The Use of Underground Research Facilities for the Demonstration of Safety of Geological Disposal – 15094

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ABSTRACT

Many countries are progressing towards developing research programmes related to the development of geological disposal facilities and as part of these research programmes many countries have constructed or are planning to construct Underground Research Facilities (URFs).

The development of the safety case for geological disposal facilities, which covers both the operational phase and the post-closure phase, is built on the acquisition and integration of all necessary data including data on the natural and engineered barriers, on the facility itself (design), on the operation of the disposal facility, and in the specific case of geological disposal facilities, the conditions at the depth of disposal relevant for both in-situ and waste emplacement states. Taking these conditions into account can make the demonstration of safety more complex and demanding than for near surface disposal facilities.

Most if not all of the countries well advanced in the development of geological disposal facilities have also developed underground research facilities to support the decision processes within their disposal facility development programme.

Underground Research Facilities play an essential role in the demonstration of safety of geological disposal facilities and a distinction has to be made between data acquired from surface based investigations and boreholes and those data and experiments carried out in-situ.

The use of in-situ data contribute to build confidence in the demonstration of safety and contribute to public confidence and acceptance of geological disposal facilities. Further discussion will elaborate on whether to use the URF as part of a future disposal facility or not, with an emphasis on the transposition of data from the experimental site to the disposal site and how this is addressed and validated in the demonstration of safety.

INTRODUCTION

The development of a geological disposal facility for high level radioactive waste does not specifically require the preliminary development of an underground research facility. Within the IAEA safety standards on the disposal of radioactive waste [1, 2, 3] there is no specific requirements or recommendations on the need to construct underground research or characterization facilities.

However most if not all of the programmes for the management of high level radioactive waste in progress around the world have constructed or are planning to construct such underground research facilities.

The demonstration of safety of geological disposal facilities through the development of the safety case and supporting safety assessment [3] is built on the acquisition and integration of all necessary data including data on the natural and engineered barriers, on the facility itself (design), and on the operation of the disposal facility. Data for the purpose of understanding the disposal facility and its evolution with time and for the purpose of the demonstration of safety are acquired from surface investigations but also in situ through the development and use of underground research facilities.

The present paper discusses the role of underground research facilities in the development of safe geological disposal facilities. More specifically the paper addresses the link and complementarity between the data obtained from surface investigations and data collected from in-situ research for the purpose of the demonstration of safety of geological disposal facilities. The paper also discusses the evolution of the safety case all along the development of the disposal facility and the concomitant collection of additional data, in particular through the development of in situ research programmes. Finally, the roles of underground research facilities as well as the advantages and possible drawbacks of developing such research facilities are discussed and used to conclude on whether or not underground research facilities should be required for the development of all geological disposal facilities.

DISCUSSION

Geological disposal is the emplacement of solid radioactive waste in a stable geological formation, at least a few hundred metres below ground level [2, 3]. A distinctive feature of geological disposal is that post-closure safety of the facility is provided, in part, by passive means inherent in the characteristics of the geological formation. This implies that the safety of the facility after closure does not rely on future human actions or interventions.

Because of the above and other elements, the demonstration of safety of geological disposal facilities, through the development of a safety case and supporting safety assessments is a complex and long process which requires the collection of large amounts of data on the different components of the facility. At all steps in the development of a geological disposal facility the demonstration of safety of the disposal project relies on a detailed characterization and understanding of the different components of the facility (host rock, engineered barriers…) and their properties as well as the interactions between these different components.

Among these components the host rock is one of the main elements and its characterization has to be performed to the appropriate level of detail to support the demonstration of safety. In this regard, Requirement 15 of [1] indicates that the site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time.

As one of the essential inputs for the safety case of geological disposal facility, much attention is given to the characterization of the host rock in the first phases of development as part of the site selection and site characterization processes but also all along the development of the disposal facility. Rock characterization starts with surface investigations as well as borehole sampling which allow collecting host rock samples from the foreseen depth of disposal. Samples are used not only to characterize the host rock itself (mineralogy, geochemistry, mechanics) but also to

carry out experiments to understand the long term behaviour of the rock in simulated disposal conditions and to evaluate the consequence of the interactions of the different components of the disposal facility with the host rock in terms of physico-chemical properties (desaturation, evaluation of the excavation disturbed zone, cement-rock interactions, iron-rock interactions, etc.).

As mentioned earlier there is no international position that prevents developing a safety case and establishing a safe geological disposal facility only using surface investigations and the collection of samples at the disposal depth from the surface. But such an approach would likely make the demonstration of the safety of the disposal facility more complex.

Such an approach would also not decrease the amount and amplitude of uncertainties on the rock characteristics and behaviour. Indeed in the first phases of developing a geological disposal facility the safety case is rather generic, established on the basis of limited amounts of data. Safety assessments carried out on the basis of this preliminary characterization are consequently rather simplified, in many cases by using conservative assumptions. Such preliminary safety assessments will allow identifying uncertainties and, with the view to manage and reduce these uncertainties for the purpose of demonstrating the safety of the facility, research programmes are defined and implemented. Using URFs to give access to in situ samples and testing locations will contribute to carry out dedicated research programmes and to reduce the uncertainties.

Surface based characterization and experiments on samples collected from the surface give a first overview of the characteristics of the host rock and, through experiments, provide preliminary results on the behaviour of the host rock in potential disposal conditions. Experiments performed in surface laboratories on rock samples aim at reproducing, as realistically as possible, the conditions of disposal. But the results obtained in surface laboratories are ideally confirmed in real in-situ conditions using underground research facilities. Such an approach builds confidence in all stakeholders, including the proponent.

Many experiments are carried out in a first approach in laboratories such as cement-clay interactions, desaturation experiments, iron-clay interactions, diffusion experiments, etc., but most if not all of them will later be performed and hopefully confirmed in in-situ conditions when a URF is available. Moreover, in many cases experiments carried out in surface laboratories will be used to design and develop in-situ experiments (scoping calculations, scaling effects, etc.) and in this regard are complementary to URF experiments and build confidence.

The demonstration of safety of the facility will also benefit from results of real disposal conditions experiments or “demonstrator/mock-up experiments”. Indeed URFs give an opportunity to study the long term behaviour of disposal conditions as many experiments are developed, or are planned to be performed, in URFs through mock-up experiments of the behaviour of disposal galleries and disposal cells closure systems (seals).

URFs can in some cases be used by the regulatory body or technical support organizations to develop its own research programmes on the behaviour of the host rock in simulated disposal conditions, with the view to build its own expertise in the safety of geological disposal. Such expertise will then be used to evaluate the safety of geological disposal programmes as part of the licensing process.

URFs established at one stage in the development of the geological disposal facility are obviously considered a complementary tool to surface investigations. As such URFs reinforce the demonstration of the safety of the geological disposal facility and contribute to reassure the operator as well as the regulator on the safety of the facility. It also contributes to build confidence of all stakeholders, including the public, in the safety of the facility.

Beside their benefit for the demonstration of long term safety of geological disposal facilities, URFs are of strong benefit for studying operational safety including waste disposal operations, ventilation processes, and waste emplacement equipment and processes. URFs will also allow testing of construction techniques, including their effects on the rock properties.

In some cases URFs are developed as part of the future disposal facility, and in this case the facility is sometimes called a rock characterization laboratory as it is the case with the Finnish underground rock characterization facility ONKALO. In other cases the URF is not considered as part of the future geological disposal facility. In this latter case the safety case will have to address how the data collected in the URF and the results of in situ experiments are transposable to the actual site of the future geological disposal facility.

CONCLUSION

The use of URFs or underground rock characterization laboratories is of high added value for the safety case development of geological disposal facilities. Their role is essential in understanding the long term behaviour of the disposal facility but also in the operation of the disposal facility. The safety case for a geological disposal facility is the primary way to demonstrate its safety in the licensing process. The safety case evolves along with the development of the geological disposal facility. In the first steps the safety case is rather generic and is built on simple data and assumptions while the need for more realistic, accurate and representative data increases along with the development of the disposal facility. Moving from a generic to a site specific safety case requires the accumulation of additional and more representative data and in this regard the use of Underground Research Facilities is essential. In addition URFs are also essential tools for studying the real disposal conditions in particular the operational and long term behaviour of all disposal components (natural and engineered barriers) in such conditions.

Even if there is no specific requirement on the use of URF in the development of disposal facilities, their establishment as part of disposal programmes and in particular as part of the development of geological disposal facilities seems obvious. IAEA safety requirements on disposal of radioactive waste indicate that the site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time, and in this regard URFs play an essential role. This is not to suggest that elaborate full-scale URFs are required for every disposal programme, however, much operational, design, and long-term safety information can be obtained through the use of URFs. In fact, one of the essential services that can be provided to repository programmes around the world is the facilitation of possible cooperative work at URFs [4, 5].

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