The TIMODAZ project – Main Issues

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Nature and scope of the project

In all nuclear power generating countries, the management of spent nuclear fuel and long lived radioactive-waste is an important environmental issue today. Disposal in deep clay geological formations is one of the promising options worldwide to dispose of these wastes.

In this concept of the geological disposal system, the host clay formations is considered as a principal barrier on which rest the fulfilment of key safety functions. Hence, preventing unnecessary damage to the host formation is one of the objectives of repository design. A proper evaluation of the Damaged Zone (DZ) in the host formation is thus an important item for the long-term safety of underground disposal.

In any case, the excavation process of the geological repository cavities (disposal drifts, transport galleries and access shafts) and its later operation inevitably lead to the creation of a Damaged Zone (DZ) within the clay around the engineered part of the disposal system (Davies and Bernier, 2005). The role that the so-called Excavation Damaged Zone (EDZ) may play in the transport of radionuclides following closure of the repository and degradation of the waste packages has been the research subject of the EC FP5 project SELFRAC (SELFRAC, 2007).

As a side effect of radioactive decay, vitrified high-level wastes and spent fuel release significant amount of heat, even after several decades of cooling in surface facilities. The influence of the thermal load generated by the radioactive waste on the performance of the disposal system is particularly important since the early transient THM (Thermo-Hydro-Mechanical) perturbation might be the most severe impact the repository system will undergo on a large spatial scale and in a relatively short period of time. Assessing the consequence of the thermal transient on the performance of the disposal system is the main objective of the proposed TIMODAZ project.

The TIMODAZ project (Thermal Impact on the Damaged Zone Around a Radioactive Waste Disposal in Clay Host Rocks) focuses on the study of the combined effect of the EDZ and the thermal output from the waste on the repository host rock. The influence of the temperature increase on the evolution of the EDZ as well as the possible additional damage created by the thermal load will be studied. The chemical evolution as well as its interaction with the THM processes around the underground repository will be addressed, but in limited extent, in the project.

Main issues related to the thermal impact

The disposal of heat emitting radioactive waste will induce disturbances in the host rock. The disturbances can be of different types and are often coupled: thermal (T), hydraulic (H), mechanical (M) and chemical (C). The THMC responses will highly depend on the initial and the boundary conditions imposed by the repository design, as for example:

- the hydraulic boundary conditions around the waste imposed by the repository design
- the pore pressures reached around the disposal gallery before the waste disposal
- the mechanical conditions imposed by the lining

- etcetera

The overpressure generated in the host rock by the temperature rising depends highly on the hydraulic boundary conditions of the disposal gallery. This will in turn be controlled by the hydraulic properties of the seal closing the disposal gallery and by the saturation of the engineered components reached before the disposal of the waste. The thermal induced pore pressure build-up will be much more pronounced if a rather impermeable hydraulic boundary condition is assumed. The impermeable boundary condition constitutes therefore a more critical situation for the host rock.

During the open drift period, pore water will flow from the host rock towards and into the disposal tunnels. Depending on the different national concepts and especially on regulatory guidelines with respect to monitoring and reversibility, such open drift phases could range from one month to a few years. On the one hand, the long term drainage of the disposal gallery will enhance the hydromechanical coupling due to the pore pressure drop and induce contracting strains that are able to create additional plastic deformation and/or damage (micro-macro) and thus increase the DZ that may have been limited by tunnel support. On the other hand, this may constitute, from a purely thermo-hydro-mechanical point of view, a favourable factor (less thermal induced pore pressure build-up) for the safety of the repository system. Meanwhile, the open drift will be ventilated and suction (possibly partial de-saturation) could evolve in the rock close to the tunnel wall. This suction could improve the hydro-mechanical properties of the rock (decrease the permeability and increase the shearing strength). However, the excess desaturation may evoke additional damage through tensile failure and will affect the THMC coupled responses of the repository system (oxidation, etc.). The long term drainage also favourises the sealing process as observed in Boom Clay around the URL HADES.

Consequently, the maximum thermal source term is not the only issue to be considered when assessing the thermal impact of heat emitting waste. Other design issues controlling the hydraulic conditions of the repository system are also important to be taken into account.

Project structure and objectives

The project is broken down in 7 Work Packages (see Figure 1).

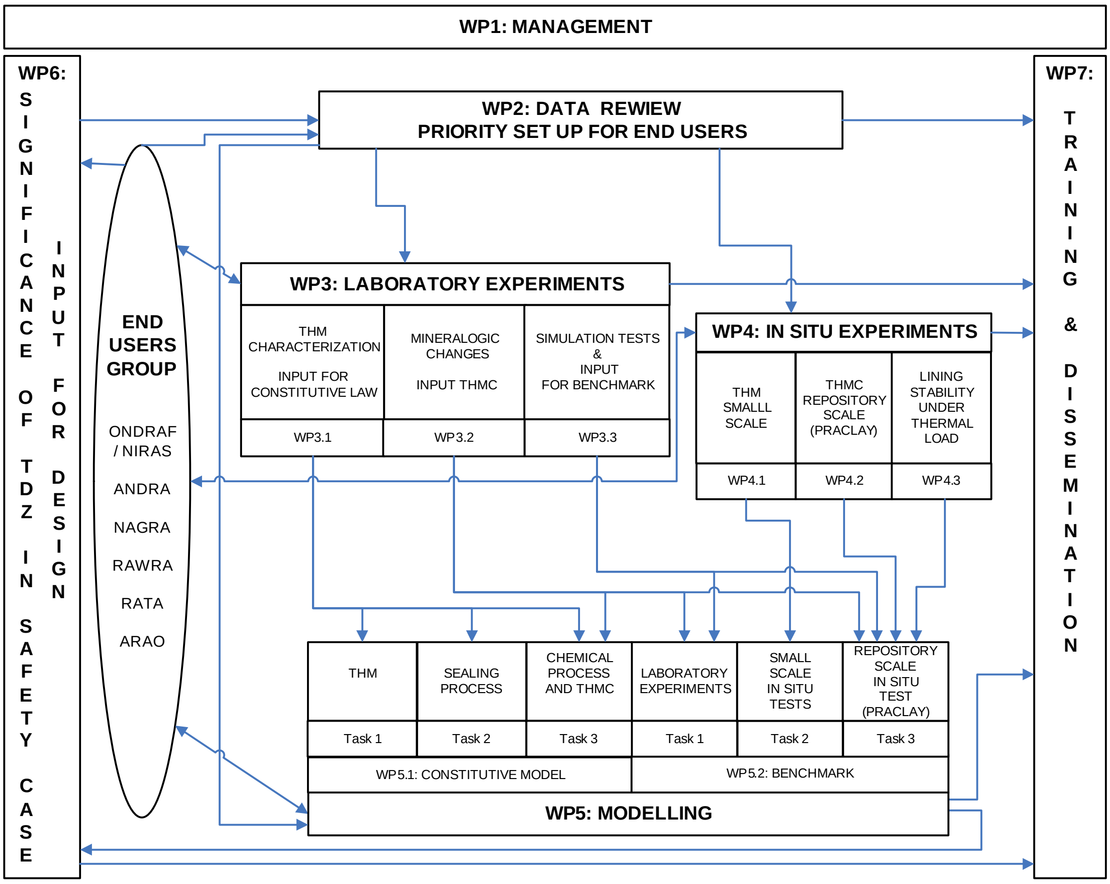

Figure 1: Structure of the TIMODAZ project

Three types of clay are investigated in TIMODAZ project: the Boom Clay in which the Belgian Underground research laboratory HADES is constructed, the Opalinus Clay in which exists the Switzerland Mont Terri rock laboratory) and the Callovo-Oxfordian argilitte where the French URL is excavated in Bure). Even if the characteristics of these clays are different, the THM processes governing the fracturing and the sealing present some similarities. Therefore, the first deliverable of the project will be a synthesis integrating the work previously performed on these three types of clay in surface laboratories and in-situ facilities (WP2).

In order to strengthen the knowledge of the fracturing and the sealing process under evolving thermal conditions, specific laboratory tests will be performed during the course of TIMODAZ project (WP3). In particular, the effects of the temperature on damaged clay as well as on the clay properties will be investigated. Special attention will be given to study the possibility of the creation of an irreversible damage. The tests include the study of the desaturation/resaturation processes on ambient and at different temperatures. Some tests will be complemented with a radionuclide migration test, in order to evaluate any possible relict of preferential migration along the sealed fracture. Different chemical conditions will be considered: chemical undisturbed, oxidised and alkaline environment. Mineralogical analyses will be performed and linked to the hydromechanical observations. These laboratory tests will provide the necessary data for the numerical models to be used in TIMODAZ.

Results from previous and current THM in-situ tests realised in HADES and Mont Terri laboratory will be available for the project. Additional small scale in-situ THM test will be conducted at Mont Terri to test the temperature effect on the fracturing and sealing process. The results of these in-situ tests will be very useful to provide the link between pure lab testing and full scale tests (WP4).

The thermal impact on the stability of the lining will also be investigated. This issue is particularly important in term of operational safety when the retrievability of the radioactive waste is considered (WP4.3).

Different numerical codes will be evaluated by participation in Benchmark tests for modelling of THM processes in clays. Sealing and chemical processes induced by THM phenomena will also be incorporated in some computer codes (WP5). The modelling work together with the results of the lab and the in-situ tests should give clear indication on the evolution of the DZ with time upon temperature evolution. After such an independent validation, a good prognosis is expected for the application of the codes to simulation at spatial and time repository scale. In this perspective, an important objective of the project will be to perform predictive simulations of the large scale heater test PRACLAY that will be performed in the HADES underground laboratory at Mol.

Particular attention will be given to determine which conditions and phenomena could lead to irreversible modifications of the clay properties, which directly affect the safety functions of the disposal system. These properties are the watertightness, or low permeability of clays, a slow diffusive transport combined with the absence of preferential migration pathways for solutes and sealing capacity. The TIMODAZ project will assess under which conditions these basic properties of clay can be altered during a thermal transient phase and to what extent the required basic safety functions of the repository system can be affected.

Social impact of the project

Public and political perception with respect to the nuclear waste issue will play a major role in determining the future of nuclear energy. The results of the TIMODAZ project will be situated in the context of the long-term performance of a repository. Participants in TIMODAZ will situate their results in these design and long term performance contexts, with the constant support of performance assessment and under the watch of the End Users Group. All of the experimental works to be performed in TIMODAZ in WP3 and WP4 will contribute to a better understanding of the processes occurring within the clay around a disposal system for heat-emitting waste in clay during the thermal transient phase. As this transient should span over several centuries, the development and testing of sound, phenomenology-based models in WP5 is an essential step towards meeting the Safety Case requirement of adequate understanding of the long-term evolution.

The knowledge gained within the TIMODAZ project will allow to assess the significance of the TDZ (Thermal Damaged Zone) in the Safety Case for disposal in clay host rock and provide direct feedback to repository design teams. To ensure an appropriate and continuous link between the end-user needs and the priorities of the TIMODAZ project, the following end-user group has been constituted: ONDRAF/NIRAS (BE), NAGRA (CH), ANDRA (FR), RAWRA (CZ), ARAO (SI) and RATA (LT). This group will be active throughout the duration of the project.

Scope of this lecture

As a introduction of the training course, this lecture will begin with a general presentation of the actual repository designs for HLW and spent fuel in Belgium, Switzerland and French, the corresponding temperature evolution in the near field of the host rocks, possible thermal impact on the host rocks and the time and scale evolution of the DZ around the disposal gallery will be illustrated to give a general background of the TIMODAZ research. Then a detail presentation of the TIMODAZ project will be given: scope of the research, structure and objectives of the project.

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