GEOSAF II: Task Group on Operational Safety

Progress Report

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1 Introduction

1.1 Background

International inter-comparison and harmonization projects are one of the mechanisms developed by the IAEA for examining the application and use of Safety Standards, with a view to ensuring their effectiveness and working towards harmonization of approaches to the safety of radioactive waste management.

In the particular field of disposal of radioactive waste, during the period 2008-2011 the international project on demonstrating the safety of geological disposal project (GEOSAF) was organised by the IAEA.

The objective was the examination of arguments, assessments and supporting evidence developed in order to provide a reasonable level of assurance of safety to all interested parties. GEOSAF provided a systematic review of elements important for regulatory bodies engaged in the licensing process of geological disposal facilities. The focus was on the safety cases and the supporting safety assessments for the post-closure phase for such facilities.

At the end of GEOSAF, Member States decided that it would be beneficial to pursue working on the development of the safety case for geological disposal, giving a higher focus on the relations between operational phase and post-closure safety.

GEOSAF PART II was initiated with the objective to reach a joint understanding of, and work towards harmonization of views and expectations regarding the safety of the operational phase for geological disposal of radioactive waste and its interrelation with the post-closure safety.

The implications of operational safety on the long-term safety are not addressed by the current international guidance. Therefore, additional specific guidance on this topic could be developed.

To achieve this last objective, in the final year of the GEOSAF II project a dedicated Task Group was launched. The aim of this group was to provide recommendations to the GEOSAF II core group and the IAEA concerning potential benefits from issuing a TECDOC on this topic. For that purpose, a broad range of existing IAEA publications was examined. A gap analysis was performed and rationale for additional guidance was provided.

1.2 Context and Objective

GEOSAF II examined the interrelationship between the post-closure safety and the operational safety of geological disposal facilities. During the discussion, concern was also expressed that significant safety risk exists during the operational phase itself. This is, amongst others because of concurrent mining/construction work underground combined with handling heavy loads of radioactive material from the surface to the underground facility. Therefore, an assessment was made upon whether dedicated guidance is required also in this area or whether this is already available in existing IAEA documentation or elsewhere. For that purpose, a Task Group was formed.

The Task Group examined in which area additional guidance may be required, whether such guidance already exists, and if so, whether or not such information is readily accessible in existing relevant documents, including IAEA Safety Standards, Safety Reports and TECDOCs. This was done to identify whether all subjects have been covered and whether there are any gaps, as well as whether the information is too scattered to be readily used. The outcome would reveal any potential need for guidance. Other work will identify sources of information to assist in producing the guidance, if decided to do so.

The methodology used for the project work was optimized towards meeting the overall objectives, in practice delivering answers to the key questions (cf. below). The Task Group implemented the work through two consultancy meetings within the final year of the GEOSAF

II project. If new guidance will be established, additional confirmation would be beneficial in order to provide confidence that all relevant topics have been identified and characterized.

2 Working methodology and organisation

The Terms of Reference (ToR) developed in the framework of the GEOSAF II specified the focus and the scope of the operational safety Task Group as:

- Does IAEA provide a comprehensive set of guidance documents for member states to address the operational safety requirements underlined in the existing standards?
- Are there gaps in the IAEA existing documentation as to the achievement of the practical implementation of the existing requirements?
- Among these gaps, is there any other source of documentation from other international organizations and/or national schemes that may fill them in practice?

In order to answer these questions, the following methodology was developed and used:

1. Three questions were formulated that capture the situation at the outset:
    a. For the purpose of addressing operational safety issues, where in the existing corpus of IAEA publications is which type of information available? Furthermore, how can this information be gathered in order to address the operational safety issue?
    b. More specifically, is there already relevant guidance and/or recommendations for the operational safety of geological disposal facilities within the corpus of the IAEA publications (including Safety Standards other than those focused on safety assessment or the management of radioactive waste, such as those addressing NPP's, radiation protection, site evaluation, research reactors), and if so, where?
    c. If there are provisions related to operational safety in other IAEA documents than those consulted "by default", are these provisions complete?

    In response to these three questions, a completeness check is performed making use of a broad set of the existing documents.
2. There are many hundreds of potentially relevant IAEA publications. Consequently, the work started with a document screening. This screening was done based on the title, the table of contents and the nature of specific publications, based on the knowledge of the Task Group. Documents considered were IAEA published Safety Standards, Safety Standards under development, draft Safety Standards posted for official comments from the Member states as well as other IAEA publications (e.g. TECDOC). This initial "raw list" consisted of about 400 publications. After this first screening, the list could be reduced to about 60 documents (see Figure 1 and Figure 2).

    The documents remaining after ranking (Figure 2) were also classified according to the topics as shown in the "IAEA Safety Series pie chart" (see Fig. 3), with Nuclear Power Plants (NPPs), Radioactive Waste Management (RWM), Decommissioning (DECOM), etc.
3. As the next step, the operational safety Task Group, divided into three working groups (5 persons each), checked the proposed ranking and suggested some additions of relevant publications within the IAEA corpus. Then the list of documents was correspondingly extended to 130 publications, followed by revision of the individual document ranking.

Published Safety Standards	Topics	Ranking (1st screening
Organization and Staffing of the Regulatory Body for Nuclear Facilities Safety Guide	**NPP**	**2**
Series No. GS-G-1.1, published Thursday, September 05, 2002. English, Full Text (154 kb).		
This publication is also available in French Spanish Russian Chinese		
Review and Assessment of Nuclear Facilities by the Regulatory Body Safety Guide	**NPP**	**2**
Series No. GS-G-1.2, published Thursday, September 05, 2002. English, Full Text (194 kb).		
This publication is also available in French Russian Chinese		
Regulatory Inspection of Nuclear Facilities and Enforcement by the Regulatory Body Safety Guide	**NPP**	**2**
Series No. GS-G-1.3, published Friday, September 06, 2002. English, Full Text (204 kb).		
This publication is also available in French Spanish Russian Chinese		
Documentation for Use in Regulating Nuclear Facilities Safety Guide	**NPP**	**2**
Series No. GS-G-1.4, published Monday, September 09, 2002. English, Full Text (176 kb).		
This publication is also available in French Spanish Russian Chinese		
Regulatory Control of Radiation Sources Safety Guide	**NPP**	**2**
Series No. GS-G-1.5, published Monday, December 13, 2004. English, Full Text (575 kb).		
This publication is also available in French Spanish		
Arrangements for Preparedness for a Nuclear or Radiological Emergency Safety Guide	**Emergency**	**2**
Series No. GS-G-2.1, published Wednesday, May 23, 2007. English, Full Text (1070 kb).		
This publication is also available in Spanish		

(.....)

Safety standards under development	Topics	Ranking
DS488 - Design of the Reactor Core for Nuclear Power Plants DPP488	**NPP**	
DS487 - Design of Fuel Handling and Storage Systems for Nuclear Power Plants DPP487	**NPP**	
DS486 - Establishing the Safety Infrastructure for a Nuclear Power Programme DPP486		**1**
DS485 - Ageing Management and Programme for Long Term Operation for Nuclear Power Plants DPP485	**NPP**	**1**
DS484 - Site Evaluation for Nuclear Installations DPP484	**SITING**	**1**
DS483 - Severe Accident Management Programme for Nuclear Power Plants DPP483	**NPP**	
DS482 - Design of Reactor Containment Systems for Nuclear Power Plants DPP482	**NPP**	
DS481 - Design of the Reactor Coolant System and Associated Systems in Nuclear Power Plants DPP481	**NPP**	
DS479 - Operating Experience Feedback for Nuclear Installations DPP479		
DS478 - Safety of Nuclear Fuel Cycle Facilities DPP478	**FUEL**	**1**
DS477 - The Management System for the Predisposal and Disposal of Radioactive Waste DPP477	**RWM**	**1**
DS476 - Safety of Research Reactors DPP476	**RR**	
DS475 - Arrangements for Public Communications in Preparedness and Response for a Nuclear or Radiological Emergency DPP475	**EMERGENCY**	
DS474 - Arrangements for the Termination of a Nuclear or Radiological Emergency DPP474	**EMERGENCY**	
DS473 - Regulatory Body Functions and Processes DPP473	**Legal FW for safety**	

(.....)

Draft Safety Standards posted for offical comments by Member States	Topics	Ranking
DS360 - Safety of Nuclear Fuel Reprocessing Facilities	**FUEL**	**1**

Other IAEA publications (to be completed)	Topics	Ranking
OSART guidelines: Reference report for IAEA Operational Safety Review Teams (OSARTs)	**NPP**	
IRS guidelines: Joint IAEA/NEA International Reporting System for Operating Experience	**NPP**	
TECDOC 630: Guidelines for the operation and closure of deep geological repositories for the disposal of high level and alpha bearing wastes	**RWM**	**1**
Cementitious Materials in Safety Cases for Geological Repositories for Radioactive Waste: Role, Evolution and Interactions	TECDOC-1732, 2014	
The Use of Numerical Models in Support of Site Characterization and Performance Assessment Studies of Geological Repositories	TECDOC-1717,2013	
Guidance for preparation of a safety case for a dual purpose cask containing spent fuel (Draft report of WASSC/TRANSSC joint working group 2011-2013)	TECDOC-DRAFT, 2013	
Review of Sealed Source Designs and Manufacturing Techniques Affecting Disused Source Management	TECDOC-1690, 2012	
Progress in Radioactive Graphite Waste Management	TECDOC-1647, 2010	
Characterization, Treatment and Conditioning of Radioactive Graphite from Decommissioning of Nuclear Reactors	TECDOC-1521, 2006	

Figure 1. Excerpt from "raw list" with more than 400 IAEA publications. Ranking: 1 = highly relevant; 2 = potentially relevant.

Results of the 1st screening	Topics	Ranking
The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste	**RWM**	**1**
Governmental, Legal and Regulatory Framework for Safety General Safety Requirements Part 1	**Legal FW for safety**	**1**
Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards	**RP**	**1**
Safety Assessment for Facilities and Activities General Safety Requirements Part 4	**SA**	**1**
Predisposal Management of Radioactive Waste General Safety Requirements Part 5	**RWM**	**1**
Decommissioning of Facilities General Safety Requirements Part 6	**DECOM**	**1**
Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants Safety Guide	**NPP**	**1**
Instrumentation and Control Systems Important to Safety in Nuclear Power Plants Safety Guide	**NPP**	**1**
External Events Excluding Earthquakes in the Design of Nuclear Power Plants Safety Guide	**NPP**	**1**
Seismic Design and Qualification for Nuclear Power Plants Safety Guide	**NPP**	**1**
Protection Against Internal Fires and Explosions in the Design of Nuclear Power Plants Safety Guide	**NPP**	**1**
Fire Safety in the Operation of Nuclear Power Plants Safety Guide	**NPP**	**1**
A System for the Feedback of Experience from Events in Nuclear Installations Safety Guide		**1**
Evaluation of Seismic Safety for Existing Nuclear Installations Safety Guide		**1**
Conduct of Operations at Nuclear Power Plants Safety Guide	**NPP**	**1**
Severe Accident Management Programmes for Nuclear Power Plants Safety Guide	**NPP**	**1**
Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants Safety Guide	**NPP**	**1**
Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants Safety Guide	**NPP**	**1**
Safety of Nuclear Fuel Cycle Facilities	**FUEL**	**1**
Occupational Radiation Protection Safety Guide	**RP**	**1**
Occupational Radiation Protection in the Mining and Processing of Raw Materials Safety Guide	**RP**	**1**
Fundamental Safety Principles	**SAFETY PRINCIPLES**	**1**
Geological Disposal Facilities for Radioactive Waste Specific Safety Guide	**RWM**	**1**
Storage of Spent Nuclear Fuel	**FUEL**	**1**
Establishing the Safety Infrastructure for a Nuclear Power Programme Specific Safety Guide		**1**
Deterministic Safety Analysis for Nuclear Power Plants Specific Safety Guide	**NPP**	**1**
Volcanic Hazards in Site Evaluation for Nuclear Installations	**SITING**	**1**
Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors	**RR**	**1**
The Safety Case and Safety Assessment for the Disposal of Radioactive Waste	**RWM**	**1**

Figure 2. Excerpt from the 1st screening (ranking 1) with ~60 publications. NPP: Nuclear Power Plant; RWM: Radioactive Waste Management; DECOM: Decommissioning, etc.

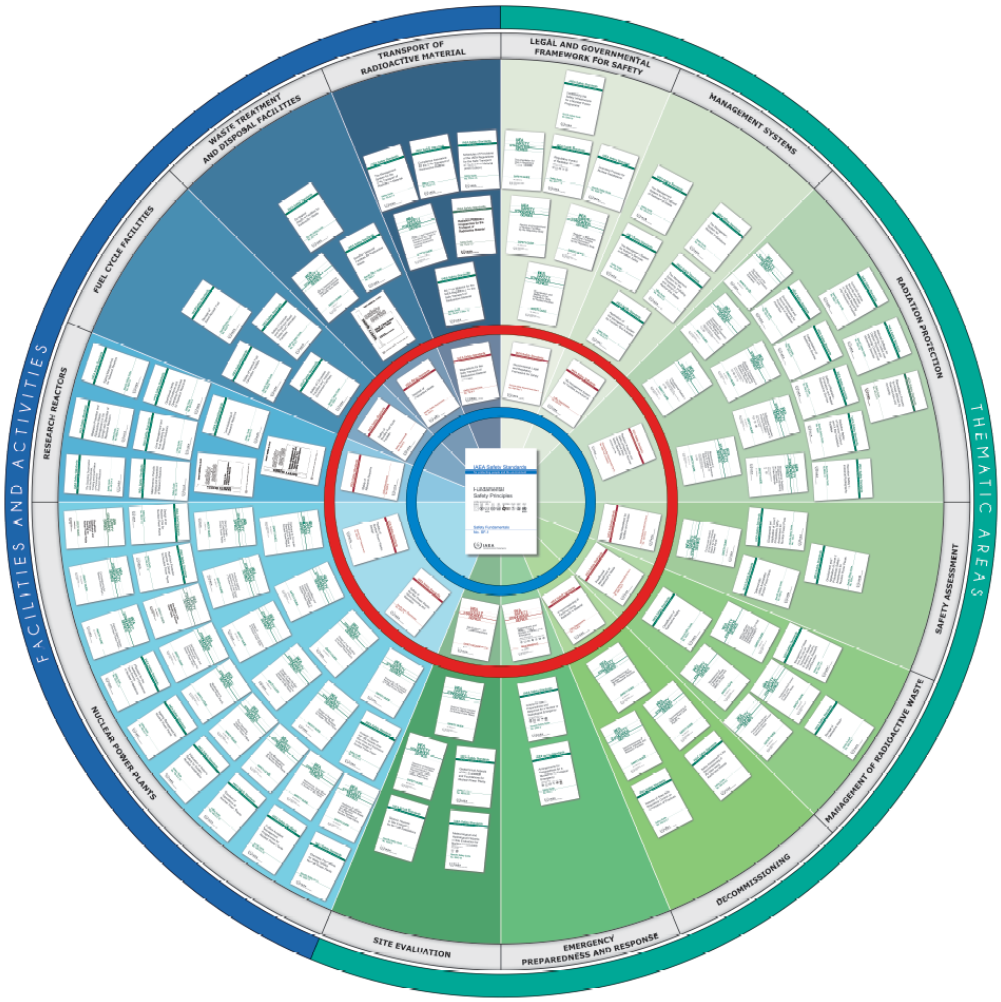

Figure 3. IAEA safety standards (pie chart).

4. As the next step, two different approaches were taken in order to develop the list of topics relevant for operational safety, including grouping/delineating them by introducing a hierarchy of topics.

   Approach 1: (WG of 10 experts) was based on the skim-reading of the IAEA publications (Table of contents (TOC), relevant chapters, etc.).

   Approach 2: (WG of 5 experts) consisted of work on a "reference list" from a totally different set of documents/material. The key materials used were the findings of the SITEX project (that produced a list of topics, of which one is related to operational safety and divided into several subtopics), the GEOSAF I project companion report related to operational safety, as well as the experience from the Canadian uranium mining. This group also introduced topics based on the expert judgment.

   After two days of work, the workgroups generated updated lists. Excerpts of these lists are given in Figure 4 and Figure 5.

Interdependencies			GSR Part 4		
Basic considerations	Radiation protection		TECDOC 630	Section 2.2	
	Industrial health and safety	Ground control	TECDOC 630	Section 2.3	
		Fire protection			
		Ventilation control			
		Hazardous material control			
	Quality assurance		TECDOC 630	section 2.4	
	Safety culture	Artefacts	TECDOC 1707		
		Espoused values			
		Basic assumptions			
	Graded approach	Classification of SSC (maturity, complexity)	TECDOC 1740		
		Application (inspection, safety etc)			
	Retrievability	Complete, partial or no backfill	NWT-1.21		
	Safeguards	Design constraints	NWT-1.21		
Operational process	Receipt of the waste		TECDOC 630	Chapter 3	
	Buffer storage		TECDOC 630		
	Waste package preparation		TECDOC 630		
	Transfer of waste from surface to underground		TECDOC 630		
	Emplacement of waste		TECDOC 630		
	Partial backfilling and sealing		TECDOC 630		
	Support facilities and service		TECDOC 630		
	Construction of additional drifts		NWT-1.21		
On-going radiological monitoring and testing	Normal operation - surface		TECDOC 630	Section 4.2	
	Normal operation - underground	Air sampling	TECDOC 630		
		Water sampling	TECDOC 630		
	Abnormal conditions		TECDOC 630		
	Baseline monitoring	Natural RN content and background levels of radioactivity in the environment	TECDOC 1208	Section 2.2	
	Safeguards	Disturbance of engineered barriers	TECDOC 1208	Table 1	
		DIV - Design information verification	NWT-1.21		
		Visual observation, camera surveillance, satellite imagery, remote radiation monitoring, seal identification and verification, cask integrity checks,	NWT-1.21	Annex 1	
		Verification of operation as planned and facility design as planned	NWT-1.21	Section 5	
On-going non-radiological monitoring	Baseline monitoring	Meteorology, hydrology, hydrochemistry, local ecology, geomorphological processes, tectonic activity, geothermal heat flow, land use in the surrounding region	TECDOC 1208	Section 2.2	
	THMC effects of excavation		TECDOC 1208	Table 1	
	Degradation of repository structures after excavation		TECDOC 1208	Table 1	
	Behaviour of waste packages and buffer materials		TECDOC 1208	Table 1	
	Near field chemical interaction		TECDOC 1208	Table 1	
	Changes to the geosphere		TECDOC 1208	Table 1	

Figure 4. Excerpt of the provisional list of subtopics drawn by the WG 1, based on the skim-reading of the IAEA publications.

NPP	Mine	DGR	Diff. Emp.	*Comment*	Safety Topic Keywords	Safety subtopics
y	y	y	increased time period	*Even neglecting post closure consdiderations, the anticipated operational period of DGRs make these consideration more difficult and more important*	Protection of present and future Generations	
y	y	y	increased time period	*Even neglecting post closure consdiderations, the anticipated operational period of DGRs make these consideration more difficult and more important*	Protection of the environment	
y	y	y	no real difference		Defence in Depth	
y	n	n	difference in emphasis	*Passive shutdown systems likely to be more important in NPPs*	Passive Means (no operator involved)	ventilation systems
						fire protection
						seismic resistant structures
						containment
y	y	y	no difference		Codes&Standards	
y	n	y	difference in philoph.	*I&C in NPPs & DGRs used to mitigate accidents; in Mines of no consequences*	Isolation and Containment	
n	n	y	difference in emphasis	*Retrievability is unique to DGR & Storage Facility; Reversibility applies to all*	Reversibility /Retrievability	
n	y	y	difference	*Construction & Operation do not normally occur during the lifecycle of the facility, except for mines and possibly DGRs*	Concurrent activities (eg. waste movement & mining)	
y	y	y	no difference		Management	Mgt. Safety culture
						Mgt. Responsibilities
						Mgt. Structure (organisation, …)
						Mgt. System (work control, communication, verification, safety processes, corrective action programme, …)
y	y	y	increased time period	*Even neglecting post closure consdiderations, the anticipated operational period of DGRs make these consideration more difficult and more important*		Mgt. Records, knowlegde & reporting

Figure 5. Excerpt from the reference list of subtopics drawn by WG 2 based on SITEX, companion report of GEOSAF I and their expert judgement.

5. In order to populate the "reference list" and to give it a new stimulus, in a next step the WENRA report was also used. The WENRA report is mainly based on a screening of the IAEA publications, but with a different perspective (regulatory).

6. A comparison of the outcome of those two groups was made in order to identify where topics were common or did not exist in the reference list. If some topics were missing in the reference list, they were added (cross-fertilisation). A colour code was used to ensure traceability: green meaning common topics from both lists; blue to highlight topics not included in the "reference list" and black to point out topics that were unique in the reference list and therefore missing in the list of subtopics drawn up on the basis of the IAEA publications. This way of working harmonized the two different lists of topics, without losing track of their origin.

7. At this point, the two lists were frozen with respect to the list of topics.

   The working group working on the "reference list" provided comments on the relevance of topics not originally included in this list. The exercise was then extended to all the subtopics in order to compare their relevance to nuclear power plants (NPP), mines and deep geological repositories (DGRs).

   The other working group looked for IAEA references for sub-topics that were introduced through comparison with the "reference list"

8. The list of subtopics drafted from the IAEA publications was polished. Since it was not possible, given the limited time and resources, to go through all the possible existing publications, the way of fulfilling the list of subtopics had to be checked from a completeness point of view. If additional randomly selected publications do not provide new topics, the list may be considered as sufficiently robust. The initial set of 18 skim-read publications was extended. The skim-reading was stopped after 29 documents as the number of items was judged to have converged.

9. The list of subtopics from the IAEA publications was then merged with the reference list in order to produce a "consolidated list" of 295 topics.

10. The consolidated list of the 295 topics together with the 116 publications was used to build a matrix. A methodology flow chart for establishing the matrix is shown in Figure 6.

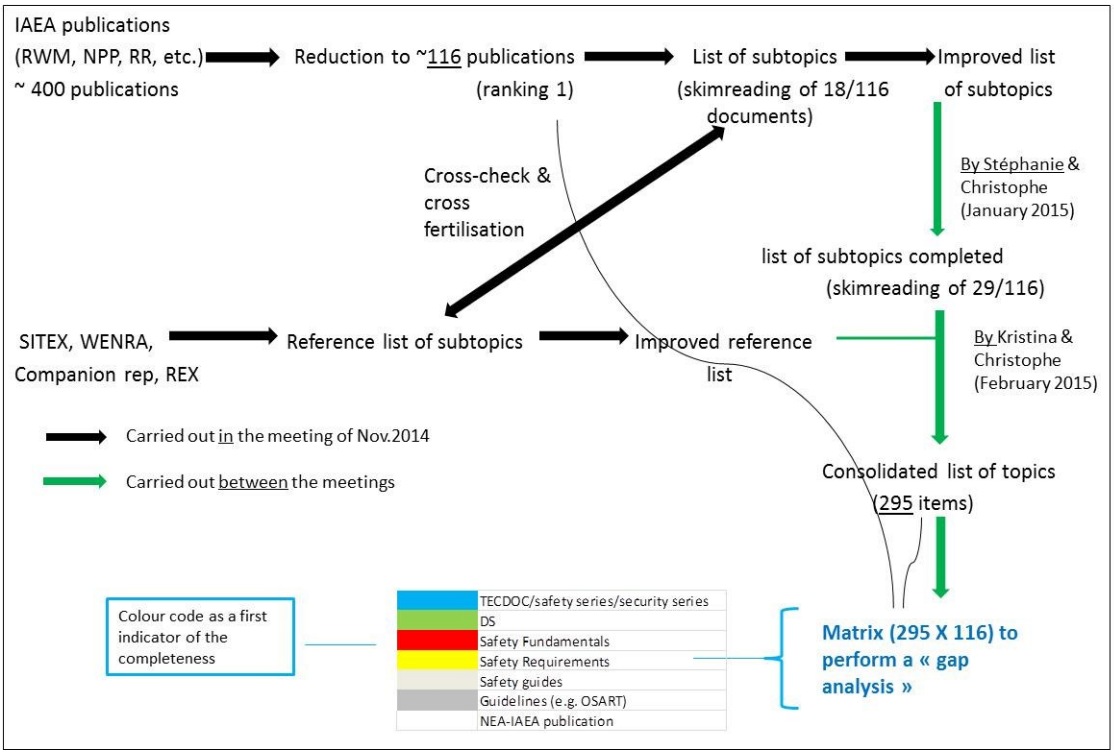

Figure 6. Methodology flow chart for establishing a matrix with topics and publications.

11. In order to make the gap analysis, different qualifiers were used:
    a. The classification of the publication regarding their scope (1 to 4), see upper part/above the red line of Figure 7 (1 for publication focusing on geological disposal, 2 for publication focusing on disposal in general, 3 for publication focusing on waste management and 4 for other publications).
    b. The classification of the publications with respect to their relevance for a particular topic (0 to 2), see lower part/under the red line of Figure 7 (with 0 for a topic not covered by the publication, 1 for a topic partially covered/mentioned and 2 for a topic well covered by the publication).
    c. The topics were classified as specific to operational safety of geological disposal or generic (e.g. retrievability is specific whereas management system is generic), not reproduced in Figure 7.
12. A provisional gap analysis was performed to identify topics specific to operational safety of geological disposal facilities that are not or poorly covered by the existing guidance.
13. The matrix tool is available to perform further and additional analyses.

TOPICS / PUBLICATIONS	SSG-14	TECDOC630	NEA, RWM,	DS447	TRS-427, 20	TECDOC 151	GS-G-1.4
SCOPE OF THE PUBLICATION **1 = GEOLOGICAL DISPOSAL in the title** **2 = DISPOSAL in the title (but different of 1)** **3 = related to RWM (but different of 1 and 2)** **4 = other publications**	1	1	1	3	3	3	4
Documents and records	0	1	0	1	1	1	1
information management system	0	1	0	0	1	1	1
classification and archiving	0	0	0	0	0	1	0
physically separate locations for storage	0	0	0	0	0	0	0
traceability and maintainance of information	0	0	0	0	0	1	1
information retrievability	0	0	0	0	0	1	1
Inventory	0	0	0	1	0	1	1
Characteristics of the waste emplaced	0	0	0	1	0	2	0
Location of waste packages in the repository	0	0	0	0	0	0	0
Repository structure	0	0	0	0	0	0	1
Surrounding geology and hydrogeology	0	0	0	0	0	0	0
Safeguards requirements	0	0	0	0	0	0	0
R&D	0	0	0	0	0	0	1
support both: operation & long term needs (eg. Shotecrete)	0	0	0	0	0	0	1
Repository closure	1	2	0	0	0	0	0
Backfilling and sealing	1	2	0	0	0	0	0
Removal of equipment	0	2	0	0	0	0	0
Removal of ground support systems	0	2	0	0	0	0	0
Removal of miscellaneous items	0	2	0	0	0	0	0
Correction of deteriorated conditions	0	2	0	0	0	0	0
Potential emplacement of subsurface markers	0	2	0	0	0	0	0
Sealing of exploratory boreholes	0	2	0	0	0	0	0

Figure 7. Excerpt of the matrix showing the three hierarchical levels (0 to 2) of the topics (below the red line) and the assigned scope (1 to 4) of the publications (above the red line).

3 Limitations and choices

The challenge in this work was, after detailing the scope of operational safety, how to ensure the comprehensiveness of topics and sources of guidance (check against existing IAEA documents, other documents, expert judgement, ….). To meet this challenge, the Task Group followed an approach for information and knowledge. The existing IAEA documents ("known knowns") were complemented with other independent sources of information (SITEX, WENRA etc.) in order to delineate less known areas ("known unknowns"). As for the "unknown unknowns", similar to a FEP-approach, it is a forthcoming and on-going process.

To start the work, the Task Group made a screening of about 400 IAEA publications (published Safety Standards, draft Safety Standards, Guidelines etc.). These publications were not only related to radioactive waste management. A limitation of the screening is that it was based on titles and tables of contents only. Another limitation is that only 29 of the 116 publications remaining after the first screening were skim read in order to build the list of topics, sub-topics and sub-sub-topics related to operational safety. The skim-reading stopped after 29 documents when the number of items was judged to have converged. Even with the 295 items resulting from this process, it is evident that some topics could not be fully covered by the subtopics and therefore the level of detail varied.

Each IAEA document in the subset of 116 publications kept for the matrix was assessed for its relevance for each item. However, this could only be achieved by skim-reading (number of documents in the time available). The scale used for the assessment varied between the sub-groups due to differences in interpretation. For example; '2' is interpreted as « very well covered » by some but others would not grant a '2' unless the coverage was fully comprehensive for a geological disposal facility. Besides, the division of the scale into only three categories imposes limitations. Finally, judgment of coverage using the defined scale reflects individual experience in a particular topic and therefore introduced variability in the marking.

In order to support the presentation of the results, the Task Group decided to assign either "**s**pecific" (to operational safety of geologic disposal) or "**g**eneric" to each topic. This assignment is based on expert judgement by the members of the Task Group.

One may observe that some items appear more than once in the matrix (in sub-topics), but if so in different contexts (main topics). This is a deliberate choice in order to avoid losing information.

4 Results

The publications assessed are compiled in Appendix 1, giving the type and the assigned scope (1 to 4). The results of the current analysis with the established matrix are summarised in Appendices 2 and 3.

The analysis indicates that much information already exists on operational safety or at least can be used to frame the reflection about operational safety for geological disposal. Nevertheless, 94 out of 145 topics (65%), specific to operational safety of geological disposal facilities are not or poorly addressed by the existing guidance (see Appendix 2). For these topics, the development of a dedicated guidance may be necessary. Some important examples are: "documents and records regarding characteristics of the waste emplaced and location of the waste packages in the repository", "emergency response", "erosion", "natural fires", "mining activities" and "concurrent activities". Concurrent activities refer to e.g. the emplacement of waste and excavation of underground tunnels or rooms that might be conducted in parallel in a geological disposal facility.

For the generic topics related to operational safety, information not contained in publications specifically related to geological disposal (scope 1) can generally be found in publications on disposal (scope 2), on radioactive waste management (scope 3) or in "others" (scope 4) (see Appendix 3). This is exemplified by the topic "Management system". If developing new guidance for these topics, information in publications with scope 2, 3 or 4 may be used as a starting point.

Several generic topics are not addressed in publications related to geological disposal, nor to disposal in general (scopes 1 and 2). Examples are "Conventional Waste management" (see Figure 8), "Safeguard requirements" and "Threat assessment". These topics may need further consideration.

Topics	Specific / Generic	# of occurence in guidance with scope			
		1	2	3	4
Mgt. System	G	0	4	6	38
Conventional Waste management	G	0	0	4	1

Figure 8. Table with an excerpt of the results from the analysis showing the number of occurrences of two generic topics in documents with scopes 1, 2, 3 and 4 (specific to geological disposal, to disposal, to radioactive waste management and finally, to "others").

There is no topic in the list not covered at all (at least superficially, ranking 1) and by at least one publication (at least "general in scope"). This reflects the recursive methodology used where topics were identified from existing IAEA publications. However, topics were also identified from other documents and from expert judgement, and the analysis shows that there are no complete gaps. Consequently, if new Guidance is established, the concern is more about the level of detail than about the comprehensiveness and variability of the topics.

5 Conclusions

The objective of the work has been to examine to which extent guidance is required on operational safety of geological disposal facilities, in particular whether such guidance already exists, and if so, whether or not such information is readily accessible in a small number of well identified documents. In order to meet this objective, a matrix has been developed as a tool for performing gap analysis. The matrix contains topics identified as important to operational safety of a geological disposal facility and the coverage of these topics in IAEA documents.

The developed matrix has been used to perform an analysis of potential gaps in the IAEA documents. This analysis also illustrates how the matrix can be used in support of developing new guidance.

The analysis indicates that much information already exists on operational safety. This information can be used to frame the reflection about operational safety for geological disposal. There are, however, several topics specific to operational safety of geological disposal facilities for which the development of dedicated guides may be necessary. This should be confirmed by more detailed analyses in order to give firm conclusions on the specific need for additional guidance.

There is no topic in the list that would not be covered at all, at least partially and by at least one publication "general in scope". This conclusion is valid for "generic" and "specific" topics. This means that within the limitations of the methodology used, there were no topics identified from other than IAEA documents as well as from Expert Judgement that were not at least found in the IAEA documents. Consequently, if more detailed analysis confirms the need for "new" guidance (e.g. TECDOC...) that work can start using material spread over the existing publications. In order to identify the location of existing guidance in the existing set of documents, the "matrix" can be used. For those reasons, the concerns with developing new guidance are not the variability of topics, but rather defining the desired level of detail.

In summary, the matrix developed has been identified to be a tool that could be used in forthcoming analysis for the need of guidance specific to operational safety of geological disposal facilities. It can also be used for identifying locations of information in existing documents. The methodology followed in setting up the matrix is based on comparing non-IAEA documents and expert judgement with the existing body of IAEA documents. In order to ensure that topics nevertheless have not been missed, an additional review should precede the start of establishing new guidance.

References

GEOSAF, International Intercomparison and Harmonization Project on Demonstrating the Safety of Geological Disposal, Report on the GEOSAF Working Group on Operational Safety, IAEA (2011), http://www-ns.iaea.org/downloads/rw/projects/geosaf/companion-report-on-operational-safety.pdf

SITEX, Deliverable D-N°2.1 – Overview of Existing Technical Guides and Further Development, EC (2014), http://sitexproject.eu/index_1.html#deliverables

WENRA Working Group on Waste and Decommissioning (WGWD), Radioactive Waste Disposal Facilities Safety Reference Levels, WENRA, (2014), http://www.wenra.org/media/filer_public/2015/03/18/srl_disposal_final_version_2014_12_22.pdf

Appendix 1. IAEA publications used in the gap analysis

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
SSG-14	Geological Disposal Facilities for Radioactive Waste	2011	Specific safety guide	1
NW-T-1.19	Geological Disposal of Radioactive Waste: Technological Implications for Retrievability	2009	Technical report	1
NW-T-1.21	Technological Implications of International Safeguards for Geological Disposal of Spent Fuel and Radioactive Waste	2010	Technical report	1
TECDOC 563	Siting, design and construction of a deep geological repository for the disposal of high level and alpha bearing wastes	1990	Technical document	1
TECDOC 630	Guidelines for the operation and closure of deep geological repositories for the disposal of high level and alpha bearing wastes	1991	Technical document	1
TECDOC-1208	Monitoring of geological repositories for high level radioactive waste	2001	Technical document	1
NEA, RWM/R	Cementitious Materials in Safety Cases for Geological Repositories for Radioactive Waste: Role, Evolution and Interactions	2012, rev 3	NEA-IAEA publication	1
	In total 7 publications with scope 1			
GS-G-3.4	The Management System for the Disposal of Radioactive Waste Safety Guide	2008	Safety guide	2
SSG-23	The Safety Case and Safety Assessment for the Disposal of Radioactive Waste	2012	Specific safety guide	2
SSG-29	Near Surface Disposal Facilities for Radioactive Waste	2014	Specific safety guide	2
SSG-31	Monitoring and Surveillance of Radioactive Waste Disposal Facilities	2014	Specific safety guide	2

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
SSR-5	Disposal of Radioactive Waste	2011	Specific safety requirement	2
NW-T-1.2	The Management System for the Development of Disposal Facilities for Radioactive Waste	2012	Technical report	2
NW-T-1.20	Disposal Approaches for Long Lived Low and Intermediate Level Radioactive Waste	2009	Technical report	2
TECDOC-975	Regulatory decision making in the presence of uncertainty in the context of the disposal of long lived radioactive wastes	1997	Technical document	2
TECDOC-1129	Inspection and verification of waste packages for near surface disposal	2000	Technical document	2
TECDOC 1368	Safety considerations in the disposal of disused sealed radioactive sources in borehole facilities	2003	Technical document	2
TECDOC 1380	Derivation of activity limits for the disposal of radioactive waste in near surface disposal facilities	2003	Technical document	2
	In total 11 publications with scope 2			
GS-G-3.3	The Management System for the Processing, Handling and Storage of Radioactive Waste Safety Guide	2008	Safety guide	3
GSG-3	The Safety Case and Safety Assessment for the Predisposal Management of Radioactive Waste	2013	Safety guide	3
GSR Part 5	Predisposal Management of Radioactive Waste	2009	General Safety requirements	3
WS-G-1.2	Management of Radioactive Waste from the Mining and Milling of Ores	2002	Safety guide	3
WS-G-2.5	Predisposal Management of Low and Intermediate Level Radioactive Waste	2003	Safety guide	3
WS-G-2.6	Predisposal Management of High Level Radioactive Waste	2003	Safety guide	3
WS-G-6.1	Storage of Radioactive Waste	2006	Safety guide	3
DS454 (rev. of	Predisposal Management of Radioactive Waste from the Use of	2014	Draft Safety guide	3

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
WS-G-2.7	Radioactive Materials in Medicine, Industry, Agriculture, Research and Education			
DS448	Predisposal Management of Radioactive Waste from Nuclear Reactors	2014	Draft Safety guide	3
DS447	Predisposal Management of Radioactive Waste from Nuclear Fuel Cycle Facilities	2013	Draft Safety guide	3
TRS-427, 204	Predisposal Management of Organic Radioactive Waste	2004	Technical report	3
TECDOC 1515	Development of Specifications for Radioactive Waste Packages	2006	Technical document	3
	In total 12 publications with scope 3			
GS-G-1.4	Documentation for Use in Regulating Nuclear Facilities Safety Guide	2002	Safety guide	4
GS-G-2.1	Arrangements for Preparedness for a Nuclear or Radiological Emergency Safety Guide	2007	Safety guide	4
GS-G-3.1	Application of the Management System for Facilities and Activities Safety Guide	2006	Safety guide	4
GS-G-3.2	The Management System for Technical Services in Radiation Safety Safety Guide	2008	Safety guide	4
GS-G-3.5	The Management System for Nuclear Installations Safety Guide	2009	Safety guide	4
GS-R-part 7, superseded GS-R-2	Preparedness and Response for a Nuclear or Radiological Emergency	2014	Draft General safety requirements	4
GS-R-3	The Management System for Facilities and Activities	2006	Safety requirements	4
GSR Part 1 rev. 1	Governmental, Legal and Regulatory Framework for Safety	2014	Draft General safety requirements	4
GSR Part 3	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards	2014	General safety requirements	4

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
GSR Part 4 Rev. 1	Safety Assessment for Facilities and Activities	2014	Draft General safety requirements	4
GSR Part 6	Decommissioning of Facilities	2014	General safety requirements	4
NS-G-1.5	External Events Excluding Earthquakes in the Design of Nuclear Power Plants Safety Guide	2003	Safety guide	4
NS-G-1.6	Seismic Design and Qualification for Nuclear Power Plants	2003	Safety guide	4
NS-G-1.7	Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants	2004	Safety guide	4
NS-G-2.1	Fire Safety in the Operation of Nuclear Power Plants	2000	Safety guide	4
NS-G-2.2	Operational Limits and Conditions and Operating Procedures for Nuclear Power Plants	2000	Safety guide	4
NS-G-2.3	Modifications to Nuclear Power Plants	2001	Safety guide	4
NS-G-2.4	The Operating Organization for Nuclear Power Plants	2001	Safety guide	4
NS-G-2.6	Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants	2002	Safety guide	4
NS-G-2.7	Radiation Protection and Radioactive Waste Management in the Operation of Nuclear Power Plants	2002	Safety guide	4
NS-G-2.8	Recruitment, Qualification and Training of Personnel for Nuclear Power Plants	2002	Safety guide	4
NS-G-2.11	A System for the Feedback of Experience from Events in Nuclear Installations	2006	Safety guide	4
NS-G-2.12	Ageing Management for Nuclear Power Plants	2009	Safety guide	4
NS-G-2.13	Evaluation of Seismic Safety for Existing Nuclear Installations	2009	Safety guide	4
NS-G-2.14	Conduct of Operations at Nuclear Power Plants	2008	Safety guide	4
NS-G-2.15	Severe Accident Management Programmes for Nuclear Power Plants	2009	Safety guide	4

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
NS-R-3 Rev. 1	Site Evaluation for Nuclear Installations	2015	Draft Safety requirements	4
NS-R-5 Rev. 1	Safety of Nuclear Fuel Cycle Facilities	2014	Draft Safety requirements	4
RS-G-1.1	Occupational Radiation Protection	1999	Safety guide	4
RS-G-1.2	Assessment of Occupational Exposure Due to Intakes of Radionuclides	1999	Safety guide	4
RS-G-1.3	Assessment of Occupational Exposure Due to External Sources of Radiation	1999	Safety guide	4
RS-G-1.4	Building Competence in Radiation Protection and the Safe Use of Radiation Sources	2001	Safety guide	4
RS-G-1.6	Occupational Radiation Protection in the Mining and Processing of Raw Materials	2004	Safety guide	4
SF-1	Fundamental Safety Principles	2006	Safety fundamentals	4
SSG-2	Deterministic Safety Analysis for Nuclear Power Plants	2009	Specific safety guide	4
SSG-9	Seismic Hazards in Site Evaluation for Nuclear Installations	2010	Specific safety guide	4
SSG-12	Licensing Process for Nuclear Installations	2010	Specific safety guide	4
SSG-15	Storage of Spent Nuclear Fuel	2012	Specific safety guide	4
SSG-16	Establishing the Safety Infrastructure for a Nuclear Power Programme	2011	Specific safety guide	4
SSG-21	Volcanic Hazards in Site Evaluation for Nuclear Installations	2012	Specific safety guide	4
SSG-22	Use of a Graded Approach in the Application of the Safety	2012	Specific safety	4

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
	Requirements for Research Reactors		guide	
SSG-25	Periodic Safety Review for Nuclear Power Plants	2013	Specific safety guide	4
SSG-26	Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material	2012	Specific safety guide	4
SSG-27	Criticality Safety in the Handling of Fissile Material	2014	Specific safety guide	4
SSR-2/2 Rev. 1	Safety of Nuclear Power Plants: Commissioning and Operation	2015	Draft Specific safety requirement	4
SSR-6	Regulations for the Safe Transport of Radioactive Material	2012	Specific safety requirement	4
TS-G-1.2 (ST-3)	Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material	2002	Safety guide	4
TS-G-1.3	Radiation Protection Programmes for the Transport of Radioactive Material	2007	Safety guide	4
TS-G-1.4	The Management System for the Safe Transport of Radioactive Material	2008	Safety guide	4
TS-R-1 (ST-1, Rev.)	Regulations for the Safe Transport of Radioactive Material	1996	Requirements	4
WS-G-2.3	Regulatory Control of Radioactive Discharges to the Environment	2000	Safety guide	4
WS-G-2.7	Management of Waste from the Use of Radioactive Material in Medicine, Industry, Agriculture, Research and Education	2005	Safety guide	4
WS-G-5.1	Release of Sites from Regulatory Control on Termination of Practices	2006	Safety guide	4
WS-G-5.2	Safety Assessment for the Decommissioning of Facilities Using Radioactive Material	2008	Safety guide	4
DS453	Occupational Radiation Protection	2014	Draft Safety guide	4
DS442	Regulatory Control of Radioactive Discharges to the Environment	2014	Draft Safety guide	4

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
DS360	Safety of Reprocessing Facilities	2014	Draft Safety guide	4
OSART guidelines	Reference report for IAEA Operational Safety Review Teams (OSARTs)	2005	Guideline	4
IRS guidelines	Joint IAEA/NEA International Reporting System for Operating Experience	2010	Guideline	4
Safety series n°1	Examples of Safety Culture Practices	1997	Safety report	4
Safety series n°3	Equipment Qualification in Operational Nuclear Power Plants: Upgrading, Preserving and Reviewing	1998	Safety report	4
Safety series n°6	Safety Issues for Advanced Protection, Control and Human-Machine Interface Systems in Operating Nuclear Power Plants	1998	Safety report	4
Safety series n°8	Preparation of Fire Hazard Analyses for Nuclear Power Plants	1998	Safety report	4
Safety series n°9	Safe Handling and Storage of Plutonium	1998	Safety report	4
Safety series n°21	Optimization of Radiation Protection in the Control of Occupational Exposure	2002	Safety report	4
Safety series n°33	Radiation Protection against Radon in Workplaces other than Mines	2003	Safety report	4
Safety series N°49	Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials	2006	Safety report	4
Safety series n°62	Proactive Management of Ageing for Nuclear Power Plants	2009	Safety report	4
Safety series n°74	Safety Culture in Pre-operational Phases of Nuclear Power Plant Projects	2012	Safety report	4
NG-G-2.1	Managing Human Resources in the Field of Nuclear Energy	2009	Guide	4
NG-T-1.1	Managing Organizational Change in Nuclear Organizations	2014	Technical report	4

IAEA publication		Year	Type of publication	Scope of the publication 1 = Geological disposal 2 = Disposal 3 = Related to RWM 4 = Other
NG-T-1.2	Establishing a Code of Ethics for Nuclear Operating Organizations	2007	Technical report	4
NG-T.1.4	Stakeholder Involvement Throughout the Life Cycle of Nuclear Facilities	2011	Technical report	4
NG-T.2.2	Commissioning of Nuclear Power Plants: Training and Human Resource Considerations	2008	Technical report	4
NG-T-2.3	Decommissioning of Nuclear Facilities: Training and Human Resource Considerations	2008	Technical report	4
NG-T-2.7	Managing Human Performance to Improve Nuclear Facility Operation	2013	Technical report	4
NG-T-3.6	Responsibilities and Capabilities of a Nuclear Energy Programme Implementing Organization	2009	Technical report	4
NG-T-3.10	Workforce Planning for New Nuclear Power Programmes	2011	Technical report	4
NP-T-2.8	International Safeguards in Nuclear Facility Design and Construction	2013	Technical report	4
TECDOC 1347	Consideration of external events in the design of nuclear facilities other than nuclear power plants, with emphasis on earthquakes	2003	Technical document	4
TECDOC 1458	Effective corrective actions to enhance operational safety of nuclear installations	2005	Technical document	4
TECDOC 1580	Best Practices in the Utilization and Dissemination of Operating Experience at Nuclear Power Plants	2008	Technical document	4
TECDOC 1581	Best Practices in Identifying, Reporting and Screening Operating Experience at Nuclear Power Plants	2007	Technical document	4
TECDOC 1653	Best Practices in the Management of an Operating Experience Programme at Nuclear Power Plants	2010	Technical document	4
TECDOC 1707	Regulatory Oversight of Safety Culture in Nuclear Installations	2013	Technical document	4
TECDOC 1740	Use of a Graded Approach in the Application of the Management System Requirements for Facilities and Activities	2014	Technical document	4
	In total 86 publications with scope 4			

Appendix 2. Topics assessed as specific to operational safety of geological disposal facilities and their assessed coverage in IAEA publications of different scope

Topics with 0 or 1 in coverage is assessed as not or poorly covered. These are marked in yellow colour in the column scope Geological disposal

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Documents and records	Characteristics of the waste emplaced		1	4	9	2
	Location of waste packages in the repository		0	3	3	0
	Surrounding geology and hydrogeology		0	3	4	2
R&D	Support both: operation & long term needs (e.g. shotcrete)		0	4	1	4
Emergency preparedness	Emergency response		0	4	6	33
Hazards approach	Hazard identification, assessment & mitigation		0	6	10	19
Operational radiological risk	POIE: External natural factors		1	5	4	9
	POIE: External natural factors	*Meteorological events*	0	4	4	12
		Seismic events	0	2	4	9
		Ground instability	1	2	4	4
		Landslides	0	1	3	3
		Erosion	0	0	3	3
		Natural fires	0	1	3	4
		Volcanism	0	0	3	4
Operational radiological risk	POIE: External human factors		0	4	3	8
	POIE: External human factors	*Explosion*	0	0	3	12

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Fire	0	2	3	14
		Mining activities	0	0	3	1
		Flying objects	0	0	3	3
		Aircraft crash	0	1	3	8
		Sabotage	0	0	3	3
		Theft	0	0	1	3
		Nearby industrial activities	0	0	3	5
		Transport infrastructure	0	0	3	5
		Nearby military activities	0	0	3	3
		Civil strives/war	0	0	3	3
		Electromagnetic interferences	0	0	1	3
		Dam failure	0	0	3	2
Operational radiological risk	POIE: General and specific internal operation factors		0	1	3	5
	POIE: General and specific internal operation factors	*Loss of power*	0	0	3	6
		Loss of ventilation	0	0	1	3
		Loss of containment	0	1	1	2
		Loss of confinement	0	0	1	1
		Loss of instrument control	0	0	1	1
		Lack of maintenance	0	1	1	3
		Failure of emergency equipment	0	0	1	2
		Loss of utilities	0	0	1	1
Operational radiological risk	POIE: Long term facilities specific events/features		1	6	2	6
	POIE: Long term facilities specific events/features	*Waste Acceptance Criteria, WAC*	2	6	7	1
		Container damage	0	4	2	2
		Criticality	0	1	2	6

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Inspection problems	0	1	3	2
		System, structure, component (SSC) damage	0	1	1	4
		Adequate understanding and confidence in post-closure safety	0	7	1	4
		State system of accounting for and control of nuclear material	1	1	4	2
Interdependencies	Between implementation steps		1	1	6	7
	Between roles and responsibilities		0	1	3	14
Basic considerations	Radiation protection	*Radiation protection in the operational period*	2	6	5	22
		Special circumstances	1	2	1	11
		Local rules, supervision and personal protection equipment	0	0	2	10
		Intervention in emergencies	0	2	1	10
Passive Safety/ Means (no operator involved)	Seismic resistant structures		0	1	1	4
	Industrial health and safety	*Ground control*	0	0	1	1
		Fire protection	0	0	4	9
		Ventilation control	0	0	2	4
		Hazardous material control	0	2	1	5
		Dust control	0	0	1	4
		Worker exposure to gases, worker exposure to ground conditions (e.g. floods, rockfall, etc.)	0	0	3	0

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Rules, limits & conditions (e.g. emission limits)	0	1	2	3
Passive Safety/ Means (no operator involved)	Safety approach		1	9	6	19
	Retrievability		2	4	3	1
	Retrievability	*Complete backfill - early closure*	2	0	1	0
		Partial Backfill - stepwise implementation	2	1	1	0
		No backfill - open repository	2	0	1	0
		Implications of timescales and retrieval strategies (early closure)	2	3	1	0
		Waste package integrity control	2	2	3	1
		Ventilation, cooling, water pumping	0	0	1	0
		Implications of the host rock	1	1	1	0
		Maintaining accessibility to emplacement cells, galleries, …	1	0	1	0
		Implications of additional foreign material	0	1	1	0
		Record keeping	0	2	4	0
		Cost factors	1	0	2	0
		Ethical and societal considerations	1	0	1	1
Passive Safety/ Means (no operator involved)	Mutiple safety functions	*Containment*	1	5	4	2

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Isolation	3	6	4	2
		Sub-criticality	1	2	2	4
		Heat removal	1	1	2	3
Passive Safety/ Means (no operator involved)	Safeguards	*Design constraints*	3	1	0	4
		Retrievability, retrieval actions	2	0	0	1
Passive Safety/ Means (no operator involved)	Depth of disposal		0	4	0	0
Construction of a disposal facility			3	7	6	18
Construction of a disposal facility	Safety & performance targets		3	8	3	8
Concurrent activities (e.g. waste movement & mining)			1	0	0	0
Operational process			4	8	7	13
	Operational methodology & philosophy		0	5	3	5
	Operational methodology & philosophy	*Design for disposal, not extraction (mines), cultural differences*	0	4	1	4
Operational process	Operation of a disposal facility		4	7	3	5
	Waste package preparation		2	1	7	4
	Transfer of waste from surface to underground		2	0	0	2
	Emplacement of waste		3	2	3	0
	Partial backfilling and sealing		3	2	0	0

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
	Construction of additional drifts		1	0	0	0
Operational process	Retrieval actions		3	3	2	0
	Retrieval actions	*Occupational radiological and conventional risks*	3	1	1	0
		Environmental risks	2	2	1	0
		Handling and transport	3	1	2	3
		Deteriorated packages, backfill and host rock	3	0	1	0
		Safeguards	3	1	0	2
		Cost factors	1	0	0	0
On-going radiological monitoring and testing	Safeguards	*Disturbance of engineered barriers*	3	0	0	2
		DIV - Design information verification	1	0	0	2
		Visual observation, camera surveillance, satellite imagery, remote radiation monitoring, seal identification and verification, cask integrity checks	2	2	0	1
		Verification of operation as planned and facility design as planned	2	0	0	6
On-going non-radiological monitoring	THMC effects of excavation		1	2	0	0
	Degradation of repository structures after excavation		1	1	0	0

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
	Behaviour of waste packages and buffer materials		4	2	1	0
	Near field chemical interaction		1	3	1	0
	Changes to the geosphere		1	2	0	0
	Waste package		4	4	1	1
	Backfilling - partial		4	2	0	0
	Sealing - partial		4	2	0	0
	Host rock		2	2	1	1
	Excavated accessible environment		2	2	0	0
Performance confirmation - monitoring	Considerations in planning and design	*Amount of underground access*	1	0	0	1
		Extension/timing of backfilling and sealing	2	1	0	0
		Extension/timing of ventilation	1	0	0	0
Performance confirmation - monitoring	Retrievability in case of performance failure		3	3	1	0
	Retrievability confirmation/monitoring		3	3	1	0
	Type and frequency of inspections		0	2	1	5
Repository closure			5	6	0	0
Repository closure	Backfilling and sealing		5	6	0	0
	Backfilling and sealing	*Removal of equipment*	2	2	0	0
		Removal of ground support systems	2	2	0	0

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Removal of miscellaneous items	1	1	0	0
		Correction of deteriorated conditions	1	0	0	0
		Potential emplacement of subsurface markers	1	0	0	0
		Sealing of exploratory boreholes	1	0	0	0
Future use of the site	Institutional control provisions		1	4	1	1
	Institutional control provisions	*Markers, HI-provisions*	1	1	0	1
Effective corrective actions	System and equipment performance	*Compatibility of materials*	0	1	1	6
		Environmental conditions	1	2	1	7
Siting	Screening / selection process		1	5	3	9
	Screening / selection process	*Planning and general studies*	2	2	4	3
		Area survey	2	2	2	4
		Preliminary investigations	2	3	3	5
Siting	Site evaluation		2	7	4	13
	Site evaluation	*Site characterisation*	2	8	4	12
		Site confirmation	2	4	4	7
		Geological, hydro-geological, geochemical and geomechanical characteristics	4	6	4	5
		Tectonic, climatic and erosion conditions	3	4	4	8
		External human induced events (aircraft crashes, chemical explosions,…)	2	3	4	8
		Population distribution	1	3	3	4

Topics assessed as specific to operational safety of geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Uses of land and water in the region	1	3	2	5
		Geotechnical hazards (slope instability, subsidence, uplift,…)	1	4	4	3
Stakeholder engagement	Regulator, Public, Workers, Waste Owners, Facility Owner, Government		3	8	7	23

Appendix 3. Topics assessed as generic for geological disposal facilities and their assessed coverage in IAEA publications of different scope

Topics with 0 or 1 in coverage is assessed as not or poorly covered. These are marked in yellow colour.

Topics assessed as generic for geological disposal facilities			**Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:**			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Documents and records			3	8	10	41
Documents and records	Information management system		2	3	8	27
	Information management system	*Classification and archiving*	0	4	5	18
		Physically separate locations for storage	0	3	1	3
		Traceability and maintenance of information	0	7	6	20
		Information retrievability	0	5	4	13
Documents and records	Inventory		0	5	9	6
	Repository structure		0	5	3	2
Safeguards requirements			0	0	2	2
R&D			0	2	2	6
Management			1	9	8	52
Management	Responsibilities		1	9	8	43
	Structure (organisation, …)		1	7	5	33
	System (work control, communication, verification, Mgt. & oversight of contactors, safety processes, corrective action programme, …)		0	4	6	38

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Codes&Standards			1	4	3	20
Emergency prepardness			0	5	8	37
Threat assessment			0	0	0	4
Hazards approach			1	7	10	25
Periodic Safety Review			2	4	5	19
Periodic Safety Review	Ensuring and keeping safety case valid		2	3	5	7
	Reliability & preventitive maintenance, in-service inspection		1	3	4	7
Operational radiological risk			1	5	3	21
Interdependencies			1	4	9	12
Interdependencies	Multidisciplinary - expertise		0	3	3	4
Basic considerations			1	9	6	24
Basic considerations	Safety Strategy		0	8	5	18
	Safety Strategy	*Prioritisation*	1	1	4	13
Basic considerations	Radiation protection		4	7	7	38
	Radiation protection	*Reference levels*	1	6	2	16
		Dosimetric quantities	0	2	1	16
		Dose limits	1	4	4	21
		Limits on exposure for radon progeny and thoron progeny	0	0	2	7
		Optimization of radiation protection for practices	0	4	4	18

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Health surveillance	0	1	3	13
		Classification of areas	0	1	1	11
		Radiation protection in the post-closure period	2	8	2	4
		Personal protective equipment	0	0	2	6
		Worker exposure to radiation	2	2	5	21
		Public exposure to radiation and other emission limits (e.g. effluent limits, dose limits, air emission limits)	2	6	5	21
Passive Safety/ Means (no operator involved)			1	7	3	13
Passive Safety/ Means (no operator involved)	Industrial health and safety		2	2	3	8
	Quality assurance		2	6	7	35
	Quality assurance	*Self-assessment*	0	3	6	21
		Peer review	1	3	4	16
		Internal audit	0	3	5	15
		Control of purchasing	0	3	3	12
Passive Safety/ Means (no operator involved)	Safety culture		0	5	4	30
	Safety culture	*Artefacts*	0	0	1	2
		Espoused values	0	2	2	8
		Basic assumptions	0	2	3	11

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Passive Safety/ Means (no operator involved)	Step by step development and evaluation		2	7	6	11
Passive Safety/ Means (no operator involved)	Graded approach		0	7	3	19
	Graded approach	*Classification of SSC (maturity, complexity)*	0	3	2	9
		Application (inspection, safety etc)	0	5	2	7
Passive Safety/ Means (no operator involved)	Defence in Depth		0	4	2	18
	Defence in Depth	*Avoidance of single failure criteria*	0	3	2	8
	Robustness		0	5	2	3
	Multiple safety functions		2	6	4	10
	Safeguards		5	1	0	8
	Environmental and non-radiological concerns		1	5	6	13
Construction of a disposal facility	Procurement		1	2	2	6
	Procurement	*Equipment qualification, selection and management of contractors*	1	2	2	9
	Adaptive management		0	1	1	7
	Adaptive management	*Flexibility/responding to changing conditions*	0	1	1	7
	Commissioning		0	2	4	12
	Human factors in design		0	1	1	8
	Optimization		0	6	3	3

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Operational process	Commissioning		0	3	3	13
	Receipt of the waste		1	3	8	2
	Buffer storage		2	1	5	1
	Support facilities and service		1	1	3	1
	Maintenance & inspection		0	5	6	12
Operational process	Design and operational processes modifications		2	7	2	16
	Design and operational processes modifications	*Design and development review, verification, validation*	1	7	2	8
		Design change control	0	4	1	11
		Data analysis	0	3	1	8
Operational process	Surveillance and control of passive safety features		2	4	2	4
Security			1	2	3	10
Security	Access, sabotage		0	1	1	6
Conventional Waste management			0	0	4	1
Conventional Waste management	E.g. excavation waste handling system (solid & liquid), industrial waste (oils, etc.), domestic waste		0	0	1	1
Ageing management			0	4	1	16
Design of a monitoring programme			4	6	2	18
On-going radiological monitoring and testing			4	4	6	19

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
On-going radiological monitoring and testing	Normal operation - surface		3	2	5	12
	Normal operation - underground		3	2	2	6
	Normal operation - underground	*Air sampling*	3	1	3	8
		Water sampling	3	1	3	5
On-going radiological monitoring and testing	Inspection		1	6	1	12
	Abnormal conditions		2	2	1	9
	Baseline monitoring		1	4	3	10
	Baseline monitoring	*Natural RN content and background levels of radioactivity in the environment*	1	2	3	5
	Safeguards		3	1	0	4
On-going non-radiological monitoring			2	3	4	5
	Baseline monitoring		1	3	4	4
	Baseline monitoring	*Meteorology, hydrology, hydrochemistry, local ecology, geomorphological processes, tectonic activity, geothermal heat flow, land use in the surrounding region*	2	2	1	5
Performance confirmation - monitoring			4	5	1	15

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
	Considerations in planning and design		1	5	1	7
	Site characteristics		1	4	2	6
	Site characteristics	*Geologic framework of host rock/site host rock/geological settings*	2	4	1	3
		Hydrogeological, hydro-chemical, environmental responses due to construction and operation	1	1	0	2
Performance confirmation - monitoring	Analysis and response to the main objectives		0	3	1	4
	Deviation from expected results		0	3	1	7
	Periodic review of the monitoring and surveillance programmes		1	3	2	9
Decommissioning of surface facilities			2	2	8	18
	Potential decontamination of buildings, plant and equipment		1	0	5	8
	Spoil material/deposit management		1	0	0	2
Future use of the site			1	3	1	4
	Restoration of the surface environment		1	1	1	2
Operational feedback/Corrective action programme			0	5	2	24

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
Operational feedback/Corrective action programme	Addressing the root causes		0	2	2	17
	Selecting corrective actions		0	4	2	22
	Conservative decision making		0	2	2	17
	Prioritisation		0	0	1	11
	Prioritisation	*Nuclear safety*	0	0	0	2
		Radiation safety	0	0	0	7
		Industrial safety	0	0	0	4
		Environmental impact	0	0	0	5
		Security	0	0	0	4
Operational feedback/Corrective action programme	Corrective action implementation		1	2	2	23
	Tracking of corrective action effectiveness		0	2	2	15
	Preventing repetition		0	2	2	18
	Rally commitments		0	0	0	7
	Indicators		0	3	2	17
	Self-assessment		0	3	2	15
	Peer review		0	2	2	10
	Benchmarking		0	1	1	9
Effective corrective actions			0	2	2	27
Effective corrective actions	Human performance		0	3	2	28
	Human performance	*Human performance errors*	0	1	1	12
		Human environment conditions	0	1	1	16

Topics assessed as generic for geological disposal facilities			Number of IAEA publications assessed as partially cover/mention the topic (1) or well cover the topic (2) in publications with the scope:			
Topic	**Sub-Topic**	**Sub-sub-Topic**	**Geological disposal (1)**	**Disposal (2)**	**Waste management (3)**	**Other (4)**
		Person-machine interface	0	0	0	9
		Organisational factors/procedures	0	2	2	19
		Training	0	4	2	36
		Work practices	0	1	2	23
Effective corrective actions	System and equipment performance		1	4	3	12
	System and equipment performance	*Margins*	0	0	0	7
		Maintenance modes and frequency	1	1	2	8
		Quality of repairs	0	0	1	5
		Qualification of manufacturers and contractors	1	0	0	7
		In-service inspection programmes	0	3	2	11
		Redundancy and diversity	0	0	1	3
		Use of proven systems and equipment	0	1	2	13
		Validation of software	0	2	1	10
Effective corrective actions	Corrective action database		1	4	2	13
	Corrective action management report		0	3	2	13
Siting			1	6	6	15
Stakeholder engagement			4	9	7	26