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THERESA

Coupled Thermal-Hydrological-Mechanical- Chemical Processes for Application in Repository Safety Assessment



Project description & Status

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Objectives and Implementation Approach

This project aims to develop a scientific methodology for evaluating the capabilities of mathematical models and computer codes used in Performance Assessment (PA - using process level models) or Total System Performance Assessment (TSPA - mostly using simplified PA models) and applied to the design, construction, operation, performance and safety assessment, and post-closure monitoring of geological nuclear waste repositories, based on the scientific principles governing coupled thermo-hydro-mechanical and chemical (THMC) processes in geological systems and geo-materials. The project work concentrates on the most essential issues for PA, with focus on rock salt, buffer materials and the buffer-rock interface, as guided by the tool of Issue Evaluation Tables (IET). The evaluation is carried out by scientific/technical auditing (TA) procedures. The evaluation examines the participating teams' codes and approaches in terms of system characterisation (conceptualisation, simplification, mathematical representation and parameterisation), flexibility in handling realistic *in-situ* geological conditions, capacities in uncertainty source identification and treatment, and computational aspects. The evaluation is organised around numerical simulations of small-to-moderate scale laboratory tests, specifically defined generic Bench-Mark Tests (BMT), and large-scale in-situ experiments (Test Cases - TC) involving coupled THM, HMC or THMC processes in rock salt and buffer material, so that simulations and evaluations are conducted within a realistic physical context. This project represents a coherent and logical effort based on sound scientific principles, and with potentially far-reaching consequences in the field of nuclear waste disposal.

The work is implemented through five work packages (WPs). WP1 is the overall planning package, designed to oversee the implementation of the other four work packages throughout the duration of the project. WP2 will, in "Issue Evaluation Tables" (IETs), identify the specific issues in PA that are related to THMC modelling, and will, through continuous updating, guide the project in addressing the relevant issues. WP3 and WP4 are the packages addressing numerical modelling of coupled THMC processes in salt and buffer, respectively. WP5 is defined to implement the TA of the models and codes applied in WP3 and WP4, according to specifically developed IETs and TA procedures. The exchange of ideas and work implementation check-ups will be achieved mainly through regular workshops and specific task force group meetings.

Organization

The THERESA project has 16 partners as listed below:

Royal Institute of Technology (KTH), Sweden, also serves as the coordinator of the project;

Swedish Radioactive Safety Authority (SSM) (replacing Swedish Nuclear Power Inspectorate (SKI), since July 1, 2008), Sweden;

Swedish Nuclear Fuel and Waste Management Co. (SKB), SKB;

Federal Institute for Geosciences and Natural Resources (BGR), Germany;

DBE Technology GmbH (DBE), Germany;

Forschungszentrum Karlsruhe GmbH (FZK), Germany;

Gesellschaft für Anlagen- und Reaktorsicherheit GmbH (GRS), Germany;

Institut für Gebirgsmechanik GmbH (IfG), Germany;

Nuclear Research and Consultancy Group (NRG), The Netherlands;

Technische Universität Clausthal (TUC), Germany;

Centre International de Méthodes Numériques en Ingénierie (CIMNE), Spain;

Cardiff University (CU), UK ;

Posiva Oy (POSIVA), Finland;

Marintel Ky (Marintel), Finland;

Quintessa Limited (Quintessa), UK;

Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France.

The 16 partners form the Steering Committee that is chaired by the project coordinator and is the only overall decision making body of the project. A Scientific Advisory Committee (SAC), of five independent (outside THERESA project) and internationally well known experts in the field of coupled THMC processes and their impact on safety of underground radioactive waste repositories in different rocks, was established to review the research programme and scientific quality of the work results. The main responsibility of SAC is to review the scientific contents of the Issue Evaluation Tables for WP3 and WP4 as described in the relevant section about WP2 below.

Work Packages and current status

Five Work Packages (WPs) were defined for the project.

WP1: Project plan. This work package defines the technical contents, milestones, deliverables and time schedule for each work package. An initial version of the plan was completed in the first 3 months of the project and was progressively updated with the progress of the project. The WP1 group members are DBE, KTH, SKB, SKI/SSM, coordinated by KTH.

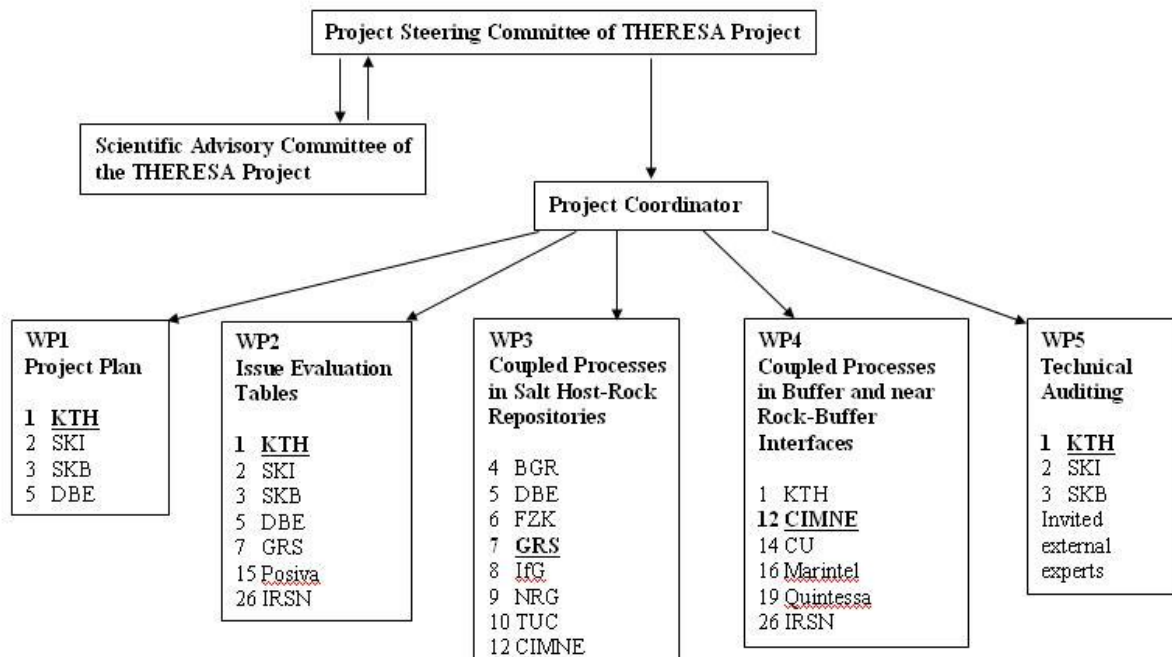
WP2: Issue Evaluation Tables (IET). This work package defined key scientific issues that should be considered for two main WPs, WP3 and WP4 as described below, for modelling coupled THMC processes in rock salt and buffer materials used in repositories in crystalline rocks. The buffer-rock interface effect should also be investigated. The initial IET tables for WP3 and WP4 were drafted by the respective WP groups and submitted for review by a Science Advisory Committee (SAC). The IETs can be modified and updated according to comments of SAC members. These two IETS serve as guidelines for scientific research carried out by WP3 and WP4 groups. The two initial IETs for WP3 and Wp4 were reviewed and passed by the SAC and was used for research work by WP3 and WP4 groups. The WP2 group members are DBE, KTH, SKB, SKI/SSM, coordinated by KTH. The members of SAC are five independent international experts outside THERESA project.

WP3: Modelling coupled THMC processes of rock salt as potential host rock for nuclear waste repositories. The group members of WP3 consist of BGR, CIMNE, DBE, FZK, GRS, IfG, NRG, and TUC and the activities are coordinator by GRS. The rock salt damage in coupled THM and/or THMC processes and its impact on repository long-term safety as well as its consideration in PA/TSPA is the major concern of the research. Significant progress have been made in development of computer codes, constitutive models, simulations of existing laboratory experiments and testing large scale rock salt samples.

WP4: Modelling of coupled THM and/or THMC processes in buffer (mainly bentonite) and buffer-rock interfaces. The group members of WP4 consist of CIMNE, CU, IRSN, KTH, Marintel, Quintessa and Posiva, and the activities are coordinator by CIMNE. Significant progress have been made in development of computer codes, constitutive models, simulations of three Bench-Mark Test (BMT) problems on coupled THM behaviour of buffer materials and development of buffer-rock interface model. Modelling of full scale of the CRT (Canister Retrieval Test) at SKB's Äspö Hard Rock Laboratory, Sweden in progress.

WP5: Technical auditing (TA). This work package concerns the examination of objectives, scientific/technical contents and performance of computers codes applied for WP3 and WP4, based guideline of IETs defined in WP2. The member of the WP5 consists of KTH, SSM /SKI and SKB, coordinated by KTH. The criteria and methods of TA were defined and were applied for technical auditing of the computer codes to be applied for WP3 and WP4 with evaluation comments. The TA of the laboratory experiments and BMT problems of WP3 and WP4 are in progress.

Figure 1 shows the formation of the 5 WPs.



The main research was performed in WP3 and WP4, organized by GRS and CIMNE, respectively, and the project coordinator's main responsibility is the management of the project economy and coordinating the activities of the work packages, in addition to coordinate the work for WP5.

Three PhD students (one in KTH, one in CU and one in TUC) are educated in the project and they have been contributing significantly to the progress of the project.

International Co-operation activities:

The participants of the THERESA project have been active in attending international conferences such as Euradwaste 2008 conference, Oct. 2008, Luxemburg and SINOROCK 2009 in association with International Society for Rock Mechanics), Hong Kong, China, May 2009, with presentations, discussions and contributions to items of importance for panel discussions and conclusions.

An international conference on THMC processes and their impacts on safety of underground radioactive waste repositories was jointly initiated by the THERESA project and a sister project sponsored by EC, TIMODAZ. The conference to be held during Sep. 29 – Oct. 1, 2009, in Luxemburg is sponsored by EC and seven main government or industrial organizations: GRS (Germany), DBE (Germany), Posiva (Finland), SKB (Sweden), NAGRA (Switzerland), ONDRAF/NIRAS (France) and SCK.CEN (Belgium). In addition, RAWRA, BfS, IRSN, and ENRESA will also support this event by in-kind contributions.

One general keynote lecture and three field-oriented keynote lectures (on crystalline rocks & buffer materials, clay formations and salt formations, respectively) will be given, plus a number of selected oral and poster presentations. In-depth discussion in three workshop groups (crystalline rocks & buffer, clay and salt) will be organized and led by group chair-persons and rapporteurs.

About 70 abstracts have been submitted to the THMC conference, and were reviewed and selected. 14 abstracts were contributed by THERESA project partners with 7 from WP3 and 7 from WP4 groups, respectively.

Publications:

A number of international and national scientific papers were and will be published, based on research results generated in WP3 and WP4 of the THERESA project. Full information on publication are not available yet. A few of them are listed below:

Blümling, F., J.-F. Aranyossy, L. Jing, X. L. Li, P. Marschall, T. Rothfuchs and T. Vietor (2008): Disturbed and damaged zones around underground openings - effects induced by construction and thermal loading. Proceedings of Euradwaste 2008, Oct. 2008, Luxemburg.

Jing, L., R. W. Zimmerman, A. Sjöland, C. Lilja, T. Rothfuchs and A. Gens (2007): Technical Auditing Report of Phase 5.1, WP5. European Commission, THERESA project, Deliverable D15, public.

Tong, F., L. Jing and R. W. Zimmerman (2009): An effective thermal conductivity model of geological porous media for coupled thermo-hydro-mechanical systems with multiphase flow. Int. J. Rock Mech. Min. Sci., 2009 (In Press).

Tong, F., L. Jing and R. W. Zimmerman, 2009. Modeling multiphase flow, deformation and heat transfer in buffer (2009): Oral presentation on May 20, 2009, at Int. Conf. SINOROCK 2009, Kong Kong, China, May 19-22, 2009. Full publication details in conference proceedings will be added later when available.

Wieczorek, K., T. Rothfuchs, C.-L. Zhang, Th. Spies, U. Heemann, Chr. Lerch, S. Keesmann, A. Pudewills, P. Kamlot, J. Grupa, K. Herchen, S. Olivella, Chr. Spiers (2008): THERESA Work Package 3: Evaluation and Improvement of Numerical THM Modelling Capabilities for Rock Salt Repositories, Poster presented at the EURADWASTE Conference, Luxembourg, 20-23 October 2008.

Wieczorek, K., T. Rothfuchs, C.-L. Zhang, Th. Spies, U. Heemann, Chr. Lerch, S. Keesmann, A. Pudewills, P. Kamlot, J. Grupa, K. Herchen, S. Olivella, Chr. Spiers (2007): Compilation of existing constitutive models and experimental field or laboratory data for the thermal-hydraulic-mechanical (THM) modelling of the excavation disturbed zone (EDZ) in rock salt, European Commission, THERESA project, Deliverable D5, public.

Wieczorek, K., T. Rothfuchs, C.-L. Zhang, Th. Spies, U. Heemann, Chr. Lerch, S. Keesmann, A. Pudewills, P. Kamlot, J. Grupa, K. Herchen, S. Olivella, Chr. Spiers (2008): Calibration of Thermal-Hydraulic-Mechanical (THM) Models of the Excavation Disturbed Zone (EDZ) in Rock Salt, European Commission, THERESA project, Deliverable D6, public.

Zhang, C.-L., Wieczorek, K., Rothfuchs, T. (2009): Laboratory Benchmark Tests on Rock Salt, European Commission, THERESA project, Deliverable D7, public.

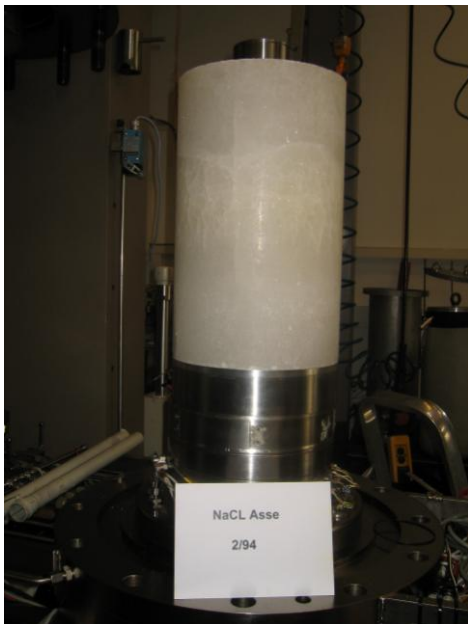
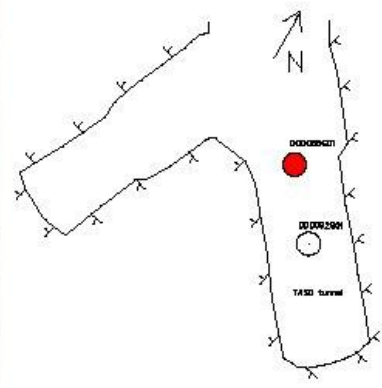


Figure 1. Testing equipment and salt samples of large sizes tested in laboratories at GRS for research on damage behavior and impacts during coupled THM processes, WP3, THERESA project.



(a)



(b)



(c)



50 mm copper

Estimated weight (kg):

Copper canister	7,400
Insert	13,600
Fuel assemblies (BWR)	3,600
Total	24,600

(d)

Figure 2. The full scale Canister Retrieval Test (CRT) at SKB's Äspö hard Rock Laboratory (HRL), Sweden, used for WP4, THERESA project. a) Illustration of the experimental set-up and the location in the TASS tunnel; b) The deposition hole after installation of the mats during installation of the bottom block; c) Installation of the canister; and d) KBS-3 canister parameters.