INTERNATIONAL ATOMIC ENERGY AGENCY

WAGRAMERSTRASSE 5, P.O. BOX 100, A-1400 VIENNA, AUSTRIA
FACSIMILE: (+43 1) 26007, TELEPHONE: (+43 1) 2600

GEOSAF

The International Intercomparison and Harmonisation Project

on

DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL

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DEMONSTRATING THE SAFETY OF GEOLOGICAL DISPOSAL

1 Scope of the project

The IAEA has convened a number of **international intercomparison and harmonization projects** on the safety of radioactive waste management; in particular on the issues related to safety assessment, carried out in support of safety demonstration for radioactive waste management facilities and activities, decommissioning projects and radioactive waste disposal facilities.
International intercomparison and harmonization projects are one of the mechanisms developed by the IAEA for examining the application and use of safety standards, with a view to ensuring their effectiveness and working towards harmonization of approaches to the safety of radioactive waste management.

The GEOSAF project complements the experience gained in a number of similar international projects undertaken by the IAEA relating to safety demonstration. These include: the project Improvement of Safety Assessment Methodologies for Near Surface Disposal Facilities for Radioactive Waste (ISAM), which was completed in 2000, and the project Application of Safety Assessment Methodologies for Near-Surface Radioactive Waste Disposal Facilities (ASAM); the international project Evaluation and Demonstration of Safety during Decommissioning of Nuclear Facilities (DeSa); the international project Safety Assessment Driven Radioactive Waste Management Solutions (SADRWMS); and the international project on Environmental Modelling for Radiation Safety (EMRAS).

GEOSAF has been established to work towards harmonization in approaches to demonstrating the safety of geological disposal with a special emphasis on the expectations from the regulatory authorities engaged in the licensing process with respect to the development of the safety case. GEOSAF provided a forum to exchange ideas and experience in developing and reviewing the safety case.
It also aimed at providing a platform for knowledge transfer. With more countries contemplating embarking on nuclear power and existing producers seeking to define national policies and strategies aiming at covering all elements of the fuel cycle, such a platform is considered apposite. The need exists also to maintain existing knowledge bases.

The project focused on the Safety Case [1, 2], a concept that has gained in recent years considerable prominence in the waste management area and is addressed in several international Safety Standards [3].

GEOSAF gave particular attention to the evolution of the safety case with the development of a disposal project and particularly to the regulatory expectations on the development of the safety case in order to enable decisions to be made as part of the licensing process. Whilst the project addressed the elements of the safety case necessary for safety demonstration and the work necessary to support the various safety arguments, it also considered the process of reviewing and evaluating the safety case by regulatory authorities or technical safety organizations (TSOs) and the needed resources for conducting this technical review. That is the reason why the project involved regulatory authorities, technical safety organizations and waste management organizations responsible for the development and operation of geological disposal facilities.

GEOSAF addressed geological disposal defined in SSR5 [4] as a “facility constructed in tunnels, vaults or silos in a particular geological formation (e.g. in terms of its long term stability and its hydrogeological properties) at least a few hundred metres below ground level. Such a facility could be designed to accept high level radioactive waste (HLW), including spent fuel if it is to be treated as waste. However, with appropriate design a geological disposal facility could receive radioactive waste of all types [5]”.

2 Main outcomes

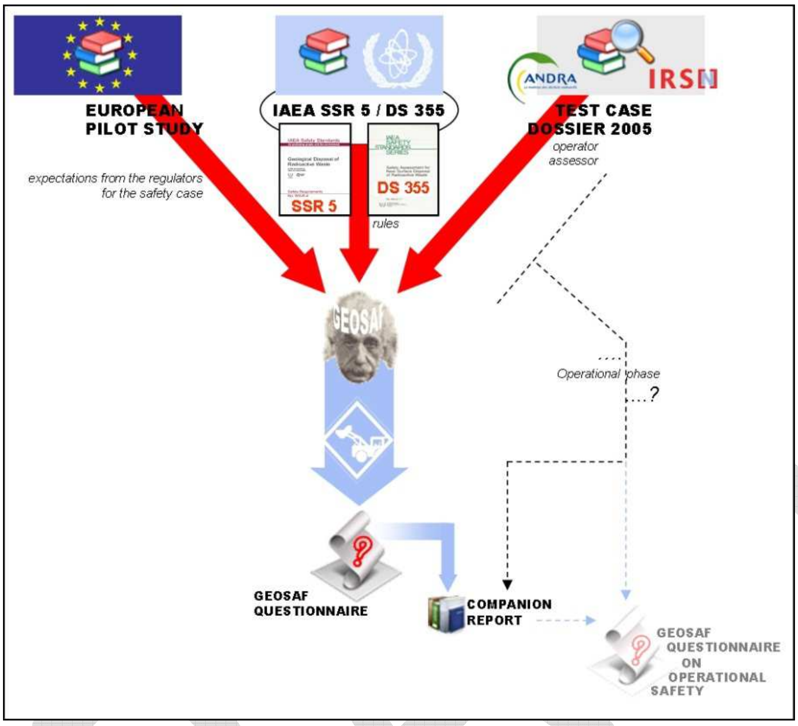
In order to foster harmonization and common understanding of key issues for demonstrating safety and reviewing it, GEOSAF worked towards the development of a questionnaire devoted to review the Safety Case that would structure a foreseen IAEA review procedure.

Noting that, after decades of long term safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase of a geological disposal, GEOSAF decided to launch a specific programme of work on the safety of the operational phase. The outcomes of this pilot study are documented in a companion report attached to this main project report. It is expected from that pilot study that it will serve as a basis of a potential further work.

3 Working methodology

In practice GEOSAF has developed its own work on the ground of the work of the European Pilot Study (EPS) [6] on the Regulatory Review of a Safety Case for Geological Disposal of Radioactive Waste (French Nuclear Safety Authority initiative) and on two IAEA safety standards: (i) the Specific Safety Requirements on Disposal of Radioactive Waste, SSR-5 [4], (ii) the Draft Safety Guide on the Safety Case and Safety Assessment for Radioactive Waste Disposal [1].
In addition, with the view to contributing to the development of a questionnaire devoted to review the Safety Case that would structure a foreseen IAEA review procedure, GEOSAF carried out an exercise on the development and technical review

of a real national case, namely the French Safety Case presented in the *"Dossier 2005 Argile"* [7,8,9,10] by the French WMO (ANDRA), for demonstrating the feasibility of a geological disposal in a clay formation. The *"Dossier 2005 Argile"* was technically reviewed by the IRSN, the French Radiation Protection and Nuclear Safety Institute in order to advise the French Nuclear Safety Authority (ASN). The technical opinion of IRSN was published on its website [11].



4 Main achievements

4.1 European Pilot Study review

The *European Pilot Study,* a French Safety Authority's initiative, develops how a regulator should review a safety case and the expected content of the SC at each stage of the development of a geological disposal. It was therefore considered useful for the GEOSAF project both to get familiar to this already harmonized vision at a European level and to review this document and provide inputs to the group in charge of updating the EPS with the objectives of improvement and clarification.

In order to perform the review of the *European Pilot Study* two working groups were created for crossing views from regulators and operators: (i) WG1 aiming at reviewing the *European Pilot Study* framework with a focus on the content of the safety case and its evolution, (ii) WG2 aiming at reviewing the *European Pilot Study* with a focus on the regulatory and technical reviewing process, considering the necessary organization and resources to be developed by the regulator or the technical safety organization. The groups elaborated a number of recommendations that were discussed with the EPS group and gave rise to particular emphasize in the follow up of the EPS work. Main issues concerned:

4.1.1 Organizational aspects for the regulatory body or TSO

- Elaborating guidance: some guidance should be provided on the preparatory activities to be undertaken by the assessors to be ready for the technical and regulatory review (e.g. Review of key reports and technical publications from proponents, Development of Guidance documents (for example as in Canada, France, etc.)…). GEOSAF discussed the issue of the appropriate time for setting (regulatory) requirements but did not reach a consensus: one the one hand, early definition of requirements provides security in that the stakeholders know the "rules of the game" from the beginning. On the other hand, an early definition increases the likelihood of very generic and unspecific requirements while a later definition would allow accounting for the evolving knowledge

- <u>Being involved in the project at the earliest :</u>
    - Assessors should be involved in review activity early before a safety case is actually submitted to any licensing process.
    - Periodic meetings with proponents to give feedback, either in the form of formal review reports and/or informal discussion
    - However the reviewers should be careful of not being involved into the choices that are of the responsibility of the implementer and to avoid co-development of the safety case.

- <u>Develop competences and structure the review process</u> :
    - Perform independent research externally and in-house on key safety aspects by expertise organizations or expertise units from the authorities, on areas which are complex and need better understanding, development of modelling capabilities in order to perform independent calculations and assessment, etc
    - Seek expert input with external independent experts
    - Establish a team of reviewers. It is anticipated that in early stages, activities are focused on geoscientific disciplines (geology, hydrogeology, geomechanics, geochemistry…). At later times before submission of the safety case, other experts should be involved (fire protection, criticality, ventilation, transportation, radiation protection, biosphere modelling, dose calculation, etc.)
    - the regulatory and expertise activities in preparation for the licensing review of the safety case should focus on key aspects that are relevant to safety, in order to identify gaps and provide feedback to the proponents before they finalize their safety case.
    - Adequate resources should be allocated to the expertise body,

- Participation in international activities (such as GEOSAF and the NEA/IGSC)
- Organizational factors (such as maintaining competencies) are a crucial issue w.r.t. the evolution of a project lasting over decades and should be more explicitly accounted for.

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4.1.2 Improvement for more detailed guidance

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- GEOSAF generally agreed with the stages proposed in the EPS: conceptualization, siting, design, construction, operation, closure. However, because jurisdictions differ between countries, a license, permit or approval is not always required at the end of each stage.
- GEOSAF generally agreed that the safety case provided by the proponent at the end of each stage should be reviewed by the regulators, even if it is not formally submitted in support of some kind of license, permit or approval. Decision points, however, might be taken either by a policy-maker or by the implementer / operator. The issue is all the more important because the safety case has to inform these decisions and consequently has to be tailored accordingly
- GEOSAF generally agreed with the detailed regulatory expectations provided by the EPS for the conceptualization, siting and design stages but emphasized in particular the need for clarifying the fact that the requirement for multiple lines of arguments / confidence building (e.g. by means of natural analogues or by using different indicators than dose) should be made more explicit in the report rather than focusing on radiological impact assessment in order to clarify that safety assessment is much broader than just a set of dose calculations.

There should be some guidance on the need for site-specific information that would require some degree of field investigations, versus published data for each stage. In general site-specific data become more important in later stages (e.g. design versus conceptualization, etc.).
- To address the siting strategy or approaches that could be used for siting
- The question of selection of time frame for impact assessment should be discussed
- The importance of natural analogues and paleohydrogeology as strong safety arguments in support of the safety case should be more emphasized in the EPS.
- The question of optimization in site selection, facility design should be discussed
- It should also be noted that at the siting stage, not only the host rock characteristics (geology, hydrogeology, geochemistry, geomechanics, thermal, etc.) should be determined but also the characteristics of the surrounding environment that might impact on the performance of the disposal facility.

Other guidance may be developed:
- There should be some guidance on at what stage an Underground Research Laboratory may be needed
- For the design stage, there should be some more guidance :
    - On what to expect from the proponent for their proposed monitoring program. What, where and when do they measure?
    - How to address rules, regulations, codes, and standards (including those from outside the nuclear regulation, e.g. engineering design standards) to be accounted for during the design step
- For preparing for the operational phase, the guidance should develop
    - How to address evolution from preliminary to definitive waste acceptance criteria during the design and construction phases
    - allowance for analyzing and managing incidents and accidents

    - operational rules to handle unexpected conditions (e.g. when is an unexpected condition "fatal"?)
    - commissioning and testing services as an identified activity/step; operations would not be licensed until all (control and) safety systems are checked and proven;
- For the closure and post closure phase GEOSAF recommends accounting more explicitly in the guidance:
    - for the necessity to address issues linked to the closure of the facility and its safety in relation to the closure concept already in early development phases
    - for the possibility of a post-operational open phase including monitoring issues and to address them
- In addition GEOSAF considers that the relationship of the safety case to Environmental Impact Assessment activities should be addressed.

The guidance should also account for the need to present the overall safety strategy in the safety case. The evolution of the safety strategy over the project's duration should be addressed.

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4.1.3 Overlapping/interactions between activities

GEOSAF recommends better addressing overlap and interplay between activities during the different stages of disposal development. For example, site characterization results will have an influence on the disposal facility layout, and it is conceivable if not likely that layout modifications will take place even during construction and emplacement. Furthermore, construction, emplacement, and closure might or will go on in parallel: While some emplacement fields are already sealed, in others emplacement will go on while a third part is under construction. This interplay is not very well visible in the 2007 document but the group believes that using decision points will help resolving this issue.

It should also be noted that even if the design was developed for construction purposes, there still should be flexibility for this design to be modified during construction and in later stages if the need arises.

4.2 Review of the Draft Safety Guide on The Safety Case and Safety Assessment for Radioactive Waste Disposal [1]

Regarding the review of the *Draft Safety Guide on The Safety Case and Safety Assessment for Radioactive Waste Disposal*, comments were received from Belgium, Canada, France, Germany, Japan, Slovakia and USA. Comments could be classified in following categories:

- clarity and consistency of definitions of main principles
- The Safety Guide seems to focus mainly on post-closure safety of deep geological disposal. More or separate guidance should be provided on pre-closure safety; and on surface facilities (mainly for LLW, NORM and Mine wastes)
- Time frames

- Intrusion
- Institutional Control
- Stakeholders involvement
- Regulatory Process
- Integration of safety and security
- Important principles should be defined clearly upfront; For example, Safety Case and Safety Assessment. It was acknowledge that definitions could vary between different States, however principles remain the same.
- Other examples of clear definitions that were required concerned the issues of containment and isolation, the graded approach, the safety strategy, the defence-in-depth vs multiple barrier, etc.
- More guidance on institutional control, long term care and maintenance, to protect against intrusion and natural processes.

Those outcomes are detailed and integrated in the section related to the description of the questionnaire in the present report.

4.3 Questionnaire development

Based on the requirements of *the Specific Safety Requirements on Disposal of Radioactive Waste SSR-5* [3], the IAEA Secretariat prepared a series of questions aiming at

- assessing whether the safety issues addressed and the key arguments provided by the operator comply with IAEA safety standards SSR-5;
- guiding the review process performed by the regulator and/or the TSO

4.3.1 Working methodology

GEOSAF participants were invited to assess the relevance of the questions addressing the requirements. The questions were separated into three groups: group 1 from requirement #1 to #10, group 2 from requirements #11 to #19 and finally group 3 from requirements #20 to #25.
Group 1 was particularly in charge of assessing the questions by looking at a real-life situation where a deep geological disposal facility is planned, and for which a draft safety case has been prepared (*"Dossier 2005 Argile"* and the related IRSN technical review).
The other groups reviewed the proposed questionnaire on the basis of the *Specific Safety Requirements on Disposal of radioactive Waste (SSR-5).*
This review allowed to clarify a number of requirements and associated questions and to improve the relevance and understanding of the questions.

4.3.2 Briefing session on French case "Dossier 2005":

A presentation of the structure and main results of the "Dossier 2005 Argile" was given by Andra. The purpose of the dossier was to demonstrate the feasibility of the deep geological disposal in the Callovo-Oxfordian clay formation investigated using in particular the Bure URL. Andra explained how was developed the comprehensive understanding of the disposal evolution with time in an integrated approach called

"APSS". The needs for multi-disciplinary skills, simulations/experiments capabilities, and traceability were discussed. Discussions took place on the necessity to either simplify or increase the complexity of the modelling depending on the calculation times and being less conservative and more realistic. Andra also presented and explained the use of indicators different from dose as mass rate decay, delay or molar flow.

Then IRSN presented the approach followed since 1997 to review the SC developed by Andra. Key aspects of IRSN regulatory review concerned the inventory, the knowledge of the site, the performances of the engineered components, the disturbances and interactions caused by the disposal facility, the necessity to develop in situ demonstration tests to support safety demonstration as well as the safety assessment methodology and the accounting for uncertainties. The close follow-up of Andra work by IRSN and the nuclear safety authority (ASN) since the conceptualization phase, the legal framework (2 acts in 1991 and 2006 framed the development of deep geological disposal as reference solution for managing HLW and assigned clear responsibilities and means to the WMO Andra) as well as independent research carried out by IRSN to support regulatory review were judged favorable conditions by French actors to progress in the way of deep geological disposal creation.

4.3.3 Draft questionnaire

The questionnaire is presented in **Appendix 1**.

It only concerns geological disposal for high level radioactive waste. The number of questions for each requirement is not linked to the importance of the requirement itself. The relevance of detailed specifications for actions that concern the distant future was considered as an open issue by the members who asked the question of the reliability of the answers and arguments presented given the associated uncertainties?

The work undertaken for developing the questionnaire and reviewing the SSR-5 standards contributed to identify areas where, according to the view of the GEOSAF members, requirements and the way of complying with deserved more attention and better mutual understanding. In particular, participants considered as well that some comments arising from the review of the questionnaire were very instructive and suggested that they could be transformed into additional questions or subsidiary questions to illustrate better their meanings. This work was not undertaken in the framework of the first part of GEOSAF and could be envisaged as part of the follow up of the project. These comments are developed in **Annex1** and synthesize the discussions and needs for clarifications that arose from the GEOSAF group.

4.4 The operational safety working group

Volunteers developed the working methodology devoted to this specific group and based as far as possible their work on exchanges with mining industry that a priori faces hazards possibly to occur in an underground nuclear facility. It is expected from this group that it identifies a first approach for developing safety demonstration of the operational phase. This approach shall take into account constraints that come from a geological disposal facility, which combines safety issues derived, on the one hand from classic nuclear facilities and on the other hand from construction and operation of an underground nuclear installation.

During the course of the project, GEOSAF members have noted that, after decades of long term safety development, little work was undertaken internationally to develop a common view on the safety approach related to the operational phase. It is the reason why GEOSAF decided to launch a programme of work on this topic. This programme included amongst other visits of underground facilities including mines. The programme of work of a dedicated working group on operational phase safety (OPS Working Group) tackled the following issues:

a. Explore hazards associated with the underground facility operation with a view to integration of them into the Safety Case
b. In addition to hazards, consider the activities undertaken in parallel, e.g. emplacement, construction, monitoring, safeguards, maintenance and closure.
c. Long-term safety implications of the operational activities
d. Quality assurance activities in the operational safety
e. Cultural difference between miners and nuclear industry
f. Explore the implications of working in different rock types
g. Explore computer aids to assessing underground hazards
h. Explore the implications of restrictions on damage to the host rock
i. Implications of handling heavy items
j. Implications of operating in an underground nuclear licensed environment – Synergies and conflicts with conventional mining regulation
k. Practical application of controls over life time of the facility

The overall objective of the group is :

- to develop an assessment methodology based on a questionnaire on operational safety in a similar manner as the questionnaire developed for reviewing long term safety;
- to test the questionnaire against existing or ongoing development documents or approaches

In December 2009, as a preparatory work for this group, GEOSAF visited the Klerksdorp Moab Khotsong mine. The mine focuses on gold exploration up to more than 3000 m deep. The visit gave access to a depth of 3108 m in addition to a meeting with the mine management board during which exchanges on safety issues took place i.e. eliminating unsafe acts 96%, risk assessment for surface area, shaft barrel and underground, prevention escape procedures and controls flammable gas, fires, ventilation. Regarding radiation and fire risks, preliminary thoughts from the GEOSAF group about main differences between conventional mines and « classic » nuclear facilities were:

- Higher air flow rates / renewal rates
- Higher temperatures
- Higher hygrometry
- New pollutants and more dust (gases?, silica…)

New issues for the geological disposal arose concerning:

- co-activity : conventional and nuclear activities
    - Static and dynamic confinement
- A specific issue for the nuclear ventilation : HEPA filters' deteriorations

- Classical deterioration due to temperature, moist air, high flow rates, clogging, etc.
- Unknown deterioration due to new pollutants
- Need of new air purification equipment?
  - For dust
  - For new pollutants
- Need of air conditioning?

This OPS Working Group met **20-22 July 2010** at the **Canadian Nuclear Safety Commission (CNSC) premises in Saskatoon-Canada** and organised the visit of the **Mc Arthur River uranium mine** followed by discussions with staff **from CAMECO** (mine operator) on the radiological and operational safety issues. Because the remaining time was limited before the end of GEOSAF project (June 2011), and the scope of the operational phase safety group very large, the group argued that a "**pilot study**" should be initiated at this time with the view to validating the working methodology on one safety topic of interest for the operational phase.
As a 1st step, the group supported its discussion for selecting the hazards and events to be dealt with in the pilot study based on the WIPP Operational safety report that have been put at the disposal of the group and on the hazard/event matrix of the WIPP.

I. The **questionnaire** and the operational safety **assessment methodology** could be derived from the following issues (preliminary discussion):
- Identify hazards/envelope scenarios and their relationship on operational safety and long term safety
- Which ones are specific to nuclear facilities? To underground facilities? To standard industrial facilities …?
- Identify regulations or standards, for industrial and nuclear facilities for protection against the hazards.
  - Do such standards exist?
  - Are they adequate for a deep geological disposal? if not recommend development of new regulations
- Describe the facility, its safety functions, its systems and operational processes. Determine which systems could be integrated in the design and operational procedure to deal with the hazards
- Develop controls to prevent/mitigate the hazards and their impact on operational & long term safety
- Continuous feedback and improvement. Operators / member states may need to build [regulatory] requirements!
- …

II. **Validation of the pilot study** :
Hazard/event selected for the pilot study was related to **Fire**
Different items were discussed:
- WIPP methodology as illustration of existing approach regarding the selected hazard/event
- Existing code: e.g. in Canada Fire Protection code, part of National Building Code, provincial mining code. No specific code for fire protection for

underground facility. No code or standard, guidance for deep geological disposal
- Systems and design to tackle fire: limit fire size, ventilation system, fire suppression system, specific administrative control, vehicle barriers, grading and sloping, etc…
- Impact of fire accidents during operation on degradation of geological and engineered barriers, effects on criticality…
- Systems to mitigate fire hazard, like the ventilation shafts, influence long term safety, by being potentially preferential contaminant pathways
- …

The Pilot study should be issued as a GEOSAF companion report [12].

Appendix 1

Draft questionnaire

Requirement 1: Government responsibilities

The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities are clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility.

1.1 What is the legal and regulatory framework and how does it provide the basis for the development of a radioactive waste disposal facility and its associated safety case?

1.2 What roles and responsibilities are identified within the legal and regulatory framework associated with the derivation of regulatory requirements?

1.3 What arrangements are in place and how is it demonstrated that adequate funding is available to conduct research for development of the safety case and for the development of the radioactive waste disposal facility?

Requirement 2: Responsibilities of the regulatory body

The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.

2.1 What are the legal and regulatory requirements imposed upon the facility and its associated safety case?

2.2 What is the licensing process in terms of the communications between the regulator(s) and the operator during the development of the safety case?

2.3 What regulatory guidance has been developed to clarify regulatory requirements on radioactive waste disposal and the associated safety case?

2.4 What system is required to document the procedures used to evaluate the safety of facilities and activities proposed for licensing?

2.5 What procedures are in place to inform and direct the operator in respect of the regulatory process for different steps in the development and licensing of a radioactive waste disposal facility?

2.6 What guidance is provided on the procedures that will be applied to assess compliance of the licence application with safety requirements?

Requirement 3: Responsibilities of the operator

The operator of a disposal facility shall be responsible for its safety. The operator shall carry out safety assessment and develop a safety case, and shall carry out all the necessary activities for siting, design, construction, operation, closure and, if necessary post closure surveys, according to national strategy, in compliance with the regulatory requirements and within the national legal infrastructure.

3.1 What process is in place to develop a safety case? How is this process envisaged to change with the steps in the development of a disposal facility?

3.2 What human resources are assigned to different waste management functions? How are staff competences levels established and maintained?

3.3 What processes are in place to engage in dialogue between operator and all interested parties, including the waste producers?

3.4 How does the safety case inform that the structure and organisation of the operator contribute to design a radioactive waste disposal facility that is practicable and safe?

3.5 What programme of research and development is carried out or envisaged in support of safety during siting, design, construction, operation, closure of the facility?

3.6 What process is used to establish all the technical specifications used for controlling activities and processes relevant to safety throughout the development, operation and closure of a disposal facility?

3.7 What process is used to identify and retain all the information relevant to the safety case?

Requirement 4: Importance of safety in the process of development and operation of a disposal facility

Throughout the development of a disposal facility, an appropriate understanding of the relevance and implications for safety of the available options shall be developed by the operator, for achieving the ultimate goal of providing an optimized level of operational and post-closure safety.

4.1 What process is in place to ensure that the implications for safety are taken into consideration and that there is an adequate level of confidence in safety before key decisions are taken?

4.2 How is the optimization of safety taken into consideration in the decision-making process?

4.3 How is it determined that before construction activities are commenced that there is sufficient evidence for the feasibility and effectiveness of design features important to safety to perform their design functions over the intended timeframes?

4.4 How is it demonstrated that before construction activities commence there will be sufficient evidence that the performance of the backfilling, sealing and capping will function as intended to fulfil design requirements?

4.5 What approach is used to determine that an adequate level of characterization has been carried out before construction commences?

Requirement 5: Passive means for the safety of the disposal facility

The operator 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.

5.1 What processes are in place to ensure that the passive measures (applied either during operational phase or after closure) are evaluated and optimized throughout siting, design, construction, operation, and closure of the facility?

5.2 What active measures are in place or envisaged for the radioactive waste disposal facility to complement the passive measures?

5.3 To the extent that some active measures are adopted, what process is put in place to ensure these are minimized?

Requirement 6: Understanding of a disposal facility and confidence in safety

The operator of a disposal facility shall develop an adequate understanding of the facility and its host environment and the factors that influence its post-closure safety over suitably long time periods, so that a sufficient level of confidence in safety is achieved.

6.1 What factors (features, events or processes) of the facility and its host environment are important to safety?

6.2 How have these factors been identified?

6.3 In respect to 6.1 and 6.2 how is it demonstrated that these factors are sufficiently well characterized and understood?

6.4 What kind of less quantifiable factors (such as for example paleohydrogeology, natural analogues, or the use of known technology…) are used to complement the confidence in safety?

6.5 How is it demonstrated that the knowledge base related to the performance of the disposal system has been developed and contributed to an increased level of confidence over time?

6.6 In respect to 6.5, how is this knowledge base used to demonstrate the reliability or robustness of design features important to safety?

6.7 How is it demonstrated that the appropriate range of possible disturbing events and processes (for the operational phase but also regarding post closure), including those of low probability, is taken into consideration in the safety case?

6.8 In regards to 6.7, how is it determined to what extent safety functions may be degraded by these disturbing events and processes?

6.9 What approach (methods, or measures, or procedures…) is in place to address uncertainties including their identification, characterization and management?

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 is 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.

7.1 What safety functions are associated with the various engineered and natural features of the disposal facility? During what timeframe are the functions intended to be effective?

7.2 What safety functions, if any, are provided by active as opposed to passive means and what are the corresponding time frames?

7.3 How is it demonstrated that a sufficient margin of safety will remain if a particular safety function does not perform fully as intended?

7.4 How is it informed that safety functions, if any, are complementary?

7.5 How is overall adequacy of the multiple safety functions evaluated and what approach is taken to demonstrate that safety is not unduly dependent on any single safety function (application of the defence in depth principle)?

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 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.

8.1 What are the general characteristics of the site and of the disposal facility that are foreseen to provide containment?

8.2 What degree of containment is claimed for the components of the waste disposal system including the waste form, packaging, and other engineered and natural features?

8.3 How is it demonstrated that the major part of activity will decay in situ within the designed containment configuration?

8.4 What is the intended design lifetime of the containment configuration and how is this deemed to be adequate?

8.5 How is it established that the migration of radionuclides outside of the disposal system will only occur after the heat produced by radioactive decay within the waste has substantially decreased?

8.6 How is the release of any gaseous or airborne radioactive material from the waste form or waste packages demonstrated to be acceptable?

8.7 How is it demonstrated that the safety criteria have been met over the stipulated timeframes?

8.8 How has uncertainty been accounted for and managed in assessing radiological impacts?

8.9 Are indicators of safety other than radiation dose made use of and how is this done?

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.

9.1 What are the general characteristics of the site and of the disposal facility that are foreseen to provide isolation?

9.2 What are technical basis for designing features whose lifetime must be consistent with the timeframes over which they are intended to provide isolation?

9.3 What is the anticipated duration of any administrative controls providing for isolation and how is it derived?

9.4 What factors have been identified that could impact the isolation function of the disposal facility and what measures have or will be taken to minimize the influence of these factors?

9.5 How is it demonstrated that the facility has been located in a suitable host geology that will allow the disposal system to provide adequate isolation of radioactive waste?

9.6 How is it demonstrated that the safety criteria have been met over the stipulated timeframes?

9.7 How has uncertainty been accounted for and managed in assessing radiological impacts?

9.8 Are indicators of safety other than radiation dose made use of and how is this done?

9.9 In cases where human intrusion events could give rise to the radiation dose criteria for intrusion being exceeded, how were alternative design options considered before deciding on the final design?

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.

10.1 How is it demonstrated that the passive safety features will be robust enough (since repairing or upgrading is not envisaged within their intended lifetime)?

10.2 What is the basis for the programme of surveillance and monitoring of passive safety features and how is the adequacy of the programme addressed in the safety case for each different step of the facility lifecycle?

10.3 What monitoring and surveillance will be carried out at the different steps of the facility development, operation, closure and post closure to ensure that passive safety features are or will fulfil their assigned safety function after closure?

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.

11.1 What are the major steps that have been identified for the life cycle of the facility and what are the regulatory decisions associated with these steps

11.2 What iterative evaluations have been conducted of the performance and safety of the disposal system in each step?

11.3 How was considered the possible development of different activities (construction, operation, closure) at the same time in the facility?

11.4 In respect to 11.3, how was assessed the safety of the facility, before and after closure, when considering such activities conducted in the same time?

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 operator, 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.

12.1 What safety objectives and safety principles have been identified as a basis for the safety case?

12.2 How is each element of the safety case addressed and enhanced at each step of the facility life cycle?

12.3 What measures are in place to ensure adequate confidence in the safety of the facility at each of the major decision steps?

12.4 How is it ensured that the adequacy of the scientific basis for safety assessment and the various supporting analyses is evaluated?

12.5 What process is in place to ensure the access of interested parties to the safety case and all supporting assessments and analysis?

12.6 What is the process of regulatory review associated with the different steps? What was the process for assessing the relevance of the technical and scientific arguments developed in the safety assessment (for example by performing technical review in support to the regulatory review?)

12.7 What approach has been used to demonstrate that safety requirements have been met when deciding to move to the next step?

12.8 What arrangements are in place to undertake periodic safety reviews, including update of the safety case, during the operational period?

12.9 What role does the safety case play in supporting the decisions to be taken to move to subsequent steps?

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.

13.1 How is the adequacy of design and operational features evaluated?

13.2 What approach has been used in order to assure that the safety case addresses as well operational as long post-closure safety?

13.3 How is it demonstrated that the feasibility of implementing the design is addressed?

13.4 How do the safety case and the supporting assessments demonstrate adequate defence in depth provisions?

13.5 How does the safety assessment process demonstrate that all relevant accident or disturbing event scenarios have been analysed, including those of lesser frequency?

13.6 How does the safety case address occupational exposure and public exposure arising from operation (anticipated or unanticipated operational occurrences) during the facility lifetime, and on what basis?

13.7 What approach is adopted to consider the consequences of unexpected events and processes that test the robustness of the disposal system?

13.8 What approach is taken to develop a reasonable level of assurance that all the relevant safety requirements will be complied with and that radiation protection has been optimized?

13.9 What sensitivity analyses and uncertainty analyses have or will be undertaken to obtain an understanding of the performance of the disposal system and its components under the range of normal evolutions and potentially disturbing events?

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.

14.1 What is the scope and structure of the documentation which makes up the safety case and supporting safety assessment for the different steps of the project?

14.2 What is the process used to develop and maintain the safety case and supporting safety assessments documentation to assure justification (sufficiently detailed and argued), traceability and transparency?

14.3 How are assumptions and decisions that play a role in the development of the safety case and associated safety assessments documented and recorded?

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.

15.1 What is the planning basis for the site characterization program?

15.2 What is the appropriate site characterization program for the different phases of disposal facility development?

15.3 What general approach is taken to iterate the site characterization work with the safety case and supporting assessment?

15.4 What approach is taken to characterize the surface environmental features including natural aspects such as:

- hydrology,
- meteorology,
- flora and fauna,
- anthropogenic activities in the site environs relating to normal residential patterns,
- industrial and agricultural activity,
- natural background radiation, and
- the radionuclide content in soil, groundwater and other media

15.5 What approach is taken to characterise the geological aspects such as:

- long term stability,
- faulting and the extent of host rock fracturing;
- seismicity;
- volcanism;
- confirmation of the volume of rock suitable for the construction of disposal zones;
- geotechnical parameters relevant to the design;
- groundwater flow regimes;
- geochemical conditions;
- mineralogy

15.6 What approach is taken to identify the features, events and processes that could have an impact on safety and which are to be addressed in the safety case and supporting safety assessment?

15.7 What approach is adopted to develop understanding of the site to support the conceptual models used in the safety assessment?

15.8 What general approach is taken to determine the extent of characterization necessary for different parameters?

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.

16.1 What is the basic design and how is it justified that it is complementary with the host environment?

16.2 How is it justified that optimal use has been made of the safety features offered by the host environment?

16.3 What measures have been taken to ensure that the layout is designed so that waste is emplaced in an appropriate location in consistency with the safety case?

16.4 How has the feasibility of fabrication of waste containers and of the construction of engineered barriers been justified?

16.5 How is it justified that appropriate materials are used in the facility design?

16.6 What design considerations address the long-time performance requirements of the disposal facility? Are natural and archaeological analogues taken into consideration, and if so, how?

16.7 If design features are incorporated to facilitate retrievability, how is it justified that safety is not compromised?

16.8 How is it justified that sufficient flexibility exists in the design to allow for variations such as in rock conditions or groundwater conditions in underground facilities?

16.9 How does the design ensure that in the event that fissile materials are present in the waste a sub-critical configuration will be maintained?

16.10 How is it justified that the design provides safety during the operational period?

16.11 How does the design handle with the possible development of different activities (construction, operation, closure) at the same time in the facility?

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.

17.1 What construction techniques have been decided upon and how have they been demonstrated to be compatible with the various safety functions described in the safety case?

17.2 How have the construction techniques been deemed to be feasible in particular in an underground environment and what evidence is provided of their adequacy (for instance by means of in situ demonstration tests) ?

17.3 How has it been demonstrated that excavation and construction activities will be carried out in such a way as to avoid unnecessary disturbance of the host environment?

17.4 How is it demonstrated that sufficient flexibility exists in the construction techniques to allow for variations such as in rock conditions or groundwater conditions in underground facilities?

17.5 What plans have been developed to ensure that ongoing excavation and construction does not compromise either operational or post-closure safety?

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.

18.1 How is it demonstrated that all operations and activities important to safety are subjected to limitations and controls?

18.2 How does the safety case address and justify the operational management arrangements which are used to ensure that the safety objectives and criteria are met?

18.3 What provisions are in place pertaining to maintaining active controls for safety, while the facility remains unsealed following emplacement of waste??

18.4 What approach has been used to ensure that when fissile material is disposed of in the facility it will be managed and emplaced in a configuration that will remain sub-critical?

18.5 What approach has been used to assess the possible evolution of the nuclear criticality hazard after waste emplacement, including in the post-closure period?

18.6 How is it demonstrated that configuration management processes are adequate and effective?

18.7 How is it demonstrated that the safety documentation is managed, updated, and preserved, especially with plant modifications, to assure safety?

18.8 What system(s) are used to ensure that all documentation associated with operations such as operating procedures, specifications and emergency plans is subject to appropriate control procedures?

18.9 What processes and plans are in place to address abnormal operations and emergency situations?

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.

19.1 What are the elements of the closure plan and how do they relate to the initial design of the facility?

19.2 In consistency with requirements 1 – 3, what arrangements have been made to ensure the availability of the necessary technical and financial resources to achieve closure?

19.3 What plans are in place for closure and seal or capping designs and how are they updated as the design of the facility is developed?

19.4 What arrangements are in place to ensure that the disposal facility will be closed in accordance with the conditions set for closure by the regulatory body in the facility's authorization (e.g. license or certification), with particular consideration given to any changes in responsibility that may occur at this stage?

19.5 What particular considerations have been given to the implications of closure operations being performed in parallel with waste emplacement operations?

19.6 How is a delay in backfilling, the placing of seals or capping for a period after the completion of waste emplacement evaluated with respect to operational and post-closure 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.

20.1 What approach is used to derive the waste acceptance criteria (WAC) and verify that they will allow for safe disposal with regard to both operational and long term safety?

20.2 How is the WAC demonstrated to be consistent with the safety case?

20.3 What measures are taken to ensure that the quality control of waste packages, including control of waste preconditioning process(es) and verification of outputs' conformance with the WAC, relies on an appropriate characterization of waste ?

20.4 How are responsibilities, allocated with regard to waste form and waste package compliance with the WAC, clearly defined and applied?

20.5 How does the WAC take into account the need for handling of waste packages included in the acceptance process in a manner that will not cause damage to the packages?

20.6 What plans are in place to deal with non-compliant waste packages including those misloaded, misplaced, physically damaged or QA non-compliant and to prevent recurrence?

20.7 How was uncertainty in overall safety assessment results dealt with in establishing the WACs? Are the WACs a reflection of an expected case mean outcome, an expected case extreme outcome, or a low-likelihood disturbed case mean or extreme outcome?

20.8 What arrangements/agreements are or will be in place to ensure and verify that waste intended for disposal is characterized to provide sufficient information to ensure compliance with the WAC?

20.9 How does the corrective action program ensure that initial deviation from the WAC will not have a detrimental effect on long term performance?

20.10 What processes are in place to deal with changes in inventory or waste forms that may arise?

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.

21.1 What are the objectives, monitored attributes or parameters and reference performance criteria for the monitoring programme and on what basis are they determined?

21.2 What data collection and monitoring strategies are planned to be carried out during siting, construction, operation and closure of the disposal facility to demonstrate that the evolution of the disposal is consistent with the conditions considered in the safety case (and assumptions made in the safety assessment) ?

21.3 How do the monitoring programmes consider:

- providing information for input to or modification of the safety assessment?,
- the assurance of operational safety, and operability of the facility?
- emphasis on safety and security?

21.4 How are deviations from the reference criteria managed and what actions are proposed if monitoring identifies conditions or behaviour not accounted for in the safety case?

21.5 How is it demonstrated that monitoring programmes are designed and implemented so as not to adversely affect overall level of safety of the facility?

21.6 What extent of periodic or continuous review or other degrees of flexibility have been included in the monitoring programme to enable revision and updating during the development and operation of the facility or when unanticipated conditions emerge?

21.7 How are the resources available to undertake and sustain the monitoring programme shown to be adequate?

21.8 How have actual or proposed monitoring programmes for other facilities of a similar nature, including existing closed near-surface disposal facilities been taken into consideration?

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

22.1 What are the plans for institutional controls for a deep disposal and how are they consistent with the approach for post- closure safety in the safety case?

- Which measures (technical, legal, administrative and financial) are foreseen in order to prepare for monitoring during the post-closure phase?
- how are local land use controls/site restrictions considered?
- what are the plans and the organisation defined to ensure that local, national and international records are preserved and for how long?
- what use is to be made of surface and/or subsurface markers and what regulatory or other basis defines the requirements for these markers?

22.2 What are the responsibilities for the developer, regulator, and government during the period of institutional controls?

22.3 If no institutional control is required beyond closure, has this been justified in the safety case and what reasons have been provided?

22.4 After the period of institutional controls, what status is envisaged for the facility?

22.5 How does the safety case (post-closure phase) address and justify the method and time period the system will be monitored?

22.6 What arrangements assure the ability to pass on information about the disposal facility and its contents to future generations to enable them to make any future decisions on the disposal facility and its safety?

22.7 How will institutional controls be harmonized with other activities that may be occurring in parallel (safeguards activities, environmental impact…)

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.

23.1 What nuclear safeguards plans are envisaged?

23.2 What considerations have been given to nuclear safeguards being achieved by remote means (e.g. satellite monitoring, aerial photography, micro seismic surveillance and administrative arrangements)?

23.3 How will safeguard monitoring and other monitoring and surveillance activities be organized in order not to compromise safeguards and safety functions?

23.4 What measures have been taken to ensure that safeguards related activities will not compromise post-closure safety?

23.5 What consideration has been given to the interface issues between the system of accounting for and control of nuclear material (nuclear safeguards) and the safety of the facility?

23.6 How will the continuity of knowledge important to safeguarding the system be maintained and controlled for use by only those identified entities who have a need to know?

23.7 What procedures are set up to integrate monitoring and safeguards activities in respect of?

- exchange of information and measurement data

- coordination of changes in testing and measurement techniques
- worker safety monitoring

23.8 The continuation of safeguards and monitoring after closure may be beneficial to improving confidence in post-closure safety – what consideration has been given to this factor and how is it integrated with post-closure institutional controls?

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.

24.1 What measures are planned to prevent the unauthorized access of individuals and the unauthorized removal of radioactive material (e.g. in respect to nuclear terrorism and criminal intent)?

24.2 What plans are in place that can demonstrate that safety and security are approached in an integrated manner?

24.3 How is it planned that security measures (e.g., access control program) will be coordinated during parallel activities (e.g., construction, waste emplacement, and closure and sealing of rooms, galleries, boreholes, shafts or drifts)?

24.4 What approach is planned to ensure that the level of security required is commensurate with the level of radiological hazard and the nature of the waste?

24.6 Is consideration given to ensure that an emergency response to one part of the system will not lead to security vulnerability in another part of the system?

24.7 If security is required in the post-closure period, what are the security plans?

- do the security plans describe what level of security is required?
- do the security plans describe how long security is to be applied and do they provide a technical basis for the timeframe**?**

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.

25.1 What are the elements and structures of the management system?

25.2 How does the management system define the roles, responsibilities, authorities and organizational structure for implementing processes to ensure an adequate level of quality in all safety related activities and functions?

25.3 How does the management system accommodate the evolution of the facility from siting through final closure?

25.4 What is done to ensure and document that the level of attention assigned to decisions is commensurate with their importance to safety?

25.5 How does the management system consider uncertainty in the information used in making decisions?

25.6 How is it demonstrated that the management system will comply with international standards on management systems?

25.7 What is the process for identification of safety related issues and assuring that corrective actions are taken at an appropriate level, verified and documented?

25.8 How is the continued adequacy and effectiveness of the management system assured?

25.9 How is it assured that the relevant activities, systems and components are identified and evaluated?

25.10 How does the management system provide:

- that the necessary quality of data has been achieved;
- that safety related components have been supplied and used in accordance with the relevant specifications;
- that safety related activities have been performed in accordance with the relevant specifications;
- that the requirements for waste acceptance have been met and that waste has been emplaced in the disposal facility in accordance with the applicable quality and technical requirements.

25.11 How are financial, administrative, managerial, competence and other resources ensured for retention of records over the necessary time period?

25.12 How is a “knowledge management system” implemented in order to:

- enable changes in management and key personnel,
- support and accommodate changes in information technology, and
- assure identification and preservation of that portion of the information important to safety and any reassessment of the facility in the future?

25.13 How does the management system promote a safety and security culture? What measures are in place?

25.14 How does the management system provide assurance of quality in the design and operational features addressed in the safety case?

25.15 How is the management system structured in order to contribute to the defence-in-depth?

Annex1 Remaining questions

The work undertaken for developing the questionnaire and reviewing the SSR-5 standards contributed to identify areas where, according to the view of the GEOSAF members, requirements and the way of complying with deserved more attention and better mutual understanding. In particular, participants considered as well that some comments arising from the review of the questionnaire were very instructive and suggested that they could be transformed into additional questions or subsidiary questions to illustrate better their meanings. These comments are developed below.

Requirement 1: Government responsibilities

The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities are clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility.

Geological disposal programmes last over decades and this particular aspect must be reflected by the various organizational factors that will be put in place. It concerns in particular issues related to competence building and allocation of sufficient resources (human, financial…) to allow the development of the project in consistency with IAEA safety standards.

Requirement 2: Responsibilities of the regulatory body

The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.

The Group discussed the issue of the appropriate time for setting (regulatory) requirements but did not reach a consensus: Early definition of requirements provides security in that the stakeholders know the "rules of the game" from the beginning. On the other hand, an early definition increases the likelihood of very generic and unspecific requirements while a later definition would allow accounting for the evolving knowledge.

Regulators and/or TSOs should be involved early before a safety case is actually submitted. Some guidance could be provided on the activities by the regulators and/or TSOs to prepare for that review that could include:

- *Review of key reports, technical publications from proponents*
- *Development of Guidance documents (for example Canada, France, etc.) for proponents to develop safety case*
- *Independent research performed externally and in-house on key safety aspects , on areas which are complex and need better understanding, development of modelling capabilities in order to perform independent calculations and assessment, etc. (see Appendix on TSOs research capacities)*
- *Participation in international activities(such as GEOSAF and IGSC)*
- *Seeking expert input with external independent experts*
- *Periodic meetings with proponents to give feedback, either in the form of formal review reports and/or informal discussion (see Appendix on French study case)*

The regulators' resources can not match the operators'. The regulatory activities in preparation for the review of the safety case should then focus on key aspects that are relevant to safety, in order to identify gaps and provide feedback to the proponents before they finalize their safety case. Adequate resources should be allocated, and responsibilities should be defined. A team of reviewers should be established. It is anticipated that in early stages, activities are focused on geoscientific disciplines (geology, hydrogeology, geomechanics, geochemistry…). At later times before submission of the safety case, other experts should be involved (fire protection, criticality, ventilation, *transportation, radiation protection, biosphere modelling, dose calculation, etc.)*

WG1 notices that the perception of independence can vary between States, depending on the socio-political situation. In practice, a regulator, although independent, must however interact with the proponents. What degree of interaction is acceptable and tolerable before independence is perceived to be affected is a question every country should ask itself.

Requirement 3: Responsibilities of the operator

The operator of a disposal facility shall be responsible for its safety. The operator shall carry out safety assessment and develop a safety case, and shall carry out all the necessary activities for siting, design, construction, operation, closure and, if necessary post closure surveys, according to national strategy, in compliance with the regulatory requirements and within the national legal infrastructure.

The group discussed the issue to present the overall safety strategy approach to the project in the Safety Case. The evolution of the safety strategy over the project's duration should be addressed.

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 is 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.

The group discussed the issue to test the robustness of the system by deriving scenarios that assume partial or *total failure of different safety functions, and how the design accommodate these?*

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 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.

H*ow is **containment** defined ?*

IAEA Safety Glossary 2007 Edition defines containment as “Methods or physical *structures* designed to prevent or *control* the release and the *dispersion* of *radioactive substances*. Although related to *confinement*, *containment* is normally used to refer to methods or *structures* that perform a *confinement* function, namely preventing or controlling the release of *radioactive substances* and their *dispersion* in the environment. See *confinement* for a more extensive discussion”.

SSR-5 section 3.39: The containment of radioactive waste implies designing the disposal facility to avoid or to minimize the release of radionuclides.

G*EOSAF group reviewed the requirement and the explanatory clauses that follow the requirement. The group considers that this requirement should explicitly mention both normal evolution and altered evolution scenarios. However, the participants noticed that DS-355 provided more detailed guidance on scenario definitions. Concerning clauses 3.40 and 3.42, the group considers that the guidance provided related to container integrity is not always practicable or necessary in order to have safe containment. Some concepts do not rely on container integrity. For example, in the dry salt concept, containers might fail earlier due to mechanical impact, but due to dry conditions, radionuclide migration is controlled and minimized. In any case, the demonstration must be made* *about the ability of the concept to contain activity, even when unexpected or altered situations occur.*

The degree of containment for different engineered and natural barriers is calculated in the Dossier 2005 for different radionuclides and several scenarios. For Iodine 129 originating from spent fuel, in the normal evolution scenario, the Safety Assesment results showed (Figure 1):
Total containment in the containers during the first 200 years; total failure of the containers at 10,000 y. The peak release of I-129 from the containers into the disposal facility occur shortly after 10,000 y.
The flux into the Callovo-Oxfordian (COX) starts at approximately 220 years, peaks at approximately 10,000 yr. The flux out of the COX into the overlying formation starts at 300yr and peaks at 200,000 yrs.
The flux into the shaft is only 0.0008% of the total release from the wastes. Only 3x10^{-5} of the total release exits the shaft at more than 100,000yr.

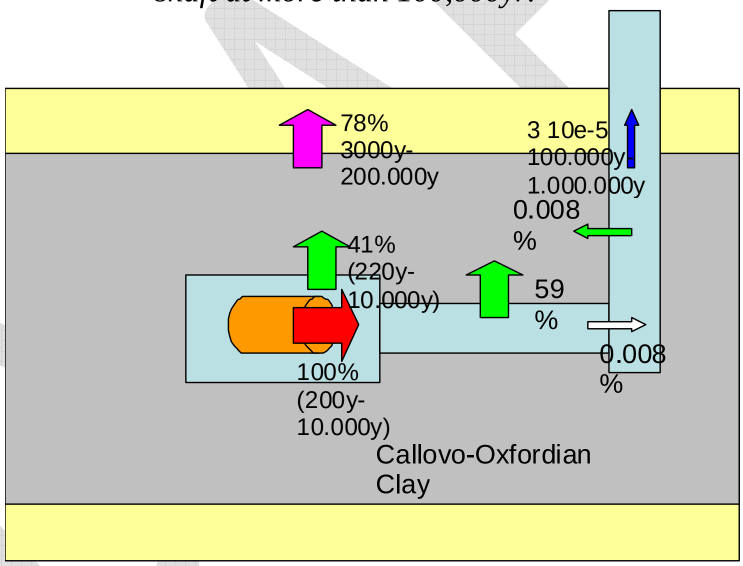

Figure 1: Illustration of the containment provided for I-129 in the normal evolution scenario in the French Dossier 2005. The % of flux, the starting time, and the time to peak, are shown for different compartments.

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.

H *ow is* ***isolation*** *defined ?*

There is no definition for isolation in the IAEA Safety Glossary 2007 Edition.
SSR-5 section 3.44 Isolation means design to keep the waste and its associated hazard apart from the accessible biosphere (see figure 2). It also means design to minimize the influence of factors that could reduce the integrity of the disposal facility. Sites and locations with higher hydraulic conductivities have to be avoided. Access to waste has to be made difficult without, for example, violation of institutional controls for near surface disposal. Isolation also means providing for a very slow mobility of radionuclides for migration from disposal facilities.

T *he definition of Isolation given in SSR-5 (as cited in the first sentence above) is applicable for waste, but not the radionuclides. However, in the last three sentences, hydraulic conductivities of the host media and slow mobility of radionuclides were invoked. The group is of the opinion that these characteristics are rather related to containment of radionuclides and not isolation of the wastes. It suggests, and adopted the following definition to carry on with the workshop:*

From GEOSAF understanding, isolation means spatial separation of the wastes from the biosphere; while containment means prevention and/or minimization of migration of radionuclides through the different barriers of the disposal system.
The following figure schematically shows this understanding:

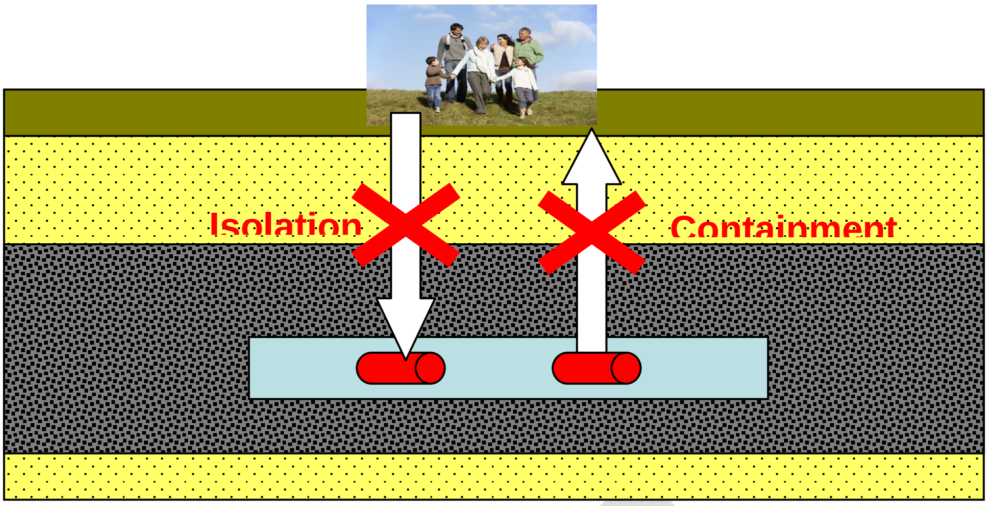

Figure 2: illustration of the isolation and containment concepts

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 GEOSAF group generally agrees with the stages proposed in the European Pilot Study (see annex 2) but noted differences in approaches between steps defined in SSR-5, Req.3 and the phases taken into consideration by the EPS group. The identified phases defined in the EPS present in particular a first phase called "conceptualization phase" prior to the siting phase as well as specific regulatory milestones regarding authorization for construction, operation and closure as stated below.

However, because jurisdictions differ between countries, a license, permit or approval is not always required at the end of each stage. We also generally agree that the safety case provided by the proponent at the end of each stage should be reviewed by the regulators, even if it is not formally submitted in support of some kind of license, permit or approval. Decision points, however, might be taken either by a policy-maker or by the implementer / operator. The issue is all the more important because the Safety Case has to inform these decisions and consequently has to be tailored accordingly.

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.

Clarification should be provided on the meaning of managerial control measures and regulatory control.

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.

This requirement doesn't address the process of siting before engaging in characterization process of a site. More guidance on siting procedure is needed, with respect to, as example, the location away from mineral resources and geothermal activity...There should be as well some guidance on at what stage an Underground Research Laboratory may be needed.

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.

The group recommends that the uncertainties associated to the accurate consideration of the waste inventory be *anticipated in the development of the disposal project. Indeed as the disposal project will be developed over several decades, uncertainties on the planned inventory have to be taken into account in the design of the facility and in the demonstration of safety (for example taking margins in the volume and inventory of waste when designing the facility and making the safety assessment).*

The compatibility between the waste acceptance criteria and the evolution of the disposal concept (selection of site, characterization of pore water, geometry and dimension of the disposal layout, knowledge of the inventory…) must be ensured.

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

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The group raised issues on the role of inadvertent human intrusion in the safety case for deep geological disposal.

In relation with isolation requirement, the purpose of a deep geological disposal is to reduce the possibility of any human intrusion in the waste disposal tunnels as long as potential hazards linked to the waste activity could cause unacceptable radiological impact. The depth and the absence of valuable natural resources close to the disposal location are specific conditions that contribute to minimize the likelihood of such an intrusion.

Nevertheless, intrusion in the disposal may be accounted for with the view to guiding conception of the disposal with respect to optimization strategy of the design and to assessing the robustness of the disposal. As an example, in the Dossier 2005 Argile, Andra assessed the consequences of a drilling borehole through components of the disposal. This could result in a potential contamination of aquifers due to the connection between disposal tunnels and geological surroundings. Lessons learnt from this scenario were that the modular architecture of the disposal facility *and the low hydraulic characteristics (permeability, hydraulic gradients…) of the host rock and of surrounding formations allowed for a strong limitation of the radionuclide release and transfer through the borehole to the aquifers. These results completed the set of arguments gathered by Andra (the French waste management organization) in favor of the robustness of the disposal concept but didn't aim at assessing the consequences of a plausible situation.*

Regarding the compliance with radiological criteria, SSR5 introduces updated recommendations in accordance with ICRP103 for the case of inadvertent human intrusion in the disposal. However, since the likelihood of inadvertent intrusion is low, the associated risk is likely to be outweighed by the higher level of protection and safety afforded by the disposal of waste in comparison with other strategies.

The group also raised issues on the need and duration of institutional control including surveillance and monitoring (SSR-5 does not accept to rely on ongoing (perpetual) control as a safety measure, although this is common practice for example when managing mining waste)

SSR-5, 5.11 states that "The status of a disposal facility beyond the period of active institutional control differs from the release of a nuclear installation site from regulatory control after decommissioning inasmuch as release of the site of a disposal facility for unrestricted use is generally not contemplated. […]". As a matter of fact, the radioactive source term of a geological disposal will remain in place after closure and dismantling of surface facilities (such an installation is designed for that purpose!). As a consequence, even if the long term safety demonstration does not rely on perpetual institutional control and is based on passive features linked to the characteristics of the disposal:

- *it should be stated that there is no a priori desire to abandon the disposal site after post-closure phase,*
- *it shouldn't be stated that the disposal site after post-closure phase will be abandoned,*
- *record keeping of the site should be envisaged on a time frame in accordance with the duration of the hazards caused by the activity of the waste.*

Annex 2 European Pilot Study

The pilot study aims at developing, amongst European regulators common positions on the safety approach to geological disposal of radioactive waste. More specifically the approach focuses on the content of a safety case for a geological disposal and the way this safety case should be reviewed by the authorities. Some flexibility in the process of submitting and reviewing a safety case is included in the EPS to take into account the different existing regulatory regimes and administrative procedures existing amongst various countries.

In the process of up-dating and completing the EPS (version 2010), the redactors have taken into account the comments of the review by GEOSAF of version 2007 of the EPS and above all the necessity for flexibility. Other comments have been integrated in the document.

According to the EPS, and in accordance with international standards and recommendations, a disposal facility and its safety case should be developed in a step-by-step manner with well-defined decision points. Safety arguments must be continuously refined and supporting safety assessments must be undertaken iteratively as the disposal facility is developed. The structure of the assessments is expected to be consistent throughout for more efficient regulatory review. It is acknowledged that the degree to which a step-by-step process is legally implemented in regulations varies from country to country, and the responsibilities of the regulator at decision points may also vary. However, it is recommended that the regulator should be involved from the earliest stages in the development of a disposal facility, even if initially the role is less formal and decisions or opinions of the regulator may not be legally enforceable.

The safety case can be presented in various formats, but its content should be a collection of documented arguments and evidence supporting the safety of the disposal facility to allow for key decisions relating to progressing to the next phase of development of the disposal to be made. A safety strategy, which sets out the high-level approach for achieving safe disposal needs to be established from the beginning of the project. Elements of the safety assessments supporting the safety case are those related to: assessment of the robustness and performance of the site and engineering of the facility; assessments of impacts to people and the environment, assessments of the management system. The safety case must include an integrated assessment of the overall arguments. The manner and extent to which these elements are assessed during the process of developing and implementing the facility will vary with the phase reached.

Version 2010 develops new expectations for the safety case : the safety case should cover both the operational phase and post closure phase and demonstrate operational safety together with long term safety. It is considered that in the process of optimization, long term implications should be emphasized for the choice of the best option. It is acknowledged that depending on national regulations, operational and long-term aspects may be addressed under separate regulations and reviewed by different licensing bodies.

The assessment of the impact of the disposal facility should also cover the non radiological impact, however, in this domain and, depending on the national context, different licensing bodies may be concerned and the emphasis given to non-radiological impacts may vary with the licensing body.

The safety case must set out clearly information on the design, construction and operational options considered and the key features on which safety relies. The safety case will need to acknowledge and accommodate uncertainties. It should include a program of work to acquire enough knowledge to demonstrate confidence in the safety of the disposal system. Assessing the soundness of the proposed options is essential to enable the project to move forward from one step to the next.

Actual version of EPS (2010) covers all the phases of the development of a disposal facility which describe broadly the progressive development of a disposal facility (and its safety case):

*The **conceptualisation** 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 stage should guide the implementer on the likelihood of achieving the necessary demonstration of safety.*

*The **siting** phase, during which the implementer identifies potentially suitable sites that are compatible with the design concept and characterises these sites to the extent that a decision can be made on the preferred site.*

*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 assessment, to support the implementer's application to construct the facility. This is used by the regulator to decide whether to grant a licence for the implementer to construct the facility and is the crucial milestone in the development of a disposal facility.*

*The **construction** (and application for operation) phase, during which the implementer demonstrates that it has built the facility in accordance with the terms of the construction licence. In preparing for operation, the implementer will need to demonstrate safety during operation and radiation protection of workers and members of the public. The* *regulator would decide whether to grant a separate licence before emplacement of waste in the facility.*

The ***operational*** *phase, during which the implementer emplaces waste packages in the disposal facility, may build new disposal units, backfill and possibly seal, either temporarily or permanently, parts of the disposal facility where waste emplacement has been completed ; develops its application to close and seal the facility, and prepares a draft plan for post-closure institutional controls, monitoring and surveillance. Towards the end of this phase the regulator will decide whether to grant a license for the implementer to close and seal the facility.*

The ***post-closure*** *phase : the implementer will demonstrate that it has closed the disposal facility in accordance with safety requirements and present a firm plan for institutional controls and continuing monitoring and surveillance. At this stage the regulator will confirm what controls, monitoring and surveillance are required and for how long.*

The EPS identifies when certain information would generally be foreseen, but it is expected that national programs may have different requirements. Regulatory decisions will govern the progression through the stepwise process. In nearly all programs, formal decisions are expected at least from the point of disposal facility construction and, in some countries regulatory decisions will also be needed in earlier phases (conceptual and siting phases). Political decisions may also be required in addition to regulatory actions.

Annex3 National programmes

The purpose of this annex is to draw a picture of the progress and status of the different national disposal programmes that are developed within the member states. This information was gathered from the different participants but it does not reflect an official position of the organisations or member states involved in GEOSAF. It aims at presenting what could be the possible regulatory process envisaged by the member states for licensing the disposal.

Regulatory Approvals and HLW/SNF Disposal Programme Structure and Status

L : licence[1] P : permit[2] A : approval[3] D : decision[4]

* : HLW/SNF Disposal Programme status

Authorization for:	Belgium	Bulgaria	Canada	China	Czech Republic	Finland	France	Germany	Hungary	India	Indonesia	Japan	Korea	Pakistan	Portugal	Saudi Arabia	Slovenia	South Africa	Ukraine
Conceptualization / generic design		D	*				L[8]	*	*	*	A				16	L		D	A
Site identification / screening	D	A		*	*		L[8]			12	A	*A		*		L		D	L
Site selection		A		6	P[7]						A	A				L	L	D	
Site detailed characterisation		D	A[5]			*D	* A[8]		A		P	A[13]							L
Detailed design								L	P		L	L					L	D	L
Site preparation			L						DL		P					17	L	L	L
Construction		A	L		P	L	L[8]	A[9]	L[10]		L	A	L	L					
Commissioning	L	L							L		L	A	P	L			L		L
Operation			L	6	P	L			L	12	L	A	L					L	
Decommissioning	L	L	L						L		L		P	P			L		18
Closure / sealing	L	L			P[7]	L		A[9]			L	A	P	A				L	
Post-closure	L								11		P	A[14]	D				L		18
Abandonment	L		L			A					P	15							

Footnotes

[1] Licence: a legal document issued by the regulatory body granting authorization to perform specified activities related to a facility or activity (in the context of this document, related to management of spent fuel or of radioactive waste), typically specifying conditions on those activities, responsibilities for reporting by the licensee, and compliance oversight by the issuing authority

[2] Permit: written order giving permission to act (may specify conditions on those actions)

[3] Approval: formal pronouncement that something is good or satisfactory

[4] Decision: formal judgement (of question, etc.)

[5] Approval from federal Minister of Environment based on an Environmental Assessment. The subsequent licensing decisions are by the nuclear regulator (CNSC).

[6] Internal decision made by a team of experts in China Atomic Energy Agency (CAEA); regulations that address the procedure of site selection and the type of authorization for each step in the procedure are not formalized yet

[7] Also an EIS submitted to Ministry of Environment for approval

[8] In France the programmes are defined by Law (see the Additional Notes for explanation) and ‘site selection’ and ‘site detailed characterisation’ refer to the disposal area in the vicinity of the URL at Bure. It is undecided if operation will be authorized by a licence or by an approval to commence.

[9] Approval of German Mining Authority for underground works

[10] Environmental Licence based on EIA

[11] At least 50 years of Institutional Controls

[12] Internal decision by team of scientist/engineers in National Agencies; regulatory aspects not formalized yet in India

[13] Siting is divided into 3 phases (Literature Survey, Preliminary Investigation, Detailed Investigation) with approval of Minister of METI at end of each phase. Site Investigations, Design and Safety Assessment are performed iteratively by NUMO within each phase.

[14] In the Japanese programme, Closure (of the underground disposal facility) is before Decommissioning (of the surface facility)

[15] Disbandment of NUMO will be separately laid down by law.

[16] Portugal has no HLW, and no legislation relating to HLW

[17] On-going programme is for storage of unused radioactive sources – licensed up to site selection, following steps to operation are on-going

[18] Regulation after operations is not yet defined

Additional Notes

Belgium
- Decision in Principle on concept by Minister of Interior Affairs, leading to site identification and screening
- Approval of site selection by communities and government ministers
- Environmental Impact Report also required following detailed design
- Remaining licensing steps specified in FANC note 007-020-N Rev. 1, will be translated to a Royal Decree in the future:.
- Licence for construction and operation
- Licence for completion of activities and start of surveillance and monitoring (following operations)
- Licence for closure (may be combined with Licence for completion of activities and start of surveillance and monitoring)
- Licence for confirmation of closure and short period of post-closure activities (continued surveillance)
- Licence for retrieval of regulatory control

Bulgaria
- Decision by Council of the Ministry and Permission by the nuclear regulator (BNRA) on the conceptualization and generic design
- Decision on site characterization needed before Order to Design by BNRA
- Construction requires Order and permission by BNRA
- Subsequent licences issued by BNRA
- Need for authorizations for post-closure and abandonment not yet known

Canada
- Licences are for a fixed period (typically 3-5 years) and must then be renewed
- Environmental Assessment is re-visited and updated as needed at each licence application

China
- Although the law of the People's Republic of China on Prevention and Control of Radioactive Pollution addressed that the HLW should be disposed in deep geological formation, regulations addressing the siting and operation of a disposal facility (including defining the steps in facility development and the authorizations needed at each step) are not formalized yet in China
- Safety assessment and engineering is in the conceptualization and generic design stage
- Management system is in the conceptualization and generic design stage
- Siting is in the site identification / screening stage

Czech Republic
- Authorizations are needed under the Construction Law and Atomic Act
- Permit for Site Confirmation (at site selection) requires Introductory Safety Report / Safety Case and EIA submitted to Minister of Environment
- Permit for Construction requires Preliminary Safety Report

- Permit for Operation (planned for 2065) requires a pre-operational Safety Report / Safety Case, including Waste Acceptance Criteria
- Permit for Closure requires a Final Safety Report / Safety Case and EIA submitted to Minister of Environment

Finland
- Decision in Principle on selected site includes: the community accepts, the government (STUK) approves and Parliament ratifies
- Construction Licence (expected in 2012), Operating Licence and Closure Licence require government (STUK) approval
- STUK inspects operations, and there are periodic renewals of the Operating Licence
- Abandonment is with government (STUK) approval

France
- Site selection for creation of Underground Research Labs (URLs) was licensed by the regulator under the Law of 1991
- Feasibility of geological disposal in clay investigated by the means of the Bure URL was approved by the regulator in 2006 and a new Law of June 2006 established the new programme for the creation (site preparation and construction) application to be submitted in 2015.
- Selection of a disposal site in the vicinity of the URL, additional characterization if needed for the purpose of confirmation and reference design is expected to lead to a construction licence by 2016 (+ a new law on reversibility) and an operating licence or approval for starting operations by 2025
- Further licensing steps are not yet defined

Germany
- Entries in the table reflect the present situation, applied to LILW facilities; a finer breakdown for SNF/HLW is under discussion
- Licensing decision (plan approval) at the detailed design / site preparation stage includes EIA

Hungary
- Approval of a Geological Research Plan for site characterization is not prescribed legally
- Permit based on a final report of site investigations justifying the site suitability
- Preliminary Decision in Principle of the Parliament and an Environmental Licence based on an EIA required prior to site preparation
- Construction Licence is based on architecture design
- Commissioning Licence is based on a pre-commissioning safety case; Operating Licence is based on a pre-operational safety case
- Closure Licence is based on a “final” safety case

India
- Regulatory aspects of the disposal of HLW are not yet finalised, however all developments regarding conceptual design, generic sites and R&D programme are informally communicated to the regulatory body

- Conceptualization, site identification/screening, site selection and site characterization are subject to an internal decision by a team of scientists and engineers and National Agencies

Japan
- Siting divided into 3 phases (Literature Survey, Preliminary Investigation, Detailed Investigation) with approval by METI at end of each
- Site investigations, Design and Safety Assessment are performed iteratively within each phase
- Nuclear Safety Commission’s requirements specify exclusion of sites with unsuitable geologic conditions
- Siting Approvals: Selection of Preliminary Investigation Areas (at end of Literature Survey phase), Selection of Detailed Investigation Areas (at end of Preliminary Investigation phase), Selection of Final Disposal facility Site (at end of Detailed Investigation phase)
- License for radioactive waste management in detailed design phase
- Authorization for commissioning, operation and post-operation after licensing requires: Confirmation for Waste form and Measures for Safety Operation, Approval for the Design and the Construction Methods of Disposal facility; Pre-operational Inspection; Inspection of Welding Methods; Periodic Inspection of Facilities; Notification of Commencement, Cessation or Restart of the Management; Recording and Record Keeping; Approval for Operational Safety Programme and Operational Safety Inspection; Approval for Physical Protection Programme and Physical Protection Inspection; Approval for Closure Plan and Confirmation of Closure in Each Process; and Approval for Decommissioning Plan and Confirmation of Completion of Decommissioning.
- Closure of the underground disposal facility precedes Decommissioning of the surface facility
- The licensee shall perform dose assessment at most every 20 years after licensing.
- All types of authorizations are relevant to the Minister of METI.

Pakistan
- Dry storage is under consideration for spent fuel
- DGNR is in the process of siting disposal facilities, with first priority being near-surface disposal. Potential formations have been identified.
- If spent fuel is declared a waste, then siting process for deep geological disposal facility must be started.
- Regulator is involved with site characterization, detailed design and site preparation prior to licensing construction.
- Operations are under stringent regulatory control

Portugal
- The Directorate General for Energy is responsible for licensing of all installations of the nuclear fuel cycle, including the Portuguese Research Reactor. (RPI) at ITN premises. DG also authorizes the transfer of spent fuel from RPI to the USA as per existing return agreement.

- The Independent Commission on Radiological Protection and Nuclear Safety (CIPRSN) verifies and evaluates the conditions of application of the legislation regulating licensing of all installations and activities that produce radioactive waste
- Currently Portugal does not have HLW to manage, and there is no plan or specific legislation for HLW in Portugal.
- ITN, besides being a research institute, has the legal ability to authorize transfer of radioactive waste between Portugal and other Member States, to evaluate radioactive waste transport safety and collects, segregates, conditions and temporarily stores the treated waste (cement drums) at a storage facility.
- There is nothing in Portuguese legislation concerning radioactive waste storage or disposal in terms of installations characteristics.
- ITN and the producers of radioactive waste follow international good practices (IAEA, etc.)

Kingdom of Saudi Arabia
- Table entries are based on a project to develop a facility to store non-used Radioactive Sources.

South Africa
- Decision on site selection will be based on an EIA
- Construction Licence will include “cold” commissioning; Operating Licence will include “hot” commissioning
- Not yet in the conceptualization stage; at the first step of establishing a science strategy and reaching agreement with the regulators on the development steps and approvals process.

Ukraine
- Site Screening and Site Selection requires a Licence and a Decision under a special law
- Licensing requirements after operations have not been defined, but they will likely include a decommissioning licence

Annex4 Example from the French case and the role of IRSN in developing expertise functions

Independent research activities for performing the technical review process and ensuring the necessary support to the regulatory body

close follow up of the scientific knowledge gained by the WMOs when developing the disposal project and reported in the safety case for external review

In the field of radioactive waste safety, IRSN develops a pluri-annual research programme so as to develop IRSN staff skills and anticipate the needs for new knowledge necessary to perform comprehensive safety reviews of high quality. This research programme, launched initially to support IRSN assessment of Andra's file on the "feasibility of reversible geological disposal in clay" issued in December 2005, is now structured upon the new main steps related to the development until 2015 of the high-level and long-lived intermediate-level waste disposal facility project as prescribed by the French Planning Act of 28 June 2006 on the sustainable management of radioactive materials and waste. This act plans a licence application to be submitted in 2015 for the creation of a deep geological disposal facility. IRSN research programme is annually updated and periodically reviewed by a scientific committee and organised along 4 types of research activities devoted to addressing several "key safety issues" defined by IRSN as follows.

Taking into consideration the feedback and main conclusions drawn from the regulatory review of the "feasibility of reversible geological disposal in clay" in 2005, IRSN has identified a number of important issues, grouped hereafter in " key safety issues", on which researches should be carried out with priority from 2006 to 2015. The issues presented hereafter, which relate only to the Meuse/Haute-Marne site, do not anticipate on the possible emergence of other issues of importance for establishing the safety demonstration during further steps of project development. However at this stage of the project, IRSN gives priority for examining:

- the confinement capabilities of the sedimentary host rock and the identification of possible fracturing in the host formation and the geological layers surrounding it,
- the perturbations due to excavation or due to the interactions between different components,
- the waste degradation,
- the uncertainties on corrosion rates of metallic components, due particularly to a lack of knowledge on transient environment conditions and their duration,
- the dimensioning hypotheses for the various disposal facility components, with the aim at constructing containment barriers that are as effective as is reasonably possible,

- the construction/operational safety (accounting for reversibility) particularly with respect to the risk of explosion relevant to hydrogen produced by radiolysis in waste cells, the ability to remedy a situation caused by a package fall in cells and the possibility of retrieving waste,
- the sealing capabilities with the view to assessing the likely performances of a sealing engineered structure, taking into account the effects of potential disturbances over time or difficulties for emplacing seals at industrial scale,
- the long term performances of the disposal facility with emphasis on hydrogeological modelling, integrated transfer of radionuclides and biosphere modelling. It is particularly important to be able to rule on whether or not localised preferential transfers exist and to assess their influence on the general flow patterns.

Definition of safety research activities

The above mentioned "key" scientific and technical topics should also be of prime concern for the implementer since they relate to "key" safety issues for demonstrating the overall safety of the disposal facility, and the level of funding that the implementer should afford to research activities of concern for safety should be naturally much higher than those of the regulator and technical safety organisation (TSO). This is fully justified by the different respective roles played by both entities but it is of assessor's duty to be able to cover all the safety case issues with care to make appropriate balance between topics that must be addressed by R&D programme or topics that do not require specific R&D development. In this last case, the regulator or TSO should be able to explain why it is not necessary to develop its own research capabilities. In this respect, some aspects are not addressed by IRSN R&D programme because either they relate to conception/construction demonstration tests that are of implementer responsibility or because IRSN considers that the scientific knowledge is sufficiently shared by different stakeholders and well managed by the operator. Considering the elements that justify IRSN R&D programme, 4 categories of major questions are addressed: the adequacy between experimental methods and data foreseen, the knowledge of complex coupled phenomena, the identification and confidence in components performances and the ability of the components to practically meet in-situ the level of performances required. Addressing these questions requires the research programme to be developed along the following lines:

- test the adequacy of experimental methods for which feedback is not sufficient. The assessment of their validity allows addressing the consistency and degree of confidence of the data produced,

- develop basic scientific knowledge in the fields where there is a need for better understanding the complex phenomena and interactions occurring all along the life of the disposal facility and their influence on nuclear safety, so as to preserve an independent evaluation capability in these matters,

- develop and use numerical modelling tools to support studies on complex phenomena and interactions so as to allow IRSN assessing orders of magnitudes of components performances and physico-chemical perturbations but independently than specified and estimated by implementers,

- perform specific experimental tests aiming at assessing the key parameters that may warrant the performances of the different components of the disposal facility. Such experiments are designed in particular to simulate the behaviour of components in altered conditions and allow IRSN delivering appraisal on the specifications of construction that are to be proposed by implementers.

These studies are carried out by the mean of experiments performed either in IRSN surface laboratories, or in the Tournemire Experimental Station (TES) operated by IRSN in the south-east of France. The TES is a former railway tunnel crossing a 150m meters thick Toarcian argillite formation and has been intensively used for some 20 years to perform in-situ experiments devoted to better understanding:

- the diffusion mechanisms in stiff clay (origin of over-pressures and influence of pore size on water-rock interactions…). Many characterization methods (devoted to characterise movement of natural tracers…) have been tested,

- the hydraulic role of faults/joints : survey methods (seismic survey analysis combined with others methods…) used to identify fractures in clay and their potential as water pathway have been tested,

- the differential fracturing phenomenon in clay and its high damping potential,

- the EDZ development: characterisation methods and modelling have been used and developed taking advantages of, on the one hand the 100 years passed since tunnel construction, and, on the other hand the observation of new drifts recently drilled,

- the clayey materials evolution due to cement-clay / iron-clay interactions by characterisation and modelling of 10-year old in situ experiments (using a coupled transport/chemistry code Hytec developed by Ecole des Mines de Paris),

- the chemical conditions during transient processes and the specific effects of the presence of micro-organisms or of redox conditions (characterisation of processes upon Tournemire data) on the waste or engineered components degradation over time,

- the parameters that will have to be specified and controlled in situ to warrant the performance of seals and concrete liners; a dedicated *in-situ* mock-up is under development and will be implemented in TES to study altered evolution of seals,

Besides the Tournemire Experimental Station, specific studies are in progress in complementary scientific fields with the view to:

- better knowing, on the one hand of the physical and chemical properties of the concretes in their initial and altered state and, on the other hand, of the influence of industrial implementation conditions on their performances,

- better understanding the transient phenomena and in particular the behaviour of hydrogen generated by corrosion and radiolysis and its influence on water flow; these studies are addressed by experimental, theoretical and modelling developments,

- better knowing of the waste performances,

- better knowing of the transfer properties of radionuclides and chemical elements under disposal facility conditions (data base review),

- modelling flow and transport of radionuclides by developing computer models simulating the underground flow patterns at various scales in the vicinity of the Bure site as well as radionuclide migration from the waste packages to the biosphere (3D computer code MELODIE),

- modelling the biospheres of interest for the Bure site (existing and possible in future).

In addition, the safety researches to be possibly undertaken related to operational safety and reversibility issues are in a preliminary phase devoted to the definition of targeted actions.

Organisational aspects

Because of the complexity and large scope of issues to be addressed, IRSN promotes a multi-disciplinary approach integrating experimentalists, modellers and experts of safety who work together on each of the topics of interest for safety. This synergy between research engineers and experts in safety assessment is a valuable tool to ensure consistency and quality of technical assessment. Scientific partnerships with research facilities and universities is the preferred strategy of IRSN in order to be able to take benefit of high level scientific skills in different specialities and for a duration compatible with the planned time frames of the assessment process (several decades).

Part of IRSN research programme is integrated in the EURATOM Framework Programme related to radioactive waste management research. IRSN is involved in 6th and 7th Framework Programmes which offer a valuable framework for achieving results and for sharing experience among countries involved in waste safety. IRSN supports also international research programmes as the Mont Terri project as well as bilateral cooperation with homologous organisations in foreign countries.

Quality and independency of research programme carried out by IRSN allow building and improving a set of scientific knowledge and technical skills that serves the public mission of delivering technical appraisal and advice. In particular they contribute in improving the decisional process by making possible scientific dialogue with stakeholders independently from regulator or implementer.

Conclusion

Because of time constraints, it is of crucial importance to be able to anticipate the development of knowledge and resources required to assess risks posed by nuclear facilities in the future, and in particular waste management safety. It is the reason why

IRSN has identified very early in the French geological disposal facility project development the scientific issues that had to be addressed in priority. This enabled IRSN to optimise the resources allocated to research. These resources are periodically assessed with respect of the progress made in studies, the new issues to be taken into account and duly planned, as well as the regulatory review agenda that requires to swap research and assessment activities.

The research activities carried out by IRSN are developed in consistency with conclusions drawn from the stepwise regulatory process that allows periodically addressing the remaining issues that must be dealt with to improve the safety demonstration. The expected outcomes of IRSN R&D programme are clearly identified with respect to the safety review approach, paying in particular a specific attention on which phenomena that must be studied by the TSO so as to ensure appropriate independent judgement of the level of safety that the disposal facility may reach. It is also a duty for TSO to be able to deliver opinion on the consistency and degree of confidence of the data produced as well as on the ability of the implementer to realise, at industrial scale, components that will perform “as designed”.

But the efficiency of the research carried out by the regulator or the TSO does not rely only on technical skills but also on its ability to promote synergy between experts in charge of assessment and researchers. This contributes highly in guiding research efforts that must be made for the purpose of maintaining the quality of the regulatory review. In complement, high scientific skills ensure efficient technical dialogue between the implementer and the evaluator which is also a necessary condition to achieve valuable assessments.

Illustration of the organisation of the technical dialogue between the different actors (WMO, TSO and authority)

Interaction between ASN (the authority), IRSN (the TSO) and Andra (the WMO) was undertaken in order to come to a common understanding that the regulatory requirements and expectations are met. The ASN performed regular inspections of the Meuse Haute-Marne URL, and published in 2006 its official opinion on Dossier 2005. The IRSN established a constant dialogue with ANDRA and ASN all along the development of the project, whatever it was formally requested by law (license application, decree…) or not. IRSN carried out periodic technical expertise of the progress of the safety case (from 1997 to 2005). This agreement between all the parties allowed defining periodic meeting points for important steps. These steps were in particular related to key safety questions that were ought to be dealt with by Andra: the structural characteristics of the site, the hydrogeological settings, the geochemical containment characteristics of the host rock, the main perturbations and their influence on the properties of the disposal components, the technical feasibility of the seals and the influence of the operation phase and retrievability conditions on the disposal concepts. IRSN opinion about the feasibility of a deep geological disposal in the callovo-oxfordian clay investigated by Andra with the Bure URL was published in 2006 as well as the ASN opinion.

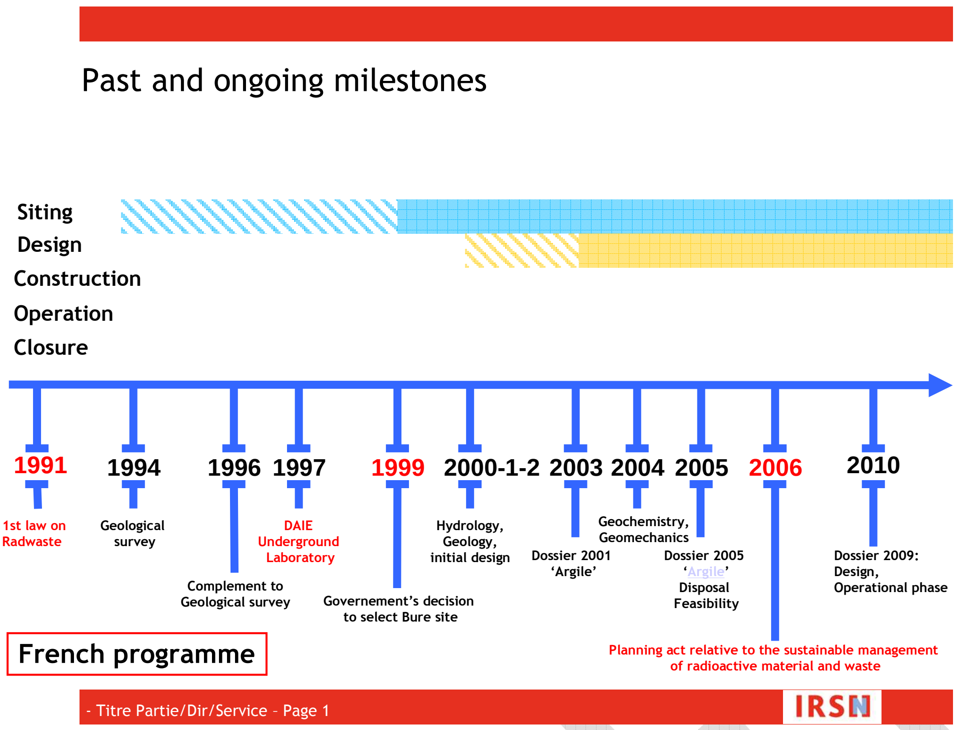
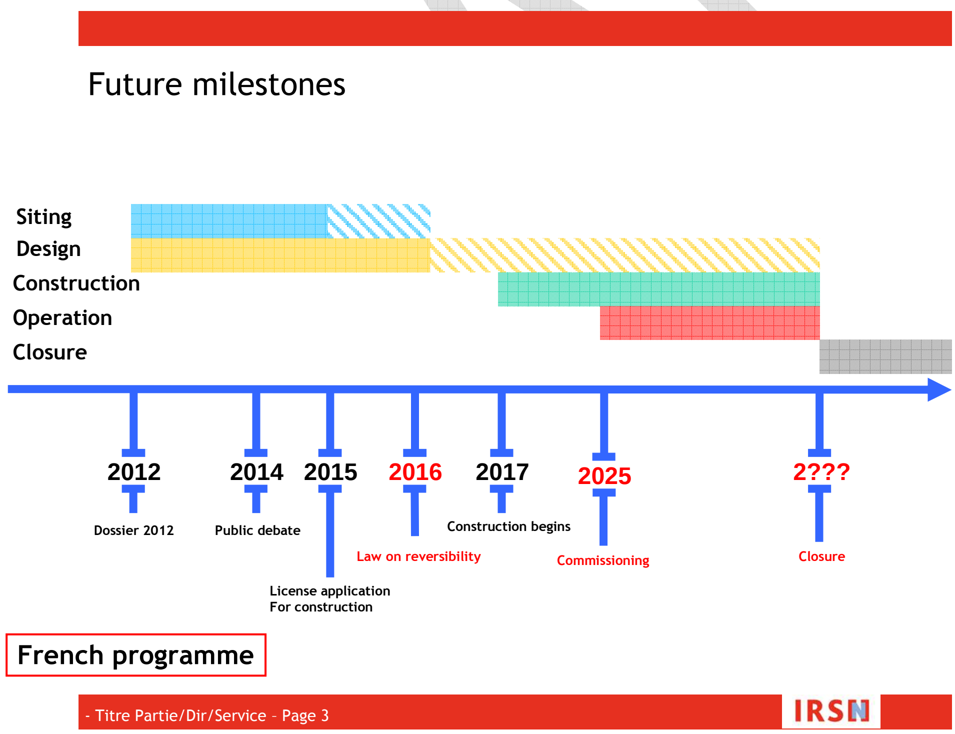


Illustration of the close technical follow up by TSO of the scientific development of the content of the safety case



Annex5 Example from the French case: staged development of the safety case by Andra

The 30 December 1991 Waste Act initiated a research process into different methods for managing high-level long-lived radioactive waste. In this framework, Andra has conducted work to investigate the possibility of a deep geological waste disposal facility, considering two rocks of differing nature, clay and granite. Some conclusions may be highlighted in the case of the clay medium studied at the Meuse/Haute-Marne site.

Fifteen years of considerable progress in research

Deep geological disposal has been investigated since the sixties in various western countries. *However, the period 1991-2005 in France was marked by acceleration in the progress of research. From this point of view, the 30 December 1991 Waste Act was a catalyst*. The schedule set by this Act led to bringing together skills and concentrating energy to produce a dossier in 2005 based on solid scientific and technical knowledge.
A significant step forward in knowledge
Assessing the feasibility of a disposal facility requires acquiring knowledge and investigating various fields: waste and material behaviour, history and properties of the geological medium, architectural design, understanding the phenomena occurring within a disposal facility, modelling interactions, assessing safety. *An extremely rich harvest of results was reaped about all these topics. Fifteen years of research have laid down the foundations of a solid corpus of scientific and technical knowledge, providing an accurate view of the major issues and properties of all the disposal facility components.*
Now, is available, for example, a historical view of the argillite layer studied at the Meuse/Haute-Marne site, from its deposition 155 million years ago. The Callovo-Oxfordian argillites have been surveyed extremely carefully, both though samples and *in situ*, providing an intimate knowledge of their properties. In this field, their mature degree reached by these investigations places them at the forefront of our knowledge of the geology of the Paris Basin.

The advantage of the Meuse/Haute-Marne site where a wide range of measuring and investigative techniques have been used

In the case of the clay medium study, a decisive contribution of the period was the possibility of carrying out very thorough investigations on a specific site, the Meuse/Haute-Marne one. Andra has been exploring the site and its environment since 1994 and thus has acquired a thorough knowledge of the actual conditions of the geological medium.

With its two shafts and over 300 m of drifts, *the Meuse/Haute-Marne Underground Laboratory is currently a leading-edge scientific facility, comparable to similar international ones*. An important experimental programme is carried out and notably concerns: rock permeability with its chemical and diffusion properties, rock mechanical characteristics with its behaviour when excavated. It has produced very significant data, but also constitutes a valuable asset for future years. If so wished, it will be capable of supporting a study and detailed design approach through the production of measurement records over long periods, thus completing the results already acquired.

To investigate the Meuse/Haute-Marne site, Andra set out to gather together the widest possible range of measuring tools and survey technologies. Exploring the clay geological medium is a complex undertaking, requiring very specialized technologies, for example for measuring the permeability of a rather impervious medium or characterizing water that is present only in a very small quantity in the rock, which makes its extraction difficult.

From the start of the research programme, Andra built very strong ties with all its foreign counterparts so as to transpose, elaborate or validate the investigation technologies it needed. This preparatory work then enabled it to be immediately operational on the Meuse/Haute-Marne site.

The last fifteen years have therefore witnessed the development and improvement of a wide array of measuring and characterization technologies brought to their best level. For example, oil exploration technologies have been adapted and improved for meticulous geological exploration. All possible facets of investigatory means were used: surface observations (e.g. with the seismic survey), measurements on samples, testing and sampling in vertical or practically horizontal directional boreholes, characterizations in shafts and drifts. *The diversity of the experimental tools used provides complementarity and redundancy between measurements, which increases confidence in the results obtained.*

Confirmation by foreign underground laboratories

In parallel with the programme carried out in France, foreign underground laboratories have played a very important part through their methodological and theoretical contribution, in particular those of Mol in Belgium and Mont Terri in Switzerland. The Mol laboratory has seen the development of measurement technologies for appraising all the phenomena present in clay. The Mont Terri laboratory has been used to prepare experiments conducted at Bure by offering the possibility of full-scale repetition. In addition, the similar nature of the two clays (Opalinus clay in Switzerland and Callovo-Oxfordian argillites) led to establishing an essential point: *at Mont Terri, it was shown that the results found on samples were also representative of large-scale tests*. This constitutes a weighty support for the work carried out at Bure. Furthermore, the models prepared based on the samples extracted at Bure were corroborated *in situ* at Mont Terri.

Foreign laboratories thus provided methodological and theoretical validation for the analytical approach conducted in France.

Mobilization of a high-level scientific community and integration of research at the international level

Another basic asset of the research programme carried out since 1991 lies in the mobilization of the scientific community. At the launch of the process, the research remained relatively restricted to a circle of specialists or to a small number of bodies responsible for the work. Andra strived to involve the widest possible scientific community in its work. In other words, rather than keeping the investigations and research in-house or developing its own special skills, it always preferred to use the best laboratories in France or internationally for each topic. This meant a great deal of effort in arousing scientists' interest and familiarizing them with the problems involved.

In the end, this policy proved successful. It enabled nearly a hundred laboratories at the national and international level to be brought together around the theme of geological disposal. With their different perspectives these laboratories could pool their expertise, and develop cooperation and interdisciplinary outlooks. This is all the more important in that the originality of the research on disposal entails the need to muster together very varied scientific fields in order to achieve an overall understanding. At the same time, Andra instituted support for research training, in the form of thesis grants, which meant having active scientific resources readily available; about fifty or so young researchers over five years, were specifically dedicated to Andra research topics.

Mobilizing the scientific community ensured that the production of results was conducted and discussed according to the current standard of the academic world and within a framework of excellence. The scientific initiative was not limited to mobilizing the French scientific community. *Andra has specifically extended its activity within an international framework,* by developing close partnerships with both its counterpart agencies in Europe and international research establishments. As an illustration, the Meuse/Haute-Marne underground laboratory has regularly hosted scientists from international organizations who have used their expertise in experimental work. The research has thus benefited from the best international skills. *Thus, after fifteen years, the French research programme is well-placed internationally and enjoys there cognition of its foreign counterparts.*

Regular external assessment

Finally, a programme of this scope would not be complete without assessments. *Andra regularly uses external experts and reviewers for comparing its study programmes, research and results with the best international practice*. An international review of its programmes was carried out in 2002 / 2003 and was very encouraging regarding the work conducted. In the spirit of progress driving the research, the recommendations of this review were integrated into the documents produced for 2005.

Andra strived to encourage the publication of its results in the best international scientific journals, at a rate of some forty articles a year over the last three years. Critical examination of the results obtained is mandatory for publication, which is also a guarantee of work quality.

The research programme therefore was provided with the tools needed for producing quality scientific data, within a framework characterized by stringency and concerned for scientific excellence.

The basic feasibility of geological disposal in a clay formation has now been established

Assessing the basic feasibility of geological disposal consists mainly in obtaining an overall perspective of the data collected on each research topic in order to build up an overview of the disposal system and assess whether it can protect man and the environment from the radioactive waste that would be emplaced there. All the elements gathered to date support its basic feasibility, for several reasons.

The Meuse/Haute-Marne site offers favourable geological conditions

The Callovo-Oxfordian layer combines some very useful properties, matching those expected for the design of a disposal facility in a clay medium.

Firstly, the layer is of considerable thickness (130 metres) and is broadly unaffected by faults. Its geological history is well-known. Since its deposition this history has been very quiet, which is a major argument for confirming its homogeneity and its extreme stability. It is almost not subject to earthquake and seismic phenomena.

The layer contains very little water, which movement is extremely slow, due to its very low permeability. Physical and chemical characterizations further show that it has a strong ability to retain and trap most of the chemical elements and radionuclides present in the waste.

It is suited to excavation by mining techniques and building structures within it only causes moderate disturbances, which are not in principle capable of creating preferential flow pathways. There is a wide zone of more than 200 km2 within which, *a priori*, these properties are met (the so-called transposition zone).

Finally, putting the collected data together has provided a model of the overall geology of the sector, including the formations above and below the Callovo-Oxfordian. *The geological medium therefore intrinsically offers favourable characteristics making it suitable for hosting a disposal facility*.

Architectures have been designed to make the most of the favourable geological conditions

It is not just a matter of having a geological medium with the right qualities; it is necessary to make the most of it appropriately. Engineering studies have defined simple and robust disposal concepts suited to the characteristics of the argillaceous layer, taking the utmost advantage of its qualities.

These concepts include cautious choices providing therefore design margins. The work has not been pursued up to the optimization stage, but has established that the proposed architectures were realistic, capable of being constructed and used to host the waste without any special difficulty. These architectures include numerous features promoting overall safety, such as module separation, which compartmentalizes the disposal facility zones, or its general lay-out, which limits the possibilities of water circulation. *In-depth design and engineering work thus supports the favourable natural properties of the medium and helps make the most effective use of them. In addition, studies relating to operational and nuclear safety, based on feedback from other mining or nuclear facilities, demonstrate the possibility of safe operation without any impact on the environment.*

Reversibility at the heart of the investigation approach and translated in concrete practical terms

The architectures drawn up for the disposal facility were selected according to their ability to allow for reversibility. The requirement of reversibility involves a cautious approach to waste management in an uncertain universe .It refers closely to the precaution principle. It also meets a legitimate requirement for modesty on the part of the scientist. When evolutions have to be forecast over very long periods and complex phenomena have to be managed, reversing the process must be possible.

Andra has developed a concrete approach to reversible disposal that is more than just the technological possibility of retrieving packages. It may be defined as a possibility for progressive, flexible, stepwise management of the disposal facility. The objective is to allow future generations freedom of decision in waste management. Consequently, Andra has opted not to set a predetermined duration for reversibility. This involves offering as great a flexibility as possible in the management of each stage, allowing for the possibility of maintaining the status quo before deciding on the next stage or going backwards. The disposal facility design (modular architecture, simplified operation, dimensioning and choice of durable materials, etc.) aims at allowing the widest possible choices.

Reversible disposal can thus serve two purposes. It can be managed as a storage facility with emplacement of waste and, if so desired, its retrieval by simple reversal of the disposal process. Obviously, maintaining this reversibility assumes human intervention, without, however, causing excessive workloads. But what basically distinguishes it from simple storage is that *it includes the possibility of being progressively closed, so as to be able to subsequently evolve safely and passively without human intervention*.

Investigations have shown *that a disposal facility installation was reversible for a period of two to three centuries, with no intervention other than standard* maintenance and monitoring *operations*. Beyond this period, it would be necessary to carry out more extensive interventions, which remain technically possible.

The argillaceous geological medium and the concepts developed by Andra meet the reversibility requirement and make it a flexible tool in radioactive waste management. Reversibility also enables progressive confidence building in the disposal facility safety demonstration, while leaving always open the ultimate possibility of evolution independently of human intervention.

A safety overview that demonstrates the absence of significant environmental impact

Would the choice be made to close the disposal facility, a detailed assessment has been made of its behaviour overtime and its possible impact on man and the environment. Based on the scientific data obtained and the proposed disposal facility architecture, an analysis has been made of the disposal facility post-closure evolution. This consisted in reviewing all the phenomena that will occur in it, examining their interactions, modelling the effects of possible disturbances so as to, *in fine*, predict waste behaviour and appraise the mechanisms capable of leading to a release of radioactivity. *A major achievement of the research is to have built up a history of the disposal facility over the next few hundred thousand years which provides an* *understanding of the system evolution*, key parameters, risks and corresponding uncertainties.

Based on this very detailed view of the disposal facility and its components, the safety studies aimed to give a simplified and cautious representation for assessing its performances. The evolution of the disposal facility under normal conditions has been represented and modelled using computational tools integrating recent advances in digital simulation (ALLIANCES platform). The objective was to examine the disposal facility safety functions efficiency. These functions translate the expectations from a disposal facility, expectations which themselves justify the utility of this technical system. By means of various indicators, analysis has shown that the three safety functions ("preventing water circulation", "limiting radionuclides release and immobilizing them", "delaying and reducing radionuclide migration") were achieved by the proposed system. The cautious or even pessimistic choices made provide significant safety margins. Thus, all the assessments display a high degree of robustness. The analysis showed that these conclusions were not only fulfilled only under normal conditions, representative of the most probable evolutions, but also in altered configurations, clearly more penalising: a failure in disposal facility components or an intrusion by drilling a borehole into the disposal facility should not prevent the latter from fulfilling its functions, effectively protecting man and the environment from the disposed radioactive waste.

Overall, performance analysis shows that safety does not depend on a single element, but is based on defence-in-depth which involves multiple and redundant components. The presence of several elements that can takeover from one another in case of failure thus constitutes a considerable added value of the current disposal facility design and ensures the robustness of the disposal system. Following the calculations performed within the framework of the safety model under normal evolution, the disposal facility performances meet the dose compliance recommended by the basic safety rule RFS III.2.f, with significant margins. The impacts caused by vitrified high-level waste (C waste) and long-lived intermediate-level waste (B waste) are several orders of magnitude below the reference standard set at a quarter of the permissible dose for the public (i.e. 0.25 mSv per year).The situation of great degradation of all the disposal facility components, the geological medium included, was studied as well. It also led to an impact compatible with the references in terms of dose. In conclusion, the safety approach underpins the disposal facility feasibility study. In the light of current knowledge and by adopting cautious hypotheses, the consequences for man and the environment that a possible disposal facility could entail, appear to comply with the standards and recommendations in force. This conclusion has been reached with significant safety margins.

Research that could be carried out with a view to site qualification and technological development

The research programme conducted over the past fifteen years included the necessary material to answer the basic feasibility issue. We may assume that this is confirmed with reasonable confidence. However, this is only basic feasibility (in its principle) and uncertainties do remain. There could be no question at this stage of an industrial approach or a complete performance and safety assessment, which would be essential for formally filing a licence application.

Without anticipating any decisions that the Parliament may consider appropriate, a few elements are necessary to clarify the current state of the investigations and identify the prospects that they may open up, where appropriate.

Four elements must be taken into account:

- Although most of the parameters needed for assessing safety have been obtained in conjunction with the underground laboratory, experiments have only been carried out over short periods. Without calling into question the previous conclusions, a reasonable caution involves obtaining a series of data over longer periods, allowing experiments to carry on acquiring knowledge over subsequent years. This work, to be performed at the same time as other developments, will reinforce the overall approach;
- Disposal facility architecture has been assessed from on basic studies and feedback from other facilities. At this stage no full-scale technological testing of disposal facility structures has been carried out. This would appear premature for establishing basic feasibility. In order to progress beyond this, it would be useful to construct demonstrators of disposal cells *in situ* and to actually test the possibilities of implementing the solutions investigated in an underground environment. Consolidating and optimizing the engineering would also be useful to reach industrial objectives, if required.
- Research aimed at mainly characterizing the zone in the immediate vicinity of the underground laboratory. Studies at larger scale and with a wider mesh were conducted over a transposition zone of 200 km2. However, the fine, detailed characterization of this zone has not been carried out. This means in particular that the issue of siting a possible disposal facility within this zone cannot be achieved at present and calls for additional qualification work;
- Finally, some elements of the disposal facility system are currently represented using simplified and pessimistic models. This obviously adds safety margins, since effects favourable to disposal facility safety are neglected. However, as part of a more exhaustive approach, it would be useful to quantify these margins and reduce the residual uncertainties at the same time. We should then be in a position to appraise, even more accurately, the level of confidence attributable to the safety assessments. These various elements help clarify the main guidelines of the possible work programme beyond 2006, should the evaluators and reviewers confirm the relevance of Andra conclusions and should the Parliament decide to pursue work on deep geological disposal.

For the period beyond 2006, with all the reserves already made, Andra has tried to construct a development scheme aiming at producing a safety report with a dateline of a decade. Initially, we should pass from the current phase of basic feasibility to a phase of development, optimization and detailed studies. This phase could extend over a period of approximately five years. It would first answer any possible questions raised by the evaluators in 2006 and focus increasingly on technological aspects and industrial implementation, while seeking to optimize the current proposed design. This would allow a progressive transition from a scientific to an industrial situation:

- Firstly, the necessary information would have to be gathered for siting a possible disposal facility installation. Accordingly, the transposition zone should be better defined based on additional information to that used to date, then a zone matching the footprint of a possible disposal facility could be characterized in further detail in order to qualify it. This overall reconnaissance would especially include a large-scale seismic survey taking up the most of previous results on the analysis methods and their representativeness.

- From a scientific point of view, the research would basically relate to two major issues: changes of scale (to confirm the detailed validity of data obtained over limited intervals of time and space) and validating the understanding of phenomena and their couplings (full-scale and in situ) while accurately assessing safety margins. From a technological viewpoint, the issues to be tackled would relate to study the construction of disposal facility infrastructures, together with handling or monitoring operations. As part of this, the Meuse/Haute-Marne laboratory is a tool for acquiring data and performing technological experiments directly within the concerned medium. These experiments would have two objectives: at first, full scale testing of the construction processes with their associated techniques and tools. Secondly, full scale validation (i.e. in a representative structure) of the scientific knowledge acquired from samples or at intermediate scale (for instance, experimental results obtained in drifts with regard to geomechanics). These tests would complete the progressive approach of scale change, in conjunction with design iterations.

This phase of development, optimization and detailed studies could be concluded with an overall technical assessment, an intermediate milestone before possible transition to a subsequent development phase. Beyond this phase, assuming that the various scientific results and techniques are deemed favourable, it would be possible to pass on to an industrial development stage. In order to provide an order of magnitudes, such an approach might lead to an industrial installation by 2025.

Therefore, an analysis was conducted to specify the conceivable stages for pursuing research beyond 2006,if such were the conclusion of the Parliament. It offers an initial development scheme taking stock of the significant findings of the 1991-2005 period.

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