INTERNATIONAL ATOMIC ENERGY AGENCY

INTERNATIONAL PEER REVIEW ON

THE "SAFETY OPTIONS DOSSIER"

OF THE PROJECT OF DISPOSAL OF RADIOACTIVE WASTE IN DEEP GEOLOGICAL FORMATIONS: CIGÉO

PEER REVIEW REPORT

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Paris, France

FINAL REPORT

FOREWORD

The French Nuclear Safety Authority (ASN) is preparing the evaluation of a license application for the creation of a deep geological disposal facility, called Cigéo, for intermediate-level (ILW) long-lived and high level (HLW) radioactive waste in 2018. This license is preceded by the submission of a "Safety Options Dossier" to the French Nuclear Safety Authority. This gives Andra - the French Radioactive Waste Management Agency - the possibility to already get the advice from ASN in preparation of the licence application on the safety principles and approach. The dossier sets out the chosen objectives, concepts and principles for ensuring the safety of the facility.

ASN requested the IAEA to organize an international peer review of the "Safety Options Dossier". This report presents the consensus view of the international group of experts convened by the IAEA for carrying out the review. The experts act in a personal capacity and the view presented here may not necessarily coincide with that of their country or organization or the IAEA.

The review was carried out against the relevant IAEA safety standards and proven international practice and experience.

The peer review was requested by ASN. The basis of this review are the documents provided by Andra as the agency responsible for the development of the Cigéo project and, as such, responsible for its safety. Consequently, for practical reasons, the findings of the reviews are addressed directly to Andra. The report is however primarily submitted to the French Nuclear Safety Authority; it is for ASN to use the review outcomes to further follow on with Andra's project.

The review team would like to express appreciation to ASN and Andra for the open and constructive discussions and their assistance during the preparation and conduct of the mission.

SUMMARY

At the request of the French Nuclear Safety Authority (ASN), the IAEA convened from 6 to 15 November a team of international experts to review the "Safety Options Dossier" of the Cigéo Project on the disposal of intermediate level long lived and high level radioactive waste in the Callovo-Oxfordian (COX) formations of Meuse/Haute Marne. This strategic dossier sets out the chosen objectives, concepts and principles for ensuring the safety of Cigéo.

The review focused on the strategy of research & development and knowledge acquisition, the approach for defining scenarios for operational and post-closure safety assessment. It also addressed the approach for post Fukushima actions.

The step-wise and iterative process for the Cigéo development has included the publication of several safety and feasibility related dossiers, their regulatory review, interaction with the local stakeholders and public and national public debates. The International Review Team (IRT) considers that the decision to introduce an industrial pilot phase and the preparation of a Safety Options Dossier is commendable. It confirms the responsiveness of Andra to the public consultation and is a good example of taking account of the public's concerns and proposals in the Cigéo development programme.

Related to the management of the Cigéo project, the IRT acknowledged that the Operations Master Plan is a good project management tool that can play an important role in the communication and consultation of Andra's planning of future activities with the safety authority, the public and other stakeholders. For enhancing the management and building confidence among regulator and stakeholders the IRT considers that Andra should:

- Specify how new information will be used when proceeding from one stage to the next in the incremental development of the Cigéo project and describe the link between the milestones of the Cigéo development process, the regulatory authorization process and key milestones in Andra's R&D plan.
- Develop a strategy to ensure that data and information important for operations and post-closure safety can be updated, preserved and understood over the more than one hundred years of expected operation of Cigéo.
- Clarify its updated R&D plan consistent with the development of Cigéo by identifying and prioritising R&D activities; describing the intent of the R&D; and defining the link between the R&D and the stage in the programme.
- Further address in the development of its monitoring plan implemented during the operational phase: the relationship between the monitoring parameter(s) and post-closure safety; the feasibility of the monitoring activities planned to function over the operational period including equipment maintenance or replacement and potential detrimental impact on post-closure safety barrier performance.
- Further strengthen the dialogue with the waste producers and seek possibilities for overall optimization of waste predisposal management and disposal of the waste.

Based on the Safety Options Dossier and the discussions during the review mission, there is reasonable assurance about the robustness of the disposal concept. Noting that in many areas research is on-going both for demonstration of safety or confirmation, the IRT identified a few other areas - gas generation and transport, description of disposal facility components ageing during the operational period, uncertainties related to the re-saturation time of the disposal cells and effects on the degradation of the waste packages, role of microbes and potential for biofilms

during the operational period and implications of undetected faults - where studies should continue to further strengthen confidence in the safety case.

The IRT considers that Andra implements a good overall management process to systematically define and investigate safety scenarios. The IRT appreciates the use of what-if scenarios, as this enables Andra to get a good understanding of the disposal facility system behaviour under extreme conditions and to illustrate the disposal system robustness. However, the IRT is in the opinion that, in order to further demonstrate the robustness of the disposal system, Andra should

- Consider water conducting features within the COX in the frame of what-if calculations in order to further demonstrate robustness of the disposal system.
- Substantiate why there is no need for including any initially defective HLW containers or early failure of HLW containers in the normal evolution scenario.
- Include in its safety case and safety assessment microbial activity at the sleeve/back fill interface supported by research on microbial activity as necessary.

Andra has covered the human intrusion scenarios in depth, assigning them to altered evolution scenarios or to the group of what-if scenarios. Internationally, it is understood that there is no reliable scientific basis for predicting the process or likelihood of inadvertent human intrusion. In accordance with international practice, Andra should treat human intrusion separately from the other scenario groups without any judgement on probability of occurrence.

The IRT considers that Andra‘s methodology for evaluating operational safety is comprehensive and systematic. With regard to post Fukushima actions Andra has used ASN specifications for the "stress tests" on nuclear installations as a guideline for integrating complementary safety assessments into the design of Cigéo. The IRT is in the opinion that Andra should consider the use of filtration of exhaust air from the underground facility and evaluate the robustness of its design for the removal of high water ingress from tunnels/ramp sections.

The time schedule to prepare Cigéo license application by 2018 is challenging. The Safety Options Dossier is a valuable preliminary step before license application as it provides a basis to evaluate at a strategic level the key aspects relevant for Cigéo development and preparation of the license application. The IRT therefore encourages ASN, IRSN and Andra to use the review of the Dossier as a basis to further precise the expectations for the license application. This is especially important as the planned Cigéo facility is one-of-a-kind.

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1. INTRODUCTION

1.1. Background

The French Nuclear Safety Authority (ASN) is preparing for the evaluation of the license application for the Cigéo project of geological disposal of high level radioactive waste and intermediate level long lived radioactive waste in argillaceous formations, to be submitted by Andra – the French National Radioactive Waste Management Agency – in 2018.

This Cigéo project will consist of surface facilities that, amongst other things, will be used to receive and prepare waste packages and the underground disposal facility at a depth of ca. 500 metres in an argillaceous rock formation.

Following a public debate in 2013, Andra proposed the establishment, once license has been granted, of an industrial pilot phase for the development of the project. Andra also proposed to submit in advance to the license application a "Safety Options Dossier" to ASN. The dossier is a strategic step prior to the license application of presenting the main technical options ensuring the safety of the disposal project.

On the request of ASN, the whole "Safety Options Dossier" will be submitted to an evaluation prior to the license application by the French Standing Groups of Experts on "Waste" and "Laboratories and Plants" with the support of IRSN (French Technical Support Organization).

ASN expects that the dossier "explicitly sets out the chosen objectives, concepts and principles for ensuring the safety of the facility when in operation and over the long term [...]. These demands are accompanied [...] by a detailed list of the information needed for the safety options report to be properly examined" (letter by ASN from 19 December 2014; ref. CODEP-DRC-2014-039834).

With the view of complementing its instructions, ASN requested the IAEA to organize an international peer review of the "Safety Options Dossier". The agreed terms of reference are given in Appendix 1.

1.2. Objective, scope and organisation of the review

The objective of the peer review was to provide an independent international evaluation of the "Safety Options Dossier". In this respect the following reports were submitted to the review team:

- Safety Options Report – Post-closure part;
- Safety Options Report – Operating part;
- Proposed operations master plan;
- Development plan for Cigéo project components.

Further reference to the "Safety Options Dossier" in this report means the above set of reports.

The review assessed the following aspects:

- The strategy of research & development and knowledge acquisition (including the demonstrators) and its adequacy with the phased development of the facility. In particular the review will address the expectations at the different phases of development of the facility to match the authorization process.
- The approach for definition of long term safety scenarios including intrusion scenarios, safety scenarios during operation (excluding malevolent acts), and the plan for surveillance during operation.
- Post Fukushima actions (e.g. extreme scenarios).

The review was carried out against the relevant IAEA safety standards and proven international practice and experience. In the present report, the findings from the experts are supported by the IAEA safety standards which are referred to in italics in the text.

The review has been organized by IAEA's Department of Nuclear Safety and Security in cooperation with the Department of Nuclear Energy. The international review team, hereafter referred to as "IRT", comprised Felix Altorfer (Switzerland), Björn Dverstorp (Sweden), Klaus Fischer-Appelt (Germany), Jussi Heinonen (Finland), Doug Ilett (UK), Timothy McCartin (US) and Geert Volckaert (Belgium). The team is supported by two Scientific Secretaries from the IAEA, Gérard Bruno from the Waste and Environmental Safety Section and Philippe Van Marcke from the Waste Technology Section. Brief CV's are included in Appendix 2.

The review was based on the examination of the reports, which were delivered to the experts in July 2016. Following a preliminary analysis of the reports by the experts, a series of questions was sent to Andra in October 2016, which served as a basis for the presentations and discussions during the review mission from 7 until 10 November 2016 in Paris.

This report presents the consensual view of the experts based on the documentation submitted by Andra for the purpose of the review, the presentations by Andra during the review mission and the subsequent discussion. The experts act in a personal capacity and their view may not necessarily coincide with that of their country or organization or the IAEA.

The peer review was requested by ASN. The basis of this review are the documents provided by Andra as the agency responsible for the development of the Cigéo project and, as such, responsible for its safety. Consequently, for practical reasons, the findings of the reviews are addressed directly to Andra. The report is however primarily submitted to the French Nuclear Safety Authority; it is for ASN to use the review outcomes to further follow on with Andra's project.

1.3. Structure of the review report

During the review mission Andra first explained the history and context of Cigéo, the role of the Safety Options Dossier in relation to the licensing process and its safety strategy. Following this discussion the review areas defined in the terms of reference were addressed.

This report follows this same structure:

- Chapter 2: Cigéo licensing process;
- Chapter 3: The strategy of research & development and knowledge acquisition;
- Chapter 4: The safety assessment scenario methodology;
- Chapter 5: Post Fukushima actions.

Appendices 1 and 2 contain respectively the agreed terms of reference of the peer review and the CVs of the member of the review team.

2. CIGÉO LICENSING PROCESS

In 1991, the Act n° 91-1381 of 30th December 1991 on the management of radioactive waste gave Andra the task of assessing the feasibility of a waste disposal facility in a deep geological formation, particularly through the construction of underground laboratories. ASN issued a basic safety rule (RFS III.2.f) in 1991 that set out the long term safety expectations for the disposal facility, the design principles, the criteria used to select suitable geological media and the terms of studies, and defined the fundamental objectives that must guide research on disposal. ASN has replaced the basic safety rule in 2008 with Safety Guide on the permanent disposal of radioactive waste in deep geological disposal facilities.

During the disposal site screening, site selection and Cigéo development Andra has published safety and feasibility related dossiers to support decision making. Each intermediate iteration associated with the various milestones in the development of the Cigéo project has been reviewed by ASN.

The license application for Cigéo to be submitted in 2018 is framed by the Environment Code (L. 542-10-1), the Decree n^{o} 2007-1557 of 2 November 2007 and required by the Act n^{o}2006-739 of 28 June 2006.

2.1 Public engagement

Andra's position

The main Cigéo milestones have included public engagement and dialogue. Besides the interaction with the local stakeholders and public, e.g. the Local Information and Follow-up Committee (CLIS), national public debates have been organized in 2006 for the Andra's Dossier 2005 and in 2013 for the Cigéo project.

The 2013 public debate had notable effect on Cigéo project. For example, Andra decided to introduce industrial pilot phase for confirmation of planned disposal facility operations. Andra also decided to submit to the ASN the Safety Options Dossier to prepare for review of the license application for Cigéo.

IRT observation

The decision to introduce an industrial pilot phase and preparation of a Safety Options Dossier is commendable. It confirms the responsiveness of Andra to the public consultation and is a good example of taking account of the public's concerns and proposals in the Cigéo development programme.

2.2 The Safety Options Dossier

Andra's position

French nuclear legislation states that nuclear operators have a possibility to ask ASN for its opinion concerning all or some of the options it has chosen to ensure the safety of the installation. Legislation or regulations do not specify in detail the content of Safety Options

Dossier prepared for this request of ASN opinion. According to Andra based on examples from other nuclear facilities, the reports usually present at least in general terms the key safety options which govern the project design, but do not describe in detail the safety demonstration or description of the technical solutions.

ASN decided, based on the specificity of the deep geological disposal, to express to Andra its expectations for the Safety Options Dossier by letter in December 2014 (ref. CODEP-DRC-2014-039834). In its letter, ASN set out its expectations as regards the safety options for Cigéo. In particular, ASN requested that "*First of all, these safety options must cover the entire installation, that is to say the surface facilities, the underground facilities and the surface-underground connections, at the preliminary design study (PDS) stage. Particular attention must be paid to the completeness of the submitted dossier with regard to the notion of disposal system defined in the ASN Safety Guide. The submitted dossier shall be a standalone dossier, explicitly presenting the objectives, concepts and principles adopted to ensure the safety of the facility when in operation and over the long term, at the different phases of the facility's life cycle: design, construction, functioning, final shutdown, decommissioning or closure, maintenance and surveillance, depending on the facility sub-units concerned. The level of detail presented shall be proportional to the significance of the risks and associated drawbacks*."

IRT observation

The concept of a Safety Options Dossier is a valuable preliminary step before the submittal of a license application. It provides a basis to evaluate at a strategic level the main options taken for demonstrating safety, key design options and planned facility construction and operation. The IRT recognises that the Safety Options Dossier is not meant for demonstrating compliance with regulatory requirements. However, it contributes to the dialogue between Andra and ASN on the key aspects relevant for Cigéo development and preparation of the license application. This is especially important as the planned facility is one-of-a-kind.

2.3 License application and interaction between ASN and Andra

Andra's position

Andra indicated during the peer review discussion that the plan is to further develop initiate the exchange with ASN about the license application preparation by the end of 2016 or beginning of 2017. Andra presented the work necessary for preparing the license application by 2018. This work involves for example completion of the overall safety demonstration and safety and sensitivity analysis, finalization of facility detailed design and other elements discussed further in latter parts of this report.

At the same time the ASN review process for Safety Options Dossier and related documents is ongoing.

IRT observation

The time schedule to prepare Cigéo license application by 2018 is challenging. It is good practice that regulator and implementer have a dialogue on the expectations to ensure common expectations for license application content. The IRT therefore encourages ASN, IRSN and Andra to use the review of the Dossier to further precise address the expectations for the license application.

2.4 Interaction with waste producers

Andra's position

Andra presented the broad variety of waste types to be disposed in Cigéo, resulting from France's diverse nuclear programme. Regarding the respective responsibilities, Andra is responsible for the disposal of the waste packages. The waste producers are responsible for the predisposal activities.
Drawing up a qualitative and quantitative inventory for Cigéo, it is necessary that there is collaboration between Andra and the waste producers discussing the industrial scenario for the operation of nuclear facilities adopted in the industrial waste management programme (PIGD). During the review discussions Andra described the interactions with the waste producers in compiling the waste inventory and package types.

IRT observation

The IRT understands that optimizing the waste forms and conditioning methods involves both the waste producers and Andra's waste acceptance criteria. Taking into account the long operational lifetime of Cigéo, it is important for Andra to ensure that waste producers are regularly informed of the waste acceptance criteria and that post-closure safety aspects are considered for future optimization of waste conditioning methods and waste forms. In accordance with IAEA safety standards (e.g. safety Requirements on Predisposal Management of Radioactive Waste, (GSR Part 5), Requirement 6 [1]) the interdependences between all steps of radioactive waste management, including disposal, should be taken into account.

SUGGESTION

The IRT encourages Andra to further strengthen the dialogue with the waste producers and to seek possibilities for overall optimization of waste predisposal management and disposal of the waste.

Safety Requirements on Predisposal Management of Radioactive Waste, Requirement 6: Interdependences

"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."[1]

3. THE STRATEGY OF RESEARCH & DEVELOPMENT AND KNOWLEDGE ACQUISITION

3.1 Cigéo post-closure safety strategy

Andra's position

Cigéo is designed to isolate the waste from humans and the biosphere and to confine it in the deep geological formation. These post-closure safety functions apply over very long time scales (up to hundreds of thousands of years), passively, i.e. without the need for maintenance or monitoring. According to the Safety Options Dossier, post-closure safety relies principally on the favourable properties of the selected host formation which is based on extensive knowledge accumulated from past siting and research conducted over the last 25 years. The underground facility and the engineered barriers are designed to limit radionuclide releases by favouring the migration pathway through the clay rock.

IRT observation

Based on the Safety Options Dossier and the discussions during the review mission, the IRT concludes that there is reasonable assurance about the robustness of the disposal concept. Noting that there are many research areas where studies are on-going both for demonstration of safety or confirmation (e.g. the knowledge of the Callovo-Oxfordian clay, the seals, etc.), the IRT identified the following areas to strengthen Andra's existing knowledge base (not in priority order):

- Gas generation and transport;
- Description of disposal facility components ageing during the operational period in particular those of the disposal cells;
- Uncertainties related to the re-saturation time of the disposal cells and effects on the degradation of the waste packages;
- Role of microbes and potential for biofilms during the operational period;
- Assessing implications of undetected faults.

SUGGESTION

The IRT encourages Andra to continue studies on the areas identified above to further strengthen confidence in the safety case.

Safety Requirements on Disposal of radioactive waste (SSR-5), Requirement 13: Scope of the safety case and safety assessment:

"With regard to safety after closure, the expected range of possible developments affecting the disposal system and events that might affect its performance, including those of low probability, have to be considered in the safety case and supporting assessment by the following means:
(a) By presenting evidence that the disposal system, its possible evolutions and events that might affect it are sufficiently well understood;
(b) By demonstrating the feasibility of implementing the design;
(c) By providing convincing estimates of the performance of the disposal system and a reasonable level of assurance that all the relevant safety requirements will be complied with and that radiation protection has been optimized;
(d) By identifying and presenting an analysis of the associated uncertainties."[2]

3.2 Technological Readiness Level approach

Andra's position

In the report on Development Plan for the Cigéo project components (PDD) Andra describes the application of the international TRL (technical readiness levels) scale for quantification of the technological readiness of an item (equipment, component, system, etc.). The TRL scale, originally applied in other industrial areas, is part of the international standard ISO 16290: 2013. The use of the TRL scale is primarily related to the level of readiness of the performance of the components of the disposal system and is not a safety analysis as such. The TRL scale has previously been applied to industrial operations but the application to the Cigéo project involves unique aspects regarding the conditions in the underground facility and the gradual development of the disposal facility.

Andra has established a Requirement Management System to organise and trace the requirements related to the safety functions (operational and post-closure) which will be used to check that the technical solution fulfils the requirements and therefore the safety functions.

IRT observation

The application of the TRL scale appears to be a good tool for the internal management of the development of disposal facility components, including interaction with sub-contractors. The TRL scale provides a structured overview of the different steps of development of individual components and the successive demonstration and confirmation of their performance in the disposal facility, which is particularly important considering the more than 100-years long operational and gradual-construction period. However, because the TRL scale primarily is linked to requirements on the performance of individual components, it cannot substitute overall updates of the post-closure safety case.

Once the safety case is developed, the benefits of the TRL could be enhanced by clarifying the link between the TRL-scale and post-closure safety, for example by describing the role of the TRL-scale in the periodic updates of the post-closure safety case.

3.3 Long term planning of the incremental development of the Cigéo project

Andra's position

The proposed Operations Master Plan (PDE) describes the reference progression of the Cigéo project, i.e. the waste inventory to be emplaced in it and the consecutive steps in building the industrial, operational and closure facilities as envisaged by Andra based on studies conducted up to 2015. It also describes how Cigéo, in terms of reversibility and during its entire service life, will not bind future generations to the choices our generation has made. Rather, it will provide them with options for managing radioactive waste. These options may relate to future developments of the facility, changes to the inventory — particularly in the event of changes to France's energy policy (e.g. the decision to dispose of spent fuel) — or the removal of emplaced packages. The proposed Operations Master Plan (PDE) will be submitted to the stakeholders for consultation according to the process outlined below.

IRT observation

The Safety Options Dossier outlines a comprehensive national programme and a credible long term plan for the management of intermediate-level (ILW) and high level (HLW) radioactive waste in France. This long term plan, which is based on 25 years' of siting, site characterisation, research and development in the Bure underground research laboratory, allows for successive adaptation of the disposal facility taking into account technical and scientific developments and confirmation of facility operation.

As a result of the public debate on the Cigéo project held in 2014 Andra drafted the PDE, which outlines the so-called "reference" progression of the Cigéo project, as envisaged by Andra at the end of the basic engineering design, explains the objectives of the industrial pilot phase, and presents the choices offered by retrievability as regards the management of the Cigéo project. According to Andra this document is a forerunner of a project governance tool that will be periodically updated throughout Cigéo's operation. This tool can play an important role for communication and consultation of Andra's planning of future activities in the development of the Cigéo project with the safety authority, the public and other stakeholders.

Keys stages and milestones in the disposal facility development have been identified in the PDE, but there are some uncertainties regarding what information is needed to move from one stage to the next and how the key milestones in the Cigéo development process match the regulatory review process. One such example concerns the transition from the pilot phase to routine operations.

There is a need to clarify, on part of Andra, the process for systematic updating of the site description and the safety assessment during the pilot phase and the following gradual construction of the underground facility. This description should take into account the main steps in the incremental development of the facility, milestones in the long term research and development plan for the Cigéo disposal facility and regulatory authorizations required.

GOOD PRACTICE

The Operations Master Plan (PDE) is a good project management tool that can play an important role for communication and consultation of Andra's planning of future activities in the development of the Cigéo project with the safety authority, the public and other stakeholders.

SUGGESTION

Andra should specify in more detail how new information will be used when proceeding from one stage to the next in the incremental development of the Cigéo project (outlined in the PDE) and describe the link between the milestones of the Cigéo development process, the regulatory authorization process and key milestones in Andra's R&D plan.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 11: Step by step development and evaluation of disposal facilities

"Step by step development and evaluation of disposal facilities Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system."[2]

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 12: Preparation, approval and use of the safety case and safety assessment for a disposal facility

"A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step."[2]

Safety Requirements on Disposal of Radioactive Waste (SSR-5),Requirement 3: 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." [2]

3.4 The Industrial Pilot Phase

Andra's position

Following the public debate on the Cigéo project held in 2013, Andra introduced an industrial pilot phase with the objectives of confirming different aspects of facility operation and allow for optimisation of disposal facility components and design solutions. The experiences of the pilot phase will be evaluated and documented in a report supporting the transition to the routine operations.

IRT observation

The concept of an explicit industrial pilot phase to confirm different aspects of disposal facility technology and operation is commendable, although the exact scope remains to be developed. It provides a framework for dialogue with ASN and other stakeholders and for developing confidence in Andra's capability to operate the facility safely prior to the start of routine operations. The inclusion of inactive demonstrators for disposals cells and seals will also provide additional information in support of the post-closure safety case (Safety Requirements on Disposal of Radioactive waste (SSR-5), Requirement 11 [2]).

3.5 Knowledge management

Andra's position

Andra states in its Safety Options Dossier that due to the gradual deployment of the Cigéo facility and the continuous increase in knowledge, the project's development will exceed the scope of the detailed engineering design and continue for several decades.

Andra has a number of databases and information systems in place (e.g. science for geological site, engineering components, radionuclide inventories, waste packages, requirements management system).

At the construction licence application deadline, project reference will comprise the entire set of:

- The robust, demonstrated solution for the construction phase (T1) and for the subsequent construction phases (TU) proposed at that time and proposed as constructed for the T1 phase;
- The design changes envisaged for the subsequent TU phases in the light of their completion deadlines; and
- The method and the estimated schedule for their demonstration and gradual integration into Cigéo construction.

At each stage of the project's development, progress on the studies of these various optimizations and analysis of their intersecting impacts in terms of safety and technical

execution and cost challenges will be used to define which of these variants can be integrated into a proposed construction configuration and which must continue to be studied concomitantly and according to what timeline.

IRT observation

The IRT acknowledges the effort Andra undertakes to collect and document scientific data and the decision making process. During the construction and operational period of Cigéo an enormous amount of information will be produced and filed. In the view of the challenges of preserving up-to-date, accessible and understandable information about the safety case over many decades, there is a need that Andra develops a coherent long term strategy for knowledge and information management.

RECOMMENDATION

Andra should develop a strategy to ensure that data and information important for operations and post-closure safety can be updated, preserved and understood over the more than one hundred years of expected operation of Cigéo.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 25: Management systems

"Management systems to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety."

"An appropriate management system that integrates quality assurance programmes will contribute to confidence that the relevant requirements and criteria for site selection and evaluation, design, construction, operation, closure and safety after closure are met. The relevant activities, systems and components have to be identified on the basis of the results of systematic safety assessment. The level of attention assigned to each aspect has to be commensurate with its importance to safety. The management system is required to comply with the relevant IAEA safety standards on management systems." [2]

3.6 Research and Development

Andra's position

Since 1991 Andra is running a comprehensive research project including a broad combination of laboratory research, surface and drilling based site investigations, research in the Bure URL and model development.

In the Dossier 2005 Andra gave a state-of-the-art global overview of this research on which basis Andra confirmed the Callovo-Oxfordian clay (COX) as suitable geological medium. The review of Dossier 2005 oriented the further research and the outcome of e.g. the further geological investigation led to the proposal of the zone of interest for detailed investigations ZIRA in 2009. The continued R&D led in 2015 to the confirmation of the favourable properties and robustness of the COX in the Safety Options Dossier.

The current R&D plans for the Cigéo project are developed along 3 possible lines of action:

1. Understanding of processes (THMCR);
2. Supporting the development phases of the disposal installation i.e. DAC (license application), Industrial Pilot Phase (T1), later phases; and
3. Understanding of the behaviour of components of the disposal installation.

There is a process for deriving the key R&D challenges. Plans for the further R&D are drawn-up and are updated in a bi-annual cycle. This is amongst other factors based on reviews and design studies. Andra's R&D plan was not included in the Safety Options Dossier.

IRT observation

Although the R&D plan did not make part of the review documents, the process for planning the R&D in support of Cigéo development was discussed during the review. The process by which the R&D activities are identified and prioritized was not explained to the IRT. Consequently, it was not always clear what Andra is expecting as an outcome from the planned research, development and demonstration (RD&D) projects. The sensitivity and uncertainty analysis should be used to help identify those priorities (See Section 4.4).

As part of Andra's strategy for research and development, an updated R&D plan in support of the development of Cigéo should distinguish between R&D to be included in the safety evaluation (update of the safety file for the "confirmation authorization by ASN"), R&D done for further optimization of the facility design and R&D performed to maintain knowledge and understanding on the disposal concept.

It should also be clarified which R&D outcomes are expected at what stage in the programme, i.e. (1) R&D that is completed at the time of the license application, (2) R&D planned during the industrial pilot phase, and (3) R&D planned for after the industrial pilot phase. For the R&D planned during the pilot phase it should be identified what confirmation is sought through this R&D.

The updated plan should also highlight which R&D will be done in the Meuse/Haute Marne URL.

According to the IRT, such an updated R&D plan should be made available to regulatory bodies to support the regulatory review process.

RECOMMENDATION

Andra should clarify its updated R&D plan consistent with the development of Cigéo by:

- Identifying and prioritising R&D activities;
- Describing the intent of the R&D; and
- Defining the link between the R&D and the stage in the programme.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 3: Responsibilities of the operator

"3.13. The operator has to conduct or commission the research and development work necessary to ensure that the planned technical operations can be practically and safely accomplished, and to demonstrate this. The operator likewise has to conduct or commission the research work necessary to investigate, to understand and to support the understanding of the

processes on which the safety of the disposal facility depends. The operator also has to carry out all the necessary investigations of sites and of materials and has to assess their suitability and obtain all the data necessary for the purposes of safety assessment". [2]

3.7 Monitoring

Andra's position

Monitoring is a regulatory requirement just as for any other BNI (Basic Nuclear Installation) with the purpose to protect public security, health and safety, protection of nature and the environment. Some additional requirements specific for the disposal installation have been formulated in the framework of the pre-closure surveillance requirements and the post-closure safety. Andra has started to take into account the specificities of the monitoring related to the long period over which the disposal facility is implemented. The PDE presents the evolution of monitoring activities over the implementation of Cigéo. Andra presented the approach to monitoring for the different phases of the development of the disposal and how the needs evolve.

The principles of the monitoring for the operational and post-closure phase are given in the respective Safety Options reports. In particular, Andra has proposed the components important for post-closure safety and the related monitoring parameters during construction and operation. The principles for the monitoring in the Industrial Pilot Phase and for the possibility to retrieve the waste are described in specific documents. A summary of this was presented.

Monitoring and data acquisition will be undertaken during excavation of the structures in order to validate the geological model and its supporting physical-chemical parameters. The verification of the important characteristics of the host rock, taken as input data for the assessment of post-closure safety (mechanical behaviour, extension, structure, permeability of the damaged area around the structures, etc.) forms part of the monitoring programme conducted at the start of construction of the structures, during the industrial pilot phase (and continued beyond).

As part of the monitoring programme, special monitoring measurements will be taken on parts of the underground structures, (stretches of ramp and of shafts, stretches of drifts or parts of intersections, of ILW and HLW disposal cells), chosen as being representative of a series of structures, or because of their particular location (e.g. at the position of a future seal) in respect of the operating or post-closure safety objectives.

Additionally, regarding surveying of the environment, Andra established in 2007 the Perennial Observatory of the Environment (OPE) to provide a precise description of Cigéo's environment and to monitor its long term development. The OPE has implemented a multi-disciplinary observation programme (water, air, flora, fauna, human aspects) for a period of at least 100 years. Andra presented the comprehensive environmental monitoring that is already running and is publicly available through their website i.e. the Perennial Observatory of the Environment (OPE).

IRT observation

Andra is implementing the OPE and is in the process of developing a monitoring programme for the underground facility. The public access to this environmental data is consistent with international practice and an element to build public confidence. Andra is encouraged to continue this practice.

Andra's monitoring plans implemented during the operational phase and related to long term safety are less mature. From the documentation and discussions with Andra, the feasibility of the proposed post-closure safety monitoring activities as well as their relationship to safety was not always clear.

Andra should specify the intent for the monitoring activities for the each of the next phases of the development of the disposal facility (e.g. monitoring for operational safety versus performance of barriers relied on for post-closure safety).

RECOMMENDATION

Andra should further address in the development of its monitoring plan implemented during the operational phase:

- The relationship between the monitoring parameter(s) and post-closure safety;
- Their feasibility of the monitoring activities planned to function over the operational period including equipment maintenance or replacement; and
- Potential detrimental impact on post-closure safety barrier performance.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 21:Monitoring programmes at a disposal facility

"A programme of monitoring shall be carried out prior to, and during, the construction and operation of a disposal facility and after its closure,[...] This programme shall be designed to collect and update information necessary for the purposes of protection and safety. Information shall be obtained to confirm the conditions necessary for the safety of workers and members of the public and protection of the environment during the period of operation of the facility. Monitoring shall also be carried out to confirm the absence of any conditions that could affect the safety of the facility after closure."[2]

4. THE SAFETY ASSESSMENT SCENARIO METHODOLOGY

4.1 Post-closure safety assessment scenario development

Andra's position

Andra's approach to derive scenarios to assess post-closure safety taking into account existing uncertainties is based on the following steps:

- Phenomenological Analysis of Repository Situations (PARS): to describe the evolution of phenomenological processes which affect natural and engineering components for operational and post-closure safety;
- Qualitative Safety Analyses (QSA): to derive normal and altered scenarios.

These steps are the basis for the subsequent numerical conceptualisation for processes that affect safety functions as well as the quantitative post-closure safety assessment. Andra also uses the NEA FEP catalogue as a verification tool to ensure completeness of its safety understanding.

Andra developed different categories of scenarios:

- Normal Evolution Scenarios (NES), which describe evolution presented by two situations: reference situation with best estimated values and a bounding situations which takes conservative parameter values into account;
- Altered Evolution Scenarios (AES), which cover less likely scenarios assuming malfunctions of technical components (seals and container failures);
- What-If-Cases which bases on extreme very unlikely assumptions in order to investigate the reaction and robustness of the disposal system;
- Human Intrusion Scenarios.

Considering the particular what-if scenario identified in the Safety Options Dossier regarding the undetected heterogeneities, Andra expressed the need to exchange with ASN and IRSN to be able to define the assumption of this scenario.

IRT observation

In general the IRT considers that Andra implements a good overall management process to systematically define and investigate safety scenarios. The IRT especially considers the PARS system (Phenomenological Analysis of Repository Situations) to be a comprehensive method of describing significant phenomena and their interaction with respect to safety implications. Furthermore Andra's overall process is an important part of its iteration of the disposal facility design with overall aim of optimization.

The IRT also appreciates the use of what-if scenarios, as this enables Andra to get a good understanding of the disposal facility system behaviour under extreme conditions and to illustrate the disposal system robustness.

Although Andra has argued on the basis of the results of their extensive site investigation that the likelihood of water conducting features (e.g. fractures) occurring in the ZIRA area will remain insignificantly low, the IRT suggest that Andra should take into account fracturing of the COX in the frame of what-if scenarios.

Scoping calculations of the required spatial extent and hydraulic characteristics of water conducting features would enable Andra to illustrate:

- The high safety performance of the COX, contributing significantly to the overall disposal system robustness in the post-closure phase;
- The impact of the range of these features within the ZIRA COX on safety to evaluate the robustness of the concept.

RECOMMENDATION

Andra should consider water conducting features within the COX in the frame of what-if calculations in order to further demonstrate robustness of the disposal system, especially the safety performance of the COX.

SSR-5, Requirement 13:Scope of the safety case and safety assessment

"The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and

the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met.

4.17. With regard to safety after closure, the expected range of possible developments affecting the disposal system and events that might affect its performance, including those of low probability, have to be considered in the safety case and supporting assessment by the following means:
(a) By presenting evidence that the disposal system, its possible evolutions and events that might affect it are sufficiently well understood;
(b) By demonstrating the feasibility of implementing the design;
(c) By providing convincing estimates of the performance of the disposal system and a reasonable level of assurance that all the relevant safety requirements will be complied with and that radiation protection has been optimized;
(d) By identifying and presenting an analysis of the associated uncertainties." [2]

4.2 HLW container failure scenario

4.2.1 Manufacturing defects

Andra's position

Andra assumes for the normal evolution scenario (NES) of its safety analysis, that no HLW containers are defective at the time of the disposal facility closure. This will be achieved by a robust design and quality control process to eliminate the possibility of container defects. For the reference situation and the bounding situation, the containers are assumed to lose their leaktightness after 4,300 years and 500 years respectively.

An altered evolution scenario (AES) and a what-if scenario consider immediate loss of containment of a limited number of emplaced HLW containers, and all emplaced HLW containers, respectively. Neither scenario suggests a significant effect on dose in the post-closure period.

IRT observation

Due to the large number of containers to be disposed, there is always a residual probability of defects related to manufacturing and welding (every industrial process has some deviations in the production process). Defects (penetrating and/or non-penetrating) might lead to early failure of containers. The IRT recognises that because of the strength of the Cigéo geology, loss of containment of HLW containers earlier than expected after facility closure is not predicted to cause a significant effect on dose. However, the IRT suggests that Andra clarifies its reasoning for excluding the possibility that any of the HLW containers lose their containment earlier than expected in the post-closure period.

RECOMMENDATION

Andra should substantiate why there is no need for including any initially defective HLW containers or early failure of HLW containers in the normal evolution scenario.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 7: Multiple safety functions and Safety Guide on Geological Disposal Facilities for Radioactive Waste (SSG-14)

"4.16. The performance of a geological disposal system is dependent on different physical components and other features having different safety functions, the importance of which may vary over different time periods. To meet the requirement for multiple safety functions, it is necessary for the safety case to explain and justify the functions provided by each physical component and other features and indicate the time periods over which they are expected to perform. It is also necessary for the safety case to identify the complementary safety functions that will be effective if a physical component or other safety function does not fully perform."[2[. [3]

4.2.2 Microbial activity

Andra's position

Andra states in Safety Options Dossier that the size of the pores in the undisturbed COX or clay seal cores do not allow for significant bacterial growth, due to a lack of space, free water or nutrients. Within the cement-based materials, it is expected that microbial activity will be unlikely, in particular at the interfaces and/or in fractures. In the connected fracture rock zone, the occurrence of bacterial activity will depend on the size of fractures. Any activity that did develop would be limited due to the diffusion conditions and the pore size. The possibility of migration can only be envisaged in a medium that presents high porosity and under the effect of convective transport conditions.

IRT observation

The IRT learned that no effect from bacterial activity in the concrete components, undisturbed clay rock or clay seal cores has been adopted in the scenarios. Microbial activity at interfaces such as the sleeve/clay in the excavated disturbed zone or cementitious material could lead to an increased corrosion rate for metallic parts in the disposal facility. An increased corrosion rate and thus an early loss of the protection function of the sleeve could in turn lead to an increased corrosion rate of HLW-containers. Microbial activity might have an influence on the lay-out of the HLW-cells.

RECOMMENDATION

Andra should include in its safety case and safety assessment microbial activity at the sleeve/back fill interface supported by research on microbial activity as necessary.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 7: Multiple safety functions, and Requirement 3: Responsibilities of the operator and Safety Guide on Geological Disposal Facilities for Radioactive Waste (SSG-14)

"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.

3.13. The operator has to conduct or commission the research and development work necessary to ensure that the planned technical operations can be practically and safely accomplished, and to demonstrate this. The operator likewise has to conduct or commission the research work necessary to investigate, to understand and to support the understanding of the processes on

which the safety of the disposal facility depends. The operator also has to carry out all the necessary investigations of sites and of materials and has to assess their suitability and obtain all the data necessary for the purposes of safety assessment."[2], [3]

4.3 Human intrusion scenario

Andra's position

Andra considers borehole drilling from the surface as the only type of inadvertent human intrusion (HI), given the geological context of the zone of interest for detailed survey (ZIRA) and the depth at which the disposal facility is located. The 6 borehole scenarios are derived regarding three aspects:

- The purpose of the borehole and the geological target formation: target depth and borehole diameters are determined by the technical objective of the borehole and the target geological formation.
- The location of the borehole: the types of possible consequences in terms of deterioration of disposal facility function and modification of the migration conditions for radionuclides and toxic elements are determined by the location of the borehole with respect to the facility architecture (disposal cells and other structures), and with respect to the hydrogeological context.
- Time-based aspects: the possible types of interaction between the borehole and the disposal facility, along with the activity levels of the radionuclides that may be mobilised, are determined by borehole life phases (drilling, use and disuse), in association with the re-saturation situation and evolution of disposal facility components.

According to an estimated risk of occurrence Andra assigns 4 HI scenarios to the group of AES whilst two "very unlikely" HI scenarios, which tend to maximise impacts assigned to the group of what-if cases (conservative characteristics for the intrusive borehole, position of the borehole in the highest activity areas of the ILW or HLW sections).

IRT observation

In general Andra covered the human intrusion scenarios in depth. The analysis of the purpose and location of the borehole and the influence of the borehole depth was carried out according to ASN's guideline "Safety guide on the permanent disposal of radioactive waste in deep geological disposal facilities".

Internationally it is understood, that there is no reliable scientific basis for the prediction of the process or likelihood of inadvertent human intrusion. Since the prediction of resource needs and technological abilities of generations in the far future is speculative, human intrusion scenarios intrinsically cannot be classified according to their probability of occurrence. Furthermore it has to be taken into account that it is impossible to completely eliminate the risk of HI. The risk of HI is an imminent consequence of the principle of concentrate and contain.

RECOMMENDATION

In accordance with international practice, Andra should treat human intrusion separately from the other scenario groups without any judgement on probability of occurrence.

Safety Requirements on Disposal of Radioactive Waste (SSR-5), Requirement 4:Importance of safety in the process of development and operation of a disposal facility

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

"3.20. Consideration has to be given to locating the facility away from significant known mineral resources, geothermal water and other valuable subsurface resources. This is to reduce the risk of human intrusion into the site and to reduce the potential for use of the surrounding area to be in conflict with the facility. The safety of the facility has to be considered at every step in the decision making process to ensure that safety is optimized in the sense discussed in the Appendix."[2]

Appendix A.6 of SSR-5:

"The possibility exists that in the future, an activity or activities undertaken by people could cause some type of intrusion into a disposal facility for radioactive waste. It is not possible to say definitively what form such an intrusion will take or what the likelihood of the intrusion event will be, owing to the unpredictability of the behaviour of people in the future. […]"[2]

4.4 Sensitivity and uncertainty analysis

Andra's position

Andra quantifies the uncertainty of its performance assessment and safety assessment indicators (uncertainty analysis) and the weight of those uncertainties (sensitivity analysis) using a broad range of modern tools and techniques. The investigation of scenario situations and models is treated by deterministic and stochastic approaches, whilst input data are analysed using mono and multi-parametric deterministic or probabilistic methods. Correlations and constraints between input data are identified.

At a higher, concept design level, Andra uses performance assessment to investigate the influence of factors such as inventory location, thermal loading, presence of organics and drift geometry on facility performance. This allows optimisation of the facility design.

IRT observation

Through discussion with the IRT, Andra showed that it applies a systematic and state-of-the-art approach to sensitivity and uncertainty analysis. However, the process by which Andra uses the results of its sensitivity and uncertainty analysis to help setting the priority and direction of its R&D programme is unclear (see also section 3.6).

4.5 Operational safety

Andra's position

The Safety Options Dossier describes three primary principles for design of the disposal facility considering specific characteristics of a facility:

1. An underground facility located at a depth of around 500 m, of reduced geometry and

long connecting drifts, requires specific operating, intervention and evacuation conditions.
2. An operating phase lasting around one hundred years, with the disposal facility being developed in successive phases, presents a need to factor in the risks related to performing underground construction work and nuclear operations in parallel.
3. A coordinated approach encompassing operating safety and post-closure safety that will integrate any changes in the design while ensuring post-closure safety throughout the entire development cycle of the Cigéo project.

Andra considers such an approach, connecting operating safety with post-closure safety, will enable possible optimisation and operating feedback to be managed effectively, integrating any changes in national and international regulations and practices while ensuring implementation of the principle of defence in depth. The possibility of integrating new technical solutions into the design of the disposal facility will thus be confirmed, based on analysis of whether they are compatible with safe facility operation and comply with the post-closure safety requirements.

Andra has explained in the dossier its objective throughout the operating period is to protect people (workers and the public) and the environment based on effective management of the risks resulting from the radioactivity of the waste. Risk management is achieved by the performance of the nuclear safety functions in the facility design for:

1. Containment of radioactive substances to protect against the risk of their dispersion;
2. Protection people from exposure to ionising radiation;
3. Preventing criticality;
4. Removal of the heat produced by waste; and
5. Removal of gases formed by radiolysis in order to manage explosion risks.

IRT observation

The following observations are based on the documentation and information provided by Andra. The IRT focused his review on the methodology of defining the scenarios to consider for the demonstration of safety. Andra has described its approach for the surface facilities and underground facility and has appropriately provided greater attention to the special challenges of operational safety underground, e.g. fire and evacuation from the underground. The IRT considers Andra's methodology for evaluating operational safety is comprehensive and systematic. Andra has presented information in the Safety Options Dossier that covers a wide range of internal and external hazards and the risks for the surface and underground facilities. Andra has also considered retrieval operations and closure activities in assessing the risks for the public and workers. The IRT appreciates that Andra has considered both combinations of events as well as the risks associated with co-activity resulting from simultaneous or successive performance of operations in the same geographical zone or requiring the same utilities or services (various operations and interferences between these operations are likely to transfer potential hazards from one zone to another, or from one activity to another).

Andra has highlighted the concern for the potential for fire in the underground and has appropriately provided significant information on the prevention and protection measures required to reduce the risks identified. The discussions included ventilation and filtration systems for the ILW disposal cells (e.g. redundant air supply and extraction functions, sensors at the ILW cell exit, switches to emergency generators located at the surface); simple, robust ventilation system operating principles for underground drift ventilation are as follows (e.g. limiting actions and changes required when switching ventilation between nominal conditions

and fire conditions); the design of the disposal cell and the ventilation system to withstand potential hazards (in particular collision, earthquake, rising temperatures, etc.); and the presence of filtration rooms (DNF of cells) containing the filtration housings of the ILW disposal cells. However, a scenario where the wrong compartment doors are closed or where the wrong ventilation protocol is activated is not described. Such a scenario could result from human error and examining the effects of such a scenario could be useful to give an idea on the robustness of the system.

The IRT considers Andra has also given significant and appropriate attention to evacuation of personnel from the underground given the current stage of design. In particular, Andra has described in the dossier its approach for evacuation of a large number of construction personnel at the bottom compared with the evacuation routes to the surface (a combination of shelter in place and organised and accompanied evacuation) as well as evacuation in a fire situation (each zone has its own routes for evacuation of personnel, however, in the case of a fire situation evacuation of personnel is possible from the operating zone via the construction zone and vice versa).

The IRT was impressed with Andra's approach for documenting lessons learned from other tunnel and mine accidents to provide guidance on the best practices for the future construction and operation of Cigéo and, more especially, for the underground infrastructure: surface-bottom connections including the waste package ramp, service ramp, shafts and underground facility. The IRT understands that at this stage of the design the risk analyses is expected to continue and Andra will use the results to further assist the detailed design.

Andra discussed its approach for estimating radioactive exposure to the public during operations and stated its intention for using the same assumptions, where appropriate, for estimating worker exposures. The IRT observed that certain conservative assumptions (e.g. radionuclide release from the waste containers) for use in estimating public exposures could be overly conservative for estimating worker exposures due to the proximity of workers to potential releases. Thus, estimates for worker exposures may require the use of more realistic assumptions.

SUGGESTION

Andra should consider the use of filtration of exhaust air from the underground facility as a defence in depth measure for limiting radioactivity releases due to incidents or accidents.

Safety Assessment for Facilities and Activities (GSR Part 4 Rev. 1), Requirement 10: Assessment of engineering aspects

"It shall be determined in the safety assessment whether a facility or activity uses, to the extent practicable, structures, systems and components of robust and proven design."[4]

5. POST FUKUSHIMA ACTIONS

Andra's position

The Safety Options Dossier describes Andra's approach to complementary safety assessments (CSA), which may also be referred to as "stress tests". The CSA assesses the safety margins of nuclear facilities with regard to extreme natural phenomena, and testing facility safety functions that could lead to feared situations. In particular the dossier states "the purpose of the stress tests is to assess the robustness of the installation in the light of the events which occurred at

Fukushima, that is extreme natural phenomena compromising the safety of the installations."

For example, the dossier describes the potential for an explosion in the ILW cells resulting from the consequences of an earthquake of greater intensity than the safe shutdown earthquake or a long-duration loss of electrical power and described design controls for such a scenario (e.g. enhanced stability of air return drifts to prevent obstruction of renewal air circulation in the cells; the presence in the installation of ultimate backup mobile electrical power means and the deployment on the site of trained response crews able to utilise the emergency power within a time-frame shorter than the time taken for the lower explosion limit to be potentially reached in an ILW disposal cell).

IRT observation

Andra has drawn upon specifications for the "stress tests" on nuclear installations drawn up by ASN in the wake of the accident in Fukushima as a guideline for integrating complementary safety assessments into the design of Cigéo. In discussions with Andra, the IRT learned that Andra has considered an appropriate range of natural events (e.g. tornados and seismic activity) in the design of the facility to withstand extreme events (e.g. seismic event with a ground motion 1.5 times larger than events considered credible for the region). Additionally, safety dossier discusses the types of accident conditions that could lead to extreme conditions that are being evaluated as part of the detailed engineering design (APD) to help ensure the robustness of the design of the facility. In particular, Andra has considered fires, explosions, and containers falls as resulting from a large seismic event as well as a total loss of on-site electrical power.

The IRT supports Andra use of the CSA as a means to identify the main functions and systems/equipment affected by extreme events and improving, as necessary, important protective safety functions in as part of the APD.

SUGGESTION

Andra should evaluate the robustness of its design for removal of high water ingress from tunnels/ramp sections crossing the upper aquifer combined with failure of power supply to pumps due to the occurrence of a potential extreme event.

Safety Assessment for Facilities and Activities (GSR Part 4 Rev. 1), Requirement 10: Assessment of engineering aspects

"It shall be determined in the safety assessment whether a facility or activity uses, to the extent practicable, structures, systems and components of robust and proven design."[4]

APPENDIX 1: TERMS OF REFERENCE

1. Introduction

In line with the license application in 2018 of the creation of the geological disposal of high level and intermediate level radioactive waste in France, Andra will submit early 2016 to the French Nuclear Safety Authority (ASN) a « Safety Options Dossier - DOS», presenting the main technical options ensuring the safety of the disposal project.

The whole "Safety Options Dossier" will be submitted to an instruction by ASN with the support of IRSN (French Technical Support Organization) and the French Standing Groups of Experts on "Waste" and "Laboratories and Plants".

With the view to complement the instruction by ASN, and in line with the recommendation of the IAEA Nuclear Safety Action Plan encouraging the Member States to voluntarily host IAEA peer reviews, including follow-up reviews, on a regular basis; the French Nuclear Safety Authority requested the IAEA to organize and perform in 2016 an International Peer review of some elements of the "Safety Options Dossier".

2. Objective

The peer review will provide an independent international evaluation, based on the requirements set out in the IAEA safety standards, of the "Safety Options Dossier" (Dossier d'Options de Sûreté – DOS) submitted by the French National Radioactive Waste Management Agency (Andra) to the French Nuclear Safety Authority (ASN).

The review, organized in the IAEA by the Department of Nuclear Safety and Security in cooperation with the Department of Nuclear Energy, will be performed against the relevant IAEA Safety Standards and proven international practice and experiences with the combined expertise of the international peer review team.

3. Scope

The peer review will assess the following aspects of the "Safety Options Dossier":

- The strategy of research & development and knowledge acquisition (including the demonstrators) and its adequacy with the phased development of the facility. In particular the review will address the expectations at the different phases of development of the facility to match the authorization process,
- The approach for definition of long term safety scenarios including intrusion scenarios, safety scenarios during operation (excluding malevolent acts), and the plan for surveillance during operation.
- Post Fukushima actions (e.g. extreme scenarios). This point will be addressed under the form of discussion.

4. Basis for the review

As indicated earlier the peer review will be carried out against the relevant IAEA safety standards and proven international practice and experience.

The basis for the review is the "Safety Options Dossier" developed by Andra. According to Andra the planning for delivery of the Dossier to ASN and the documentation for the purpose of the peer review is the following:

- Date of delivery of the DOS to ASN: April 2016

- English translation of documents for the peer review: 2 Months

A non-exhaustive list of references as support to the peer review is given in Section 9 below.

5. Modus operandi

The working language of the mission will be English.

According to the planned delivery of documentation as indicated in section 4, the peer review is planned to be performed according to the following schedule:

- Reception of English documents: July 2016
- Preliminary analysis by the experts July August 2016
- Questions to the counterpart: September 2016
- Peer review mission:10 days
    - arrival for Sunday meeting,
    - work Monday to Friday: exchange with Counterpart(s) on the basis of preliminary analysis and drafting of recommendations and suggestions
    - Saturday-Sunday: drafting of the report
    - Monday: Delivery of draft report/recommendations – fact checking and discussions
    - Tuesday: Official delivery

6. International peer review team

The IAEA will convene a team of international experts to perform the peer review according to the agreed Terms of Reference. The team will comprise 7 qualified and recognized international experts mainly from regulatory bodies and technical support organizations with experience in the safety of disposal of radioactive waste and radiation protection and 2 IAEA staff respectively from the Waste and Environmental Safety Section (Department of Nuclear Safety And Security) and the Waste Technology Section (Department of Nuclear Energy). The peer review team will be led by a Chairman. The IAEA will formally inform France regarding the composition of the proposed review team prior to conducting the mission.

7. Reporting

The findings of the peer review will be documented in a final report that will contain the proceeding, the recommendations and suggestions. The report will reflect the collective views of the team members and not necessarily those of their respective organization or Member State or the IAEA.

The Peer Review Report will be delivered to the French Nuclear Safety Authority, for fact-checking only, prior to finalization.

According to preliminary discussions the French Nuclear Safety Authority indicated its intention to publish the final report of the peer review. Communication on the organization and outcomes of the peer review is planned.

8. Funding of the peer review

The peer review activities will be funded by France. The costs for the services will be limited to the travel costs and per diem of the peer review team (external experts and IAEA staff) and external expert fees in line with IAEA Financial Regulations and Rules. A provision of 10 days of home based assignments for the preliminary review of the documentation by the experts will also be included in the overall cost.

The costs of official publication of the final report of the peer review (see Section 7 above) will also be covered by France.

9. Reference documentation for the review team

The IAEA Safety Standards will serve as the main referential framework for evaluation, including the followings:

— INTERNATIONAL ATOMIC ENERGY AGENCY, Fundamental Safety Principles, IAEA Safety Standards Series No. SF-1, Vienna, (2006);

— INTERNATIONAL ATOMIC ENERGY AGENCY Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - Interim Edition General Safety Requirements Part 3, IAEA Safety Standards Series No GSR Part 3, IAEA, Vienna, (2011)

— INTERNATIONAL ATOMIC ENERGY AGENCY Safety Assessment for Facilities and Activities Safety Requirements, IAEA Safety Standards Series No GSR-Part 4, Vienna, (2009);

— INTERNATIONAL ATOMIC ENERGY AGENCY, Disposal of Radioactive Waste Safety Requirements, IAEA Safety Standards Series No SSR-5, IAEA, Vienna (2011);

— INTERNATIONAL ATOMIC ENERGY AGENCY, Classification of Radioactive Waste, IAEA Safety Standards Series No GSG-1, IAEA, Vienna (2009)

— INTERNATIONAL ATOMIC ENERGY AGENCY, The Safety Case and Safety Assessment for the Disposal of Radioactive Waste, Safety Guide (DS 355 in publication – to be published under SSG-23)

— INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for Facilities and Activities, Safety Standards Series No. GS-R-3, IAEA, Vienna (2006)

— INTERNATIONAL ATOMIC ENERGY AGENCY, The Management System for the Disposal of Radioactive Waste, GSG-3.4, IAEA, Vienna (2008)

APPENDIX 2: THE PEER REVIEW TEAM

Felix Altorfer (Switzerland)

Felix Altorfer studied physics at the Swiss Federal Institute of Technology (ETH) Zurich, and obtained his doctorate in 1994 at the Laboratory for Neutron Scattering at the ETH Zurich. After working in the USA for four years at the NIST Center for Neutron Research at the National Institute of Standards and Technology, he returned to Switzerland to undertake research at the Swiss Spallation Neutron Source (SINQ) of the Paul Scherrer Institute in Villigen.
In 2002, Felix Altorfer joined ENSI, where he worked as a Modeller in the Deep Geological Repositories section; in 2009, he became Head of the Deep Geological Repositories and Safety Analyses section. His work focused on safety calculations for the compilation of the assessment on proof of waste management for highly radioactive waste in the Zurich Weinland region, and on contributions to the assessment regarding the choice of sites in connection with the sectoral plan for geological repositories; this also covered the specific design principles for deep geological repositories and the requirements for proof of safety.
In September 2010 he became Director of the Waste Management Division. On 1 August 2012 he was nominated Director of the Staff of the Directorate, which comprises the Legal Affairs, International Affairs and Communication Sections.

Björn Dverstorp (Sweden)

Björn Dverstorp holds a position as senior advisor in geological disposal at the Office for International Relations at the Swedish Radiation Safety Authority (SSM) since 2013. He has more than 25 years of experience of regulatory research and review related to radioactive waste disposal and post-closure safety assessments with the Swedish safety authorities. He was project leader of a major regulatory safety assessment (SKI SITE-94) and has led regulatory reviews of several post-closure safety assessments for disposal of spent nuclear fuel as well as a major review of the SFR repository for low and intermediate level waste. He was responsible for developing the review plan for post-closure safety of the industry's license application for a spent nuclear fuel repository in Sweden, and led the initial review of the post-closure safety case. He led the development of post-closure safety regulations at the Swedish Nuclear Power Inspectorate and at the Radiation Protection Authority. Since 2013 he is Sweden's point of contact for the Joint Convention. In 2015 and 2016 he had a leading role in a cooperative support project with the government of Georgia aiming at developing a national strategy for the management of all radioactive waste. His academic background comprises a master in geological sciences and a doctoral thesis on modelling of flow and transport in crystalline rock.

Klaus Fischer-Appelt (Germany)

Klaus Fischer-Appelt has been working in the field of disposal of radioactive waste for more than 20 years. In 1994 he joined GRS, the German technical support organisation for reactor safety and nuclear waste management. He has a doctoral degree in natural science. As a geologist he is an expert for post closure safety analyses and assessment for geologic disposal facilities. Since 2009 he is the head of the GRS department for final disposal in the division for radiation protection and environment protection. He is a member of the German Nuclear Waste Management Commission (ESK), an advisory body for the federal ministry for Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) in matters of nuclear waste management.

Jussi Heinonen (Finland)

Mr. Heinonen joined the Finnish Radiation and Nuclear Safety Authority (STUK) in September 2002. He was appointed in beginning of 2016 as director responsible for Nuclear waste and Materials Regulation. Before current position Mr. Heinonen worked from 2009 as section head for Nuclear Waste Facilities Regulation, which is responsible for the regulatory oversight of nuclear waste facilities design, construction and operation in Finland. Mr. Heinonen has been closely involved in regulatory oversight of spent nuclear fuel disposal. After joining STUK Mr. Heinonen was responsible for disposal canister and engineered barrier system oversight. Later he has been responsible for oversight of underground rock characterization facility (Onkalo URCF) construction, enlargement of Olkiluoto spent fuel interim storage and preparation to review Posiva's construction license application. Mr. Heinonen has participated in IAEA projects and missions related to waste management and he is a member of ENSREG working group on Waste Management and Decommissioning.

Doug Ilett (UK)

Doug Ilett has been working in the field of radioactive waste for more than 20 years. After his PhD in chemistry he worked at the Harwell nuclear site in the UK for AEA Technology and subsequently Serco Assurance, where he worked on a range of geological disposal and nuclear waste related projects for UK and overseas programmes. In 2002 he was seconded for a year to Nirex to work on its programme to provide predisposal advice on geological disposal to the UK nuclear industry. In 2003, he joined the Environment Agency (England) as part of its Radioactive Substances Regulation unit. Since 2007 he has managed its Nuclear Waste Assessment Team, which provides the Environment Agency's assessment capability for predisposal and disposal activities associated with all types of radioactive waste facilities, including scrutiny of the UK's developing programme for geological disposal. Doug was recently a member of the steering group of the OECD NEA's Integration Group for the Safety Case (IGSC) for 6 years and he also holds a diploma in Applied Management.

Timothy McCartin (US)

Timothy McCartin has over 35 years of experience in the field of geological disposal of radioactive waste at the U.S. Nuclear Regulatory Commission (NRC). Since joining the U.S. Nuclear Regulatory Commission, he has been involved, with increasing levels of responsibility, in the development and application of (1) performance assessment approaches and computational tools for evaluating the safety of geological disposal and (2) regulations for geological disposal. In his current position, he is responsible for ensuring technically sound performance assessment approaches and concepts are implemented at the NRC in the review of license applications of waste management facilities and the development of performance assessments of waste management facilities. He also was the technical lead for the development of 10 CFR Part 63 – the regulatory criteria that would govern any U.S. Department of Energy license application for a high level waste repository at Yucca Mountain. Additionally, he was a lead reviewer of the U.S. Department of Energy's License Application for Yucca Mountain.

Geert Volckaert (Belgium)

Geert Volckaert has been working in the field of disposal of radioactive waste for more than 30 years. After his degree in chemical engineering in 1985 he joined the Study Centre for Nuclear Energy (SCK•CEN) at Mol, Belgium, originally to work in the field of performance and safety assessment for nuclear waste disposal both at the surface and geological disposal in clay.

From 1988 onwards he was also involved in experimental work including the design, installation and follow-up in situ experiments in the underground research facility HADES in the Boom Clay. His experimental work was mainly related to backfill and sealing, and gas transport in clay. He was involved in the development of waste disposal programmes in several East European countries. He became head of the expertise group on Waste and Disposal and deputy manager for the Institute for Environment, Health and Safety of the SCK•CEN. In 2013 he joined the Federal Agency for Nuclear Control (FANC, the Belgian nuclear regulator) as head of the section for nuclear waste management and disposal. Currently the main activities of this section are the instruction of the safety file for the license application for the surface disposal of nuclear waste and the pre-licensing preparations for geological disposal of the medium and high level waste.

Gérard Bruno (IAEA)

Gérard Bruno has been working in the field of disposal of radioactive waste for more than 20 years. After his PhD in Geology he joined the French Institute for Radiological Protection and Nuclear Safety, IRSN, the technical safety organization supporting the French Safety Authority, where he mainly worked on the review of the feasibility studies for the deep geological disposal of HLW in argillaceous formations. In 2006 he was seconded in the Directorate General for Transport and Energy in the European Commission and joined the IAEA as waste safety specialist in 2009. Since August 2010 he is the Head of the Radioactive Waste and Spent Fuel Management Unit in the IAEA. The main activities of the unit are the development of safety standards on predisposal and disposal of radioactive waste as well as their application through assistance missions, peer reviews and organization of international harmonization projects.

Philippe Van Marcke (IAEA)

Philippe Van Marcke has 10 years of experience in the field of the geological disposal of radioactive waste. He joined the Belgian Nuclear Research Centre in 2007 where he mainly worked on R&D studies conducted in the underground research facility HADES in the framework of ONDRAF/NIRAS's geological disposal programme for long lived and high level waste. In 2010 he moved to the Belgian waste management organisation ONDRAF/NIRAS and coordinated the R&D studies on the feasibility of the ONDRAF/NIRAS's geological disposal programme. Since 2015 he makes part of the Disposal Unit in the IAEA. The main activities of the unit are supporting Member States to find and apply safe, prompt and cost-effective solutions for the disposal of all forms of radioactive waste.

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