Co-funded by the

European Commission

HORIZON 2020

Technical Expertise network
SITEX-II
Radioactive Waste Disposal

SITEX-II

(Contract Number: 662152)

Deliverable n°D2.1

Developing a joint review framework

Developing a common understanding on the interpretation and implementation of safety requirements

Authored by: F. Bernier (FANC), C. Castel (ASN), J. Miksova (CV REZ), L. Nachmilner (CV REZ), J. Mecke (CNSC), M. Tichauer (IRSN), M. Rocher (IRSN), K. Mannaerts (FANC), Doug Ilett (EA), P. Janssens (Bel V), M. Hugi (ENSI), G. Bastian (ENSI), M. Sentis (ENSI), N. Zeleznik (REC), Benno Haverkate (NRG), M. Surkova (FANC), G. Hériard-Dubreuil (Mutadis)

Contributors: Doug Ilett (EA), M. Sentis (ENSI)
Associated partners

Edited by: F. Bernier
Work Package 2 Leader
22/05/2018

Verified by J-P. Wouters (FANC)
22/05/2018

Approved by: D. Pellegrini
Coordinator
22/05/2018

Date of issue of this report: 15.01.2018
Report number of pages: 6 + 4 appendices

Start date of project: 01/06/2015 Duration: 30 Months

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Horizon 2020 Framework Programme		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the partners of the SITEX-II project	
CO	Confidential, only for partners of the SITEX-II project	

SITEX-II OUTLINES

Sustainable network for Independent Technical EXpertise of Radioactive Waste Disposal – Interactions and Implementation (SITEX-II)

The SITEX-II Project (Coordination and Support Action) was initiated in 2015 within the EC's Horizon 2020 programme to further develop the Sustainable Independent Expertise Function Network in the field of deep geological disposal safety. This Network is expected to ensure a sustainable capability for developing and coordinating, at the international level, joint and harmonized activities, related to the Expertise Function. SITEX-II brings together representatives from 18 organisations including regulatory authorities, technical support organisations, research organisations and specialists in risk governance and interaction with general public, including NGOs and an education institute. It is aimed at practical implementation of the activities defined by the former EURATOM FP7 SITEX project (2012–2013), using the interaction modes identified by that project. SITEX-II, coordinated by IRSN, is implemented through 6 Work Packages (WP).

WP1 - Programming R&D (lead by Bel V). The general objective of WP1 is to further define the Expertise Function's R&D programme necessary to ensure independent scientific and technical capabilities for reviewing a safety case for geological disposal. In this perspective WP1 will develop a Strategic Research Agenda (SRA) and define the Terms of Reference (ToR) for its implementation accounting for the preparatory work to be carried out in the framework of the JOPRAD project for construction of a Joint Programming of research for geological disposal.

WP2 - Developing a joint review framework (lead by FANC). The key objective of WP2 is to further develop and document in position papers and technical guides a common understanding of the interpretation and proper implementation of safety requirements in the safety case for the six phases of facility development (conceptualization, siting, reference design, construction, operational, post-closure).

WP3 - Training and tutoring for reviewing the safety case (lead by LEI). WP3 aims to provide a practical demonstration of training services that may be provided by the foreseen SITEX network. A pilot training module will focus on the development of training modules at a generalist level, with emphasis on the technical review of the safety case, based on national experiences, practices and prospective views. The training modules will integrate the outcomes from WP1, WP2 and WP4 and support harmonisation of the technical review processes across Europe.

WP4 - Interactions with Civil Society (lead by Mutadis). WP4 is devoted to the elaboration of the conditions and means for developing interactions with Civil Society (CS) in the framework of the foreseen SITEX network, in view of transparency of the decision-making process. The future SITEX network is expected to support development of these interactions at different levels of governance and at different steps of the decision-making process. Three thematic tasks, namely R&D, safety culture/review and governance will be addressed by institutional experts and representatives of CS within SITEX-II as well as externally through workshops with other CS organisations.

WP5 - Integration and dissemination of project results (lead by CV REZ). The overall objective of WP5 is to produce a synthesis of the results achieved within all the WPs of SITEX-II together with an Action Plan that will set out the content and practical modalities of the future Expertise Function network. WP5 will also foster the interactions of SITEX-II with external entities and projects, as well as the dissemination of SITEX-II results so as to allow possible considerations from outside the project in the process of developing the future SITEX network.

WP6 - Management and coordination (lead by IRSN).

Contact: D. Pellegrini (IRSN), SITEX-II Coordinator
delphine.pellegrini@irsn.fr

Further details on the SITEX-II project and its outcomes are available at **www.sitexproject.eu**

ABSTRACT

The European research project SITEX-II aims at implementing in practice the issues identified by the SITEX project (2012-2013), with a view to develop an European expertise network gathering national expertise organisations supporting the regulatory body in the field of radioactive waste management (RWM) and geological disposal (GD) of radioactive waste.

As one of the workpackage, WP2 entitled "Developing a joint review framework" aims to develop a common understanding, among regulatory bodies, Technical Support Organisations (TSOs) and Civil Society (CS), on the interpretation and proper implementation of selected high-level safety requirements issued by international entities (EC directives, IAEA, ICRP, WENRA…), as well as to develop guidance on reviewing the safety case.

This deliverable presents the activities and results of WP2 Task 2.1 "*Developing a common understanding on the interpretation and implementation of safety requirements*".

The fulfilment of the safety requirements by WMOs (implementing function) requires not only a clear formulation of regulatory expectations but also technical guidance explaining how these requirements can be met in practice and how their fulfilment should be substantiated in the safety demonstration (i.e. safety case). Four topics were discussed to share national experiences and prospective views on the interpretation and implementation of these safety requirements and/or recommendations:

- Optimisation of protection
- Waste Acceptance Criteria
- Operational issues in regards with post-closure safety
- Site characterization programme

Discussions were reported in position papers. These position papers provide a reference to national regulatory bodies when they are developing their own technical guides and to WMOs when developing the safety case during the various phases of development of a deep geological repository.

CONTENT

Appendices

1 Introduction

This deliverable aims to share national experiences and prospective views of the Expertise Function on the interpretation and implementation of safety requirements and/or recommendations. The topics selected for discussions were identified according to the priorities set up in the former SITEX (2012-2013) project and more specifically in deliverable D2.1 "*Overview of Existing Technical Guides and Further Development* " of SITEX I.

2 Outcome of SITEX I (D2.1)

The main objective of SITEX I WP2.1 was to identify the areas where development of guidance, harmonization, common positions or dialogue are needed in priority, considering the IGD-TP vision that "by 2025, the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste will be operating safely in Europe".

The WP2.1's deliverable D2-1 provides an overview of existing and available technical guides, within the SITEX consortium, addressing "safety topics" to consider in the development of a geological disposal and submission of a safety case. It identifies the common points and differences between these guides and finally identifies and prioritize the needs for further development, harmonization and dialogue.

Almost hundreds of needs were identified. Thirty-five of them are of both high level of interest and high priority. As is reasonably logical to expect, most of these priority needs are associated with the first steps of development of a repository (namely site selection and characterisation; development of the design basis and monitoring programme), with the content of the safety case and with the safety assessment (namely treatment of uncertainties, scenarios, models and timeframes).

3 Selected topics & methodology

Four topics from the list of priorities identified in SITEX I WP2.1. (see previous section) were selected by the partners:

- Optimisation of protection
- Waste Acceptance Criteria
- Operational issues in regards with post-closure safety
- Site characterization programme

Technical meetings were organised to share national experiences and prospective views on the interpretation and implementation of safety requirements and/or recommendations related to these topics.

For each topic an introductory presentation was given to feed the discussions. Based on the presentation and discussions between SITEX-II partners, key issues to be covered in the position paper were identified. The key issues were debated in the group and key messages were pointed out.

Each rapporteur gathered the conclusions of the discussions in a position paper which has been sent to the partners for comments. The comments were than collected in order to finalise the position paper.

The position papers are given in appendices 1 to 4. They provide a reference to national regulatory bodies when they are developing their own technical guides as guidance to WMOs when developing the safety case during the various phases of development of a geological disposal facility.

Appendix 1: Optimisation of protection for deep geological repository

Rapporteur: Lumir Nachmilner

A. Background

EC Horizon 2020 project SITEX II aims at the establishment of a network ensuring sustainable capacity for the development and coordination of joint and harmonised activities related to the independent technical expertise function regarding safety of deep geological repository (DGR) of radioactive waste. The expertise function is provided by organisations that are regulators and those who may support regulators (in particular technical support organizations - TSOs).

Within the SITEX II project a Task is devoted to sharing national experience and prospective views on the interpretation and implementation of selected safety requirements and recommendations. Among the topics identified according to the priorities set up in the former SITEX project (carried out within FP7 programme in 2012-13) the issue of optimisation of protection was selected.

SITEX II participants have exchanged their views and experience on how to implement in practice high level international requirements related to the optimisation of protection for DGR. Conclusions of the discussion have been gathered in this Position Paper. However, the Position Paper does not cover the issue exhaustively; it only highlights topical issues SITEX II participants feel they are worth to be raised.

B. Objectives

The objectives of this Position Paper are to:

- present a common understanding by regulators and TSO's on the interpretation and implementation of safety requirements of international organisations (IAEA, ICRP, NEA/OECD, WENRA) regarding the issue of optimisation of protection,
- formulate guidelines on how to implement these requirements in practice, in particular:
    - to give additional input to regulators and TSO when developing technical guidance, and
    - to provide a guidance to WMOs when developing the safety case during the various phases of the DGR development.

C. Scope of the Position Paper

1. The Position Paper covers optimisation of radiological protection in the sense of ICRP definition. Protection against non-radioactive pollutants is therefore not covered by the position paper as far as they do not affect the radiological protection.

    However, we recognize the importance of protection against non-radioactive pollutants; a balance should exist between protective measures against potential impacts of radioactive and non-radioactive pollutants. Depending on legislative requirements in particular countries, the ICRP optimisation principle can be extended or not to the reduction of impacts of non-radioactive species.

Supporting statements:

WENRA 2014 [8]: *protection from the non-radioactive hazardous content of the waste represents an important issue …. this issue to be duly handled by the licensee, so as to comply with the appropriate regulatory requirements.*

2. The Positon Paper adopts the ICRP (2007) definition of the radiological protection:

   The likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors. This means that the level of protection should be the best under the prevailing circumstances, maximising the margin of benefit over harm.

   The term 'prevailing circumstances' refers notably to non-technical aspects like cost, social issues, human resources, national and political context.

   Optimisation of protection is therefore understood as a stepwise comparative process consisting in iterative, systematic, and transparent evaluation of technical options and ensuring an optimized level of radiological safety, i.e. the best level of safety of a disposal facility taking into account prevailing circumstances. It is seen as the central element of the gradual construction and implementation of a geological disposal facility.

   Supporting statements:

   IAEA (2007) [3]: *Optimisation of protection is a process of determining what level of protection and safety makes exposures, and the probability and magnitude of potential exposures, "as low as reasonably achievable, economic and social factors being taken into account" (ALARA), as required by the International Commission on Radiological Protection System of Radiological Protection.*

   ICRP (2013) [7]: *Optimisation of protection is a process to keep the likelihood of incurring exposures, the number of people exposed, and the magnitude of their individual doses as low as reasonably achievable, taking into account economic and societal factors.*

   Optimisation of protection is the central element of the stepwise construction and implementation of a geological disposal facility.

   …optimisation process through a comparison (using inter-alia dose and risk indicators) of alternative options.

   … optimisation of protection is understood in the broadest sense as an iterative, systematic, and transparent evaluation of options for enhancing the protective capabilities of the system and for reducing impacts (radiological and others).

> *The stepwise decision process for geological disposal system development and implementation constitutes the framework for the optimisation process.*
>
> *Although optimisation is a continuous effort, milestones have to be defined in the stepwise process*

3. The Position Paper focuses on geological disposal; however, the outlined principles are also, in many respects, relevant for intermediate depth and surface disposal of radioactive waste.

4. For the Position Paper, it is considered that the decision on the development of a geological disposal has already been taken, as this decision constitutes a prerequisite to the start of the optimisation process.

D. Issues highlighted in the position paper

1. The role of the regulatory body

Reaching an optimized level of radiological safety throughout the process of development (e.g. design, construction commissioning), operation, decommissioning and closure of a disposal facility, is a high level international requirement ([4], [8]). The expertise function delivered by the Regulatory Body (formed by the regulator and its Technical Support Organisation) shall assess the implementation of the optimisation principle and associated requirements throughout the disposal development process. In particular, it is important that the safety case shows that the principle of optimization has been addressed in relevant choices and decisions on the disposal system [8]. Whenever desirable, the regulatory body shall perform its own studies on key elements of the safety case, in order to assess the implementation of the optimisation principle.

Optimisation includes both qualitative and quantitative judgements (see the next section). Therefore, an open dialogue between the implementer and the regulator on the optimisation methodology at early stage of the disposal development is necessary [6]. Common understanding and agreement should be reached over the approach followed to optimise radiological protection and more specifically on the safety criteria/attributes and the prevailing circumstances taken into consideration in the optimisation process (see section 2) [5]. Especially, suitability and appropriateness of these criteria/attributes as well as their weights for the associated decision should be assessed.

An effective management system for the optimisation process shall be established by the implementer and verified by the regulator. Key elements of this system comprise (i) the responsibility allocation, (ii) the provision of resources, (iii) the specification of procedures and processes, (iv) the transparent documentation, as well as (v) the systematic examination of options.

It should be noted that the devoted level of resources is specific for each country as it depends on the national context (legislative background, extent of the waste management programme, availability of technologies, expert capacities and capabilities, public engagement, etc.).

Supporting statements:

> WENRA 2014 [8]: *Throughout the process of development (e.g. design, construction commissioning), operation, decommissioning and closure of a disposal facility, the licensee*

shall aim for an optimized level of safety considering both operational and the post-closure phases.

IAEA 2011 [4]: *Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.*

WENRA (2014) [8]: *The licensee shall ensure that the safety case shows that the principle of optimization has been addressed in relevant choices and decisions on the disposal system.*

ICRP (2007) [6]: *All aspects of optimisation cannot be codified; rather, there should be a commitment by all parties to the optimisation process…..An open dialogue should be established between the Authority and the operating management…*

Where optimization becomes a matter for the regulatory authority, the focus should not be on specific outcomes for a particular situation but rather on processes, procedures and judgements.

It is important to have a dialog between the regulator and the licensee (or developer) on the optimisation methodology from the beginning

ICRP (2006) [5]: *The objective is to identify the attributes necessary to select the best protective options under the circumstances.*

IAEA (2006) [3]: *A robust and effective management system should support the enhancement and improvement of safety culture and the achievement of high levels of safety performance.*

2. Optimisation of the disposal system as a whole

Optimisation of protection process consists in identification and use of the safety criteria/attributes necessary to select the best protective technical options under the prevailing circumstances. It should also be noted that *optimisation* of protection does not necessarily mean *minimisation* of radiological impacts as the best option is not always the one with the lowest dose [5].

While performing optimisation of protection the implementer primarily focuses on radiological safety. Optimisation may concern different issues such as the site, the composition of the engineered barrier system, the disposal lay-out, the solution of co-disposal of different waste categories, etc. However the disposal system has to be optimised as a whole i.e. considering all the components of the system.

Comparison of options has to be done on the basis of safety criteria/attributes by assessing their relevance to the performance and the robustness of the disposal system. Their selection should allow the safety benefits of the considered technical options to be discussed. Their selection and their weighting should be clearly allocated to problems being solved, e.g. operational vs. post-closure safety, isolation vs. containment requirements, demonstrability vs. novelty of considered technologies, sensitivity vs. robustness of a solution, etc. Reaching adequate compromise between disposal system choices in order to reach the "optimum" level of protection. The "optimum" is considered to be reached once the benefit in protection has become small with regard to the resources needed.

Optimisation approaches might be quantitative (whenever possible) or qualitative (whenever not); Generally, the later are used more in the initial stages of the development process while the former are conditioned by sufficient knowledge of characteristics and lesser uncertainties in the description of the disposal system and, thus, are exerted in its final phase.

Within the optimisation of disposal, prevailing circumstances may have to be considered according to national context. They can bound the optimisation process to various extents, such as by limiting the available options and/or by defining additional conditions (e.g. retrievability).

Prevailing circumstances can evolve during the development and the implementation of a disposal. Changes in prevailing circumstances may lead to reconsider options that have been chosen previously.

Prevailing circumstances shall also be examined to verify that they are not impairing the safety of a disposal system; e.g. the danger of political decisions overriding the safety aspects; possible negative impacts of invasive monitoring system required by the public after the closure of the disposal; timing of the facility implementation~~,~~ etc. All such circumstances shall be clearly identified by the implementer and safety implications understood and adequately interpreted.

Supporting statements:

> ICRP (2007) [6]: *Societal values usually influence the final decision on the level of radiological protection.*
>
> NEA (2011) [11] : *Non-technical issues might constrain safety.*
>
> *It is important that these considerations are identified in a manner transparent to all involved stakeholders, and that their safety implications are generally and broadly understood.*
>
> *Socio-economic factors (including policy decisions and societal acceptance issues) can bind the optimisation process to various extents, such as by limiting the available options (e.g. siting) and/or by defining additional conditions (e.g. retrievability).*
>
> ICRP (2013) [7]: *A balance has to be struck between technical criteria related to the safety of a disposal system (long-term stability, barrier for radionuclide migration, absence or presence of natural resources in the vicinity), and local or supralocal economic and societal factors.*
>
> ICRP (2006) [5]: *The involvement of stakeholders is an important input in the optimisation process.*
>
> *The best option is always specific to the exposure situation and represents the best level of protection that can be achieved given the circumstances. Therefore, it is not relevant to determine, a priori, a dose level below which the optimisation process should stop.*
>
> *In some cases, the technical, economic, legal, or social contexts may change optimisation solutions that have been agreed previously. Such changes should be addressed on a case-by-case basis.*
>
> *Each protective option has to be evaluated according to the various criteria (either quantitatively or qualitatively)*
>
> *Optimisation is not minimisation. It is the result of an evaluation that carefully balances the detriment from the exposure (economic, human, social, political; etc.) and the resources available for the protection of individuals. Thus, the best option is not necessarily the option with the lowest dose.*

3. Operational & long term safety

Operation of a disposal facility shall be optimised to protect the facility staff and the environment similarly to any other operated nuclear facility. Optimisation of radiological protection during the operation of a nuclear facility employs therefore the control of actual doses as a feedback for direct remediation actions.

Long term aspects of a disposal safety case are significantly different from those of other nuclear facilities. In fact, optimisation of long term radiological protection asks us to take into account uncertainties regarding doses and risks for the very long term. These uncertainties increase with time and no control of actual doses can be exercised. Thus, the only approach is to optimise the performance of the disposal system and its components to fulfil to the best the safety functions (mainly containment & isolation). Assessment of the robustness of the disposal system also contributes to system optimisation as it decreases potential effects of disturbing events, processes and remaining uncertainties. This way, optimisation of long term safety can be achieved in practice by incorporating in the stepwise evolution of the safety case an ongoing questioning on the performance and the robustness of the components, which calls for the optimisation of the whole disposal system to deliver the safety functions in the long term.

As a consequence, both operational and long term protections have to be optimised from early phases and across the full lifecycle of the geological disposal, and balanced as a whole. Impacts on each other have to be duly considered and assessed at every step of the way.

Supporting statements:

> WENRA 2014 [8]: *Throughout the process of development (e.g. design, construction commissioning), operation, decommissioning and closure of a disposal facility, the licensee shall aim for an optimized level of safety considering both operational and the post-closure phases.*
>
> IAEA 2011 [4]: *Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.*
>
> ICRP 2013 [7]: *When applied to the development and implementation of a geological disposal system optimisation has to be understood in the broadest sense as an iterative, systematic, and transparent evaluation of options for enhancing the protective capabilities of the system and for reducing impacts (radiological and others).*
>
> *Radiological criteria (e.g. calculated effective dose or risk) are often of limited value for this multifactor decision due to (i) the increasing uncertainties for longer assessment time scales, and (ii) the observation that calculated radiological design-basis impacts are often so low that they do not constitute a discriminating factor for the choice of a site.*
>
> *Assessment of the robustness of the disposal system can contribute to system optimisation because it provides insight, quantitative or qualitative, into the performance of the disposal system and its components, and into the relative contributions of the various components to the overall system.*

4. Application of Best Available Technologies (BAT)

BAT application has been acknowledged as one of the items to be considered in the optimisation process; in other words, the optimisation process itself is not limited to only BAT application, it is broader.

When potential impacts in the distant future have to be dealt with, BAT may complement and support optimisation of protection through [7]:

- the implementation of the best available methodologies and scientific programme of site investigation and characterisation,
- the development of the systematic design, including the choices of best available materials and technologies, and the way of their contribution to safety (individual or combined),
- the integration of waste, site, and design characteristics within one disposal system and the iterative assessment of the capacities of the system as a whole, and
- the use of sound managerial and engineering methods and practices during system construction, operation, and closure, within an integrated management system.

Considering the duration of disposal development (several decades) best available materials, techniques and technologies may call for a revision of the disposal design. In other words, a 'BAT' proposed within the application submitted for the construction license might be out-to-date when the facility is being built. Any modifications of design, construction procedures and methods shall ensure that they will not have an unacceptable effect on operational and post-closure safety.

In some cases, BAT could lead to reverse previous decisions. Reversing the decision should be well documented, including the reasons for and the description of benefits anticipated. For this, the optimisation process is an effective and useful tool.

Supporting statements

> NEA (2011) [11]: *Today optimal solution need not be optimal in future because of change of conditions.*
>
> NEA (2010) [10]: *... feedback from performance can be used to improve on the facility's technical characteristics and management in order to keep exposures ALARA.*
>
> ICRP (2013) [7]: *The optimisation efforts can be informed by, and construction supplemented with, consideration of Best Available Techniques (BAT) as applied to all stages of disposal facility siting and design.*
>
> *Optimisation has to be understood in the broadest sense as an iterative, systematic, and transparent evaluation of protective option, including Best Available Techniques, for enhancing the protective capabilities of the system and reducing its potential impacts (radiological and others).*
>
> *Some further optimisation of the protection that will be provided during the post operational phase is still possible during the operational phase; for example, new materials or techniques may become available.*
>
> *When dealing with safety in the more distant future, optimisation can be complemented and supported by applying the concept of Best Available Technique on the various levels of the disposal system, through:*

- *the methodologies for identifying and selecting the methodological and scientific programme of site characterisation in order to assess its containment and isolation capacities now and in the distant future;*
- *the development of the system design, including the choices of materials and technologies, and the way they will contribute, individually and together, to the main aim of containment and isolation, taking due account of the characteristics of the site;*
- *the integration of waste, site, and design characteristics within one disposal system and the iterative assessment of the containment and isolation capacities of the system as a whole; and*
- *the use of sound managerial and engineering methods and practices during system construction, operation, and closure, within an integrated management system.*

WENRA (2014)- DI-53 [8]: *The licensee shall plan, assess, document and implement any modifications of design, construction procedures and methods using arrangements consistent with the importance to safety of the modification. These arrangements shall ensure that the modifications will not have an unacceptable effect on operational and post-closure safety.*

5. Optimisation process during disposal lifecycle

Waste disposal is the final stage of the waste management lifecycle. However, the optimisation process shall cover also corresponding predisposal technologies, such as conditioning and packaging, as the waste management system shall be optimised as a whole, i.e. considering all its components.

Optimisation of protection is applied continuously during the different phases of the disposal facility lifecycle. Optimisation is predominant in its development stage as nearly all aspects of optimisation for the postoperational phase must occur prior to waste emplacement.

Depending on the national approaches, siting including host rock selection is considered as part of the optimisation process or not. Anyway, siting should be based on defined criteria/attributes related to the performance of the system in terms of containment and isolation.

Since optimisation should be done in an integrative manner, the stepwise decisions have to be taken in a chronological order (e.g. we should avoid going too far in the detailed design before making a decision on the choice of the host rock and of a site.)

Any decision “to go-back” (i.e. reconsidering previous decisions/choices) should be the result of optimisation in the sense that the benefits to go back should be balanced with harm (efforts to go-back, dose detriment, ….). The fact that optimisation is a looking forward process is not in conflict with the reversibility principle as defined by NEA.

The optimisation process through the whole disposal lifetime has to be systematic and carefully structured to ensure that all relevant aspects are taken into account. The process has to be carefully documented. The optimisation process requires commitment at all levels in all concerned organisations as well as adequate procedures and resources. Therefore, the optimisation process should be an integral part of the management system (see Section 1).

In practice, different development activities may overlap to a certain extent: for example, the level of detail of the elaboration of a facility design depends on the level of knowledge gained during investigating the host rock and site as well as on the characteristics of the final waste form. The balance between the level of understanding performance and characteristics of different system components shall be attained to successfully optimise protection.

Supporting statements:

> ICRP (2013) [7]: *The decision in favour of one specific host rock or site will always be a multifactor decision, based on both qualitative and quantitative judgements.*
>
> *Nearly all aspects of optimisation for the postoperational phase must occur prior to waste emplacement, largely in the siting and design phase, with the plans to close the facility being part of the design phase. Some further optimisation of the protection that will be provided during the postoperational phase is still possible during the operational phase; for example, new materials or techniques may become available. Experience gained during the closure of parts of the facility (e.g. sealing of disposal rooms) can lead to improvements in planning for the closure of the overall facility.*
>
> *Since optimisation should be done in an integrative manner, the stepwise decisions have to be taken in a chronological order (e.g. the decisions on the choice of a host rock and on one or a limited number of sites are often prior to decisions on a detailed design)*
>
> *Optimisation of protection has to deal with the protection of workers, the public and the environment during the time of operation, as well as with the protection of future generations including possible periods of no oversight. In the long term and particularly, in the latter period, safety has to be ensured by the legacy of a passively functioning disposal system.*
>
> *As a central component, optimisation and the application of Best Available Techniques have to cover all elements of the disposal system in an integrative approach [i.e. site (including host rock formation), facility design, waste package design, waste characteristics] as well as all relevant time periods.*

6. Iterative approach to the Optimisation

The approach towards the optimisation of protection is iterative: through repetitive exercises benefits expressed in dose and risk decreasing are weighted against the needed resources (financial, human, technical) to answer whether the best has been done to reduce doses under the prevailing circumstances. The “optimum” (taking into account those circumstances) is considered to be reached once the benefit in protection has become small with regard to the resources needed. Also, the optimisation efforts should follow a graded approach taking into account the complexity of the facility and the type of waste considered.

The optimisation process is forward looking as it is searching for the best level of protection under the prevailing circumstances. Each optimisation step shall consider impacts on all following ones. Therefore, the process shall be planned and adequate milestones defined. Such milestones should be defined from the beginning together with explaining optimisation process methodology and linked to the frequency of safety case updates.

Supporting statements:

> ICRP (2006) [5]: *Design phase must also consider all the following phases. Continuous optimisation requires flexibility and adaptability*

It should be stressed that optimisation is not minimisation. It is the result of an evaluation that carefully balances the detriment from the exposure (economic, human, social, political; etc.) and the resources available for the protection of individuals. Thus, the best option is not necessarily the option with the lowest dose.

ICRP (2007) [6]: *Optimisation is always aimed at achieving the best level of protection under the prevailing circumstances through an ongoing, iterative process that involves:*

- *evaluation of the exposure situation, including any potential exposures (the framing of the process);*
- *selection of an appropriate value for the constraint or reference level;*
- *identification of the possible protection options;*
- *selection of the best option under the prevailing circumstances; and*
- *implementation of the selected option.*

The optimisation of protection is a forward-looking iterative process aimed at preventing or reducing future exposures. It takes into account both technical and socio-economic developments and requires both qualitative and quantitative judgements.

Optimised protection is the result of an evaluation, which carefully balances the detriment from the exposure and the resources available for the protection of individuals. Thus the best option is not necessarily the one with the lowest dose.

In the decision-making process, owing to the increasing uncertainties, giving less weight to very low doses and to doses received in the distant future could be considered (see also Section 4.4.7). The Commission does not intend to give detailed guidance on such weighting, but rather stresses the importance of demonstrating in a transparent manner how any weighting has been carried out.

ICRP (2013) [7]: *Although optimisation is a continuous effort, milestones have to be defined in the stepwise process, where all involved stakeholders can judge the result of the optimisation process and indicate ways to improve various elements of the system.*

NEA (2012) [12]: *Reversibility describes the ability in principle to reverse decisions taken during the progressive implementation of a disposal system; reversal is the actual action of going back on (changing) a previous decision, either by changing direction, or perhaps even by restoring the situation that existed prior to that decision. Reversibility implies making provisions in order to allow reversal should it be required.*

7. Postponing decisions on disposal

Postponing a decision on the implementation of the disposal system should be considered in the balance between benefits and harms. Doing nothing (so called “wait and see” option) is not recommended by international bodies.

Joint convention (IAEA 1996) requires that its signatories establish radioactive waste and spent fuel management policy and practices, in other words, that the management is systematically planned at generic and technical levels. It also asks each Contracting Party to take the appropriate steps to avoid imposing undue burdens on future generations.

Similarly, EU members are warned (EC 2011) that the storage of radioactive waste and spent fuel, including long term storage, is an interim solution, but not an alternative to disposal. Member States are further requested to include planning and implementation of disposal options in their national policies and to avoid any undue burden on future generations in respect of spent fuel and radioactive waste. These requests of both organisations practically disqualify indefinite delaying a decision on the implementation of a disposal system.

On the other hand, planning deferred disposal is consistent with the wording of the Joint Convention and the EC Directive 70/2011 provided that the plan includes technical measures for the safe long term storage of waste/spent fuel and a mechanism is established for creating sufficient financial resources to cover the future costs.

Optimisation of protection regarding deferred options focuses on operational aspects of long term storage facilities; long term safety becomes a subject of optimisation process only after initiating the disposal programme.

Supporting statements:

> IAEA (1996) [1]: *Each Contracting Party shall submit a national report to each review meeting of Contracting Parties. This report shall address the measures taken to implement each of the obligations of the Convention. For each Contracting Party the report shall also address its:*
>
> - *spent fuel and radioactive waste management policy;*
> - *spent fuel and radioactive waste management practices;*
>
> *Each Contracting Party shall take the appropriate steps to:*
>
> - *strive to avoid actions that impose reasonably predictable impacts on future generations greater than those permitted for the current generation;*
> - *aim to avoid imposing undue burdens on future generations.*
>
> EC (2011) [9]: *The storage of radioactive waste, including long-term storage, is an interim solution, but not an alternative to disposal.*
>
> *Member States, while retaining responsibility for their respective policies in respect of the management of their spent fuel and low, intermediate or high-level radioactive waste, should include planning and implementation of disposal options in their national policies.*
>
> *It should be an ethical obligation of each Member State to avoid any undue burden on future generations in respect of spent fuel and radioactive waste.*

E. Key messages

1. The optimisation of radiological protection is a process which consists in the identification and use of safety criteria/attributes necessary to select the best protective technical options under the prevailing circumstances.
2. Prevailing circumstances can bound the optimisation process to various extents, such as by limiting the available options and/or by defining additional conditions (e.g. retrievability). However, prevailing circumstances may not unacceptably impair safety.
3. Prior to the options comparison exercise starting, common understanding and commitment shall be reached among all concerned organisations, in particular between the implementer and the regulator, on which factors shall be taken into consideration in the optimisation process.
4. Optimisation approaches might be quantitative (whenever possible) or qualitative (whenever not).
5. The optimisation of protection process is stepwise and iterative, it shall be duly planned and adequate milestones identified upon inception.
6. Any decision “to go-back” (i.e. reconsidering previous decisions/choices) should be the result of optimisation in the sense that the benefits to go back should be balanced with harm (efforts to go-back, dose detriment, ….).
7. Optimisation of long term safety can be achieved in practice by incorporating in the stepwise evolution of the safety case an ongoing questioning on the performance and the robustness of the disposal system and its components. Both operational and long term protection have to be optimised from early phases and across the full lifecycle of the geological disposal, and balanced as a whole.
8. Application of Best Available Technologies has been acknowledged as one of the items to be considered in the optimisation process; in other words, the optimisation process itself is not limited to only BAT application, it is broader.
9. The “optimum” is considered to be reached once the benefit in protection has become small with regard to the resources needed.
10. *Optimisation* of protection does not mean *minimisation* of radiological impacts as the best option is not necessarily the one with the lowest dose.
11. The regulatory body shall verify that the optimisation principle and associated requirements have been adequately implemented throughout the disposal development.
12. The importance of protection against non-radioactive pollutants has been recognised; a balance should exist between protective measures against potential impacts of radioactive and non-radioactive species.

F. References

1. IAEA (1996): Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, IAEA International Law Series No. 1
2. IAEA (2006): Application of the Management System for Facilities and Activities**,** GS-G-3.1
3. IAEA (2007): Safety Glossary
4. IAEA (2011): Disposal of Radioactive Waste**,** SSR-5
5. ICRP (2006): The Optimisation of Radiological Protection - Broadening the Process. ICRP Publication 101b. Ann. ICRP 36 (3)
6. ICRP (2007) The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Ann. ICRP 37 (2-4)
7. ICRP (2013): Radiological protection in geological disposal of long-lived solid radioactive waste. ICRP Publication 122. Ann. ICRP 42(3)
8. WENRA (2014): Report on Radioactive Waste Disposal Facilities Safety Reference Levels
9. EC (2011): Council Directive 2011/70/EURATOM of 19 July 2011
10. NEA (2010): Optimisation of Geological Disposal of Radioactive Waste, 2010
11. NEA (2011), Reversibility and Retrievability (R&R) for the Deep Disposal of High-Level Radioactive Waste and Spent Fuel; Final Report of the NEA R&R Project (2007-2011)
12. NEA (2012): Reversibility of Decisions and Retrievability of Radioactive Waste, Considerations for National Geological Disposal Programmes, 2012

Appendix 2: Waste Acceptance Criteria for Deep Geological Repository

Rapporteur: Cécile Castel

A. Background

EC Horizon 2020 project SITEX II aims at the establishment of a network ensuring sustainable capacity for developing and coordination of joint and harmonised activities related to the independent technical expertise function regarding safety of deep geological repository (DGR) of radioactive waste. The expertise function is provided by organisations that are regulators and those who may support regulators (in particular technical support organizations - TSOs).

Within the project a Task is devoted to sharing national experience and prospective views on the interpretation and implementation of selected safety requirements and recommendations. Among the topics identified according to the priorities set up in the former SITEX project (carried out within FP7 programme in 2012-13) the issue of Waste Acceptance Criteria (WAC) for DGR has been selected.

SITEX II participants have exchanged their views and experience on how to implement in practice high level international requirements related to waste acceptance criteria for DGR. Conclusions of the discussion have been gathered in this Position Paper. However, the Position Paper does not cover the issue exhaustively; it only highlights topical issues SITEX II participants feel they are worth to be raised.

In their work regarding waste acceptance criteria, SITEX II participants particularly benefited from previous works performed in the IAEA, and in the European Pilot Group (EPG).

B. Objectives

The objectives of this Position Paper are to:

- present a common understanding by regulatory bodies and TSO's on the interpretation and implementation of safety requirements of international organisations (IAEA, NEA/OECD, WENRA) regarding waste acceptance criteria,
- formulate guidelines how to implement those requirements in practice, in particular
    - to give additional input to regulatory bodies (incl. TSO) when they are developing their technical guides, and
    - to provide a guidance to WMOs while developing the waste acceptance criteria with regard to the safety case during the various phases of the disposal facility development (taking into account the interdependencies among all steps from the origin of waste until its final disposal [1]).

C. Scope of the Position Paper and definitions used

5. The Position Paper intends to cover the lifecycle of waste acceptance criteria, including preliminary WAC and updating of WAC. It also deals with some specific aspects considered as relevant by the participants or already identified in the first SITEX project. The following subjects are developed:
   - Objectives of WAC
   - Roles and responsibilities
   - Evolution of WAC before licencing (preliminary WAC)
   - WAC: elaboration and updating
   - Characterization / Monitoring / checking compliance / Procedural aspects such as quality management and implementation
   - Dealing with departures or non-compliance
   - Parameters
6. This Paper focuses on WAC for geological disposal; however, the outlined principles can be adequately applied for disposal of radioactive waste in general.
7. For the Position Paper, it is considered that the decision on geological disposal has already been taken.
8. The following definitions are used in the position paper :

Acceptance criteria [2]

Specified bounds on the value of a functional indicator or condition indicator used to assess the ability of a structure, system or component to perform its design function.

Characterization of waste [2]

Determination of the physical, mechanical, chemical, radiological and biological properties of radioactive waste to establish the need for further adjustment, treatment or conditioning, or its suitability for further handling, processing, storage or disposal.

Characterization of waste, in accordance with requirements established or approved by the regulatory body, is a process in the predisposal management of waste that at various steps provides information relevant to process control and provides assurance that the waste form or waste package will meet the waste acceptance criteria for the processing, storage, transport and disposal of the waste.

Monitoring [2]

The measurement of dose, dose rate or activity for reasons relating to the assessment or control of exposure to radiation or exposure due to radioactive substances, and the interpretation of the results.

Preliminary waste acceptance criteria

Preliminary quantitative or qualitative criteria derived from assumptions about a future safety case or from consideration of more fundamental principles such as passive safety or minimization of the likelihood of reprocessing, specified by the regulatory body, or specified by an operator and approved by the regulatory body, for the waste form and waste package to be accepted by the operator of a waste management facility.

Quality management [2]

The function of a management system that provides confidence that specified requirements will be fulfilled.

> Planned and systematic actions are necessary to provide adequate confidence that an item, process or service will satisfy given requirements for quality; for example, those specified in the licence.

Retrievability [3]

Retrievability is the ability in principle to recover waste or entire waste packages once they have been emplaced in a repository; retrieval is the concrete action of removing the waste. Retrievability implies making provisions in order to allow retrieval should it be required.

Reversibility [3]

Reversibility describes the ability in principle to reverse decisions taken during the progressive implementation of a disposal system; reversal is the actual action of going back on (changing) a previous decision, either by changing direction, or perhaps even by restoring the situation that existed prior to that decision. Reversibility implies making provisions in order to allow reversal should it be required.

Waste acceptance criteria [2]

Quantitative or qualitative criteria specified by the regulatory body, or specified by an operator and approved by the regulatory body, for the waste form and waste package to be accepted by the operator of a waste management facility.

- Waste acceptance criteria specify the radiological, mechanical, physical, chemical and biological characteristics of waste packages and unpackaged waste.
- Waste acceptance criteria might include, for example, restrictions on the activity concentration or total activity of particular radionuclides (or types of radionuclide) in the waste, on their heat output or on the properties of the waste form or of the waste package.
- Waste acceptance criteria are based on the safety case for the facility or are included in the safety case as part of the operational limits and conditions and controls.
- Waste acceptance criteria are sometimes referred to as “waste acceptance requirements”.

(Radioactive) Waste management [2]

All activities, administrative and operational, that are involved in the handling, pretreatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

> **Predisposal management**: Any *waste management* steps carried out prior to disposal, such as pretreatment, treatment, conditioning, storage and transport activities.

D. Issues highlighted in the position papers

1. Objectives of WAC

The operational and long term safety of a disposal facility relies amongst other things on the application of a waste management system that includes waste acceptance criteria.

Arrangements for the application of WAC usually also include procedures by which wastes that do not satisfy all of the WAC may be accepted if it is demonstrated on a case-by-case basis that the waste still meets the below objectives.

The main objective of WAC is to ensure the suitability of the waste for safe disposal taking into account all stages of its management including storage and transport.

WAC are important for waste producers, waste conditioners, transporters and waste disposal operators.

WAC should be defined so that impacts on people and the environment are within acceptable limits and as low as reasonably achievable implying following objectives are met:

- The wasteform and the waste package are compatible with the arrangements for their handling, transport, storage and disposal and with any requirement of national policy (e.g. reversibility, retrievability),
- The waste, wasteform and/or waste package contribute as appropriate to the passive safety of the disposal facility,
- The waste (raw waste, wasteform, waste package) does not have properties that could unacceptably reduce the effectiveness of safety related systems during handling, transport, storage or disposal.

WAC are intended to ensure that waste accepted for disposal are consistent with the assumptions made in the safety case in order to ensure that, if the WAC are met, the waste makes the appropriate contribution to the above objectives i.e the waste performs the appropriate ‘safety functions’.

Some aspects of the WAC, such as radionuclide content, heat and gas generation, are likely to be of considerable importance to the post-closure safety case. Other aspects of the WAC such as dimensions and shielding may be important for handling and the operational safety case. Further aspects of the WAC such as the properties of the waste form and package may vary in importance depending on the safety concept.

Even when a disposal facility option is not decided yet, reasonable assurance should be provided – ideally before the waste is created but in any case as early as practicable – that waste can be accepted for disposal, i.e. waste acceptance criteria should be anticipated as far as possible by defining preliminary WAC. These preliminary WAC might not be able to take into account any requirements related to a specific disposal facility. However, it is important that the waste is conditioned in a passively safe way so that they are suitable for safe storage, while ensuring as far as possible that they are also suitable for disposal so as to reduce any future need for re-conditioning or repackaging the wastes.

2. Roles and responsibilities

The implementation of a radioactive waste management system needs technical, organizational and administrative arrangements that define competencies, responsibilities and activities of the institutions involved. Clear responsibilities have to be identified especially regarding the different controls that have to be performed and the transfer of information to guarantee full traceability and compliance of the waste packages with waste acceptance criteria. In particular, the process of development, establishment, approval and implementation of waste acceptance criteria, involves different stakeholders each having their clearly allocated responsibilities.

Waste acceptance criteria shall be defined so that waste packages are produced in a way that will allow for safe disposal. In this purpose, the responsibilities of the various organizations involved should be defined due to the fact that in practice responsibilities with regard to the waste are always turned over during the waste lifecycle. The responsibilities shall be defined without any gap and an adequate organization or structure (future implementer of a disposal facility, waste management agency or organization (WMO), …) should be put in place to define WAC so that waste can be pretreated, treated, conditioned, transported, interim stored until final safe disposal in a geological repository.

Depending on the countries radioactive waste management framework and policy, different actors could be involved. Depending also on the status of the development of the disposal (the disposal project does not exist, is in an early stage of development or the disposal is in operation), the 'organisation' of responsibilities may vary.

However, clear allocation of responsibility has to be defined for each step for different actions (waste production, waste processing, transport, storage, disposal), i.e. WAC have also to take into account these interdependencies [1].

The following responsibilities are broadly admitted:

- the producer of raw waste has to conduct characterization of the waste he produces; he has to demonstrate the compliance of the waste package to the (preliminary) WAC prior to move to the next step in the waste management cycle;
- the waste processor is responsible for safety during all processing activities and must define procedures to ensure quality control, demonstrating compliance with (preliminary) waste acceptance criteria, during the waste processing process;
- the waste storage operator is responsible for the safety of all activities related to storage of radioactive waste, WAC taking into account storage limits and conditions;
- the disposal facility implementer is responsible for the design, construction, operation and post-closure arrangements necessary to comply with national regulatory requirements, particularly with respect to safety issues. Through an iterative and continuous process, the disposal facility implementer has to define final waste acceptance criteria, consistent with the safety case of the disposal. Whenever the disposal safety case is reviewed, WAC have to be reviewed at the same time. This work should be performed in close co-operation with waste producers and waste storage operators or other institutions or organisations involved;
- the disposal facility operator must verify that the final waste package conforms to acceptance criteria for disposal (WAC) and that all involved parties have complied with the WAC during the different interdependent steps ;
- the Regulatory Body (formed by the regulator and its Technical Support Organisation) is responsible for licensing and controlling radioactive waste management facilities and activities. Every country should define the regulatory responsibilities, which could include the role of the regulatory body related to waste acceptance.

Supporting statements:

IAEA SSR-5 (2011) [4]:

- ***R3: Responsibilities of the operator*** *: The operator of a disposal facility for radioactive waste shall be responsible for its safety. The operator shall carry out safety assessment and develop and maintain a safety case, and shall carry out all the necessary activities* *for site selection and evaluation, design, construction, operation, closure and, if necessary, surveillance after closure, in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure.*

- ***R12: 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.*

WENRA (2014) [5]:

- ***Definition: Waste acceptance criteria (for disposal)*** *Criteria applicable to waste packages and unpackaged waste accepted for emplacement in a disposal facility. Such criteria must be fully consistent with the safety case for the disposal facility in operation and after closure. They may include criteria introduced for operational as well as for safety reasons. They may be specified by the regulatory body or by an operator. If specified by an operator, they may be approved by the regulatory body.*
- ***DI-75:*** *Prior the start of waste emplacement, the licensee shall specify waste acceptance criteria so as to ensure the conformity of individual waste consignments to the safety case and other aspects of the disposal arrangements. The waste acceptance criteria shall be consistent with the operational and post-closure safety case and shall be reported to the regulatory body, for approval if appropriate.*

3. Evolution of WAC before licencing (preliminary WAC)

In principle, WAC are derived from the safety case and will ensure that the actual characteristics of wastes in a disposal facility are consistent with the characteristics assumed in the safety case for the facility.

In practice, in most of the cases, there is not yet a full safety case and preliminary WAC may need to be derived from assumptions about a future safety case or from consideration of more fundamental principles such as passive safety.

The development of the WAC for disposal is an iterative process that should be carried out in parallel, and in conjunction, with the development of the repository facility design and safety assessment. Preliminary waste acceptance criteria should be made available at the earliest opportunity.

This process has to be seen as a continuous “cycle” because waste acceptance criteria can be updated even after the disposal site has been licensed.

For the inventory of waste dedicated to be disposed of in a deep geological repository, elaboration of preliminary WAC needs to take into account all the steps identified or assumed for the management of these wastes, from predisposal waste management steps to final disposal. One of the objectives is to minimize the risk of extensive re-work in the future.

Supporting statements:

IAEA SSR-5 (2011) [4]:

- ***4.1:*** *Safety assessment in support of the safety case has to be performed and updated throughout the development and operation of the disposal facility and as more refined site data become available. Safety assessment has to provide input to ongoing decision making by the operator. Such decision making may relate to subjects for research, development of a capability for assessment, allocation of resources and* ***development of waste acceptance criteria****.*

IAEA GSR-5 (2011) [1]:

- ***Requirement 6:*** *Interdependences among all steps in the predisposal management of radioactive waste, as well as the impact of the anticipated disposal option, shall be appropriately taken into account.*

WENRA (2014) [5]:

- ***DI-74:*** *The licensee shall contribute to the safe management of the waste by establishing preliminary waste acceptance criteria at the earliest opportunity. The licensee shall update such preliminary waste acceptance criteria to reflect the development of the disposal project.*

IAEA SSG-14 (2011) [6]:

- ***6.41:*** *The proposed waste acceptance criteria should be published at the earliest opportunity, to facilitate compatibility of the waste generated and its safe management at the waste generation sites prior to its emplacement in the disposal facility.*

IAEA SSG-29 (2011) [7]:

- ***6.31:*** *The proposed waste acceptance criteria should be published at the earliest opportunity, to facilitate compatibility of the waste generated and its safe management at the waste generation sites prior to its emplacement in the disposal facility.*

4. WAC : deriving and updating

Waste acceptance criteria have to be derived for each different step in the waste management system taking waste inventory, waste processing strategy ((pre)treatment, conditioning, storage, transport) and the reference end point (final disposal) into account. The basic flowchart (Appendix 1) illustrates these interdependencies implying consideration of predisposal requirements as well as those considered in specific safety assessments for transport, storage or disposal. Two particular issues have to be addressed during development of WAC: compatibility (i.e. taking actions that facilitate other steps and avoiding taking decisions in one step that detrimentally affect the options available in another step) and optimization (i.e. assessing the overall options for waste management with all the interdependencies taken into account) [1].

WAC play also an important role as a reference for qualification: acceptance of waste packages in a disposal facility requires compliance with the acceptance criteria. This implies that methods (for segregation,…) or processes (conditioning,..) have to be agreed upon in order to guarantee conformity for transport, storage or disposal.

WAC shall be derived from and based on the assumptions of the safety case (including safety margins) to ensure that the characteristics of wastes in a disposal facility at disposal time are consistent with the characteristics assumed in the safety case for the facility. This includes ensuring that:

- The characteristics of waste, waste form and/or the waste package in the disposal facility before closure are at all times consistent with the characteristics assumed in the safety case for the operational period;
- The characteristics of ageing/degrading waste, waste form and/or waste package in the disposal facility when it is closed are consistent with the characteristics assumed in the safety case for the post-closure period.

Some of the WAC are relevant to all steps of the predisposal waste management, others are more relevant to a particular management step or even waste type or category (from classification point of view).

The development of waste acceptance criteria should follow a systematic methodology, that takes into account the safety concept, including the waste form, the waste container, other engineered barriers as well as natural barriers (e.g. host location for a repository), as well as operational constraints. It is important to understand these functions holistically for the specific waste management system being considered, so that the entire process can be optimized. Failure to do so may result in waste acceptance criteria that are overly conservative and/or are not practical to enforce.

The basic methodology for developing waste acceptance criteria is:

a) Identification of the functions of the components of the system and other constraints;

b) Identification of key parameters of the waste relevant to the facility safety case(including both administrative and technical parameters);

c) Quantification of acceptable limits or ranges for these parameters, with justification related to design or licence conditions;

d) Identification of acceptable methods for calculation/measurement of parameter values and of criteria for validating the results (*see section 5*);

e) Identification of a procedure for dealing with departures (exceptions - derogations) or non-conformities to the waste acceptance criteria (*see section 5*);

f) Documenting the requirements in a concise manner and obtaining any necessary approvals of the waste acceptance criteria (including administrative controls on document revisions).

It is important to ensure that values and limits will be based on the specific conditions of the intended facility (use of parameter values developed for other facilities, instead of developing case-specific ones, can lead to the selection of inappropriate criteria).The final WAC should also take into account all necessary features for reversibility (of decisions) and retrievability (if required by national policy), i.e. the safe retrieval of waste packages already emplaced. This implies that the integrity of the packages during an appropriate period is particularly important.

WAC have to be updated regularly until the end of emplacement of waste in the disposal. The update should be an outcome of each update of the safety case. The updates should integrate lessons learnt from the application of the WAC (including dealing with non-conformity), possible changes in operation (new type of waste, new processing option…),and must be part of every review of the safety demonstration. Acceptability of a new type of waste (e.g. the new waste stream, binding materials, new processing options…) must be assessed and relevant WAC developed and approved according to the process and responsibilities defined (*see section 1*).

A good practice should be to write down the origin of the waste acceptance criteria (root cause and assumptions that lead to development of specific criteria) in order to justify them and allow a better use both by actual generations (safety culture) and by generations to come.

Supporting statements:

IAEA SSR-5 (2011) [4]:

- ***R20:*** *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.*
- ***3.14:*** *The operator has to establish technical specifications that are justified by safety assessment, to ensure that the disposal facility is developed in accordance with the safety case. This has to include waste acceptance criteria (see Requirement 20) and other controls and limits to be applied during construction, operation and closure.*

WENRA (2014) [5]:

- ***Definition: Waste acceptance criteria (for disposal)*** *Criteria applicable to waste packages and unpackaged waste accepted for emplacement in a disposal facility. Such criteria must be fully consistent with the safety case for the disposal facility in operation and after closure. They may include criteria introduced for operational as well as for safety reasons. They may be specified by the regulatory body or by an operator. If specified by an operator, they may be approved by the regulatory body.*
- ***DI-61:*** *The licensee shall plan, assess, document and implement any modifications of design, waste acceptance criteria, structures, systems and components (SSCs), operational limits and conditions (OLCs) and operational procedures and methods using arrangements consistent with the importance to safety of the modifications.*
- ***DI-75:*** *Prior the start of waste emplacement, the licensee shall specify waste acceptance criteria so as to ensure the conformity of individual waste consignments to*

the safety case and other aspects of the disposal arrangements. The waste acceptance criteria shall be consistent with the operational and post-closure safety case and shall be reported to the regulatory body, for approval if appropriate.

- ***DI-78***: *The licensee shall report changes to waste acceptance criteria to the regulatory body, for approval if appropriate. The licensee shall substantiate the consistency of any changes with the assumptions made in the safety case.*

5. Characterization / Monitoring / Checking compliance / Procedural aspects such as quality management and implementation

Waste will have to go through different interdependent operations between their production and their final emplacement in a disposal facility. These different operations may include different activities (characterization, processing, controls, transport, storage, final emplacement in a disposal facility) that may involve different actors with different responsibilities. The waste acceptance criteria documentation must be unambiguous and usable by all involved parties.

It implies to clearly identify key parameters, quantification of acceptable limits or ranges for these parameters, acceptable methods for calculation/measurement and verification of parameter values (this is especially important for properties that cannot be easily measured or can give widely differing results, depending on the assumptions), procedure for dealing with departures (exceptions - derogations) or non-conformities, and the form and the content of the corresponding records.

Suitable tests and inspections of the conditioning process of the waste (including technical and organizational aspects) should be performed and carried out routinely under cover of a quality management system. Depending on specific contractual arrangements, supervision activities may be performed by the final disposal implementer during conditioning as some control will only be possible at certain steps during the conditioning process.

Supporting statements

IAEA SSR-5 (2011) [4]:

- ***5.3:*** *Waste intended for disposal has to be characterized to provide sufficient information to ensure compliance with waste acceptance requirements and criteria. Arrangements have to be put in place to verify that the waste and waste packages received for disposal comply with these requirements and criteria and, if not, to confirm that corrective measures are taken by the generator of the waste or the operator of the disposal facility. Quality control of waste packages has to be undertaken and is achieved mainly on the basis of records, preconditioning testing (e.g. of containers) and control of the conditioning process. Post-conditioning testing and the need for corrective measures have to be limited as far as practicable.*

IAEA SSG-29 (2014) [7]:

- ***6.31:*** *The waste acceptance process established by the operator should take into account the steps of waste generation and waste processing. Depending on national responsibilities, the waste generator, the waste management organization or the operator of the disposal facility should establish and/or apply waste acceptance criteria*

> *and technical specifications and procedures for controlling waste generation, waste processing and waste characterization. This should ensure that there will be mechanisms (e.g. procedures and controls) in place during the process of waste generation and management that will ensure that the waste acceptance criteria for disposal can and will be met. As part of the waste acceptance process, the operator should carry out verifications and controls when waste is received for disposal. The major elements of the waste acceptance process should be presented to the regulatory body for approval, for example as part of the safety case for the application of a license.*

WENRA (2014) [5]:

- ***DI-79:*** *The licensee shall ensure that the waste accepted for disposal conforms to waste acceptance criteria. A conformity assessment shall be performed in accordance with written arrangements which include administrative procedures, inspections and/or tests.*
- ***DI-81****: To provide an adequate level of assurance that waste characteristics conform to the waste acceptance criteria, the licensee shall satisfy itself that the* ***management system of the organization submitting waste*** *for disposal appropriately addresses waste quality issues.*

6. Dealing with non-compliance

Treatment of departures (exceptions / derogations):

In setting WAC it will usually be necessary to make some further assumptions, for example about the types and amounts of waste that the facility will receive. However how carefully these assumptions are made, cases can be expected in which waste package does not meet all of the WAC but could eventually be accepted for disposal without compromising the safety case. A procedure should be defined for such situations to allow case-by-case consideration whether acceptance of such a waste would compromise the safety case to such an extent that consistency with basic regulatory requirements for the safety of the facility would be threatened. These situations can be referred as “departures” but should nevertheless be taken into account when reviewing the WAC.

Departures are to be detected and addressed before proceeding to the next step in management process. The operator has to inform the disposal operator that some waste will not fully comply with the WAC and ask for his judgment on a case-by-case basis.

Treatment of non-conformity:

Non-conformity can be discovered at each stage of the process (from early conditioning and even after emplacement of waste) and a procedure is needed to deal with these situations.

Individual waste packages or package consignments intended or received for disposal might not fully comply with some waste acceptance criteria for disposal. These could for instance be packages damaged by incorrect handling or by incidents, or waste packages produced under deficient process conditions.

Waste packages with minor deviations from waste acceptance criteria might still be accepted for disposal by the operator of the disposal facility after an affirmative assessment on a case-by-case basis in terms of their impact on operational and long-term safety. The responsibility for this assessment should be clearly defined "see section 2".

Non-conformities that do not meet the acceptance criteria for emplacement should lead to an analysis commensurate with the hazard and addressing the following aspects:

- Possibility to return a particular non-conforming waste package to an acceptable condition. It may include identification of possible remedial work carried out to ensure conformity (e.g., removal of minor contamination on the external surface of the package).
- Necessity to adjust the process that generated the defective waste package so that non-conforming packages are not generated due to the same cause if it is left uncorrected.
- In some cases, if the non-conformance cannot be corrected, it will lead to a rejection of the corresponding waste packages by the operator or implementer of the disposal facility. Such waste packages must be re-assessed and re-conditioned if necessary under regulatory control.

Investigations, (root) cause analysis, corrective and preventive actions must be suitably documented and should be kept with the waste package information during all steps in the waste management process.

Traceability of the non-conformity treatment is also important and the lessons learned are a key task within the objective of continuous quality and safety demonstration improvement.

In all cases of non-conformity the measures taken need to be clearly communicated to the waste generator or conditioner / processor and eventually agreed with the regulator.

A procedure in order to treat these non-conformities should be established. It should address, amongst others the conditions for return or storage of non-conforming waste packages and corresponding responsibilities.

Supporting statements:

IAEA SSR-5 (2011) [4]:

- ***5.3:*** *Waste intended for disposal has to be characterized to provide sufficient information to ensure compliance with waste acceptance requirements and criteria. Arrangements have to be put in place to verify that the waste and waste packages received for disposal comply with these requirements and criteria and, if not, to confirm that corrective measures are taken by the generator of the waste or the operator of the disposal facility. Quality control of waste packages has to be undertaken and is achieved mainly on the basis of records, preconditioning testing (e.g. of containers) and control of the conditioning process. Post-conditioning testing and the need for corrective measures have to be limited as far as practicable.*

WENRA (2014) [5]:

- ***DI-82:*** *The licensee shall establish procedures for dealing with waste that does not conform to waste acceptance criteria, and shall not accept such waste unless* *acceptability with regard to operational and post-closure safety has been demonstrated on a case by case basis.*

7. Parameters

As already mentioned before, WAC shall be derived from and based on the assumptions of the safety case and will ensure that the characteristics of wastes in a disposal facility at disposal time are consistent with the characteristics assumed in the safety case for the facility. This includes ensuring that:

- The characteristics of waste, waste form and/or the waste package in the disposal facility before closure are at all times consistent with the characteristics assumed in the safety case for the operational period;
- The characteristics of ageing/degrading waste, waste form and/or waste package in the disposal facility when it is closed are consistent with the characteristics assumed in the safety case for the post-closure period.

In order to justify compliance with the safety case of the disposal facility, WAC may include different parameters, eventually with different limit values to be checked at different steps in the management process of the waste.

WAC can in principle be defined to control a wide range of characteristics regarding the waste, its packaging and the traceability of the whole management process of the waste, thus the parameters can be of different types, not only quantitative technical ones, but also qualitative or administrative ones.

The parameters are to be defined and justified in accordance with safety requirements, by the implementer of the disposal, but from regulator point of view, following requirements are needed (indicative list):

- Administrative and quality related issues:

  Administrative requirements are generally related to traceability of wastes as well as quality assurance. These could include specifications for labelling of waste packages, specification of a quality assurance standard, quality management system (record keeping…), definition of specific responsibilities, etc. These requirements are usually generic.

- Technical issues:

  Based on compliance with the regulatory requirement and on site specific safety assessment, WAC should specify at a minimum:

  - allowable activities or concentrations of specific radionuclides in a waste package or consignment of waste, based on consideration of the activity and average concentration that can safely be handled and disposed of in the repository as a whole;
  - waste form and waste package requirements ensuring stability under all conditions expected/foreseeable during all steps from raw waste production until final disposal; relationships between these requirements and conditioning, transport, storage and final disposal operations should be taken into account; wastes received at the

disposal facility are in a chemically/physically stable form; this stability is dependent on all preceding waste management steps performed or to be performed.

- requirements regarding the wasteform, related to physical immobilization (immobilization of radionuclides, loose particulate materials, free liquids), mechanical and physical properties, chemical containment, presence of hazardous materials, gas generation hazards and wasteform evolution over time;
- requirements regarding the waste package, more related to operational safety aspects (e.g. activity content, dose rate, heat output, surface contamination, criticality safety, impact and fire performance, stackability, identification, safeguards) but can also in some cases be related to long term safety;
- restrictions/prohibitions on waste types and materials that could adversely affect the performance of the package or the disposal system;
- Complementary requirements on the waste to be disposed of depend on the radionuclide content of the waste :

The requirements dealing with the characteristics of wastes and waste packages concern the following characteristics :

- Radionuclide content
- External radiation dose rates
- Criticality
- Content of active gases
- Surface contamination
- Physical, chemical and biological properties of the waste package
- Physical integrity
- Chemical stability (durability):
- Physical stability:
- Biological stability:
- Thermal output:
- Possibility of gas generation and presence of inflammable/pyrophoric materials
- Presence of toxic and corrosive materials
- Fire resistance

Supporting statements:

IAEA SSG-14 (2011) [6]:

- ***6.38:*** *The waste characteristics important to the safety of the operational and post-closure periods are part of the relevant safety case. Waste acceptance criteria may be developed by means of an iterative dialogue between regulatory body, the operator of the facility and the generator of the waste. The criteria should include the waste characteristics important to safety in the operational period and the period after closure and typically specify the following:*

- *(a) The permissible range of chemical and physical properties of the waste and the waste form;*
- *(b) The permissible dimensions, weight and other manufacturing specifications of each waste package;*
- *(c) Allowable levels of radioactivity in each package;*
- *(d) Allowable amounts of fissile material in each package;*
- *(e) Allowable surface dose rate and surface contamination;*
- *(f) Requirements for accompanying documentation;*
- *(g) Allowable decay heat generation for each package.*

IAEA GSR-5 (2011) [1]:

- ***4.24:**: Waste acceptance criteria have to be developed that specify the radiological, mechanical, physical, chemical and biological characteristics of waste packages and unpackaged waste that are to be processed, stored or disposed of; for example, their radionuclide content or activity limits, their heat output and the properties of the waste form and packaging.*

WENRA (2014) [5]:

- ***DI-76**: The licensee shall ensure that waste acceptance criteria specify limits on important parameters such as radionuclide inventories and activity concentrations in individual waste consignments.*
  Appendix 2 presents further details of the typical content for low and intermediate level waste.
- ***Annex 2***

E. Key messages

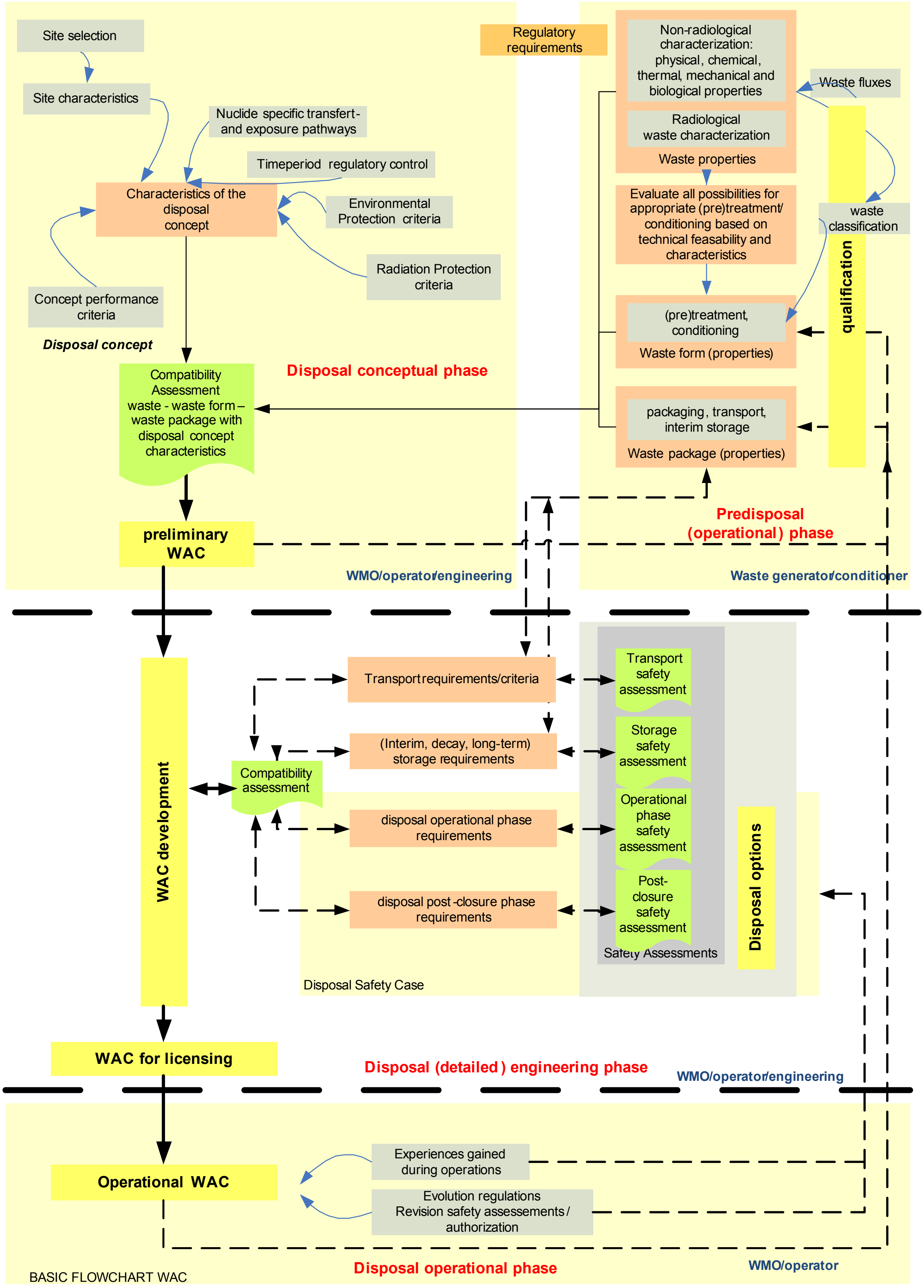
1. Defining Waste Acceptance Criteria (WAC) is a stepwise iterative process, it shall be duly planned and adequate milestones identified prior it starts.
2. Roles and responsibilities have to be precisely defined throughout the continuous and iterative process of defining WAC, allowing for thorough understanding of the criteria and their use by each interested party.
3. Preliminary WAC should be available as soon as possible including the intention for minimizing the need for any future intervention. Their updating should be done through an iterative process carried out in parallel and in conjunction with the development of disposal facility design and safety assessment.
4. Elaboration of preliminary WAC needs to take into account all the interdependent steps identified or assumed for the management of these wastes until final disposal, and their interdependencies.

5. While defining limits and parameter values, particular attention should be paid how to check compliance of waste with these limits and values.
6. Traceability of departures from WAC and non-conformity treatment is important and the lessons learned are a key task within the objective of continuous quality and safety demonstration improvement.
7. WAC may include different parameters, eventually with different limit values to be checked at different steps in the management process of the waste.

F. References

[1] IAEA (2009): GSR Part 5 Disposal Management of Radioactive Waste
[2] IAEA (2016): Safety Glossary – draft revision
[3] NEA (2012): Reversibility of decisions and retrievability of radioactive waste, No.7085
[4] IAEA (2011): Geological Disposal Facilities for Radioactive Waste, SSG-14
[5] IAEA (2014): Near Surface Disposal Facilities for Radioactive Waste, SSG-29
[6] IAEA (2011): Disposal of Radioactive Waste**,** SSR-5
[7] WENRA (2014): Report on Radioactive Waste Disposal Facilities Safety Reference Levels

Appendix: WAC-development (basic flowchart)



Appendix 3: Site characterisation program for deep geological repository

Rapporteur: Julie Mecke

A. Background

EC Horizon 2020 project SITEX II aims at the establishment of a network ensuring sustainable capacity for developing and coordination of joint and harmonised activities related to the independent technical expertise function regarding safety of deep geological repository (DGR) of radioactive waste. The expertise function is provided by organisations that are regulators and those who may support regulators (in particular technical support organizations - TSOs).

Within the project a Task is devoted to sharing national experience and prospective views on the interpretation and implementation of selected safety requirements and recommendations. Among the topics identified according to the priorities set up in the former SITEX project (carried out within FP7 programme in 2012-13) the issue of site characterization program for DGR has been selected.

SITEX II participants have exchanged their views and experience on how to implement in practice high level international requirements related to site characterization program for DGR. Conclusions of the discussion have been gathered in this Position Paper. However, the Position Paper does not cover the issue exhaustively; it only highlights topical issues SITEX II participants feel they are worth to be raised.

B. Objectives

The objectives of this Position Paper are to:

- share national experiences, best practices and present a common understanding by regulators and TSOs on the interpretation and implementation of safety requirements of international organisations (IAEA, ICRP, NEA/OECD, WENRA) regarding site characterization program.
- formulate guidelines how to implement those requirements in practice, in particular
  - to give additional input to regulatory bodies (including TSOs) when developing technical guides
  - to provide a guidance to the (prospective) licensees (Waste Management Organizations (WMOs)) on technical aspects that should be considered during the site characterization phase of the siting process for a DGR for radioactive waste.

C. Scope of the Position Paper and definitions used

1. The Position Paper provides high-level views and experience to provide guidance on technical aspects that should be considered during the site characterization phase of the siting process for a DGR for radioactive waste.
2. The following subjects are developed:
   - Overview of the siting process for a DGR, including site characterization
   - Site characterization program of the (prospective) licensee
   - Management system of the (prospective) licensee
   - Regulatory body involvement
3. For the Position Paper, it is considered that the decision to commence a process for DGR has already been taken.
4. This document does not provide guidance on finding or selecting a site, this process is up to the (prospective) licensee. However, it is expected that the site characterization phase will be carried out at a level sufficient to confirm the technical suitability of a site.

5. Protection against non-radionuclides is not covered by the position paper. However, it is noted that regulators in some countries may have to take into consideration when assessing the site suitability.
6. The following definitions are used in the position paper:

Siting [1]

- The process of selecting a suitable site for a disposal facility, including appropriate assessment and definition of the related design bases. The siting process for a disposal facility is particularly crucial to its post-closure safety; it may therefore be a particularly extensive process, and can be divided into the following stages: concept and planning, area survey, fundamental site characterization, site confirmation.

Site Characterization [2]

- *DI-32: The licensee shall prepare and implement a program for site characterization of the selected site. The program shall provide the information necessary to support the safety case*
- *DI-33:*
    - *The licensee shall conduct site characterisation of the selected site:*
    - *To establish baseline conditions for the site and the environment;*
    - *To support the understanding of the normal evolution;*
    - *To identify any events and processes associated with the site that might disturb the normal evolution of the disposal system;*
    - *To support the understanding of the effect on safety of any features, events and processes associated with the disposal system*

D. Issues highlighted in the position papers

1. Overview of siting process, including site characterization

In order to provide context, the following section describes how the site characterization fits into the overall siting process for a DGR.

The objective of the siting process [1], which includes site characterization, should be to select a site which, along with a suitable design of the repository engineered barriers, has properties which provide adequate containment and isolation of radionuclides from the accessible environment for the required period of time. The engineering suitability of the host rock has to be considered as well. During the siting process a comparison of possible sites can be done.

The IAEA identifies four stages to the siting process for a DGR:

1. A conceptual and planning stage – desktop data compilation and interpretation
2. Survey stage: regional mapping and screening
3. Site characterization stage
4. Site confirmation stage

Site characterization essentially begins at the earliest stage of the investigation of a site and is expected to become more intensive as the siting process progresses through to confirmation of the site.

Data gathered in the preliminary stages of the siting characterization process may be used to support the initial licence application and may form part of the safety case and future iterations.

Even after site confirmation, site characterization activities will be required in the initial licensing phases and are normally expected to continue into the site preparation, construction and operational phases, in order to contribute further to an adequate baseline for future monitoring and to contribute to the confirmation of assumptions made in earlier safety cases and reduce any residual uncertainties in the safety case.

Consequently, the regulatory body may have a role to play all along this siting process, from the very beginning of this process (see section 4). The early involvement of the other stakeholders (including public) may also be included in the siting process.

Supporting documents:

IAEA Glossary, 2007 [1]

> Siting - *The process of selecting a suitable site for a disposal facility, including appropriate assessment and definition of the related design bases. The siting process for a disposal facility is particularly crucial to its post-closure safety; it may therefore be a particularly extensive process, and can be divided into the following stages: concept and planning, area survey, fundamental site characterization, site confirmation*

IAEA SSG-14 [3]

> **6.5.** *Site characterization is an activity undertaken in order to understand the natural features, events and processes at a site (at the present time, in the past and potentially in the future) and to describe adequately their spatial and temporal extent and variability. Site characterization contributes to a comprehensive description of the site, which may include information concerning anthropogenic characteristics (e.g. land use and transport infrastructure for environmental studies). There should be a clear understanding of the context and of the objectives for any site characterization in order to define properly the degree and focus of the site characterization activities that will be necessary. Site characterization will comprise data acquisition (i.e. mensuration, sampling and monitoring) and the interpretation of that data to generate information and knowledge. Site characterization will essentially begin at the earliest stage of the investigation of a site and is expected to become more intensive as the facility development programme progresses through to confirmation of the site and commencement of construction.*
>
> **6.20**. *Information from site characterization activities will likely be used to inform various decision making mechanisms. Confirmation of the suitability of site conditions will provide support for regulatory approvals to progress to the next phases of the development programme, namely, construction and/or operation of the disposal facility. Site characterization should continue as long as is necessary, including into the operational period, to provide the basic data for a specific understanding of the disposal area, to support continuing excavation activities, to contribute further to an adequate baseline for future monitoring, to contribute to the confirmation of assumptions made in earlier safety assessments and to support the post-closure safety case.*

2. Site characterization program of the (prospective) licensee

As part of the siting process, the (prospective) licensee should prepare and implement a program for site characterization for the proposed site for a DGR facility. The program should provide information sufficient to support a general understanding of the site in its current state, and how the site is expected to evolve over extended time frames associated with the safety case [2]. It includes the biosphere and geosphere.

The site characterization program should establish baseline conditions for the site and environment in its undisturbed condition; support the understanding of the normal evolution; identify any events and processes associated with the site that might disturb the normal evolution of the DGR system; support the understanding of the effect on safety of these features, events and processes[2].

The site characterization program will provide the initial information for safety assessments at the conceptual stage. The data will serve as the basis for the first iteration of the full safety case and any initial geoscience verification program at the site once it has been selected. Data collected during site characterization will form the basis of descriptive site models and geological, hydrogeological, geochemical and geomechanical frameworks that will be relied on to evaluate long-term safety.

In turn safety assessment can provide important input for further characterization program steps. For example, safety assessment can show which parameters have impact on the adequacy of the characterized site. Parameters will vary depending on host rock. It is an iterative approach.

Furthermore, the data will provide baseline data for detecting potential short- and long-term environmental impacts at various stages, and for tracking throughout the lifecycle of a DGR. Baseline data is gathered during site characterization program will be used as reference for the monitoring of the DGR system overtime. Since the baseline is an outcome of the site characterization, it will be important to take into account baseline needs when developing the site characterization program.

Site characterization may involve both surface and desktop investigations to identify and understand particular features and processes. These processes are typically studied in different disciplines (hydrogeology, rock mechanics, geochemistry, etc.) but must be understood in an integrated manner.

Finally, an URL may contribute to improve the in-situ knowledge of the host rock.

Supporting documents:

Site Characterization WENRA [2]

DI-32: The licensee shall prepare and implement a program for site characterization of the selected site. The program shall provide the information necessary to support the safety case

DI-33:

- *The licensee shall conduct site characterisation of the selected site:*
- *To establish baseline conditions for the site and the environment;*
- *To support the understanding of the normal evolution;*
- *To identify any events and processes associated with the site that might disturb the normal evolution of the disposal system;*

- *To support the understanding of the effect on safety of any features, events and processes associated with the disposal system*

IAEA SSR-5 [4]

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.*

> 4.27. *Characterization of the geological aspects has to include activities such as the investigation of: long term stability, faulting and the extent of fracturing in the host geological formation; seismicity; volcanism; the volume of rock suitable for the construction of disposal zones; geotechnical parameters relevant to the design; groundwater flow regimes; geochemical conditions; and mineralogy. The extent of characterization necessary will depend on the types of disposal facility and the site in question.*

3. **Management system** of the (prospective) licensee

Site characterizing activities could take place over several years to decades and generate a larger amount of data. Therefore, the (prospective) licensee should develop and implement an appropriate and robust management system for site characterization. The (prospective) licensee should demonstrate that the results of siting and characterization activities are accurate, comprehensive, reproducible, traceable and verifiable. Margins of errors need to be clearly identified in order to treat uncertainties properly. It is also important to define upfront which data will be needed to be stored for each stage of the DGR.

The integrity, accuracy and completeness of the information and data generated as a result of the sitting and characterization activities are of utmost importance. Consistency and quality of data used to develop the safety case submitted in support of any formal licence application should be ensured by the (prospective) licensee.

Supporting documents:

IAEA SSG-23 [5]

> 4.55.*Confidence in the assessment results will be enhanced if the site characterization and safety assessment programmes are of high quality; if site data collected by the operator are consistent with other existing data in terms of parameter values and the measurement methodology applied; if the safety assessment models developed are consistent with the properties of the site and the conceptual understanding of the site based on scientific principles; and if the conceptual understanding of the site and the safety assessment models continue to be compatible with and appropriate for any new information about the site that may become available, subject to only minor refinement.*

4. Early regulatory involvement

Early consultation with the regulatory body for clarity with respect to regulatory expectations and requirements is strongly recommended as data gathered in the preliminary stages of the siting characterization process may be used to design and assess the facility and to prepare support for enviromental assessment and/or the initial licence application. As data may form part of the safety case and future iterations, it is important that the regulatory body provides early feedback to the implementer in order to prevent potential problems associated with the quality of data used for the safety assessment.

The extent of consultations between the regulatory body and the (prospective) licensee should be balanced so as to preserve the independence of the regulator while providing adequate guidance to the applicant. For example, the regulatory body may issue guidelines for site characterization program. The regulatory body may review the (prospective) licensee's management system to provide early feedback - for example that the records on the site are available for continuing preservation.

Furthermore, the regulatory body should also build its own expertise for example through an independent research&development (R&D) program.

E. Key messages

1. The Position Paper provides high-level views and experience to provide guidance on technical aspects that should be considered during the site characterization phase of the siting process for a DGR for radioactive waste.
2. Site characterizing activities could take place over several years to decades and the data gathered in the preliminary stages may be used to support the initial licence application, forming part of the safety case and future iterations. Therefore, site characteristic activities should be carried out under a robust management system.
3. Regular dialogue with the regulator from the very beginning of the process is strongly encouraged to ensure that regulatory expectations and licensing requirements are clearly understood. The extent of consultations between the regulatory body should be balanced so as to preserve the independence of the regulator while providing adequate guidance to the applicant.
4. The site characterization program should establish baseline conditions for the site and environment in its undisturbed condition; support the understanding of the normal evolution; identify any events and processes associated with the site that might disturb the normal evolution of the DGR system; support the understanding of the effect on safety of any features, events and processes associated with the DGR.
5. Baseline data gathered during site characterization program is used as a reference for the monitoring the DGR system.

F. References

[1] INTERNATIONAL ATOMIC ENERGY AGENCY (2007), IAEA Safety Glossary 2007 Edition, Vienna (2007)

[2] WESTERN EUROPEAN NUCLEAR REGULATORY AUTHORITY (2014), Report - Radioactive Waste Disposal Facilities Safety Reference Levels, December 22, 2014

[3] INTERNATIONAL ATOMIC ENERGY AGENCY (2011), Geological Disposal Facilities for Radioactive Waste, Specific Safety Guide, No. SSG-14, Vienna 2011.

[4] INTERNATIONAL ATOMIC ENERGY AGENCY (2011), Disposal of Radioactive Waste, Specific Safety Requirements, No. SSR-5, Vienna (2011)

[5] INTERNATIONAL ATOMIC ENERGY AGENCY (2012), The Safety Case and Safety Assessment for the Disposal of Radioactive Waste, IAEA Specific Safety Guide, No. SSG-23, Vienna (2012)

Appendix 4: Operational issues with regards to post closure safety

Rapporteur: Michaël Tichauer

A. Background

EC Horizon 2020 project SITEX II aims at the establishment of a network ensuring sustainable capacity for the development and coordination of joint and harmonised activities related to the independent technical expertise function regarding safety of deep geological repository (DGR) of radioactive waste. The expertise function is provided by organisations that are regulators and those who may support regulators (in particular technical support organizations - TSOs).

Within the SITEX II project a Task is devoted to sharing national experience and prospective views on the interpretation and implementation of selected safety requirements and recommendations. Among the topics identified according to the priorities set up in the former SITEX project (carried out within FP7 programme in 2012-13) the issue of operational issues with regard to post closure safety has been selected.

SITEX II participants have exchanged their views and experience on how to implement in practice high level international requirements related to the operational issues with regard to post closure safety. Conclusions of the discussion have been gathered in this Position Paper. However, the Position Paper does not cover the issue exhaustively; it only highlights topical issues SITEX II participants feel they are worth to be raised.

B. Objectives

Starting on the foundations of the SITEX and SITEX-II earlier works and the late GEOSAF and GEOSAF II IAEA international projects, this position paper aims at unveiling the key aspects of a deep geological repository (DGR) safety case (SC) evaluation, specifically on the relationships between operational phase and long term phase.

Intentionally, this paper does not try to draw the multifaceted aspects of the operational phase, which have been widely discussed and highlighted in several working groups and international projects, IAEA GEOSAF II, WENRA and OECD NEA IGSC/EGOS being the latest ones. It does not even try to list the key areas of R&D and competence building for the evaluation of the SC with regard to operational safety. On the contrary, it focuses on the main items which are of particular interest when evaluating the safety of a DGR during its operational phase. In fact, operational safety with regard to long term safety evaluation remains one of the key challenges for the expert function which forms the core of the future SITEX-Network.

C. Operational phase: expert function key challenges

The SITEX-II members embraces IAEA GEOSAF II definition of the operational phase, which consists in the period of time starting after the initial construction and commissioning, and during which activities are performed in order to deliver a defined state of the DGR and the radioactive waste it contains. This state, called in IAEA GEOSAF II lexicon the *safety envelope*, is envisioned and meticulously defined during the design phase. It corresponds with the values below which, at the start of the post-closure phase, the safety functions must fall in order to deliver post-closure safety. Whatever the wording, it consists in the overall objective the operator and/or implementer is seeking during the stepwise evolution of the SC over the lifecycle of the DGR.

For the expert function overseeing operational safety, the challenge is therefore to evaluate whether the SC shows that (i) the safety envelope allow to reach the safety objective, (ii) arguments and evidences allow to give confidence in reaching the *safety envelope*, (iii) a sound operational safety strategy, taking into account peculiarities of the operational phase, such as concurrent activities (construction, nuclear operation, maintenance, partial closure…) or the specifics given by the context of a DGR (facility size, underground risks such as fire or flooding, operation time spanning over a century and inevitable design modifications, ageing materials, monitoring, reversibility, etc.) and (iv) a capacity for *resilience* during its lifespan, whatever the incidents, accidents, design and waste acceptance criteria changes that will occur before the DGR is finally closed.

All in all, the expert function's challenge when evaluating the operational safety of a DGR is to make a statement on the *confidence* one may give on the safety strategy, the safety concept, the design and the provisions made by the implementer and/or the operator.

D. Operational safety evaluation with regard to post closure safety

Numerous arguments of the SC have to be overlooked by the expert function. To name a few, the following aspects should consider both operational and long term safety:

- the architecture of the facility;
- the design of the engineered barriers;
- the reversibility and the question of flexibility which accounts for the fact that changes will occur over time;
- closing strategy (soon, late, stepwise…) and their impact on long term safety;
- accounted scenarios, especially accident scenarios and action plans;
- safety culture and human factors;
- ageing of equipment and structures;
- monitoring and surveillance;
- quality assurance (QA) and management systems;
- the establishment and substantiation of operating limits and conditions (OLCs) and their sustainability over the operational time.

It is for instance straightforwardly noticeable that the performance of engineered barriers can be targeted to operational safety or to long term safety. The long term performance of engineered barriers is affected by the way they will be built and managed during the operational phase. The other items may not show a trivial relationship with both operational safety and long term safety, however the SITEX European network believe that their assessment is crucial as soon as during the design phase, and especially for the licensing of a DGR.

E. Architecture & EBS design

Depending on national programmes, an underground facility such as a DGR may consist in a complex network of ramps, shafts, drifts, emplacement cells, EBS, intertwined with fluxes of materials, machines, radioactive waste, workers, air, cables…. A key question for the expert function is verify that the implementer's arguments are derived from an optimization process considering both operational and long term safety. For instance, if the host rock accounts for a massively diffusive environment, the selected architecture shall show that other pathways are not significant in terms of convective transport of radionuclides: the role of engineered barriers such as plugs and seals, the drifts' length or the position of waste emplacement cells with regard to possible radionuclide exits such as shafts are of key importance.

It is important that the expert function bears in mind that a long drift may be an asset for the demonstration of post closure safety and the retardation of radionuclides transport through shafts up to the biosphere, yet in the meantime a drawback for operational safety (evacuation time, maintenance, fire risk management, duration of waste handling inside the DGR, etc.). Tackling such apparent contradictions and searching for a framework that accounts for a sound optimization of safety (including radiation protection) shall form one of the expert function's interrogations when evaluating the architecture and design aspects of the SC.

F. Reversibility and flexibility

Considering the timeframe of the operational phase of a DGR, changes *may* not but *will inevitably* occur during this period. For the expert function, this calls for the evaluation of a DGR's design and provisions that show a resiliency to change, i.e. a capacity to sustain evolutions of technology, context, society, regulation, waste forms and packages… without jeopardizing the overall objective of reaching the state defined by the safety envelope at the end of the operational phase. The SC shall therefore highlight some framework for change management encompassing every aspect of the SC (see IAEA SSG-14). In the same way, reversibility and flexibility form a major safety feature of a DGR.

For example, provisions made for retrieving waste – if such a decision is eventually taken in the future - could dramatically compete in the SC with long term safety features such as the minimization of space left inside the DGR, materials and structures interacting with EBS and the host rock, etc. It is then key to identify the reversibility and flexibility features of the DGR that may impair long term safety, and to evaluate whether a sound balance between operational safety and long term safety has been achieved in the SC. In any case, the expert function will assess that any changes in the future will be checked against the SC, especially the targets defined during the design phase, the safety strategy and the safety envelope.

G. Closing strategy

The operational aspects of the SC should also show the strategy the operator aims at developing for the final closure of the DGR. Several different ones may be provided, spanning from direct closure of emplacement cells right after waste has been disposed to massive closure works performed once every single waste package has been transferred to their final emplacement. These strategies are obviously deeply correlated with hereinabove highlighted reversibility and flexibility issues. The expert function shall verify that operational safety remains paramount to the failsafe achievement of the state defined by the safety envelope However, long term safety being the *raison d'être* of a DGR, the evaluation of the closure strategy is important to gain confidence in the design of provisions proponed by the implementer and/or operator.

H. Operational safety scenarios

Key arguments developed in the SC are shaped into the development of scenarios: normal operation (including concurrent activities of mining and nuclear operations or *co-activity*), incidental and accidental situations. For the expert function, it is therefore important to assess the pertinence and comprehensiveness of such scenarios, while remaining at the same time humble to multiple situations that cannot be guessed in advance. This calls for a specific evaluation methodology: the expert function will (i) take into account the peculiarities of a DGR to assess risks that may be different in underground spaces - fire risk is a common example which shows a track record of accidents and fatalities in conventional facilities, like mines or tunnels -, (ii) evaluate the design and provisions made by the implementer and/or operator with regard to operational safety, (iii) highlight the risks and scenarios that may also have an impact on long term safety (e.g. rock fall, flooding) and (iv) investigate whether different safety features of the facility may lessen such impacts.

For instance, retrievability may not only consist in a flexibility feature but also pave the way to specific provisions that may be of particular interest when dealing with a major accident such as a fire: obviously, if canisters and waste packages are *by design* easily retrievable thanks to structures systems (including monitoring systems) already in place, the operator may use them to mitigate the consequences. Feedback experience is also an excellent way for the expert function to underline the provisions that were *lacking* in previous underground accidental situations and evaluate whether they could be important in the context of a DGR. On the contrary, the assessment of initial features such as the waste form, the materials' interactions and – for instance - the minimization of chemical reactivity between components of the disposal system is an important milestone in gaining confidence in the resilience of a DGR in the case of an accident, i.e. its capacity to start over operation in a context and environment similar to the one that prevailed before the accident.

I. Safety culture and human factors

Human factors should be integrated throughout the SC, considering links between operational safety and long term safety. Feedback experience from existing DGRs such as the WIPP have dramatically shown that operational safety can be impaired in a very limited time with scarce early signs of loss of confidence in the operator's decline in safety culture and safe operation. Beyond common understanding that safety culture shall be promoted and sustained over time, SITEX-II believes that during the operational phase timeframe, a decline in safety provisions and practices – for any reason: lack of funding, complacency, inability to hire staff, etc. – may inevitably occur. It is therefore important to ensure right from the design phase that the facility can provide compensating measures for such a decline. The concept of a *resilient* design echoes here again. A good example can be found in safety provided by design that does not account for heavy human interaction by avoiding complex manual handling or processes.

J. Ageing of equipment and structures

Considering the duration of the operational phase, structures and materials will age and their performance with regard to safety may degrade over time. Such degradation may impact both operational and long term safety, depending on the considered structures and components, but most of all, it is important for the expert function to identify the components that may be maintained (or replaced) with relevance to their role in long term safety. In any case, a strategy for the management of ageing equipment and structures has to be evaluated by the expert function. This assessment should focus on the equipment with regard to its relevance to operational safety as well as to long term safety.

K. Monitoring and surveillance

Among the SC key items listed in this paper, monitoring (and/or surveillance, depending on national programmes' wording) strategies and implementation are of particular importance. In fact, they are critical both for operational safety (enforcement of OLCs, maintenance, regulatory oversight, emergency management, etc.) and long term safety (evolution of EBS, identification of barrier degradations, etc.). But most of all, monitoring should allow to check continuously whether any event during operation may impact the facility and the safety envelope. Two consequences can be drawn for the expert function: (i) the monitoring program should be developed by the implementer/operator as soon as the design phase and assessed against the required components' performance highlighted in the SC (ii) a sound balance between provisions made for monitoring and DGR disturbance shall be found in the SC. For instance, one can easily imagine that hundreds of wires passing through seals may impair long term safety while being used for data collection on the state of the EBS during the operational phase. On the other hand, depending on the concept and the safety assessment results, a facility with such dimensions could necessitate a massive network of sensors, detection and alert systems, relays, etc. For the expert function, it is therefore a challenge to be fully aware of the central role of the monitoring systems and disseminate the evaluation of its adequacy in every aspect of the risk assessment performed by the implementer/operator.

In addition to that, this area of knowledge is swiftly evolving and new technologies rapidly emerge, forcing the expert function to invest time and resources in R&D and competence building in order to perform a sharp assessment of the SC throughout the lifecycle of the DGR.

L. QA and management systems

QA can be often seen as a side aspect of the SC: in fact, it aims at demonstrating conformity of the facility design and operation to a reference set of documentation, which is not *stricto sensu* the demonstration that the facility is safe. The expert function shall nevertheless be aware of the prevalence of QA in the actual level of safety a facility can attain. For instance, the demonstration of many aspects of EBS performance is inherently limited by the timeframe of the operational phase: most EBS (such as drifts' seals) are designed to deliver their performance far ahead in the future, sometimes thousands of years after the facility is closed. It is then basically impossible to get a full demonstration of this performance level, thus putting a singular stress on their fabrication (materials, processes, control…). Ensuring the quality of EBS construction might be one of the only ways to get confidence on their future performance.

In this way, QA and management systems should be overlooked with a particular scrutiny, especially when they deal with components that should reach a defined state at closure, identified in the safety envelope and thus play a role in long term safety. A link can be made with the framework of justification of changes in design or operation that the expert function shall evaluate in the SC (see chapter "reversibility and flexibility"). A knowledge management system appears to be essential in order to backtrack the justifications made earlier and make sure that new requirements in design and operation do not conflict with the achievement of the safety envelope.

M. Operating limits and conditions

For any nuclear facility, the establishment and substantiation of operating limits and conditions (OLCs) and their sustainability over the operational time is one of the key aspects of the demonstration that the facility shows a high level of safety. For a DGR, this challenge is deepened by the peculiarities of the facility, like the operational phase duration and the links between operational and long term safety. Trivial examples of such relationships abound in safety cases: are variables such as temperature, pressure, moisture, etc. in the underground facility fit for human work, machine and systems performance, EBS and host rock performance stability? Are operational incidents and accidents thresholds compatible with long term safety requirements of the EBS and the (host) rock? Another example can be found in rock excavation, which is usually performed during the operational phase but not in a nuclear environment: disturbance in the rock surrounding the drifts and cells (known as excavated damage zone) might be one of the key parameters governing long term safety while being at the same time of very little interest for operational safety.

The challenge for the expert function is therefore to be very cautious on the justifications underlying OLCs that the operator wishes to retain during the operational phase: these justification shall be assessed against both operational safety and long term safety of course, and shall show as well that sufficient margins have been found in the SC (for example by design, see chapter “Architecture”). All in all, OLCs unveiling and enforcement can be linked with many other aspects highlighted in this paper, thus underlining the difficulty to assess its relevance towards the multiple variables that are in line with its definition.

N. Conclusion

Over the years, safety cases have been focused on long term safety of a DGR. In recent times, safety during the operational phase has become a hot topic for operators, the expert function, regulators, and the civil society as well, while national programmes were advancing from research to industrial projects. Alternatively, recent studies have shown at the international level that these two aspects of the SC could be influencing each other in many ways. In this context, one identified risk was to segregate long term safety and operational safety and assess them separately.

For the expert function, a challenge in the evaluation of DGR safety cases is therefore to assess operational safety with regard to long term safety *and vice versa*. SITEX-II is proponent of a particular vigilance on arguments of safety cases that are inherently developed in relation with both operational and long term safety. Among them, two specific points are made on aspects that pose great challenges to SC evaluators: monitoring and the establishment and sustainability of operating limits and conditions over the operational phase.