IRSN safety research carried out for reviewing geological disposal safety case

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Abstract. The Radiation Protection and Nuclear Safety Institute develops a research programme on scientific issues related to geological disposal safety in order to supporting the technical assessment carried out in the framework of the regulatory review process. This research programme is organised along key safety questions that deal with various scientific disciplines as geology, hydrogeology, mechanics, geochemistry or physics and is implemented in national and international partnerships. It aims at providing IRSN with sufficient independent knowledge and scientific skills in order to be able to assess whether the scientific results gained by the waste management organisation and their integration for demonstrating the safety of the geological disposal are acceptable with regard to the safety issues to be dealt with in the Safety Case.

1. Introduction

The Radiation Protection and Nuclear Safety Institute (IRSN) is the public body in charge of the scientific assessment of nuclear and radiation risks. It is mandated for advising the public authorities and contributing to public policies, for delivering services to other organisations and for developing the research activities necessary to support its scientific appraisal.
The key fields of research relate to safety of nuclear installations and waste, to severe accidents in nuclear reactors and emergency preparedness, to radioactivity and ecosystems and to radiation protection.

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

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

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

the risk of explosion relevant to hydrogen produced by radiolysis in waste cells, the ability to remedy a situation caused by a package fall in cells and the possibility of retrieving waste,

- the sealing capabilities with the view to assessing the likely performances of a sealing engineered structure, taking into account the effects of potential disturbances over time or difficulties for emplacing seals at industrial scale,
- the long term performances of the repository with emphasis on hydrogeological modelling, integrated transfer of radionuclides and biosphere modelling. It is particularly important to be able to rule on whether or not localised preferential transfers exist and to assess their influence on the general flow patterns.

2. Purpose of safety research activities carried out by IRSN

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

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

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

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

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

3. Technical means and studies

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

- the diffusion mechanisms in stiff clay (origin of over-pressures and influence of pore size on water-rock interactions…). Many characterization methods (devoted to characterise movement of natural tracers…) have been tested [1], [2]

- the hydraulic role of faults/joints : survey methods (seismic survey analysis combined with others methods…) used to identify fractures in clay and their potential as water pathway have been tested, [3]

- the differential fracturing phenomenon in clay and its high damping potential, [4], [5]

- the EDZ development: characterisation methods and modelling have been used and developed taking advantages of, on the one hand the 100 years passed since tunnel construction, and, on the other hand the observation of new drifts recently drilled, [6]

- the clayey materials evolution due to cement-clay / iron-clay interactions by characterisation and modelling of 10-year old in situ experiments (using a coupled transport/chemistry code Hytec developed by Ecole des Mines de Paris), [7]

- the chemical conditions during transient processes and the specific effects of the presence of micro-organisms or of redox conditions (characterisation of processes upon Tournemire data) on the waste or engineered components degradation over time, [8]

- the parameters that will have to be specified and controlled in situ to warrant the performance of seals and concrete liners; a dedicated *in-situ* mock-up is under development and will be implemented in TES to study altered evolution of seals, [9]

Besides the Tournemire Experimental Station, specific studies are in progress in complementary scientific fields by the means of experimental, theoretical and modelling developments with the view to:

- better understanding the transient phenomena: for example the behaviour of hydrogen generated by corrosion, the influence of radiolysis, the hydromechanical behaviour of underground spaces which are excavated, exploited and backfilled at the end of their service life… [10], [11]

- better knowing of the waste matrix and packages performances, [12]

- modelling flow and transport of radionuclides by developing computer models simulating the underground flow patterns at various scales in the vicinity of the Bure site as well as radionuclide migration from the waste packages to the biosphere (3D computer code MELODIE), [13], [14], [15]

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

Those activities involve scientific calculations with computer tools that are developed either internally or in cooperation. Those calculations aim at modelling complex processes at various scales with the view to interpreting the results of the experiments and test different assumptions to assess the influence of the data on the order of magnitude of the processes describing the evolution of the disposal in space and time. Those results are then used to assess the safety assessment developed by the waste management organisation in the safety case [16].

4. Organisational aspects

Because of the complexity and large scope of issues to be addressed, IRSN promotes a multi-disciplinary approach integrating experimentalists, modellers and experts of safety who work together

on each of the topics of interest for safety. This synergy between research engineers and experts in safety assessment is a valuable tool to ensure consistency and quality of technical assessment. Scientific partnerships with research facilities and universities is the preferred strategy of IRSN in order to be able to take benefit of high level scientific skills in different specialities and for a duration compatible with the planned time frames of the assessment process (several decades).

Part of IRSN research programme is integrated in the EURATOM Framework Programme related to radioactive waste management research which offers a valuable framework for achieving results and for sharing experience among countries involved in waste safety. IRSN is currently involved in the FORGE project (7^{th} Framework Programmes) and coordinates a work package aiming at developing experiments and models of hydrogen evolution from corrosion and water radiolysis processes. IRSN supports also international research programmes as the Mont Terri or DECOVALEX projects as well as bilateral cooperation with homologous organisations in foreign countries.

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

5. Conclusion

Because of time constraints, it is of crucial importance to be able to anticipate the development of knowledge and resources required to assess risks posed by nuclear facilities in the future, and in particular waste management safety. It is the reason why IRSN has identified very early in the French geological repository project development the scientific issues that had to be addressed in priority. This enabled IRSN to optimise the resources allocated to research. These resources are periodically assessed with respect of the progress made in studies, the new issues to be taken into account and duly planned, as well as the regulatory review agenda that requires to swap research and assessment activities.

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

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

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