4.3.2)	X	X	X	X	X	
Verification based on monitoring and when possible that the wastes behave and evolve as expected and that the impact of certain waste types on long term safety is as expected (SRL 2.4.3, SRL 4.3.2)					X	
Waste modelling						
Review of source term models (e.g., models of degradation, leaching, gas and heat production, representation of the radiological and hazardous source term in transport models, …) (SRL 2.3.5, SRL 4.2.6)	X	X	X	X	X	
Review of models used to assess criticality (e.g., to check whether the waste emplacement strategy will not cause criticality or to substantiate that in case of criticality occurring after closure, there would be no unacceptable adverse effect on post-closure safety) (SRL 2.3.5, SRL 4.2.5, SRL 4.2.6)	X	X	X	X	X	
Waste acceptance, emplacement and preservation						
Review of the arrangements for receiving, handling and emplacement of waste (SRL 2.6.4) and for dealing with waste packages that do not conform to WAC (SRL 3.3.4)	X	X	X	X	X	
Verification that appropriate WAC have been established including the verification that they ensure the compatibility of the waste with repository conditions (corrosion, mechanical loads, …) (SRL 2.6.7, SRL 3.1.1-5, SRL 3.2.1, SRL 4.3.2) and the safety case	X	X	X	X	X	
Verification that appropriate arrangements (including audits,	X	X	X	X	X	

Waste Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
procedures, inspections and/or tests) are developed / implemented to ensure compliance of the waste with WAC (SRL 1.3.4, SRL 3.3.1, SRL 3.3.3, SRL 4.3.2)						
Verification of the records of waste receipt and inventory (before and during operation) (SRL 2.7.1, SRL 3.3.2) and of the conformity of the waste with WAC (SRL 2.7.1, SRL 2.8.6, SRL 3.3.2): • Verification before the repository closure operations that the records faithfully describe the waste which is really contained in the repository and show that the waste is compatible with the repository	X	X	X	X	X	
Verification of the records of waste emplacement within the repository: • Verification that the waste records will be conserved in a durable way after the closure of the repository					X	X
Verification that operational limits and conditions (OLCs) will allow maintaining the waste in a safe state during operation (SRL 2.6.3, SRL 2.6.7)			X	X	X	

8.4 NEEDED R&D ACTIVITIES

This section describes the nature and purpose(s) of R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise "waste".

These activities may include:

- Independent source term model verification / validation (models of degradation, leaching, gas and heat production, representation of the radiological source term in transport models, …) (SRL 4.2.6)
- Independent verification of models used to assess criticality (SRL 4.2.6)
- Independent verification of material behaviour (e.g. comparison of active / inactive behaviour of matrix, degradation rate, …)
- Identification and analysis of waste-related uncertainties

Participation in international working groups.

9 Site

9.1 INTRODUCTION

Expertise in site characterization, phenomenology and modelling is needed to verify compliance with safety requirements related to the following issues (see Appendix 1):

- Site selection
- Design: compatibility with the host environment, design basis external events, …
- Construction: preservation of the safety functions of the host environment, ...
- Monitoring systems: baseline, confirmation of host rock behaviour and assumed site conditions, strengthening of system understanding, confidence building in models, verification of compliance with conditions of authorization, …
- Characterisation, knowledge and system understanding: Site-related FEPs, characterization programme, …
- Uncertainties: identification of site-related uncertainties and their management (R&D, ...)
- Scenario development
- Safety assessment models: modelling of host rock behaviour, radionuclide transport in the geosphere, biosphere, external events and processes (earthquakes, glaciation, …)

The safety case includes an analysis of the ability of the site to ensure the intended safety functions and meet technical and safety requirements [3] (feasibility, performance, robustness, …). Additionally, the assessment of the hazards associated with the repository requires sufficient knowledge, understanding and modelling capabilities of its environment.

In the early phases, the safety case will be used to guide the site investigation and characterization work required. The implementer should update the safety case progressively to incorporate information gained during the different phases of the project (site investigations, URL, construction). This will include the growing body of data about the geological environment of the repository as well as other advances in understanding [3]. In particular, the safety case will need to take into account experience and information derived from any construction activities. If there are any unexpected events of significance to safety during the construction, operational and closure periods, the safety case should report these and account for any consequences that they may have on the safety arguments.

9.2 NEEDED EXPERTISE

The specific fields of expertise needed to verify compliance with safety requirements associated with the area of expertise “site” include:

- Geo(bio)chemistry, and radionuclide transport
- Geology
- Geomorphology

- Hydrogeology
- Seismology
- Soil and rock mechanics
- Climatology
- Biosphere
- Microbiology

Each of these fields of expertise necessarily implies skills in both characterisation and modelling. A multidisciplinary approach encompassing these specific fields of expertise is also needed to deal with coupling between different types of processes. Therefore, an appropriate combination of generalists and specialists in each considered field is generally required.

9.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

The review and inspection activities that may have to be carried out at each development phase to verify compliance with safety requirements associated with the area of expertise "site" are given in the following table.

Table 5: review and inspection activities related to site.

Site **Activities** (by phase)	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Characterization & Monitoring						
Verification that the characterisation programme of the selected site(s) provides the data necessary to support the safety case (SRL 2.2.1, SRL 2.2.2): • To identify / characterise safety-relevant host rock properties and uncertainties • To establish baseline conditions for the site and the environment • To support the understanding of the normal evolution • To support the identification of possible disturbing features, events and processes (FEP's) associated with the site and the disposal facility • To support the understanding of the effect on safety of any features, events and processes	X	X	X	X	X	

Site Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
Verification that an appropriate and systematic monitoring programme of site characteristics is established (SRL 2.4.2) i.e. that allows to (SRL 2.4.3, 2.5.3): • Contribute to demonstrating adequate protection of people and the environment and demonstrating compliance with the regulatory requirements and licence conditions • Confirm that the disposal facility and system behaves and evolves as expected in the safety case • Identify any deviations from the expected behaviour of the repository • Contribute to confirming and refining the key assumptions and models made in the safety case • Enhance understanding of the environmental conditions and of the functioning of the repository • Acquire data for supporting decision-making, and • Provide background information for any post-closure surveillance programme		X	X	X	X	X[1]
Verification that a baseline state of the site and the host environment is established before starting construction and that the baseline conditions are adequate (SRL 2.4.1): • for supporting the monitoring programme, and • for evaluating the impact of the facility on the environment		X	X	X	X	
Review of field investigation procedures (e.g., data acquisition, treatment procedures, how records are maintained, …)	X	X	X	X	X	
Verification of the effective and appropriate implementation of investigation procedures: • Verification of field investigation and monitoring records(SRL 2.3.11) • Inspection of safety-relevant data measurement activities and devices performed by or for the (future) implementer (piezometric measurements, …) • Independent tests / measurements as appropriate		X	X	X	X	

[1] Duration of monitoring during the post-closure phase is country-specific.

Site Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
Safety assessment						
Review of documentation / data / models related to site and formation properties and behaviour: • Information / models demonstrating the host rock performance • Identification of safety-relevant characteristics, parameters and uncertainties (sensitivity analyses) • External perturbations considered in the design and the assessment (e.g. seismicity, glaciation, erosion, uplift, ...) • Influence of external perturbations on the containment / isolation capabilities of geological barriers • Potential interactions and compatibility between waste / EBS and the host rock • Radionuclide migration / transport processes • Monitoring data (e.g., verification that the host rock behaves as expected following construction and during operation)	X	X	X	X	X	X
Verification that the site contributes to contain and to isolate the radioactive waste from the human and from the accessible biosphere until the radioactive decay has significantly reduced the hazard posed by the waste (IAEA SSR5-R-8 and SSR5-R-9, SRL 2.1.5)	X	X	X	X	X	X
Review of the different options related to the host-rock and the site in order to verify that the decisions are the result of an optimisation process of the safety (SRL 2.1.4)	X	X				
Implementer R&D programme						
Verification that an appropriate programme to improve and confirm the understanding of the evolution of the repository (e.g. through R&D, investigations, modelling, testing and monitoring activities) is defined and implemented by the operator (SRL 2.1.8)	X	X	X	X	X	
Excavation						
Verification that excavation methods and procedures allow preserving host rock performance			X	X	X	
OLCs & Waste acceptance criteria						
Verification that the operational limits and conditions (OLCs) ensure			X	X	X	

Site Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
preservation of host rock performance (SRL 2.6.3)						
Verification of the criteria specified to ensure that waste accepted for disposal is physically and chemically stable and compatible with the host rock (SRL 3.1.4)	X	X	X	X	X	

9.4 NEEDED R&D ACTIVITIES

This section describes the nature and purpose(s) of R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise "site".

Most of these activities are potentially needed from the conceptualisation phase but will be progressively developed and refined as new information becomes available (monitoring, construction, in situ testing, …).

Participation in international working groups.

Table 6: R&D activities related to site.

Site Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
Identification, understanding, characterization and completeness check of: • The processes on which migration of radionuclides (and non-radioactive species if relevant) and safety functions assigned to the host rock rely • Design basis external events and processes (earthquakes, glaciations, erosion, subsidence, uplift, ...) • Perturbations of the EBS safety functions originating from the host rock (e.g. concrete carbonation, clogging, …) • Effects of construction and exploitation on the host rock safety functions (oxidation, microbial activity, ...) • Effects of internal (alkaline and nitrate plumes, gas generation, thermal perturbation, ...) and external perturbations (erosion,	X	X	X	X	X	

Site Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
glaciations, human activities, ...) on the host rock safety functions • The processes that may contribute to the resilience capacities of the host rock • FEP's that can have an effect on the radiological impact by affecting the environment of the repository						
Review and conduct independent research on the potentially suitable geological formations	X	X				
Verification of the feasibility of construction (SRL 4.1.2)	X	X	X	X	X	
Identification of safety-relevant characteristics, parameters and uncertainties (sensitivity analyses)	X	X	X	X	X	
Verification of values of safety-relevant characteristics and parameters	X	X	X	X	X	
Independent model verification / validation (model of radionuclide transport in the host rock and the geosphere, biosphere models, ...)	X	X	X	X	X	

10 Engineering

10.1 INTRODUCTION

Expertise in EBS characterization, phenomenology, modelling, design and construction is needed to verify compliance with safety requirements related to the following issues (see Appendix 1):

- Site selection: consideration of the feasibly of design implementation
- Design
- Construction: construction in accordance with the design, and to ensure preservation of the host rock, ...
- Operation: investigations and feedback of information on operating experience, operational limits and conditions, modifications, …
- Monitoring: baseline, confirmation of assumed EBS behaviour, strengthening of system understanding, confidence building in models, verification of compliance with conditions of authorization, …
- Characterisation, knowledge and system understanding: EBS-related FEPs, …
- Uncertainties: identification of EBS-related uncertainties and their management (R&D, ...)
- Scenario development
- Safety assessment models: modelling of EBS behaviour, radionuclide transport in the EBS, internal events and processes (e.g. gas migration, alkaline plume, heat output, …)

The safety case includes an analysis of the ability of the engineered components of the repository to provide the safety functions and meet technical and safety requirements. Additionally, the assessment of the hazards associated with the facility requires sufficient knowledge, understanding and modelling capabilities of these components.

The safety case will be periodically updated to incorporate information gained during the different phases of the project. This will include information about the facility as actually built, new developments such as new buffer materials or construction materials as well as any other advances in understanding [3]. In particular, the safety case will need to take into account experience and information derived from any construction activities continuing in parallel with operation of the facility.

The design may also evolve to some extent during the development of the disposal facility due e.g. to new engineering techniques or materials or to the feedback from operational activities or monitoring [3]. Before making any changes to systems or procedures, consideration should be given to whether the safety case is valid for the modification in question. Depending on the activities under the licence, there may be requirements for the implementer to submit changes to the regulator for approval. The significance of these changes will need to be assessed. If there are any unexpected events of significance to safety during the construction and operational phases, the implementer needs to report these and to account for any consequences that they may have on the safety arguments in the safety case.

10.2 NEEDED EXPERTISE

The specific fields of expertise needed to verify compliance with safety requirements associated with the area of expertise "engineering" are as follows:

- (Bio)geochemistry and radionuclide transport
- Geotechnics
- Civil and mining engineering
- Material sciences (concrete, corrosion, mechanics, thermal load, …)
- Hydraulics
- Handling systems

Each of these fields of expertise necessarily implies skills in both testing and modelling methods. A multidisciplinary approach encompassing these specific fields of expertise is also needed to deal with coupling between different types of processes. Therefore, an appropriate combination of generalists and specialists in each considered field is generally required.

10.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

The review and inspection activities that may have to be carried out at each development phase to verify compliance with safety requirements associated with the area of expertise "engineering" are given in the following table.

Table 7: review and inspection activities related to engineering.

Engineering **Activities** (by phase)	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Design and design basis						
Verification that the design basis (i.e., the range of conditions and events taken explicitly into account in the design) is properly accounted in the design (SRL 2.3.2, SRL 2.3.3, SRL 2.3.4)	X	X	X	X	X	
Verification that the disposal facility is designed so that the engineered components (including barriers) are physically and chemically compatible with each other, with the waste disposed of and with the host rock/environment (SRL 2.3.9) and compatible with the corresponding requirements of the safety case	X	X	X	X	X	
Verification that the engineered structures, systems and components (SSCs) have been identified and classified in accordance with their	X	X	X	X		

Engineering Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
importance for operational and post-closure safety (SRL 2.3.6)						
Verification that the design of the facility is based on applicable standards, appropriately proven techniques and the use of appropriate materials to ensure that the safety requirements will be met (SRL 2.3.7)	X	X	X			
Verification that any provisions taken to facilitate reversal of disposal operations, or retrieval of waste packages disposed of, have no unacceptable adverse effects on post-closure safety (SRL 2.1.7)	X	X	X	X		
Verification that there is adequate provisions for maintenance, testing, inspection and monitoring of structures, systems and components (SSCs), addressing also their ageing (SRL 2.3.10)	X	X	X	X	X	
Verification that any design modifications will not have an unacceptable effect on operational and post-closure safety (SRL 2.6.6)				X	X	
Construction						
Verification of the feasibility of the technical options (SRL 2.3.1)	X	X	X	X	X	
Review of construction methods and procedures, e.g., • Verification that the facility will be constructed by application of appropriately proven techniques (SRL 2.5.1) • Verification that the facility will be constructed in such a way as to fulfil the safety functions of the EBS (e.g., review of the material specifications, …) • Verification that the facility will be constructed in such a way as to preserve the post-closure safety functions of the host environment (SRL 2.5.2) • Verification that the experience feedback from the project development and from other facilities is properly taken into account (SRL 1.3.7)			X	X	X	
Verification that the disposal facility is / has been constructed in accordance with the design as described in the safety case (SRL 2.5.1): • Verification that construction procedures and material specifications are correctly applied (e.g., examination of construction records, …) • Non-destructive testing (NDT) of EBS safety-relevant properties as appropriate • Inspection of safety-relevant data measurement and testing activities				X	X	

Engineering **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
and devices performed by or for the implementer						
Interviews and observation of all parties involved in construction (management, workers, contractors, sub-contractors, …) to verify that they have a strong safety culture				X	X	
Monitoring						
Verification that before starting construction, a systematic monitoring programme of the EBS behaviour is established (SRL 2.4.2) that allows to (SRL 2.4.3): • Contribute to demonstrating adequate protection of people and the environment and demonstrating compliance with the regulatory requirements and licence conditions • Confirm that the disposal facility and system behaves and evolves as expected in the safety case • Identify any deviations from the expected behaviour of the repository • Contribute to confirming and refining the key assumptions and models made in the safety case • Enhance detailed understanding of the environmental conditions and of the functioning of the repository • Acquire data for supporting decision-making, and • Provide background information for any post-closure surveillance programme			X	X	X	
Examination of monitoring records Verification of EBS behaviours following construction and during operation (e.g. verification that the observed perturbations will not jeopardize the safety): • Behaviour of as-build EBS • Behaviour of “Dummy test” EBS (or demonstration test)	X	X	X	X X	X X	
Safety assessment						
Review of documentation / data / models related to EBS properties and behaviour: • Information / models demonstrating the EBS performance /	X	X	X	X	X	

Engineering **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
robustness • Internal perturbations considered in the design and the assessment (gas generation, ...) • Influence of internal and external perturbations on the safety functions of EBS • Potential interactions and compatibility between waste / host rock and the EBS • Radionuclide migration / transport processes • Review of monitoring data, e.g., verification of EBS / host rock system behaviour following construction and during operation: - Behaviour of as-built EBS - Behaviour of EBS in an URL						
Verification that the design of the repository and its engineered barriers effectively provide operational and post-closure safety (SRL 2.3.1)	X	X	X	X	X	
Review of the different options related to the EBS in order to verify that the decisions are the result of an optimisation process of the safety (SRL 2.1.4, SRL 4.1.10)	X	X	X	X	X	
Implementer R&D programme						
Verification that an appropriate programme to improve and confirm the understanding of the evolution of the EBS (e.g. through R&D, investigations, modelling, testing and monitoring activities) is defined and implemented by the operator (SRL 2.1.8)	X	X	X	X	X	
OLCs & Waste acceptance criteria						
Verification that the operational limits and conditions (OLCs) ensure preservation of EBS performance (SRL 2.6.3)			X	X	X	
Verification of the criteria specified to ensure that waste accepted for disposal is physically and chemically stable and compatible with the EBS (SRL 3.1.4)	X	X	X	X	X	

10.4 NEEDED R&D ACTIVITIES

This section describes the nature and purpose(s) of R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise "engineering".

These activities are potentially needed from the conceptualisation phase but will be progressively developed and refined as new information becomes available (monitoring, construction, in situ testing, …). In addition, participation in international working groups may also be helpful as part of the R&D activities to verify compliance in the area of "engineering".

Table 8: R&D activities related to engineering.

Engineering **Activities (by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Identification, understanding, characterization and completeness check of: • The processes on which migration of radionuclides and safety functions assigned to the EBS rely • Perturbations of the host rock safety functions originating from the EBS (alkaline plume, gas generation, sealing of access structures, …) (SRL 2.3.9) • Effects of construction and exploitation on the EBS safety functions (oxidation / reduction, microbial activity, ...) • Effects of internal (alkaline and nitrate plumes, gas effects, thermal perturbation, ...) and external perturbations (earthquake, erosion, glaciations, human activities, ...) on the EBS safety functions (SRL 2.3.9, …) • The processes that may contribute to the resilience capacities of EBS	X	X	X	X	X	
Verification of potentially suitable design options, materials, …	X	X	X	X	X	
Verification of the feasibility of construction (to preserve the host rock and also maintain worker safety) and closure (SRL 4.1.2)	X	X	X	X	X	
Identification of safety-relevant characteristics, parameters and uncertainties (sensitivity analyses)	X	X	X	X	X	
Verification of values of safety-relevant characteristics and parameters	X	X	X	X	X	
Independent model verification / validation (model of radionuclide transport in EBS, ...)	X	X	X	X	X	

11 Operational safety

11.1 INTRODUCTION

Expertise in the different aspects associated with operational safety is needed to verify compliance with safety requirements related to the following issues (see Appendix 1):

- Design: design of the handling equipment, design basis accidents, …
- Operation: investigations and feedback of information on operating experience; operational limits and conditions, occupational and public exposure; handling and emplacement of waste, …
- Waste acceptance: criteria ensuring operational safety, ...
- Monitoring: monitoring of occupational exposures, environmental monitoring, ...
- Characterisation, knowledge and system understanding: use of operating experience, …
- Models
- Operational safety assessment

The safety case includes an analysis of the hazards associated with the facility during operation and the ability of the operational procedures to provide the safety functions and meet technical and safety requirements. The safety case needs to be updated progressively to incorporate information gained during the different phases of the project [3]. For any changes motivated by feedback from operational activities or monitoring such as new operating practices, packaging materials, emplacement techniques or configurations, consideration should be given to whether the safety case is valid for the modification in question. Depending on the activities under the licence, there may be requirements for the implementer to submit changes to the regulatory body for approval. If there are any unexpected events of significance to safety during the construction or the operational period, the safety case should identify these and account for any consequences that they, and any changes made to operating practices as a result of them, may have on the safety arguments in the safety case.

11.2 NEEDED EXPERTISE

The specific fields of expertise needed to verify compliance with safety requirements associated with the area of expertise “operational safety” are as follows:

- Radiation protection
- Environmental monitoring
- Conventional health and safety (including explosion risks, fire protection, mine ventilation, scaling, …) (also need during construction phase)
- Mine engineering – work in (nuclear) underground facilities
- Decommissioning of surface and underground infrastructures
- Human factors / risks
- Safety Culture (part of management system)

- Risk analysis (HAZOP, …)
- Waste emplacement techniques
- Emergency preparedness
- Seismicity, hydrology, geology

11.3 NEEDED REVIEW AND INSPECTION ACTIVITIES

The review and inspection activities that may have to be carried out at each development phase to verify compliance with safety requirements associated with the area of expertise "operational safety" are given in the following table.

Table 9: review and inspection activities related to operational safety.

Operational safety **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Safety assessment						
Review of the postulated initiating events (PIEs) (SRL 2.3.2) and issues relevant to operational safety (documentation / data/ models), e.g.: • Concurrent activities (SRL 2.1.9) • Natural hazard during operation (earthquakes, floods, …) • Operational accidents (fire safety, …) • Ventilation • Waste emplacement strategy • Criticality	X	X	X	X	X	
Review of the operational safety assessment (SRL 4.2.1) including the verification that: • both occupational exposure and public exposure resulting from normal operation, and anticipated operational occurrences and possible accidents is considered (SRL 4.2.1) • all safety functions associated with operational safety are achieved during normal operation, anticipated operational occurrences and possible accidents (SRL 2.3.5) • the handling equipment is designed to take account of radiation protection aspects, ease of maintenance, and minimization of the probability and consequences of anticipated operational occurrences and possible accidents during handling (SRL 2.3.13)	X	X	X	X	X	

Operational safety **Activities** **(by phase)**	**Concept**	**Siting**	**Ref. Design**	**Construction**	**Operation**	**Post closure**
Verification that the implementer aims for an optimized level of safety (SRL 2.1.4) and that the safety case shows that operational choices and decisions derive from a process involving optimization of radiological protection (SRL 4.1.10)	X	X	X	X	X	
Verification that the safety case is updated to reflect results from analysis of operational occurrences and accidents (SRL 4.1.14) and design modifications	X	X	X	X	X	
Technical feasibility						
Verification of the technical feasibility of operation and decommissioning (SRL 4.1.2) and closure activities (e.g. sealing structures)	X	X	X	X	X	
Measurements and monitoring						
Review of the monitoring programme of occupational exposure (SRL 2.4.2)			X	X	X	
Verification of the provisions made for detecting anticipated operational occurrences and possible accidents (SRL 2.6.2)			X	X	X	
Examination of monitoring records and devices of occupational exposure (radiation, radon, …)				X	X	
Verification and independent dose / contamination measurements				X	X	
Operational limits and conditions (OLCs)						
Verification that the OLCs allow operating the facility safely (SRL 2.6.3)				X	X	
Verification of compliance with OLCs (SRL 2.6.3)					X	
Operational processes and procedures						
Review of operational processes and procedures including the verification that: • they cover normal operation conditions, anticipated operational occurrences and possible accidents (SRL 1.3.2) • all documents required for an activity (e.g.: operational procedures, operating instructions) have been prepared before beginning that activity (SRL 1.3.6)			X	X	X	
Verification that operational procedures are properly applied (in construction phase, this would be conventional health and safety)				X	X	
Review of operational process and procedure modifications (in				X	X	

Operational safety Activities (by phase)	Concept	Siting	Ref. Design	Construction	Operation	Post closure
construction phase, this would be conventional health and safety)						
Interviews and observation of all parties involved in operations (managements, workers, contractors, sub-contractors, …) to verify that they have a sufficient safety culture (in construction phase, this would be conventional health and safety)				X	X	
Maintenance, testing and inspections						
Verification that appropriate maintenance, periodic testing, and inspection programmes ensuring and confirming that SSCs are able to function in accordance with the requirements for operational safety are established, implemented (SRL 2.6.12) and revised as necessary (SRL 2.6.14)			X	X	X	
Verification that the results of maintenance, periodic testing, and inspection are recorded, assessed (SRL 2.6.13) and taken into account a.o. in the PSR (SRL 4.3.2)				X	X	
Emergency plan						
Verification that an appropriate emergency plan responding to possible accidents requiring protection of the personnel and/or members of the public is prepared, implemented and updated in light of the experience gained (SRL 2.6.8, 2.6.9, 2.6.11)				X	X	
Decommissioning						
Review of the decommissioning programme and associated financial guarantees (SRL 2.8.3)	X	X	X	X	X	
Verification that structures, systems and components (SSCs) that are not needed after closure or that may affect post-closure safety are safely dismantled and decommissioned as required (SRL 2.8.2, 2.8.4)				X	X	

11.4 NEEDED R&D ACTIVITIES

This section describes the nature and purpose(s) of R&D activities considered as suitable for verifying compliance with safety requirements associated with the area of expertise “operational safety”.

R&D activities may include independent model verification / validation:

- Gas release
- Operation accidents (fire initiation and propagation, explosion, …)

- Ventilation
- Radiation shielding
- Criticality
- Construction accidents (explosion, fire, conventional health and safety, ventilation codes), …

In addition, participation in international working groups, collaboration may form part of the R&D programme to verify compliance in "operational safety".

12 Synthesis

The regulatory review process should begin at the earliest stage in the development of a repository. This may be in the pre-licensing stage (before a licence is granted) and may include informal reviews and observational inspections to provide guidance to the implementer.

Table 10 gives a synopsis of the needed review, inspection and R&D activities identified in sections 6 to 11 as a function of the repository development stages.

The independent regulatory R&D programme as well as most of the technical issues related to safety strategy and policy, management, waste and site should be initiated from the beginning (i.e. from the "conceptual phase"). Design, feasibility and safety assessment issues related to Engineering and Operational safety have also to be considered from the beginning but implementation aspects like construction and operational issues could be investigated from the "reference phase".

In addition, participation in international working groups, collaboration may form part of the regulatory body's R&D programme.

Table 10: general overview of the needed activities (review / inspection, R&D) for the six areas of expertise as a function of the 6 repository development stages or phases.

Areas of expertise Safety topics (object of the regulatory activity)	Activity (by Phase or stage) Ref. Fig 3	Conceptualisation	Siting	Reference design	Construction	Operational	Post-closure
Safety strategy & policy							
	Rev./Insp.	X	X	X	X	X	
	R&D	X	X	X	X	X	
Management							
	Rev./Insp.	X	X	X	X	X	
	R&D	X	X	X	X	X	
Waste							
Waste characteristics and processes	Rev./Insp.	X	X	X	X	X	
Waste modelling		X	X	X	X	X	
Waste acceptance, emplacement and preservation		X	X	X	X	X	
	R&D	X	X	X	X	X	
Site							
Characterization and monitoring	Rev./Insp.	X	X	X	X	X	X
Safety assessment		X	X	X	X	X	X
Implementer R&D programme		X	X	X	X	X	
Excavation				X	X	X	
OLCs & waste acceptance criteria		X	X	X	X	X	
	R&D	X	X	X	X	X	X
Engineering							
Design and design basis	Rev./Insp.	X	X	X	X	X	
Construction		X	X	X	X	X	
Monitoring				X	X	X	
Safety assessment		X	X	X	X	X	
Implementer R&D programme		X	X	X	X	X	
OLCs & waste acceptance criteria		X	X	X	X	X	
	R&D	X	X	X	X	X	
Operational safety							
Safety assessment	Rev./Insp.	X	X	X	X	X	
Technical feasibility		X	X	X	X	X	
Measurements and monitoring				X	X	X	
Operational limits and conditions					X	X	
Operational processes and				X	X	X	
Maintenance, testing and				X	X	X	
Emergency plan					X	X	
Decommissioning		X	X	X	X	X	
	R&D	X	X	X	X	X	

13 Conclusions

Demonstrating the safety of repository is a process that needs to be undertaken systematically and through all phases/stages of the development and implementation of a disposal facility. Uncertainties must be adequately managed, safety arguments must be continuously refined and supporting safety assessments must be undertaken iteratively as the disposal facility is developed.

The regulatory process involves reviews, inspections and R&D activities to perform an independent assessment of compliance with safety requirements. The overall goal is to verify that the disposal facility will not cause an unacceptable adverse impact on human health or safety, or on the environment, both now and in the future.

The overall pre-licensing and licensing process for the establishment of a disposal facility is likely to be based on a step-wise process, where each authorization to move from one phase to another is based on an appropriate (updated) safety case. A first authorization (e.g. a general license or a site license) is followed by subsequent authorizations for e.g. start of construction, start of commissioning, start of trial operation, and start of routine operation.

The safety case submitted by the implementer in support for a governmental/regulatory authorization/decision to proceed must address all regulatory requirements relevant for the authorization at hand, i.e. the safety case will be successively developed and encompass additional and more detailed information.

From a formal point of view, the first authorization need to address fulfillment of regulatory requirements relevant for that authorization. But, it is all the same necessary that the implementer has satisfied himself and the regulatory body that he will be able to demonstrate compliance with regulatory requirements for also subsequent authorizations. The main reason being to avoid the overall licensing process being severely delayed or halted due to the sudden/late identification of non-compliance with regulatory requirements at a later stage.

It is therefore necessary that the implementer at an early stage identifies the safety issues (a complete set) for which compliance demonstration will be requested during all authorization steps. From this list of regulatory issues, the implementer should then identify what requirements need to be addressed – and to what extent compliance demonstration is needed – for each governmental/regulatory authorization/decision in the step-wise pre-licensing and licensing process.

The report provides an identification of the main key technical issues that must be assessed by the regulatory body at the different stages of repository development and identify the expertise and technical support needed to perform this independent assessment. For the purpose of this work, six areas of expertise covering most of the safety issues to be considered in a safety case have been defined: safety strategy and policy, management, waste, site, engineering, and operational safety.

The report points out that the regulatory review process for most of the technical issues should begin at the earliest stage in the development of a disposal facility (i.e. from the “conceptual phase”). Implementation aspects related to construction and operational issues could be investigated later (i.e. from the “reference phase”).

During the pre-licensing phase the process can be organized within the framework of a “service agreement” between the regulatory body and the future implementer.

In addition, participation of the country’s regulatory body and technical expertise in international working groups, collaboration with other regulatory bodies is important. Therefore, it is important to set up an international platform for regulatory bodies and expertise to commence and continue this discussions and collaborate on R&D.

14 Acknowledgement

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15 References

1. IAEA (2011). Disposal of radioactive waste. Specific safety requirements SSR-5.
2. CEC (2011). The Council of the European Union (2011). Council Directive 2011/70/EURATOM of 19 July 2011 establishing a community framework for the responsible and safe management of spent fuel and radioactive waste.
3. EPG (2010). Draft report of the European pilot study on the regulatory review of a safety case for geological disposal of radioactive waste (draft version for consultation).
4. IAEA (2012). The safety case and safety assessment for the disposal of radioactive waste. Safety Standards Series SSG-23.
5. IAEA (2002). Regulatory inspection of nuclear facilities and enforcement by the regulatory body. Safety Guide GS-G-1.3.
6. NEA (2011). Regulatory research for waste disposal – Objectives and international approaches. RWMC Regulators' Forum (RWMC-RF), NEA/RWM/RF(2010)4.
7. IAEA (2002). Organization and staffing of the regulatory body for nuclear facilities. Safety Guide GS-G-1.1.
8. IAEA (2002). Review and assessment of nuclear facilities by the regulatory body. Safety Guide GS-G-1.2.
9. WENRA (2012). Working group on waste and decommissioning, radioactive waste disposal safety reference levels, Draft report V1.4.2.
10. ICRP (2013). Publication 122. Radiological protection in geological disposal for long-lived solid radioactive waste.
11. SITEX (2013) Deliverable D2.1 – Overview of existing technical guides and further development.

Appendix 1 Safety issues identified in WP2.1 and related safety requirements[2]

Table A1. Safety requirements associated with governing principles, safety policy and strategy.

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
Governing principles			**Article 4.3**
*** Radiation protection**		**GSR Part3-R1 GSR Part3-R19 GSR Part3-R29**	**ICRP103-Ch5 ICRP103-Ch6**
- Justification		**SF-1-P4 GR Part3-R10**	
- Optimisation of protection	**SRL 2.1.1 SRL 2.1.4**	**SF-1-P5 GSR Part3-R11 SSR-5-R4**	**Article 5.1e Article 7.2**
- Limitation of risks to individuals		**SF-1-P6 GSR Part3-R12**	
+ Operational period		**SSR-5-§2.7-14**	
+ Post-closure period		**SSR-5-§2.15-19**	
*** Protection of present and future generations**		**SF-1-P7**	
*** Protection of the environment**		**SSR-5-§2.21-23**	
*** Defence in depth & Robustness**	**SRL 2.1.2 SRL 2.1.6 SRL 2.3.5**	**SF-1-P8 GSR Part3-R15 SSR-5-R7**	**Article 7.3**
*** Good engineering practice, proven techniques & feasibility**	**SRL 2.3.1 SRL 2.3.7 SRL 2.5.1**	**GSR Part3-R15**	
*** Passivity**	**SRL 2.1.3**	**SSR-5-R5**	**Article 4.3c**
*** Containment & Isolation**	**SRL 2.1.5 SRL 2.1.6 SRL 2.3.5**	**SSR-5-R8 SSR-5-R9**	
*** Reversibility/Retrievability vs. Safety**	**SRL 2.1.7**		
*** Graded approach**	**SRL 2.1.1**	**GSR Part3-R6**	**Article 4.3d**
*** Stepwise approach**		**SSR-5-R11**	
*** Concurrent activities**	**SRL 2.1.9**		
*** Responsibility for safety** (see issue "responsibilities")		**SF-1-P1**	
*** Leadership and management for safety** (see issue "Management")		**SF-1-P3**	

[2] Based on v.6 of the WP2.1 topic list

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
*** Emergency preparedness and response** (See issue "operation")		**SF-1-P9** **GSR Part3-R15** **GS-R-2**	
Safety policy & strategy	**SRL 1.1.3** **SRL 1.2.1** **SRL 1.3.5** **SRL 2.1.10** **Appendix 3**	**GSR Part4-R22** **GSR Part4-R23** **SSR-5-R4**	

Table A2. Safety requirements associated with the management.

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
Management		**SF-1-P3 GSR Part3-R5 GSR Part3-R24 GRS3 WS-R-5-Chapt.7**	**Article 7.4**
*** Responsibilities**	**SRL 1.1.1 SRL 1.1.2 SRL 1.1.3 SRL 1.1.4 SRL 1.1.5 SRL 1.1.6 SRL 1.1.7 SRL 1.1.8**	**SF-1-P1 GSR Part3-R4 GSR Part3-R9 GSR Part3-R21 GSR Part3-R22 GSR Part3-R30 GSR Part4-R3 WS-R-5-Chapt.3 SSR5-R3**	**Article 7.1**
*** Organisational structure**	**SRL 1.2.1 SRL 1.2.2 SRL 1.2.3 SRL 1.2.4 SRL 1.2.5 SRL 2.6.14**	**GSR Part3-R23 GS-R-2-§3.12 GS-R-2-§3.1-5-§3.10-11 GRS3-Section5**	
*** Management system**	**SRL 1.3.1 SRL 1.3.2 SRL 1.3.3 SRL 1.3.4 SRL 1.3.5 SRL 1.3.6 SRL 1.3.7**	**GRS3-Section5 GSR Part4-R22 SSR-5-R25**	**Article 7.2**
*** Records & knowledge keeping**	**SRL 2.7.2**		

Table A3. Safety requirements associated with the different stages of repository development.

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
Site selection		**SSR-5-R4 SSR-5-R7 SSR-5-R8 SSR-5-R9**	
Design	**SRL 2.3.1 SRL 2.3.2 SRL 2.3.3 SRL 2.3.4 SRL 2.3.5 SRL 2.3.6 SRL 2.3.7 SRL 2.3.8 SRL 2.3.9 SRL 2.3.10 SRL 2.3.11 SRL 2.3.12 SRL 2.3.13 SRL 2.3.14**	**SSR-5-R7 SSR-5-R8 SSR-5-R9 SSR-5-R16**	
Construction	**SRL 2.5.1 SRL 2.5.2 SRL 2.5.3 SRL 2.5.4**	**SSR-5-R17**	
Operation	**SRL 2.6.1**	**SSR-5-R7 SSR-5-R8 SSR-5-R9 SSR-5-R18**	
*** Investigations and feedback of information on operating experience**	**SRL 2.6.2**	**GSR Part3-R16**	
*** Operational limits and conditions**	**SRL 2.6.3**		
*** Modifications**	**SRL 2.6.6 SRL 2.6.7**		
*** Emergency preparedness and response**	**SRL 2.6.8 SRL 2.6.9 SRL 2.6.10 SRL 2.6.11**	**SF-1-P9 GSR Part3-R15 GSR Part3-R43-46 GS-R-2**	
*** Maintenance, periodic testing and inspection**	**SRL 2.6.12 SRL 2.6.13 SRL 2.6.14**	**SSR-5-R10**	
*** Occupational exposure**		**GSR Part3-R19 GSR Part3-R24 GSR Part3-R25 GSR Part3-R26**	

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
* Public exposure		GSR Part3-R29 GSR Part3-R30 GSR Part3-R31	
* Receiving, handling and emplacement of waste	SRL 2.6.4 SRL 2.3.13		
Closure & Decommissioning	SRL 2.6.5 SRL 2.8.1 SRL 2.8.2 SRL 2.8.3 SRL 2.8.4 SRL 2.8.5 SRL 2.8.6	SSR-5-R19 WS-R-5	
Period after closure and institutional controls	SRL 1.1.6 SRL 2.1.1 SRL 2.6.5 SRL 2.9.1 SRL 2.9.2 SRL 4.1.2 SRL 4.1.5 SRL4.1.11	SSR-5-R10 SSR-5-R21 SSR-5-R22	

Table A4. Safety requirements associated with waste acceptance and monitoring.

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
Waste acceptance	SRL 2.7.1 SRL 3.1.1 SRL 3.1.2 SRL 3.1.3 SRL 3.1.4 SRL 3.1.5 SRL 3.2.1 SRL 3.3.1 SRL 3.3.2 SRL 3.3.3 SRL 3.3.4	SSR-5-R20	
Monitoring	SRL 2.2.2 SRL 2.3.10 SRL 2.3.11 SRL 2.4.1 SRL 2.4.2 SRL 2.4.3	GSR Part3-R14 SSR-5-R10 SSR-5-R21	
* Occupational exposure		GSR Part3-R20 GSR Part3-R24	
* Public exposure		GSR Part3-R32	

Table A5. Safety requirements associated with the safety case and assessment.

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
Safety case and assessment		**GSR Part3-R13**	**Article 7.2**
*** Objectives and scope**	**SRL 4.1.1 SRL 4.1.2**	**GSR Part4-R2 GSR Part4-R4 GSR Part4-R14 SSR-5-R13**	
*** Graded approach**	**SRL 4.1.13**	**GSR Part4-R1**	**Article 7.3**
*** Safety Case/ Safety Assessment content vs. regulatory decision steps**	**SRL 4.1.4 SRL 4.1.5 SRL 4.1.6 SRL 4.1.7 SRL 4.1.10 SRL 4.1.11 SRL 4.1.12 SRL 4.1.14 SRL 4.1.15**	**GSR Part4-R5 SSR-5-R11 SSR-5-R12 GSR Part4-R20 SSR-5-R14**	**Article 7.3**
*** Characterization, knowledge and system understanding**	**SRL 2.1.8 SRL 2.4.3 SRL 4.1.6 SRL 4.1.8**	**SSR-5-R6**	
- Waste			
- Engineered components			
- Site	**SRL 2.2.1 SRL 2.2.2 SRL 2.5.3**	**GSR Part4-R8 SSR-5-R15**	
- Use of operating experience & monitoring data		**GSR Part4-R19**	
*** Safety assessment methodologies, approaches & tools**			
- Timescales and timeframes	**SRL 4.2.4**	**GSR Part4-R12**	
- Assessment of the possible radiation risks		**GSR Part4-R6**	
- Uncertainties	**SRL 4.1.9**	**GSR Part4-R17**	**Article 7.3**
- Deterministic vs. probabilistic approaches		**GSR Part4-R15**	
- Conservative & realistic assessments			
- Scenarios	**SRL 2.1.6 SRL 2.3.3 SRL 4.1.8 SRL 4.2.2**		
- Models	**SRL 2.4.3 SRL 4.1.7 SRL 4.2.6**	**GSR Part4-R18**	
*** Indicators & criteria**		**GSR Part4-R16 SSR-5-R13-§4.21**	

	Requirements		
SAFETY ISSUEs	**WENRA SRLs**	**IAEA Principles & Requirements**	**EC directive 2011/70/Euratom ICRP Recommendations**
*** Operational Safety assessment**	**SRL 4.2.1 SRL 4.2.3**	**GSR Part4-R7 GSR Part4-R9 GSR Part4-R10 GSR Part4-R11 GSR Part4-R13 SSR-5-R13-§4.15-16**	
*** L-T Safety assessment**		**SSR-5-R13-§4.17-21**	
- Performance, defence in depth and robustness assessment	**SRL 4.1.3 SRL 4.2.3**	**GSR Part4-R7 GSR Part4-R10 GSR Part4-R13 SSR-5-R7 SSR-5-R8 SSR-5-R9 SSR-5-R13-§4.19-20**	
- Assessment of the radiological impact	**SRL 4.1.3**	**GSR Part4-R9**	
- Integration of analyses, arguments & evidences	**SRL 4.1.13 SRL 4.2.5**	**SSR-5-R13-§4.18**	
*** Periodic safety review**	**SRL 4.3.1 SRL 4.3.2 SRL 4.3.3**	**GSR Part4-R24**	
*** Independent verification**		**GSR Part4-R21**	

Appendix 2: IAEA safety requirements and principles associated to safety issues

Fundamental Safety Principles (SF-1)

Series No.SF-1, published Tuesday, November 07, 2006

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1273_web.pdf

- **Principle 1: Responsibility for safety:** The prime responsibility for safety must rest with the person or organization responsible for facilities and activities that give rise to radiation risks.
- **Principle 3: Leadership and management for safety** (See also management system)**:** Effective leadership and management for safety must be established and sustained in organizations concerned with, and facilities and activities that give rise to, radiation risks.
- **Principle 4: Justification of facilities and activities:** Facilities and activities that give rise to radiation risks must yield an overall benefit.
- **Principle 5: Optimization of protection:** Protection must be optimized to provide the highest level of safety that can reasonably be achieved.
- **Principle 6: Limitation of risks to individuals:** Measures for controlling radiation risks must ensure that no individual bears an unacceptable risk of harm.
- **Principle 7: Protection of present and future generations:** People and the environment, present and future, must be protected against radiation risks.
- **Principle 8: Prevention of accidents** (includes the « defence in depth » principle)**:** All practical efforts must be made to prevent and mitigate nuclear or radiation accidents.
- **Principle 9: Emergency preparedness and response:** Arrangements must be made for emergency preparedness and response for nuclear or radiation incidents.
- **Principle 10: Protective actions to reduce existing or unregulated radiation risks:** Protective actions to reduce existing or unregulated radiation risks must be justified and optimized.

Preparedness and Response for a Nuclear or Radiological Emergency, Requirements (GS-R-2)

Series No.GS-R-2, published Wednesday, November 06, 2002

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1133_scr.pdf

The Management System for Facilities and Activities, Safety Requirements (GS-R-3)

Series No.GS-R-3, published Friday, July 21, 2006

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1252_web.pdf

- **Section 2: Management system**
- **Section 3: Management responsibility**
- **Section 4: Resource management**
- **Section 5: Process implementation**
- **Section 6: Measurement, assessment and improvement**

Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - Interim Edition, General Safety Requirements Part 3 (GSR Part3)

Series No. GSR Part 3 (Interim), published Thursday, November 03, 2011

http://www-pub.iaea.org/MTCD/publications/PDF/p1531interim_web.pdf

General requirements for protection and safety

- **Requirement 1: Application of the principles of radiation protection:** Parties with responsibilities for protection and safety shall ensure that the principles of radiation protection are applied for all exposure situations.
- **Requirement 4: Responsibilities for protection and safety:** The person or organization responsible for facilities and activities that give rise to radiation risks shall have the prime responsibility for protection and safety. Other parties shall have specified responsibilities for protection and safety.
- **Requirement 5: Management for protection and safety:** The principal parties shall ensure that protection and safety is effectively integrated into the overall management system of the organizations for which they are responsible.
  - **Protection and safety elements of the management system**
  - **Safety Culture**
  - **Human factors**

Planned exposure situations

- **Requirement 6: Graded approach:** The application of the requirements of these Standards in planned exposure situations shall be commensurate with the characteristics of the practice or the source within a practice, and with the magnitude and likelihood of the exposures.
- **Requirement 9: Responsibilities of registrants and licensees in planned exposure situations:** Registrants and licensees shall be responsible for protection and safety in planned exposure situations.
- **Requirement 10: Justification of practices:** The government or the regulatory body shall ensure that only justified practices are authorized.
- **Requirement 11: Optimization of protection and safety:** The government or regulatory body shall establish and enforce requirements for the optimization of protection and safety, and registrants and licensees shall ensure that protection and safety is optimized.
- **Requirement 12: Dose limits:** The government or the regulatory body shall establish dose limits for occupational exposure and public exposure, and registrants and licensees shall apply these limits.
- **Requirement 13: Safety assessment:** The regulatory body shall establish and enforce requirements for safety assessment, and the person or organization responsible for a facility or activity that gives rise to radiation risks shall conduct an appropriate safety assessment of this facility or activity.
- **Requirement 14: Monitoring for verification of compliance:** Registrants and licensees and employers shall conduct monitoring to verify compliance with the requirements for protection and safety.
- **Requirement 15: Prevention and mitigation of accidents:** Registrants and licensees shall apply good engineering practice and shall take all practicable measures to prevent accidents and to mitigate the consequences of those accidents that do occur.
  - **Good engineering practice**
  - **Defence in depth**
  - **Accident prevention**
  - **Emergency preparedness and response**
- **Requirement 16: Investigations and feedback of information on operating experience:** Registrants and licensees shall conduct formal investigations of abnormal conditions arising in the operation of facilities or the conduct of activities, and shall disseminate information that is significant for protection and safety.

Occupational exposure

- **Requirement 19: Responsibilities of the regulatory body specific to occupational exposure:** The government or regulatory body shall establish and enforce requirements to ensure that protection and safety is optimized, and the regulatory body shall enforce compliance with dose limits for occupational exposure.

- **Requirement 20: Requirements for monitoring and recording of occupational exposure:** The regulatory body shall establish and enforce requirements for the monitoring and recording of occupational exposures in planned exposure situations.
- **Requirement 21: Responsibilities of employers, registrants and licensees for the protection of workers:** Employers, registrants and licensees shall be responsible for the protection of workers against occupational exposure. Employers, registrants and licensees shall ensure that protection and safety is optimized and that the dose limits for occupational exposure are not exceeded.
- **Requirement 22: Compliance by workers:** Workers shall fulfil their obligations and carry out their duties for protection and safety.
- **Requirement 23: Cooperation between employers and registrants and licensees:** Employers and registrants and licensees shall cooperate to the extent necessary for compliance by all responsible parties with the requirements for protection and safety.
- **Requirement 24: Arrangements under the radiation protection programme:** Employers, registrants and licensees shall establish and maintain organizational, procedural and technical arrangements for the designation of controlled areas and supervised areas, for local rules and for monitoring of the workplace, in a radiation protection programme for occupational exposure.
  - **Classification of areas (controlled and areas)**
  - **Local rules and procedures and personal protective equipment**
  - **Monitoring of the workplace**
- **Requirement 25: Assessment of occupational exposure and workers' health surveillance:** Employers, registrants and licensees shall be responsible for making arrangements for assessment and recording of the occupational exposure and for workers' health surveillance.
  - **Occupational exposure assessment**
  - **Records of occupational exposure**
  - **Workers' health surveillance**
- **Requirement 26: Information, instruction and training:** Employers, registrants and licensees shall provide workers with adequate information, instruction and training for protection and safety.

Public exposure

- **Requirement 29: Responsibilities of the government and the regulatory body specific to public exposure:** The government or the regulatory body shall establish the responsibilities of relevant parties that are specific to public exposure, shall establish and enforce requirements for optimization, and shall establish, and the regulatory body shall enforce compliance with, dose limits for public exposure.
- **Requirement 30: Responsibilities of relevant parties specific to public exposure:** Relevant parties shall apply the system of protection and safety to protect members of the public against exposure.
  - **General considerations**
  - **Visitors**
  - **External exposure and contamination in areas accessible to members of the public**
- **Requirement 31: Radioactive waste and discharges:** Relevant parties shall ensure that radioactive waste and discharges of radioactive material to the environment are managed in accordance with the authorization.
  - **Radioactive waste**
  - **Discharges**
- **Requirement 32: Monitoring and reporting:** The regulatory body and relevant parties shall ensure that programmes for source monitoring and environmental monitoring are in place and that the results from the monitoring are recorded and are made available.

Emergency exposure situations

Generic requirements

- **Requirement 43: Emergency management system:** The government shall ensure that an integrated and coordinated emergency management system is established and maintained.

Public exposure

- **Requirement 44: Preparedness and response to an emergency:** The government shall ensure that protection strategies are developed, justified and optimized at the planning stage, and that emergency response is undertaken through their timely implementation.

Exposure of emergency workers

- **Requirement 45: Arrangements for controlling the exposure of emergency workers:** The government shall establish a programme for managing, controlling and recording the doses received in an emergency by emergency workers.

Transition from an emergency exposure situation to an existing exposure situation

- **Requirement 46: Arrangements for the transition from an emergency exposure situation to an existing exposure situation:** The government shall ensure that arrangements are in place and are implemented as appropriate for the transition from an emergency exposure situation to an existing exposure situation.

Safety Assessment for Facilities and Activities, General Safety Requirements Part 4 (GSR Part 4)

Series No. GSR Part 4, published Tuesday, May 19, 2009.
http://www-pub.iaea.org/MTCD/publications/PDF/Pub1375_web.pdf

Graded approach to safety assessment

- **Requirement 1: Graded approach:** A graded approach shall be used in determining the scope and level of detail of the safety assessment carried out in a particular State for any particular facility or activity, consistent with the magnitude of the possible radiation risks arising from the facility or activity.

Safety assessment

Overall requirements

- **Requirement 2: Scope of the safety assessment:** A safety assessment shall be carried out for all applications of technology that give rise to radiation risks; that is, for all types of facilities and activities.
- **Requirement 3: Responsibility for the safety assessment:** The responsibility for carrying out the safety assessment shall rest with the responsible legal person; that is, the person or organization responsible for the facility or activity.
- **Requirement 4: Purpose of the safety assessment:** The primary purposes of the safety assessment shall be to determine whether an adequate level of safety has been achieved for a facility or activity and whether the basic safety objectives and safety criteria established by the designer, the operating organization and the regulatory body, in compliance with the requirements for protection and safety as established in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [4], have been fulfilled.

Specific requirements

- **Requirement 5: Preparation for the safety assessment:** The first stage of carrying out the safety assessment shall be to ensure that the necessary resources, information, data, analytical tools as well as safety criteria are identified and are available.

- **Requirement 6: Assessment of the possible radiation risks:** The possible radiation risks associated with the facility or activity shall be identified and assessed.
- **Requirement 7: Assessment of safety functions:** All safety functions associated with a facility or activity shall be specified and assessed.
- **Requirement 8: Assessment of site characteristics:** An assessment of the site characteristics relating to the safety of the facility or activity shall be carried out.
- **Requirement 9: Assessment of the provisions for radiation protection:** It shall be determined in the safety assessment for a facility or activity whether adequate measures are in place to protect people and the environment from harmful effects of ionizing radiation.
- **Requirement 10: Assessment of engineering aspects:** It shall be determined in the safety assessment whether a facility or activity uses, to the extent practicable, structures, systems and components of robust and proven design.
- **Requirement 11: Assessment of human factors:** Human interactions with the facility or activity shall be addressed in the safety assessment, and it shall be determined whether the procedures and safety measures that are provided for all normal operational activities, in particular those that are necessary for implementation of the operational limits and conditions, and those that are required in response to anticipated operational occurrences and accidents, ensure an adequate level of safety.
- **Requirement 12: Assessment of safety over the lifetime of a facility or activity:** The safety assessment shall cover all the stages in the lifetime of a facility or activity in which there are possible radiation risks.

Defence in depth and safety margins

- **Requirement 13: Assessment of defence in depth:** It shall be determined in the assessment of defence in depth whether adequate provisions have been made at each of the levels of defence in depth.

Safety analysis

- **Requirement 14: Scope of the safety analysis:** The performance of a facility or activity in all operational states and, as necessary, in the post-operational phase shall be assessed in the safety analysis.
- **Requirement 15: Deterministic and probabilistic approaches:** Both deterministic and probabilistic approaches shall be included in the safety analysis.
- **Requirement 16: Criteria for judging safety:** Criteria for judging safety shall be defined for the safety analysis.
- **Requirement 17: Uncertainty and sensitivity analysis:** Uncertainty and sensitivity analysis shall be performed and taken into account in the results of the safety analysis and the conclusions drawn from it.
- **Requirement 18: Use of computer codes:** Any calculational methods and computer codes used in the safety analysis shall undergo verification and validation.
- **Requirement 19: Use of operating experience data:** Data on operational safety performance shall be collected and assessed.

Documentation

- **Requirement 20: Documentation of the safety assessment:** The results and findings of the safety assessment shall be documented.

Independent verification

- **Requirement 21: Independent verification:** The operating organization shall carry out an independent verification of the safety assessment before it is used by the operating organization or submitted to the regulatory body.

Management, use and maintenance of the safety assessment

- **Requirement 22: Management of the safety assessment:** The processes by which the safety assessment is produced shall be planned, organized, applied, audited and reviewed.
- **Requirement 23: Use of the safety assessment:** The results of the safety assessment shall be used to specify the programme for maintenance, surveillance and inspection; to specify the procedures to be put in place for all operational activities significant to safety and for responding to anticipated operational occurrences and accidents; to specify the necessary competences for the staff involved in the facility or activity and to make decisions in an integrated, risk informed approach.
- **Requirement 24: Maintenance of the safety assessment:** The safety assessment shall be periodically reviewed and updated.

Decommissioning of Facilities Using Radioactive Material, Safety Requirements (WS-R-5)

Series No.WS-R-5, published Wednesday, October 18, 2006

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1274_web.pdf

Disposal of Radioactive Waste, Specific Safety Requirements (SSR-5)

Series No.SSR-5, published Thursday, May 05, 2011

http://www-pub.iaea.org/MTCD/publications/PDF/Pub1449_web.pdf

Radiation protection in the operational period *(§2.7-2.14)*

Radiation protection in the post-closure period *(§2.15-2.19)*

Environmental and non-radiological concerns *(§2.21-2.23)*

Planning for the disposal of radioactive waste

Safety approach

- **Requirement 4: Importance of safety in the process of development and operation of a disposal facility**: Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the implementer. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.
- **Requirement 5: Passive means for the safety of the disposal facility:** The implementer shall evaluate the site and shall design, construct, operate and close the disposal facility in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the facility is minimized.
- **Requirement 6: Understanding of a disposal facility and confidence in safety:** The implementer of a disposal facility shall develop an adequate understanding of the features of the facility and its host environment and of the factors that influence its safety after closure over suitably long time periods, so that a sufficient level of confidence in safety can be achieved.

Design concepts for safety

- **Requirement 7: Multiple safety functions:** The host environment shall be selected, the engineered barriers of the disposal facility shall be designed and the facility shall be operated to ensure that safety is provided by means of multiple safety functions. Containment and isolation of the waste shall be provided by means of a number of physical barriers of the disposal system. The performance of these physical barriers shall be achieved by means of diverse physical and chemical processes together with various operational controls. The capability of the individual barriers and controls together with that of the overall disposal system to perform as assumed in the safety case shall be demonstrated. The overall performance of the disposal system shall not be unduly dependent on a single safety function.

- **Requirement 8: Containment of radioactive waste:** The engineered barriers, including the waste form and packaging, shall be designed, and the host environment shall be selected, so as to provide containment of the radionuclides associated with the waste. Containment shall be provided until radioactive decay has significantly reduced the hazard posed by the waste. In addition, in the case of heat generating waste, containment shall be provided while the waste is still producing heat energy in amounts that could adversely affect the performance of the disposal system.
- **Requirement 9: Isolation of radioactive waste:** The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short lived waste and at least several thousand years for intermediate and high level waste. In so doing, consideration shall be given to both the natural evolution of the disposal system and events causing disturbance of the facility.
- **Requirement 10: Surveillance and control of passive safety features:** An appropriate level of surveillance and control shall be applied to protect and preserve the passive safety features, to the extent that this is necessary, so that they can fulfil the functions that they are assigned in the safety case for safety after closure.

Development, operation and closure of a disposal facility

Framework for disposal of radioactive waste

- **Requirement 11: Step by step development and evaluation of disposal:** Facilities Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system.

The safety case and safety assessment

- **Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility:** A safety case and supporting safety assessment shall be prepared and updated by the implementer, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step.
- **Requirement 13: Scope of the safety case and safety assessment:** The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met.
- **Requirement 14: Documentation of the safety case and safety assessment:** The safety case and supporting safety assessment for a disposal facility shall be documented to a level of detail and quality sufficient to inform and support the decision to be made at each step and to allow for independent review of the safety case and supporting safety assessment.

Steps in the development, operation and closure of a disposal facility

- **Requirement 15: Site characterization for a disposal facility:** The site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time. This shall include its present condition, its probable natural evolution and possible natural events, and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility.

- **Requirement 16: Design of a disposal facility:** The disposal facility and its engineered barriers shall be designed to contain the waste with its associated hazard, to be physically and chemically compatible with the host geological formation and/or surface environment, and to provide safety features after closure that complement those features afforded by the host environment. The facility and its engineered barriers shall be designed to provide safety during the operational period.
- **Requirement 17: Construction of a disposal facility:** The disposal facility shall be constructed in accordance with the design as described in the approved safety case and supporting safety assessment. It shall be constructed in such a way as to preserve the safety functions of the host environment that have been shown by the safety case to be important for safety after closure. Construction activities shall be carried out in such a way as to ensure safety during the operational period.
- **Requirement 18: Operation of a disposal facility:** The disposal facility shall be operated in accordance with the conditions of the licence and the relevant regulatory requirements so as to maintain safety during the operational period and in such a manner as to preserve the safety functions assumed in the safety case that are important to safety after closure.
- **Requirement 19: Closure of a disposal facility:** A disposal facility shall be closed in a way that provides for those safety functions that have been shown by the safety case to be important after closure. Plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.

Assurance of safety

- **Requirement 20: Waste acceptance in a disposal facility:** Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure.
- **Requirement 21: Monitoring programmes at a disposal facility:** A programme of monitoring shall be carried out prior to, and during, the construction and operation of a disposal facility and after its closure, if this is part of the safety case. This programme shall be designed to collect and update information necessary for the purposes of protection and safety. Information shall be obtained to confirm the conditions necessary for the safety of workers and members of the public and protection of the environment during the period of operation of the facility. Monitoring shall also be carried out to confirm the absence of any conditions that could affect the safety of the facility after closure.
- **Requirement 22: The period after closure and institutional controls:** Plans shall be prepared for the period after closure to address institutional control and the arrangements for maintaining the availability of information on the disposal facility. These plans shall be consistent with passive safety features and shall form part of the safety case on which authorization to close the facility is granted.
- **Requirement 23: Consideration of the State system of accounting for, and control of, nuclear material:** In the design and operation of disposal facilities subject to agreements on accounting for, and control of, nuclear material, consideration shall be given to ensuring that safety is not compromised by the measures required under the system of accounting for, and control of, nuclear material.
- **Requirement 24: Requirements in respect of nuclear security measures:** Measures shall be implemented to ensure an integrated approach to safety measures and nuclear security measures in the disposal of radioactive waste.
- **Requirement 25: Management systems:** Management systems to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety.

Existing disposal facilities

- **Requirement 26: Existing disposal facilities:** The safety of existing disposal facilities shall be assessed periodically until termination of the licence. During this period, the safety shall also be assessed when a safety significant modification is planned or in the event of changes with regard to the conditions of the authorization. In the event that any requirements set down in this Safety Requirements publication are not met, measures shall be put in place to upgrade the safety of the facility, economic and social factors being taken into account.

IAEA Requirements not included in the list

The following requirements identified by IAEA as applying to radioactive waste disposal facilities were not included in the list:

- Governmental, legal and regulatory framework (SF-1 – P2, GSR Part 1, GSR Part3 – R2-3 & SSR-5 – R1-R3)
- Predisposal management of radioactive waste general safety requirements (GSR Part 5)
- Remediation of areas contaminated by past activities and accidents safety requirements (WS-R-3)
- Notification and authorization (GSR Part3 – R7)
- Exemption and clearance (GSR Part3 – R8)
- Radiation generators and radioactive sources (GSR Part3 – R17)
- Human imaging (GSR Part3 – R18)
- Conditions of service and special arrangements for workers (GSR Part3 – R27-28)
- Consumer products (GSR Part3 – R33)
- Medical exposure (GSR Part3 – R34-42)
- Detailed requirements for existing exposure situations (GSR Part3 – R47-52)
- Non-radiological concerns (SSR-5 - §2.20 & §2.24)

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