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TIMODAZ

Thermal Impact on the Damaged Zone Around a Radioactive Waste Disposal in Clay Host Rocks

(Contract Number: FI6W-CT-2007-036449)

Executive Summary of the activities (1st period)

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Mr. Christophe Davies (European Commission)	One electronic copy on CIRCA One paper copy	
All consortium members	One electronic copy available on the TIMOAZ web portal	

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1 Document purpose

This document provides an executive summary of the TIMODAZ project status of activities during the first period (01/10/2006 - 30/09/2007) and is intended to be a self-sufficient document for communication. It starts with the succinct information on the project : nature and scope, consortium, structure, priorities of the project, the training and dissemination / communication plans.

2 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 to dispose of these wastes worldwide.

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 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 too in the project. This study will include laboratory and in-situ experiments and modelling activities as well. Numerical tools will be developed on the basis of the experimental programme allowing a good prognosis of the THMC host rock behaviour at the time and spatial scale of a repository.

Three types of clay will be investigated: the Boom Clay, the Opalinus Clay and the Callovo-Oxfordian argilitte.

The knowledge gained within the TIMODAZ project will allow an assessment of the significance of the TDZ (Thermal Damaged Zone) in the Safety Case for disposal in clay host rock and to provide direct feedback to repository design teams. In order to ensure appropriate and continuous linkage between the end-user needs and the priorities of the project, an end-user group that will be active throughout the duration of the project has been constituted. The

following national agencies for management of radioactive waste have joined the end-user group: ONDRAF/NIRAS (BE), NAGRA (CH), ANDRA(FR), RAWRA (CZ), ARAO (SI) and RATA (LT).

3 Consortium

The research activities covered by TIMODAZ calls for multidisciplinary expertise involving both European radioactive waste management organisations together with the main nuclear research institutes supported by other research institutions, universities, industrial partners and consultancy companies (SME's).

The TIMODAZ consortium is composed of 15 participating organisations representing in total 8 countries: ESV EURIDICE GIE (BE), NAGRA (CH), SCK•CEN (BE), GRS (DE), NRG (NL), CIMNE (ES), EPFL (CH), ULG (BE), UJF (FR), ENPC (FR), CEG-CTU (CZ), ITASCA (FR), ASC (UK), ITC (CH) and SOLEXPERTS (CH).

4 The project priorities

The DZ is defined here as the zone of the host rock with Thermo-Hydro-Mechanical and Chemical (THMC) modifications induced by the repository, with major changes in the transport properties of radionuclides. These transport properties are the low permeability of clays, a slow diffusive transport combined with the absence of preferential migration pathways for solutes and some sealing capacity.

The DZ is first initiated during the repository construction. Its behaviour is a dynamic problem, dependent on changing conditions that vary from the open-drift period to the initial closure period and the entire heating-cooling cycle of the decaying waste.

The early THMC disturbances created by the excavation, the operational phase and the thermal load might be the most severe transient that the repository will undergo on a large spatial scale and in a relatively short period of time. Consequently the priorities of the TIMODAZ project have been set on the study of the combined effect of the excavation and the thermal impact on the host rocks around a radioactive waste disposal.

5 The project structure

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

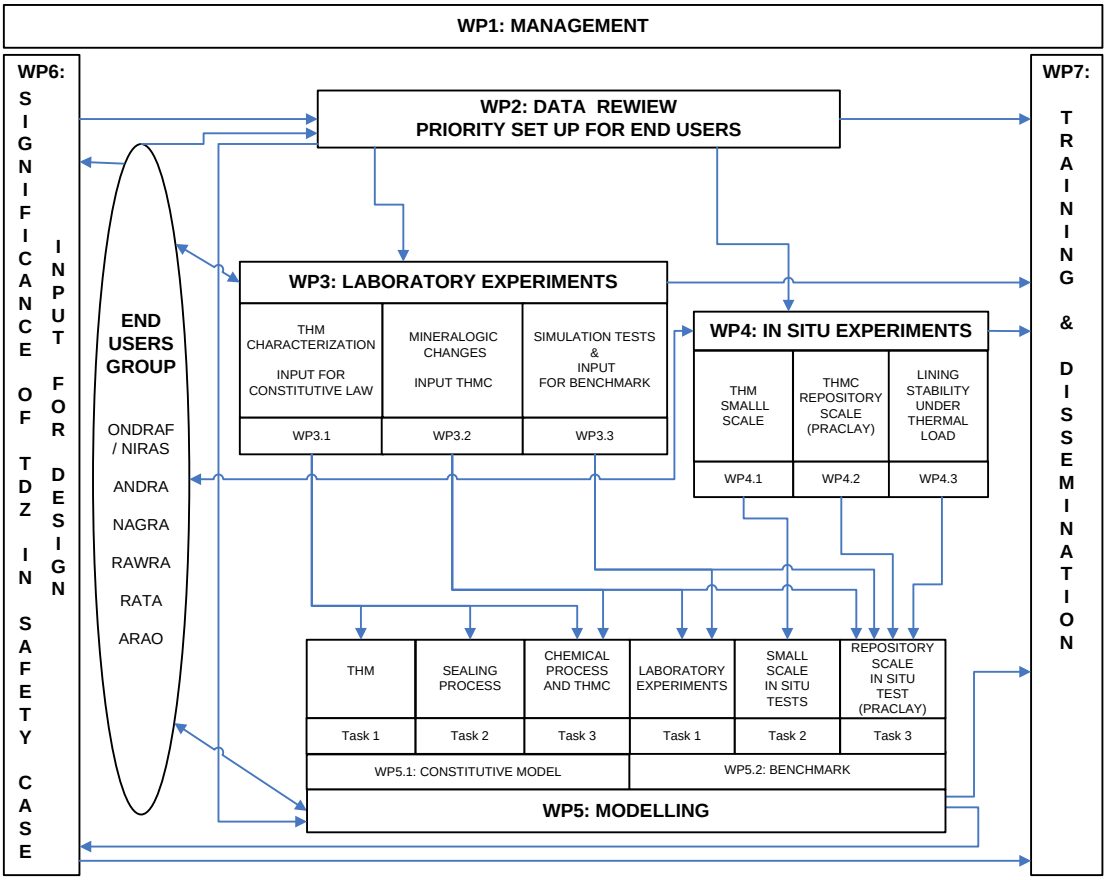

Figure 1: Structure of the TIMODAZ project

Starting from WP2-*Data review and priority set-up for end-user*, participants in TIMODAZ will situate their results in the long-term performance contexts, with the constant support of WP6-*Significance of TDZ in Safety Case*. All experimental works to be performed in TIMODAZ in WP3-*Laboratory experiments* and WP4- *In-Situ experiments* will contribute to a better understanding of the processes occurring within the clay around a disposal system for heat-emitting waste during the thermal transient phase. As this transient should span over several centuries, the development and testing of sound, phenomenology-based models in WP5-Modelling is an essential step in meeting the Safety Case requirement of adequate understanding of the long-term evolution. Knowledge management and the dissemination of results are also key elements of the TIMODAZ project. Trainings, workshops and international conferences are managed within WP7-*Training and dissemination*.

6 Results achieved during the reporting period

6.1 Management (WP 1)

The overall objective of this work-package is to manage the project effectively to ensure the integration of the results within the Safety Case and the set-up of recommendations for repository design. Other tasks of management consist in the stimulation of strong co-operation within the TIMODAZ consortium and information flow with the end-user.

The organisation of the first **end-users workshop** in 13th of June 2007 in Paris is a **milestone** of the project for this reporting period.

The end-user workshops within the TIMODAZ project are intended to enable the definition of end-user needs, to review the project and the deliverables as well as to ensure that the results of the TIMODAZ project are directly relevant to the radioactive waste management programs. If necessary, the end-users can propose a re-organisation of the project (which has to be endorsed by the governing board of TIMODAZ).

The general framework of the project and the specific scientific topics were communicated to the end-user group prior to the workshop. During the first end-user workshop, two due periodic deliverables were presented: "*The state of the art on THMC process* "(D2) and "*Significance and Current Handling of the Damaged Zone in Performance Assessment*" (D4) were presented. The status of activities of each work-package were also presented and discussed.

The end-users were asked to

- Review and give feedback on the deliverables
- Formally approve the currently foreseen programme or to suggest deviations of the work programme,
- Evaluate the applicability of the foreseen project results within a Safety Case.
- Give recommendations to or, if found necessary, reorientation of the project.

General appreciations of the end-users on the project

Based on the information available, the end-user group agreed with the continuation of the project according to the work programme presented and didn't suggest a reorientation.

Comments from end-users on the deliverables:

Concerning D2 – *State of the art on THMC*, the end-users proposed to focus this report more on the summaries and to transfer the technical details to an annex.
Concerning D4 – *Significance and Current Handling of the Damaged Zone in Performance Assessment*, the end-users thought that the document clearly describes the Safety Case point of view and the list of five questions (see below) seems to be a good tool to structure the work, collaboration and integration of the TIMODAZ project.

Recommendations put forward by the end-users

Several recommendations were put forward by the end-user group, mainly in order to

- Increase the possible direct use of the final outcome of the TIMODAZ project for a Safety Case.
- Strengthen the interaction between experimentalists, modellers and performance assessors

As a first recommendation, the end-user group proposed to clearly check, in the course of the project, to what extent the processes concerning TDZ are really similar for three types of clay studied (going from plastic clay to indurate clay). The presentations made during the workshop seemed that similar processes were expected for the three studied clays. It's acknowledged that this reasoning holds for the EDZ, the end-users suggested to develop a more careful approach until more information on the TDZ is available.

The second recommendation focused on the integration of the three domains of expertise (experimental, modelling and PA) present within the project. A possible way of integration might be achieved by making joint presentations at meetings, conferences and certainly end-users workshops of the project.

A third recommendation is also focused on integration of the different disciplines, but now at the level of the project evolution, in order to make the outcome of the project directly useful for a Safety Case.
Within deliverable 4, five different questions are put forward that need to be answered from a Safety Case point of view. The end-users appreciated very much the listing of these questions and believed that these might be used as a tool in order to strengthen the collaboration between different partners and different disciplines. Based on these 5 questions, the end-users have given some additional feedback on how the collaboration might be enhanced and lead to useful output for a Safety Case:

Q1: What is the expected evolution of the DZ around a disposal system for heat-emitting waste during the thermal period?

It is indeed one of the major tasks of a Safety Case to clearly describe the expected evolution of the disposal system. From a PA point of view, it is important to have an idea on how the damaged zone looks like at the moment of radionuclide release. Taking into account that, for all concepts (linked to the host rocks) considered in the project, the engineered barriers are such that radionuclides (RN) will only be released after several thousands of years, it is thus most important to inform on the evolution for the next 10 000 years. The end-users suggested that, on the one hand, the modellers to make already now predictions/evaluations of the evolutions for the next 10 000 year and, on the other hand, the experimentalists should try to indicate how their experiments will help in describing this expected evolution.

Q2: What are the main uncertainties about the DZ evolution and how can these uncertainties be dealt with?

Within a Safety Case, it is not only necessary to describe how the system will evolve, but also to describe which uncertainties remain on the described evolution. Consequently, it is suggested to inform on the uncertainties that are identified by the modellers (and others) and on how the experimental work is focused on these uncertainties.
To this end, the uncertainties identified in D2 – *state of the art on THMC* and the uncertainties resulting from the model exercise proposed above under *Q1*, should be addressed. Once again, the end-users stressed the long term (thousands of years) consideration, as this is the eventual input needed for performance and safety assessment.

Q3: Under which conditions can the favourable clay properties be modified during the thermal period and how much can these properties be affected?

In this respect, the end-users considered that it would be most interesting that the PA assessors can already inform to the modellers and experimentalists on:

- Which properties are the most important ones with respect to safety
- What would be a significant change of these properties.

A specific recommendation for the WP3.2 (lab tests to determine the combined effect of thermal impact and geochemistry on the mineralogy) was put forward by the end-users: clearly indicate the experimental limits and certainly compare the obtained results with geological evidence (from sedimentary basin history, etc) since the chemical changes in the clay environments considered take a lot of time.

Q4: Under which conditions do the changes in clay properties become irreversible?

The end-users reminded the partners of the project to be very careful with the term 'irreversible' and asked whether another term can be found or at least to clearly define the meaning of the term 'irreversible' within this context. Without better constraining the meaning of 'irreversible' every evolution might be considered irreversible and on top of that the term might have a rather negative connotation.

Note: this question was reformulated later on by the writers of D4 : *Under which conditions do the changes in clay properties become irreversible? i.e. under which conditions will the future properties of the clay differ from the currently observed properties?*

Q5: To which extent can temporary or permanent alterations of favourable clay properties really affect individual barriers and the safety functions of the repository, i.e. to which extent are these alterations significant from a PA point of view?

This is of course the eventual question that needs to be answered within a Safety Case. However, to which extent this question can be answered is probably strongly depending on the results that will be obtained during the project and to which extent the aforementioned questions can be answered. In order not to postpone this question to the very last moment of the project, the end-users repeated once more their recommendation to ensure interaction between PA and experimentalists and modellers already during the project. This will certainly help to evaluate in how far this question can be addressed with this project.

Technical discussion points

During the workshop, following technical issues were discussed:

Pore pressure measurements, consolidation/de-saturation effects

It was generally recognized that such measurements are very important and that both local short-term pore pressure data and also longer-term data are required. However, pore pressure is difficult for the materials with very low permeability. It was agreed that the initial state of the samples, the test conditions and the obtained results should be carefully recorded.
On the other hand it should be verified if there are better sampling techniques and devices (such as special foils etc.) which avoid loss of water/desaturation during sampling and transport. It was recommended to carry out suction measurements before the tests to estimate de-saturation of the specific sample. If possible X-ray and ultrasonic tomography before and after each test could be carried out.

Visualization of DZ

The description of the DZ remains problematic. Seismic tomography can give some indications of the extent of the excavation disturbance. Another possibility is the injection of dyed resin into the DZ of boreholes with subsequent overcoring. However, this method bears the risk of increasing the damage around the borehole. The use of markers should be considered also in lab-experiments.

Chemical processes

The formation of sulphates was discussed. After the excavation of the gallery, the system is ventilated, causing oxygen of the air to diffuse slowly into the rock. Especially in the damaged zone, oxygen will diffuse further into the clay and oxidize pyrite. This will form sulphates and thio-sulphates which can be dissolved. If bacterial activity occurs in this zone, these sulphates can be reduced by biogenic degradation of organic compounds. These processes can affect the performance of the repository system.

Impact of DZ on radionuclide migration/release and on transport parameters
The question came up on how the DZ induced variation in all transport parameters are treated. The nature of DZ is not sufficiently understood yet. It may be a connected fracture network or a slight porosity increase along preferential paths. At Mt. Terri resin was applied and the morphology of this fracture network was visualized successfully.

6.2 Data review - state of the art of THMC (WP2)

Following the recommendation of the end-users, the Deliverable 2 *"the report on the state-of-the art on THMC processes (Boom clay, Opalinus Clay and Callovo-Oxfordian Clay)"* has been re-written and delivered.

The first part of the report points out the main issues related to the thermal impact, which should reflect the viewpoints of end users. The second part is devoted to the state of the art for each investigated clay, including the main characteristics of each clay, the available THM characterisation (both laboratory and in situ), the related chemical aspects and the current development of the constitutive models. For each clay the report provides a discussion in order to:

- identify the uncertainty for each clay (uncertainty on the experimentally derived parameters, on the THMC coupling process, on the homogeneity of the clay, modelling boundary condition and initial conditions, etc)
- delineate the most important temperature-dependent material properties
- define the most important coupled processes and parameters
- assess the effect of discrete fractures and fracture connectivity on the effective hydraulic properties, to determine the importance of chemical impact
- derive/evaluate the most appropriate conceptual models and numerical codes as well as to notice the remaining uncertainties on the THM properties of the clays

This report gives a synthesis of the relevant works previously performed on the three investigated clays in surface laboratories and in in-situ facilities. The range of the most important THM parameters, the in-situ observations are presented. The accompanied uncertainty is highlighted and analysed. The modelling results of the selected in-situ tests are included. The capacity, the limitation of the developed/applied models are discussed. The associated future developments on the constitutive models are thus underlined.

It comprises thus a database and a reference document to optimise the testing procedures of the laboratory experiments and the in-situ experiments to be performed in the present project.

6.3 Laboratory and in-situ experiments (WP3 and WP4)

Based on the state of the art report, the objectives of the test programme in the TIMODAZ project have been reviewed, the protocols of the tests were established and the laboratory apparatus have been developed.

Laboratory tests under well controlled temperature/stresses/pore pressure conditions with different loading paths will be performed to determine the parameters of the Thermo-Hydro-Mechanical constitutive models used for the numerical modelling. More specifically, the thermal effects on the damaged clay and the possible damage induced by the thermal loading itself will be investigated. During the tests, different techniques will be used to evaluate the sealing/healing processes. Some tests consist in simulating the excavation of a gallery in hollow cylinders and the impact of temperature on the excavation damaged zone. Finally tests are planned to study the thermally induced modifications of the clay mineralogy which is a dominant factor influencing the key properties of the clays and their THM behaviour. Figure 2 shows an example of a triaxial cell equipped with electrical heaters developed specially for TIMODAZ project by UJF.

The following in-situ tests to be realised at Mt Terri (CH), HADES (BE) and UEF Josef underground laboratories (CZ) were designed and initiated:

- The small-scale in-situ test at Mont Terri aiming to characterise the influence of the thermal load on the THM behaviour and the sealing capacity of clays was successfully initiated.
- The ATLAS experiment realised in HADES URL has been successfully reactivated in order to have a better assessment of the THM characteristics of Boom Clay.
- The tunnel machine is ready to start the excavation of the PRACLAY gallery in which the large-scale heater experiment will be performed (see Figure 3). The feasibility of inverting measured waveform data recorded during the PRACLAY experiment was investigated using the experimental and modelling data from the OMNIBUS project, partly funded by the EC under EURATOM Framework 5.
- In the UEF Josef facility an in-situ test will be performed to study the influence of thermal impact on the stability of the lining of a disposal gallery. Meanwhile, the laboratory experiment located in the CEG's laboratory was ready to "switch on".

Figure 2: Triaxial cell with electrical heater developed by UJF

Figure 3: Tunnel machine ready to start the excavation of the PRACLAY gallery

6.4 Modelling (WP5)

Concerning modelling, all partners presented their working programme, and several general issues were addressed and thoroughly discussed. The first Benchmark concerning the laboratory experiment modelling was defined. This was done in close interaction with the laboratories responsible for the experiments. The consortium actively worked on the

computations corresponding to this first Benchmark. The results were compared and discussed between the partners.

6.5 Significance of TDZ in Safety Case and Input for Design (WP6)

The draft of the short report "*The Significance and Current Handling of the Damaged Zone in Performance Assessment"* (deliverable 4) was submitted to the end-users for reviewing.

6.6 Training and dissemination (WP7)

This work-package brings together all activities concerning training including knowledge management and transfer. Knowledge management and the exploitation and the dissemination of results are key elements of TIMODAZ.
The activities of this work packages include mainly:

- Organisation of two training courses in the following two specific domains: THMC behaviour of clays and the impact of THMC processes on performance assessment. The training constitutes an important component of the TIMODAZ project.
- Organisation of three end-users oriented workshops in order to better define end-user needs that will allow researchers to fully understand the specific problems for which their research is targeted.
- And an international conference/workshop.
- Development of the TIMODAZ web site including a knowledge management tool
- Papers and attendance at relevant conferences
- Folders

The following achievements were made in this reporting period

- A management tool based on a web portal site that contains scientific information on the project in different levels of detail was developed. In addition to the Web portal for use internal use within the consortium, the TIMODAZ Web-Based portal contain a public section open to the broad scientific community public and providing descriptive information on TIMODAZ.
- The first end-user workshop in Paris was accomplished successfully.
- The date and location for the first TIMODAZ training course were fixed ("THMC behaviour of clays and claystones", 7th to 9th July of 2008 at EPFL in Lausanne) and first draft version of leaflet was prepared to be presented at the occasion of the ALERT-Geomaterials workshop and doctoral school in Aussois, October 2007.
- The preparations for the International conference and workshop were started.
- Four TIMODAZ related publications.

7 Social impact

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. All of the experimental works to be performed in TIMODAZ will contribute to a better understanding of the processes occurring within the clay around a disposal system for heat-emitting waste during the thermal transient phase. As this transient should span over several centuries, the development and testing of sound, phenomenology-based models 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.

8 Project logo

9 Provject web site

http://www.timodaz.eu/

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