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Plug and Seal Training Workshop planning and implementation report

DOPAS Training Workshop 2015

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ABSTRACT:

A training workshop was planned and implemented as a part of the knowledge transfer from DOPAS Project results and from the process. A five-day training workshop was carried out in September 2015 in the Czech Republic. The training plan was based on four major learning units and related learning outcomes including the provision of a full learning cycle with both theoretical and hands-on application of the tasks needed to plan, to construct, and to monitor a full-scale in-situ experiment. The trainers were mainly the experiment and work package leaders of the project from eight partner organisations. The curriculum followed the content of the DOPAS Project plan starting from requirements and finishing with the technical feasibility considerations related to plugs and seals. This gave the participants an opportunity to construct and reflect on their own country's approach in contrast to the DOPAS approaches. The training workshop was run with great success and very favourable views were received to the extensive feedback that was collected from the participants and the tutors. This report describes the different stages of the workshop delivery (in Part I) and gives more detailed guidance for a potential user of the training plan and of the training materials developed (in Part II). Also the conditions of use are stated in the report and the training materials are available for download at the DOPAS Project website.

RESPONSIBLE:

Posiva Oy, Marjatta Palmu

REVIEW/OTHER COMMENTS:

Reviewed by the planning group members and by DOPAS Project Coordinator. The review comments have been incorporated into the report.

APPROVED FOR SUBMISSION:

Johanna Hansen, DOPAS Project Coordinator

Summary

The DOPAS Project is a four-year demonstration project in geological disposal funded with the partial support of the Euratom 7th Framework Programme. The DOPAS Project consortium of 14 organisations from eight European countries has carried out partly or fully five full-scale demonstration experiments in France, Czech Republic, Sweden, Finland and Germany. DOPAS Project activities included the planning and implementation of a training workshop as part of the dissemination activities. The DOPAS Training Workshop 2015 was planned during the second and third year of the project and it was implemented in September 2015 in the Czech Republic as a five day workshop.

Part I of this report includes a description of the planning, implementation and assessment of the DOPAS Training Workshop. The training plan was based on four major learning units and learning outcomes from them including the implementation of a full learning cycle with both theoretical and hands-on application of the tasks needed to plan, to construct, and to monitor a full-scale in-situ experiment. The tutors were mainly DOPAS experiment and work package leaders from eight partner organisations of the project. The training curriculum followed the content of the DOPAS Project work plan framework starting from requirements and finishing with the technical feasibility considerations related to plugs and seals. This gave the participants an opportunity to construct and reflect on their own experiences and their country's approach in contrast to the DOPAS approaches. The training workshop was run with great success and very favourable replies were received from the participants and from the tutors to the extensive feedback collected.

In addition to the implementation of the training workshop, it was agreed early on in the DOPAS Project that the training materials would be available for any interested audience on a non-commercial basis. Part II of this report describes in more detail the approaches that could be taken to reuse the training materials created for the training workshop in future training. The aim of this part is to facilitate the reuse of the training plan and the training materials from the DOPAS Training Workshop.

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List of Abbreviations

Cigéo: Centre Industriel de Stockage Géologique (Industrial Repository in France)
DAC: Demande d'Autorisation de Construction; French construction license
DGR: Deep geological repository
DOMPLU: Dome Plug (Swedish experiment)
Dossier: A report on the feasibility of deep geological disposal for high-level and long-lived radioactive waste in Andra's programme
DOPAS: Full-scale Demonstration of Plugs and Seals Project
DoW: Description of Work
EBS: Engineered barrier system
ECTS: European Credit Transfer System
ECVET: European Credit system for Vocational Education and Training
EFQ: European Qualification Framework
EDZ: Excavation damaged zone
ELSA: Entwicklung von Schachtverschlusskonzepten (development of shaft closure concepts)
EPSP: Experimental Pressure and Sealing Plug (Czech experiment)
Euratom: The European Atomic Energy Community
FP7: The Seventh Framework Programme (2007-2013) of Euratom
FSS: Full-scale Seal (French experiment)
GD: Geological disposal
HLW: High-level waste
HRL: Hard Rock Laboratory
IGD-TP: The Implementing Geological Disposal of Radioactive Waste Technology Platform
ILW: Intermediate-level waste
IPR: Intellectual property rights
KSC: Knowledge, Skills, Competence
LASA: Langzeitsicherer Schachtverschluß im Salinar (a set of experiments on shaft sealing concepts in Germany focusing on mechanical-hydraulic issues)
LAVA: Langzeitsicherer Schachtverschluß im Salinar (a set of experiment on shaft sealing concepts in Germany focusing on chemical-hydraulic issues)
LECA®: Light-weight expanded clay/concrete aggregate
LLW: Low-level waste
LO: Learning Outcome/s
LU: Learning Unit/s
L/T: Long-term
NWM: Nuclear Waste Management
POPLU: Posiva Plug
R&D: Research and development
RD&D: Research, development and demonstration
REM: Resaturation test in metric scale (French test carried out in parallel with the FSS)
RMS: Requirement management system
RMW: Radioactive Waste Management
SF: Spent fuel (SFN = spent nuclear fuel, alt. used fuel)
SCC: Self-compacting concrete
S/T: Short-term
URL: Underground research laboratory
TWS Training Workshop
VSG: Vorläufige Sicherheitsanalyse Gorleben (Preliminary Safety Analysis for Gorleben)
WMO: Waste management organisation
WP: Work package

Experiment and research facilities of the DOPAS Project partners:

BURE: Underground Research Laboratory located in France in callovo-oxfordian clay (argillite) formation

Josef URC and Underground laboratory: Underground Research Centre located at the Josef exploratory gallery in Czech Republic located in crystalline rock.

Äspö HRL: Äspö Hard Rock Laboratory, a underground research facility located in Oskarshamn, Sweden in granite.

ONKALO (URCF): An Underground Rock Characterisation Facility, located in Olkiluoto, Finland at the site of the future disposal facility for spent nuclear fuel. Located in mica gneiss and pegmatite host rock environment.

Gorleben: Salt dome in Northern Germany that has been investigated for its suitability for disposal of high-level nuclear waste for 40 years from surface and from underground by an exploration mine.

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Part I
DOPAS TRAINING WORKSHOP 2015

1 Introduction

Full Scale **D**emonstration **o**f **P**lugs **a**nd **S**eals **(DOPAS)** Project was run from 1 September 2012 to 31 August 2016. The project was partially funded from the EURATOM 7th framework programme with a grant of 8.5 million Euros and by seven European waste management organisations (WMOs) and by the German Ministry BMWi. The DOPAS Project focuses on full-scale demonstration experiments on the plugs and seals needed for the geological disposal facilities to operate and perform safely at different time scales and in different host rock environments. The whole DOPAS Project activities are summarized e.g. in DOPAS Final Project Summary Report (DOPAS, 2016).

The DOPAS Project Plan included as one of its dissemination tasks to set up a training planning group and to organise one plugs and seals training workshop that is open for participants outside the consortium. This five day "Training Workshop on the Role of Full-scale Experiments on Plugs and Seals in Demonstrating Safety and Performance of Geological Disposal" was included as a part of the knowledge transfer and experience dissemination activities of the project for technical and scientific audiences, mainly young scientists, professionals and postgraduates in geological disposal.

The objective of this DOPAS activity was to add to the scientific integration of the results and lessons learned and to share these by training of students and engineers from the EU Member States. The training workshop was planned to follow a well designed learning process and it was intended to capture all the stages of the DOPAS work plan presented in **Figure I-1** from the Description of the Work of DOPAS Project. The learning outcomes of the training were defined so that at a later stage the recognition of the learning outcomes from the training work shop could take place e.g. according to the ECVET approach (European Commission, 2012). The training workshop plan and the training process content were planned to be produced as a deliverable of the project (i.e. this deliverable report D7.2) and published on the DOPAS public website.

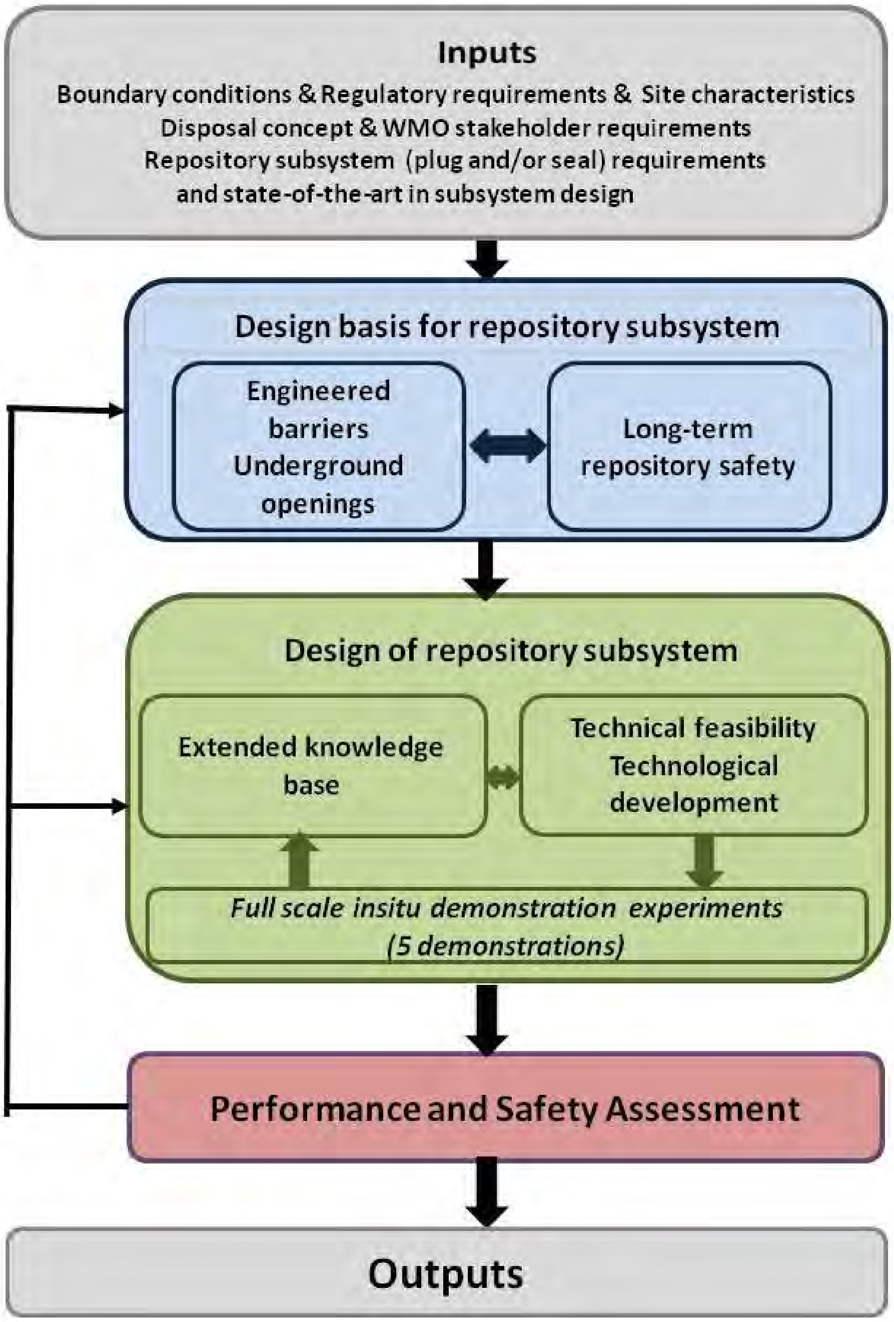

Figure I-1. Original DOPAS Project work plan framework in the DOPAS DoW (2012) © DOPAS

The open access to the training material was addressed by taking into account the national and European Union wide constraints of intellectual property rights (IPR) on training materials. This was necessary as it was originally foreseen that also trainers from outside the DOPAS consortium members could be used. Since only consortium members contributed to the training materials, there were no additional limitations to publishing the training materials. It was agreed in the planning group that the materials are published with open access for non-commercial uses except for the material that is copyrighted and marked with © in the training materials. Such materials are the prior background of the DOPAS consortium member organisations. The training workshop IPR issues will also be included as a part of the DOPAS exploitation activities.

2 Planning of the DOPAS Training Workshop 2015

2.1 Planning

The training designed was implemented in September 2015 (14-18 September 2015) after the project had been running around three years. This enabled a training design that was based on the project's original conceptual framework and at the same time, it exploited the lessons learned during the three years of implementing the experiments. The project and the training workshop started with the requirements, safety functions, and constraints of plugs and seals. This was followed until the implementation of full-scale construction of monitored repository plugs and the development of new shaft sealing components. The training workshop was designed to provide the participants a full learning/action cycle. These could be acquired by including learning activities in both theoretical knowledge and practical skills and using team work in the repository like an underground training facility environment at the Josef Underground Laboratory in Czech Republic, and at other training locations. The trainers for the workshop came from eight project partner organizations sharing the experience from all of the five DOPAS experiments: FSS in France, EPSP in Czech Republic, DOMPLU in Sweden, POPLU in Finland, and ELSA experiments from Germany.

The initial ideas for the DOPAS Training Workshop were produced in collaboration with Posiva Oy and the Czech Technical University's (CTU) Centre of Experimental Geotechnics in spring 2013, when the location and the time for the training were agreed. The week in September that had been scheduled for the training provided unhindered access for the trainees to the Josef Underground Laboratory and research centre. The other training locations were at the faculty of Civil Engineering at the CTU and at SÚRAO information centre in Prague and at the ÚJV Řež, a. s. laboratories in the Czech Republic.

The detailed content planning for the training started in May 2015 together with eight consortium members (**Table I-1**). Four planning meetings were held using remote connections (teleconferencing and a video link) and two weeks prior the workshop a face-to-face material review meeting was held in Helsinki, Finland. The planning consortium consisted of Posiva, SKB, Andra, CTU, SÚRAO, RWM and GRS. The planning was complemented with ÚJV Řež staff and with training materials from Nagra adding the ninth member to the planning group. The duration of the training workshop was fixed to five days. In addition to the planning group members, the practical implementation of the training workshop was carried out with the help of additional tutors and lecturers from the Czech Republic. The training content as it was implemented and the full list of tutors are included in **Appendix I-1** of this report.

Table I-1. Planning Group of the DOPAS Training Workshop 2015

Planning group member	Organisation, country
Marjatta Palmu, Task leader of the training workshop, WP6 leader of DOPAS	Posiva Oy, Finland
Radek Vašíček, DOPAS Training Workshop course leader	CTU, Czech Republic
Jacques Wendling, Performance assessment of Andra's programme	Andra, France
Régis Foin, FSS experiment leader	Andra, France
Jiri Svoboda, EPSP experiment leader	CTU, Czech Republic
Pär Grahm, DOMPLU experiment leader	SKB AB, Sweden
Petri Koho, POPLU experiment leader	Posiva Oy, Finland
Lucie Bělíčková, SÚRAO and Řež activities' organization	SÚRAO, Czech Republic
André Rübel, Safety and performance assessment, WP5 leader of DOPAS	GRS gGmbH, Germany
Dean Gentles, Application of lessons to other waste management programmes, WP4 leader of DOPAS	RWM Ltd, Great Britain

The planning approach was based on producing a complete action cycle for the learners based on Kurt Lewin's concept (Lewin, 1946) and on the philosophy of Dewey (in Kolb, 1984). This concept has been further applied to training and represented in Kolb's Experiential learning cycle (Kolb, 1984). This same concept was used as the basis of Deming's wheel PDSA (Deming, 1982), too, well known to people engaged in quality management and the implementation of ISO 9000 based quality systems (ISO, 2009). The application of Kolb's cycle in learning can start at any point of the cycle as long as the whole cycle is included in the learning process. In addition to this guideline, the training emphasized the need to combine both theoretical and practical activities carried out in small groups. The purpose was to ensure that the participants could learn knowledge, skills and competences (KSC) during the process. In the same way, the learning outcomes were defined by setting up the training from four main learning units following the ECVET (European Commission, 2012) approach. In the DOPAS Project, three different expert staff exchange visits had been organized and in connection with these visits, the participants had identified specific learning outcomes related to the DOPAS Project during their visits.

During the planning process, the training plan was built up and a task checklist for the training was compiled and followed up prior the implementation of the DOPAS Training Workshop (**Appendix I-2**). In a similar way the content of the learning units and other activities for the training workshop were designed and complemented during the planning process. The tutors were given prior instructions for the preparation of their training materials and for practical logistics. This material included a PowerPoint template for the presentations. The tutors had the option to use their own organisations' templates, too, providing the general guidelines regarding the presentation were complied to. A list of commonly used abbreviations was prepared to avoid opening up the same commonly used abbreviations in all presentations (see Part II and Appendices II-1 and II-5 for more details).

2.2 Learning Units of the Training

One of the main planning decisions made was to emphasize two themes in the training. First, the aim was to give the participants an orientation to reflect on the purpose of the plugs and seals and about the time that is applicable to the different plugs and seals for their isolation and containment or other functions to be fulfilled. The purposes and functions vary significantly among the various plugs and seals depending on the repository safety concept and on the host rock environment (clay, crystalline rock, and salt).

Second, the training order was planned in such a way that each of the Learning Outcomes (LOs) was presented first by introducing one experiment in detail. This was then followed by shorter introductions related to the other experiments and with an exercise or activity requiring the participants to apply what they had just learned. The approach aimed to provide the participants themselves an opportunity to start to identify and contrast the differences between the choices made for the five different DOPAS experiments, and to understand the underlying reasons for the differences. Some of the feedback on the order of the topics was mixed. However, other feedback from the participants confirmed the usefulness of this approach in creating increased interest in the participants to acquire more knowledge about their national programme and for being able to assist in the programme by using the learning outcomes.

The expected Learning Outcomes for the participants were

- To understand the process/es of designing a full-scale experiment from a set of requirements related to the performance of the safety function/s of a plug or a seal as a repository component in geological disposal.
- To be able to contrast the differences of such processes resulting from the different boundary conditions e.g. from the host rock environments (clay, crystalline rock, and salt), the experimental settings (above ground, underground experimental facilities vs. real repository conditions) and other site and disposal concept specific features.
- To comprehend the linking of different experiment project's related subprojects and tasks and their inputs and outputs as a part of the experiment implementation.
- To acquire hands-on experiences in experimenting with materials' testing and monitoring techniques needed in an experiment.
- To know how the individual experiments and their outputs contribute to the overall demonstration and demonstration programmes for safety of the waste management programmes at the different stages of repository development.

The training design consisted of four Learning Units (LU) including ten different topics in total. These were related to the desired five Learning Outcomes:

Learning Unit 1: From requirements to the design basis of plugs and seals (during training day 1) included:

- Ø Understanding requirements management and their application for plugs and seals design basis
  - The purpose of plugs and seals in clay.
  - The purpose of plugs and seals in crystalline rock.
  - Requirements - understanding and applying them (sources, requirements as a system).
- Ø Design Basis development work flow for plugs and seals. Application of requirements management system to plugs and seals and developing a design basis from them
  - Developing a design basis for an experiment.
  - Case Example of the Czech experiment EPSP.
  - Scoping the DOMPLU experiment. Moving from the initial design to an experiment in place including Exercise 1.

Learning Unit 2: Preparation of an in-situ or full-scale plug or sealing experiment (during training day 2) included:

- Ø How to come up with a coherent demonstration program for plugs and seals?
  - Theoretical basis to Andra's iterative safety assessment process and the latest safety assessment round.
  - Actual case example about one of the last rounds of safety assessment iteration in Andra's demonstrator programme in clay (FSS) - Explicit description of the last iteration cycle.
- Ø The role of instrumentation and monitoring in an experiment including the Exercise 2 (sensors, their installation and analysis of results).
- Ø Monitoring for performance assessment of experiment components (Thermal processes, Exercise 2 continuation, during training day 4).

Learning Unit 3: Design of a seal for an experiment/ demonstrator within the broader context of WMOs' RD&D programmes (during training days 3 and 4) included:

- Ø What is the state of the art in the demonstrator (RD&D) programs today?
  - Andra's scientific programme and its current state. The main questions replied to for the next safety assessment report (DAC[1] 2017) and after the submission of DAC?
  - Plugs as a part of the demonstration programmes in the Nordic countries (YJH[2] and FUD and in the stages of licensing) - including alternatives.

[1] DAC = Demande d'Autorisation de Construction French construction license.

- Behaviour of plug components and materials
  - The use of individual tests to complement existing material and process knowledge (case of REM[3] experiment).
  - Instructions for laboratory Exercises 3-4 on material behaviour at ÚJV Řež a.s.
- Introduction to Safety Assessment, and integration of the experimental work and process modelling in the safety assessment/ safety case.

Learning Unit 4: Construction feasibility of a plugging experiment (during training days 4 and 5) included:

- Practical underground work concerns in setting up an in-situ or other full-scale experiment
  - Risk management for large-scale experiments and work underground.
  - Case example of POPLU experiment (recipe development, method tests and casting, start slot location + RSC[4] and design; moving into real repository construction, as built vs. design) and related exercise on identifying and prioritizing risks for full-scale experiments.
  - Feasibility of a seal in a clay rich host environment. How to adapt the technological process including alternative concept/s?
  - Working methods underground and for the experiments.
  - Lessons learned from the experiments until today - Panel on experiences, constraints and lessons learned.
- How to further apply the lessons learned for the future
  - The use of the DOPAS experiences in a waste management programme not yet in the demonstration stage or without a site - Case of RWM Ltd.
  - Preparing for ELSA experiment.

The different learning units were tied together with more general activities like general presentations on DOPAS Project, about the Josef and ÚJV Řež facilities, and on the Czech geological disposal programme. The planning group members took turns in chairing the different training days during the week and at the same time they triggered discussions in the training group on the topics at hand.

The planned exercises (five exercises in total) included group work on experiment project management, risks, hands-on production and installation of monitoring probes/sensors into the underground facility, handling and interpretation of the measurement data, laboratory testing related to cement bentonite interaction, and uni-axial testing on material samples for identifying material strength and failure mechanisms.

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[2] YJH = 3 year Finnish R&D programme plan, FUD = 3 year Swedish R&D programme plan for nuclear waste management

[3] REM = Resaturation Echelle Métrique test (Metric test resaturation) related to the FSS experiment clay materials by Andra

[4] Rock Suitability Classification

During the last training day, the participants were given an opportunity to interview the tutors in a closing panel focusing on the lessons learned from the DOPAS experiments. In addition, the day included a self-assessment by the group on how they had obtained their set objectives for the training.

3 Implementation of the DOPAS Training Workshop 2015

The training workshop was advertised on different venues and using contact lists of the planning group in the radioactive waste management community and in the universities. Relevant websites in addition to the DOPAS website were used. These websites included e.g. the IGD-TP (www.igdtp.eu) and the ENEN association (www.enen-assoc.org) sites. The number of participants to the training workshop was limited to 12 persons. The training workshop was not oversubscribed, but some last minute cancellations enabled the participation of few more participants who had been alerted to this opportunity only after the registration closing.

The participants came from Czech Republic (3 persons), Finland, Germany (2 persons), Great Britain, Hungary (3 persons), Poland, and Sweden. Four of the participants were active students in the German and Czech universities working at the same time in organizations in the field of geological disposal. Seven of the participants came from consulting or engineering organizations, two came from waste management organizations and the rest from an authority and research organizations and universities. All of the participants had a scientific or technical background, and most of them had a background in geotechnical engineering or geology.

The training materials were distributed to the participants via a protected internet site for downloading prior the start of the workshop. The materials consisted of about 40 different presentations, of five major exercises and of other supporting materials, including presentations of the tutor organizations. Additional material included also the documentary movie "Into Eternity" by director M. Madsen that was shown at the courtesy of the movie producer: Magic Hour Films.

The first training day took place in Prague at the CTU. The purpose of the day was to provide the training participants an orientation to the training topics and at the same time to get them acquainted with each other. The content focus was on Learning Unit 1 covering the requirements and design basis of plugs and seals and on their purposes. The day included the lectures on the design of the Czech and Swedish plug experiments, EPSP and DOMPLU. The introductory day's short exercises in pairs and small groups promoted the participants to get to know each other for supportive and open-minded cooperation during the workshop.

The second day continued at the Josef facilities an hour's drive from Prague with the lectures about the facility and about the interactive process of safety assessment in the case of Andra and about the role of the FSS experiment in it. The day 2 topics belonged to the Learning Unit 2 that addressed the scope of preparatory work needed to implement an in-situ experiment in full-scale. The training also included an introduction to the Josef facilities, the role of monitoring and instrumentation in the experiments, and a hands-on exercise in preparing thermal sensor probe and its installation into the Josef underground into the vicinity of the heater assigned for this exercise purpose. The data was then collected and interpreted during the fourth day when the training group returned to Josef again.

The third training day started at ÚJV Řež a.s., where practical laboratory works continued after presentations about the broader Research, Development and Demonstration programme context that was a part of the Learning Unit 3. This unit covered further experiment design related issues in addition to the overall scope of the demonstrators and their function in the waste management programmes. French and Nordic research and development programmes (Dossier 2015, FUD and YJH-programmes) of which the experiments are a part of were introduced to the participants. The learning continued at the ÚJV Řež laboratories with the practical exercises including the measurement of and the development of understanding about material properties. Material development is an integral part in all experiment's development work during experiment design work in the DOPAS Project.

After the laboratory exercises, the group moved to the SÚRAO information centre in the centre of Prague. The focus of the late afternoon was on the Czech siting programme and on stakeholder communication. The evening ended with a "movie night" and discussions about the "Into Eternity" documentary.

The fourth training day took place in Josef again and the Learning Unit 3 continued. The content focused on the general principles of safety assessment and on the technical feasibility of the plug and seal construction. Presentation of the POPLU and DOMPLU plugs' and FSS seal's construction works were given and the participants worked on identifying the potential risks related to the experiments in the Nordic countries. The second part of the long day at Josef was spent analyzing the monitoring data from the two different thermal sensors installed in the heated rock. Finally, the day was finished with a visit into underground Josef cathedral with Czech music and a light show.

The last training day brought the group back to Prague, where the participants learned about the German ELSA experiment and about the tested materials. The content of the Learning Unit 4 addressed the feasibility of the construction of the experiments. Lessons learned from the experiments were summarized in a tutor panel. RWM Ltd as a waste management programme not yet having a site presented their planned use of the lessons learned during the project.

The afternoon was filled with the participant presentations on the results of their exercises carried out during the week. The participants received feedback from the different exercise tutors and from their peer learners on their findings. The two groups sent their exercise reports to the tutors who gave them further feedback on their excellent work. The day and the official training course finished with the participants assessment about the achievement level of their learning outcomes during the week. In practice, beautiful Prague saw still a group of enthusiastic training participants enjoying their last night in the Golden city.

4 Assessment of the DOPAS Training Workshop

The participants' activities and interaction were observed during the whole training week by the tutors. The training group worked very well together and assisted each other in the exercises. All wanted to perform their tasks very well and if they felt that they had not reached the target they had set, they felt a bit disappointed. Each completed exercise was followed by both peer assessments from the other exercise group members and by comparing the exercise outcomes with the other group's results. This interaction was complemented with the tutor/s' feedback.

In the beginning of the workshop, the participants set their own expectations and goals for the training (see ref. Palmu & al., 2013, 4) and most of their objectives were achieved. In addition to the group assessment, the participants also gave their individual evaluation of the workshop on an evaluation questionnaire. The outcomes of the evaluation varied on a scale from 1 (very poor) - 5 (very good) with results on average between 4.3 and 4.8 on nine different evaluated items. Replies were received from all participants. The tutors made a similar evaluation independently and came to the same score range in their conclusions as the participants.

The participants received a training workshop diploma with a recommendation letter from the workshop organizers supporting the recognition of the amount of work done in the workshop to equal four ECTS[5] for academic studies.

The learning outcomes of the training workshop are documented also by using the ECVET approach in the form of KSC needed for each of the learning units and related learning outcomes in the project in Part II (Appendix II-6). This documentation is intended to make it easier for any future users of the training material to apply it using the similar principles and approaches in their own training.

5 Conclusions and acknowledgements

The workshop was successfully implemented and well received from both the participants and the tutors. The planning process also assisted in structuring the connections of the DOPAS work for the tutors engaged in the process and this contributed also directly to the planning of the expert elicitation of the DOPAS Work package deliverables. Much work was done to produce the plan and to implement it. We hope that when the training workshop report comes out, also other trainers find the materials useful and use the plan and the materials in future training.

Defining and implementing the workshop content according to ECVET tools was beneficial for both – the participants and organizers - as the course provided first opportunity to experience and use the ECVET approach for many of them.

Special acknowledgements go to all the tutors, to the members of the training workshop planning group, and to Nagra contributing their materials for the training, and to the other DOPAS consortium members.

[5] European Credit Transfer System

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013 under grant agreement no 323273, the DOPAS Project.

PART II
DOPAS TRAINING WORKSHOP 2015

Part II
DOPAS TRAINING WORKSHOP 2015 IMPLEMENTATION AND LEARNING MATERIALS

1 Purpose of Part II

The purpose of this second part of this deliverable report is to describe the implementation of the DOPAS Training Workshop 2015 from such a perspective that a potential tutor planning to use the learning activities and training materials designed and produced for the training could take advantage of the process as it was originally designed. Naturally, the training materials can be used independently as part of any suitable training, too.

2 Introduction to the Underlying Learning Process during the Training

The learning approach applied to the DOPAS Training Workshop includes simplified adaptations from the Experiential Learning process described by Kolb (1984) and from the Expansive Learning process described by Engeström (1987).

According to Engeström in the learning process (i.e. the cognitive learning model), the learner is a researcher and a subject looking for a generic and functional explanation model for a specific phenomenon or entity. At the same time the learner tests the model in practice and corrects it. The process can be divided into its parts (into 5-6 parts), where each part of the process requires specific learning acts and ways of processing the object of learning. In the process the learner is the subject and the parts of the learner's process include 1) Motivation [to learn resulting from an internal cognitive conflict e.g. a gap between the current knowledge and requirements of current work.] 2) Orientation [to the object to be learned e.g. in a form of a systemic simplified model including the relationships between the components of the model instead of individual pieces of information. The orientation is aimed at helping to predict what is to be learned and how its parts related to the whole.] 3) Internalisation [of new information by memorizing, including its assimilation to the existing knowledge i.e. learning] 4) Externalisation [of what is learned is linked with internalisation and includes the application of what is learned to a new target so that the new model starts to steer the subject's activity consciously] 5) Evaluation [of the outcome from the learning includes a critical review of the validity and on the limitations of the new model learned when performing a task], and 6) Control [is about breaking down one's performance and learning outcomes in view of the new model and performing needed corrective actions for improvement]. In designing the learning process, different learning activities can be implemented to ensure that all of the parts of the learning process are covered. (Engeström 1987, 45-47)

In alignment with the process itself, Engeström has developed and transformed the model further and several references are available on the model for the interested reader (e.g. Yrjö Engeström (2001) Expansive

Learning at Work: Toward an activity theoretical reconceptualization, Journal of Education and Work, 14:1, 133-156).

Kolb's Experiential Learning (1984, 28-32) process emphasizes the learner's experience and especially the subject's prior experience related to the target of the learning as the starting point of the process. In addition, the process combines experience with perception, cognition, and behaviour. Kolb sees learning as a continuous process grounded in experience. At the same time Kolb does not emphasize the direct learning outcomes but sees learning as an emergent process whose outcomes represent a historical record and not the knowledge of the future. Also Kolb see that that learning is a tension and conflict filled process due to the need of relearning. To facilitate this relearning process, the educational process ought to bring out the learner's beliefs and theories, examine and test them, and then integrate the new more refined ideas into a person's belief system.

In respect of not emphasizing the learning outcomes, but the continuous process itself, the approach by Kolb seems to deviate from the ECVET approach (European Commission, 2012), which emphasizes the end results without the aspect of modifying continuously what is learned. However, the ECVET, too, is considered to motivate for continuous learning of new knowledge, skills and competences.

In the Experiential Learning cycle there are four modes or abilities that contribute to effective and holistic learning (**Figure II-1**). These modes are concrete experience, reflective observation, abstract conceptualization, and active experimentation. In the learning process, it is important to find a balance between these modes: i.e. to be able to act and reflect simultaneously, and to be concrete and theoretical at the same time. Imbalance can lead to suppression of the other modes in the learning process and then the learning or human adaptation process does not necessarily lead to creativity and to personal development.

The reader might already recognise that these learning processes and their predecessor's all are analogous to the scientific inquiry process and this is also noted by Kolb (1984, 32).

In the DOPAS Training Workshop planning, the purpose was to produce the complete learning cycle for the participants. However, the learning process can start at any of the four modes defined by Kolb. Kolb favours concrete experience as the starting point to ensure the motivation for learning, but the starting point can be any of the four modes. If it is to be expected that the group of trainees is likely to exercise non-learning behaviours (e.g. Kolb, 1984, 28) resulting from cognitive conflict, then starting with experience is recommended. The analogue to this in the scientific method would be to choose either inductive or deductive reasoning in scientific inquiry.

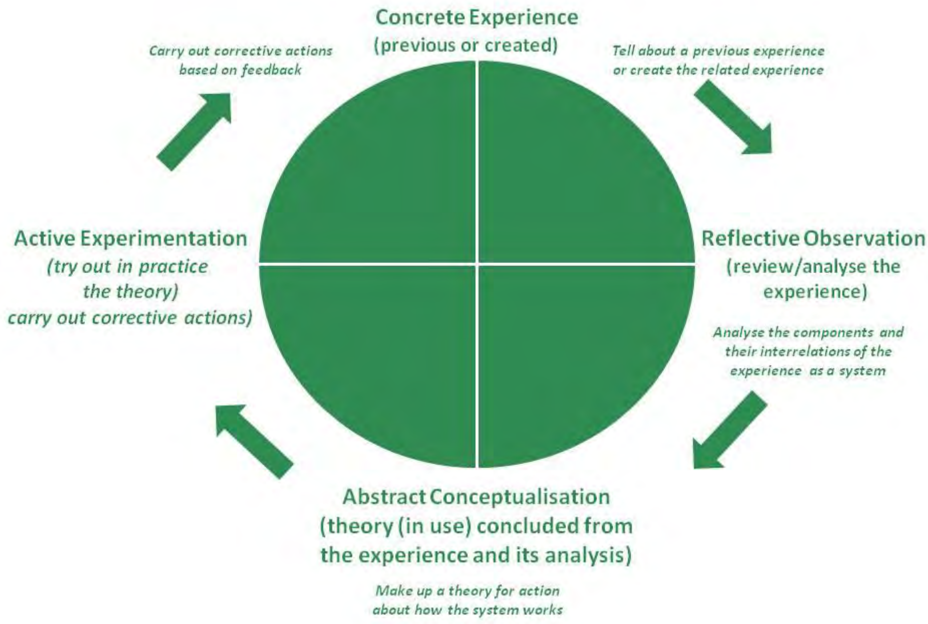

Figure II-1. Kolb's experiential learning applied for the DOPAS Training Workshop 2015. Figure adapted from S. McLeod (2013).

3 Content of the DOPAS Training Workshop 2015

The content of the training was formulated as an iterative process in the planning group. After the approach to the learning was selected and the first drafts of the four learning units and their learning outcomes were defined, the planning group members started providing inputs for the reflective, theoretical, experimental, and hand-on experience related learning activities. The content was refined between and during the following three planning meetings. By the time of training materials' review meeting in the end of August 2015, the plan was complete and the review meeting focused on the planning group's feedback and on finalising the training materials for the training workshop scheduled to start in two weeks. The training materials, excluding some learning activities that were on purpose distributed on site, were distributed to the participants via a protected website four days before the start of the training.

The content of the training as it was finally implemented is presented in **Appendix I-1**. This is also the content that was included into the diplomas given to the training participants.

4 Cross-cutting Training Themes

In addition to the generic learning approach for the training, two other cross-cutting themes were driving the training implementation.

The first fundamental principle was to highlight "time" to the participants. Time and its meaning in geological disposal were taken up on several occasions and from different perspectives, and not only from the different regulatory assessment periods for the plugs and seals. From the plugs and seals point of view, the differences in the lifetime requirement of the different plugs and seals, is one underlying reason leading different types of plug and seals solutions. And the assessment period is dependent on the national regulation and on the safety functions (if any) assigned to the plugs and seals. One aspect of time included was also the role of the plugs and seals in the overall research, development and demonstration (RD&D) programmes of the different waste management organisations. Introducing the different RD&D programmes aimed to demonstrate how this single component demonstrator contributes to the overall disposal programmes' compliance assessment and what are the future needs and plans in this area after the DOPAS Project with a total of four years' duration has ended.

The second principle was to promote integration and comparison of the different choices for the full-scale experiments regarding their requirements and design basis, design, and choice of materials in the design and their implementation. Due to this reason, the experiments were not presented as one summary per experiment neither was the emphasis on the host rock environment. Instead, the content of the different stages of the DOPAS Project (actually the individual Work package contents) were presented by giving first a more extensive case example from one experiment at a time. This case was then complemented with shorter examples on the same topic e.g. on design basis or on the design work of the other DOPAS experiments. In this way, the whole DOPAS Project framework was covered in the content. The detailed elaborated planning document for the DOPAS Training Workshop is presented in **Appendix II-1**.

Based on the tutors' observations, on the discussions during the training and on the feedback received from the participants, the comparisons could be made and the underlying differences and reasons for the different choices made in the various experiments became understandable for the participants. As some participants mentioned, there was a strong desire to get to know more about the one's own national programme and about the choices that had been made in that programme.

In addition to the training content and learning unit planning, the training included additional activities that were mainly intended for strengthening the networking between the participants. The importance of public interaction was also included into this activity part. The visit to SÚRAO's information centre in Prague and the movie night further contributed to this experience.

5 Learning Activities

DOPAS Training Workshop's training materials corresponding to the training content in Appendix I-1 for the learning activities are included in this report's **Appendix II-2** in the form of low resolution summaries. The summaries are intended to give an overview of what is available for a potential tutor and then assist in selecting training materials of his or her interest. High resolution training materials in pdf format are provided as links to DOPAS Training Workshop 2015 material list document in high resolution on the DOPAS website (http://www.posiva.fi/en/dopas) for the next five years. This solution has been implemented due to the large memory space volume required by the training materials.

The type of learning activities in this training included activities like icebreaker; reflection exercises, brainstorming, tabletop discussions, instructions, educational discussions, panel discussions and questioning; theoretical, case example, and presentation lectures; project planning and risk management exercises and exercise evaluation; hands-on work on sensors and probes, practical installation work, data analysis and thermal calculations; and laboratory testing work (weighting, pH measurements, and stress testing). The main learning activities are described in more detail in the sections of this chapter.

In planning the training, attention was paid to the structure of the training so that the training would not consist of too long sessions of similar type of learning activities. Therefore attention was paid to breaking the structure of the training days so that more theoretical lectures would be broken into smaller units, and they would be intercepted with learner-centred reflective discussions, exercises, or other types of learning activities. In some cases this was implemented artificially with the purpose to avoid too long sessions of a similar type of activity e.g. lectures or experimental work. Based on the feedback and due to the specific site conditions, the training deviated on two occasions from this: On training day 2, the preparation of the sensor probes for measuring temperatures in Josef underground took some what longer than anticipated for one of the groups. On training day 3, the morning was devoted to lectures and the afternoon for the laboratory testing work. The reason for this was due to the fact that the laboratory facilities required access clearance to a facility that handled radioactivity. It was more feasible to package activities requiring similar facilities together to avoid the need of several entries to this facility.

The training week was very intensive like it can be seen from the programme. The participants and the tutors were occupied from morning to night with the various training related activities. This meant that there was quite insufficient time left for the groups to compile their reports for the last training day. This is a major need for improvement in the future planning. Some additional three hours for the groups to work on their presentations would need to be added to the training. The exercise reports that were sent to the tutors two weeks after the training were excellent and produced with great care and attention.

5.1 Induction and Assessment Criteria Setting

The first activity in the training after the first welcomes includes an exercise that had two purposes. First, the exercise is intended to break the ice between the participants and to assist in the forming of the exercise groups for the training week. This part of the activity includes an introduction of another training participant to the whole group.

The second purpose of the exercise is to collect the expectations and objectives for learning of the participants for the training. These expectations are collectively written down, grouped by themes and presented by four different groups of participants. Further these expectations and objectives are stored for the last training day, when they are used as assessment criteria for evaluating how these expectations and objectives were obtained during the training. In general, this exercise contributed to learning to listen, to interview for data collection, to set goals individually and together and to present in English. The underlying idea of the activity for setting assessment criteria is derived from the humanistic learning approach, where adult learners learning is assumed to be directed by their own learning needs. When this is the case, the criteria for attaining the learning results needs to come from them, too.

The induction was then followed with the short overall presentation of the DOPAS Project. By this time the participants were already quite familiar with each others. This familiarity with the group reduced the threshold to ask questions from the tutors and the groups were practically formed for the training week's exercises.

5.2 Lectures

The lectures for the training were produced in alignment with the principles described in Chapters 2-4 of Part II. In the majority of cases the maximum length of a lecture was set to 45 minutes. Some exceptions were included into the programme, but attention was paid to having a sufficient amount of breaks for stretching the legs and for other purposes. This was necessary due to the long days during the training.

The lectures (in the training materials) consisted of different types of lectures. Some lectures gave a more theoretical and knowledge based information about a specific topic (like requirements management; RD&D programmes and demonstrators as part of these programmes; safety assessment). Other lectures included specific case presentations either from a waste management programme or part of the programme, or from the construction or other practical implementation of an experiment. Further the lectures addressed the research and development work and related tests needed to come up with the designs and the experiment constructs. Further the lectures gave advice on practical planning activities like project management or instrument choices for monitoring the experiments. The tutors had also taken with them host rock and construction material samples and instrumentation equipment and components for the participants' hands-on observation. During all of the lectures, questioning and educational discussions were conducted. Some lectures were either preceded or followed with participant reflection exercises (e.g. requirements) or brainstorming exercises on the topic presented. In this way the lectures and participants' experiences related to the lecture topics were integrated into a single learning activity. The presentations given at SÚRAO's information centre belonged to the lectures even though they were not directly addressing the DOPAS Project topics.

5.3 Exercises

The training workshop included five formal exercises. These exercises included: clear instructions given prior the beginning of the exercises; working on solving the instructed topic of the exercise in groups either using brainstorming, tabletop discussions, or real practical hands-on working in compliance with the given installation or testing protocols. The direct tutor guidance and assistance on request was an integral part in the carrying out of these exercises. The exercise instructions are included in the following sections. However, the data and calculation software, and the installation and testing protocols are not included to the materials as these were not developed for the training, but where pre-existing knowledge.

The participants were provided with a general introduction to the five training workshop exercises by the workshop leaders. This included the objectives of each exercise and a template for reflecting on the exercise as a part of their reporting (in **Table II-1**).

Table II-1. Summary of DOPAS Training Workshop 2015 Exercises

Exercise list for DOPAS Training Workshop 2015		
#1	Project management - Work breakdown structure (WBS). **You will learn and work** on how to scope and split a complex problem into more manageable parts in order to control time, resources, and quality.	Produce subprojects to scope and solve a complex experiment project. To be reported on Day 1
#2	Instrumentation and interpretation of results. A hands-on exercise for **preparing, installing probes, and reading results** on Days 2 and 4. **Handling** of results from the installed sensor (or other related data sets - an option if the real data sets are not available).	A preliminary report by two groups given on Day 5 Comparison of group results is important. Groups finalise their reports by 2.10.2015.
#3	Understanding the strength of concrete by doing laboratory test[6] for characterizing material strength for material selection.	Carry out stress testing and assessing which materials would you choose for your use and why? Compare. Present results on Day 5 in groups and report by 2.10.2015.
#4	Concrete - bentonite interaction. **Doing laboratory test samples for interaction in work (pH value impact).** Underlying requirement related to the material: EBS compatibility. How does concrete or concrete properties influence engineered barriers?	Based on your test results, **write an assessment** about what is required. Presentation by the groups on Day 5 and report by 2.10.2015.
#5	Safety and security is very much about **identifying and managing risk**. It also influences timetable and costs. Your task is to **manage the risks** of an experiment.	Please **identify and complement the potential risks** for the two experiments DOMPLU and POPLU. How do they differ? Compare. Presentation in by the groups on Day 5 and report by 2.10.2015.

[6] Original plan was to use a standardized test, but the exercise was carried out with a non-standardized test simulation. The change did not impact the learning process.

5.3.1 Exercise 1: Project Scoping

Tabletop exercise by P. Grahm, SKB

Exercise 1 was carried out in groups. The purpose was to learn about scoping and structuring a project (Project Management) so that the participants could create a work breakdown structure that would meet experiment objectives (Figure II-2).

This exercise was preceded with a lecture about how to create a project's work breakdown structure (WBS). The main message conveyed was that a project's scope is a balancing act between resources, quality and time available. The participants were split into three groups for the exercise.

Instruction:

- Create a Work Breakdown Structure for the DOMPLU Full-Scale Experiment.
- Focus on the project phase "Installation (including monitoring)".
- Use information in the previous presentation (DOMPLU layout, and photos from installation).
- Ask experts (if necessary).

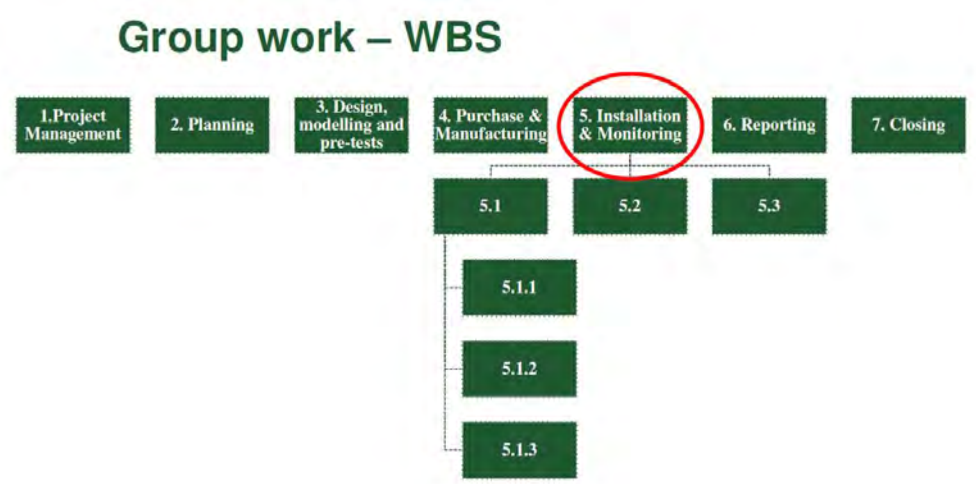

Figure II-2. Target of Exercise 1 (Source: Pär Grahm SKB. Day 1 training materials D1 1.3.2)

The exercise results were assessed and feedback given directly after the group work. The exercise replies from the groups showed two types of breakdown approaches: sequential process breakdown and a component based breakdown of the work.

5.3.2 Exercise 2: Thermal Probe Manufacturing, Installation, and Data Analysis

Hands-on and calculation exercise by J. Svoboda, CTU

Exercise 2 included hands-on activities related to the instrumentation and to the underground installation of instrumentation. The exercise started on the training day 2 and continued on training day 4 when the analysis of the results collected from the underground installation was carried out. Real data were used. Simulated data from previous data collection can be used in this exercise, too. Such data is useful when access into an underground or to another facility for the sensor preparation or installation is not possible during the training. However, the training organiser needs the suitable software and data sets in all cases.

The first part of Exercise 2 on training day 2 (Day 2) included:

- Introduction into exercise and experiment used (15 min presentation).
- Short demonstration of sensors used (5 min).
- Manufacturing of probe (assembly, testing, sealing) (75 min) Probe consisted of several thermometers that were assembled by each of the two groups.
- Preparations to getting ready/equipped for the underground facility including transfer into underground sensor location (30 min).
- Probe installation into the rock in the underground (45 min).
- Connection to data logger and measurement network (20 min).
- Heater start-up and transfer out of the underground location (20 min).

The boreholes for the sensors and data logger and the measurement network were prepared in advance by the tutors at CTU. The preparation of the probes included the assembly of the analogue and digital thermometers to the cabling following the given circuit instructions. The work took a bit longer than anticipated for the other group due to unanticipated rework.

The second part of Exercise 2 on training day 4 (Day 4) included the handling and analysis of the collected data sets:

- Raw data processing (Excel):
  - Raw sensor data from database.
  - Sensor calibration data.
  - Processing data in excel:
    - Raw -> Values.
    - Validity checks.
    - Plotting of values.
- Processed data analysis (Gnu Plot) - Option:
  - Processed data.
  - Plotting multiple sensors for cross analysis.

The data flow had been checked by the tutors in the meanwhile to ensure that real raw data were available for the data analyses. The analysis and calculation results of the two groups were compared with each other and some lessons learned were noted also from the installation process itself, which had an impact on the raw data quality. The exercise experiences were shortly presented also during the last training day (Day 5). The final results were reported in the exercise report after the training workshop.

5.3.3 Exercise 3: Simplified Stress Test of Concrete Samples

Laboratory testing and failure mode analysis exercise by P. Večerník, ÚJV Řež a.s.

Exercise 3 included a simplified demonstration of uni-axial stress testing on cement paste samples mimicking concrete to evaluate the material's compressive strength. The steps of the exercise included:

- Methodology introduction and description.
- Characterisation of samples - samples origin, samples dimensions.
- Guided tests on laboratory device.
- Evaluation of results.

Since the samples and the testing procedure made up for the exercise did not comply with the international uni-axial testing standard, the deviations from standard testing were highlighted by the tutor. The different failure mode types were demonstrated with the purpose to highlight the reliability of the test results i.e. did the failure mechanism happen as it should have happened in a standard test. The results were recorded on a template provided by the tutor in the exercise instruction (**Appendix II-3,** 1**).**

5.3.4 Exercise 4: Interaction of Concrete with Bentonite

Exercise tutoring by D. Trpkosova and K. Videnska/ ÚJV Řež a.s.

Exercise 4 introduced the participants to practical laboratory work including the preparation of different material mixtures with the required accuracy for the pH testing and for understanding the interactions of concrete with bentonite in terms of the changes in pH values. The exercise was themed: *"Evaluation of pH in cement/concrete and bentonite - role of pH in cement-bentonite interactions"* and it included:

- Methodology introduction and description.
- Preparation and characterisation of the samples - weights, volumes.
- Interaction of solid and liquid phases.
- Calibration of pH measurement electrodes.
- Guided and students' pH measurement.
- Evaluation of results.

The results were recorded on a template provided by the tutors in the exercise instruction (**Appendix II-3**, 2). The exercise demonstrated the preliminary laboratory development work needed to come up with suitable materials for the experiment designs.

In principle the exercises were carried out in two groups, but for practical sample preparation the groups were split into smaller subgroups to ensure that everyone had sufficient hands-on tasks to do during the exercises.

For experiment's practical implementation attention should be paid in the future on the boundary conditions related to pH measurements (e.g. type of water in laboratory vs. in-situ conditions). From the construction point of view a more accurate method is to provide the cement - silica ratio after the recipe specification has been defined like done in the case of the POPLU concrete materials.

5.3.5 Exercise 5: Group Exercise on Risk Management of Two Experiments

Tabletop exercise by P. Grahm/SKB and P. Koho/Posiva: Identifying and prioritizing risks for full-scale experiments.

Group 1 assessed DOMPLU risks.
Group 2 assessed POPLU risks.

Instructions for the groups:

- Practice step 2 “Identification” and Step 3 “Assessment” given in the presentation about risk management of the Nordic experiments. Use brainstorming for the identification step.
- **Focus on risks during installation of the full-scale test.**
- There is no need to identify “administrative risks” such as purchasing, contracting or lack of resources at this stage.
- Check DOMPLU and POPLU presentations for information about project objectives and technical installations.

The tutors assisted the groups with probing questions during their exercise. The exercises were reported on training day 5 including a comparison of the risks related to the installation of these two alternative plug designs for the KBS-3V disposal system. The groups successfully identified the following risk categories related to the installation and prioritized main risks under the categories:

1. Personnel risks:
   - most severe risks are rock fall related accidents and danger for electrocution.
2. Technical risks during installation:
   - logistic challenges; lifting of heavy items; concrete transports; need for redundancy of vital equipment; and electrical power back-up
3. Technical risks after the installation:
   - installed sensors not functional; unforeseen concrete cracks; water leakage through or by passing the plug
4. Timetable risks:
   - delay to the original experiment timetable.

Further, the groups proposed related risk mitigation measures as part of their exercise reporting.

5.3.6 Reporting Instructions for the Exercises

The two participant groups reported their exercise outcomes in their final exercise report for the exercises 2-5. The reporting template that was provided to the participants asked them to include answers to the following questions in their exercise report. This template served also the assessment of the participants' learning by providing self-assessment and peer assessment on the exercises:

1. Was the outcome you were intended to do in the exercise clear?
2. Summarize briefly what was done in the exercise?
3. Explain what tools/forms/equipment etc. were used and how they were used in the exercise?

4. What were the outcomes of the exercise? If there were intermediate outcomes, tell about them, too.
5. Identify what you found challenging in the exercise? Why?
6. What went well in the exercise? Why?
7. How did your exercise outcomes compare with the outcomes of the other group?
8. Give feedback on the reporting and results of the other group. On the results and the clarity of their reporting and result presentation.
9. What was your most important learning point from the exercise?

Both groups exercise reports were of top quality providing high quality reporting of the exercises and extensive self and peer assessment as requested in the template. Achievement of learning outcomes was well demonstrated in the reporting.

5.4 Additional Activities

Several types of other activities were included into the training week. These can also be count for exercises and they included the icebreaker (see 5.1), the reflection/discussion exercises on sources of requirements and on the movie "Into Eternity".

Prior the requirements management lecture, the participants were asked to name different sources of requirements. These brainstorming results were then grouped hierarchically on a flip chart to demonstrate a requirements management structure example.

For discussion about the movie, the following questions were given for reflection and at the same time the meaning of time in geological disposal was discussed:

- Your impressions about the movie? Have you seen it before/seen it for the first time?
- What did the director try to convey to the audience? How did he succeed?
- What did you like about the way of presenting his view or main message
- What would you have changed in the way of presenting his point of view/s? Why?
- Could this movie provide support for the deep repository? Would it make you uneasy about the repository?
- Did this meet what you expect from a documentary? Yes/No - Why?
- Can you separate the movie as an artwork from making a statement?
- Other comments?

Also some other examples demonstrating time in the disposal and geological context were given as resources for the participants. These included:

- Timeride by Nagra (http://www.timeride.ch) https://www.youtube.com/embed/cRo230LVzjw?rel=0 , available for public visits.

- Time Trek by the University of Turku and the Turku 2011 foundation http://www.turku2011.fi/en/time-trek_en .
- Timetravel to final disposal - Posiva YouTube (Time travel) https://www.youtube.com/watch?v=Jqsc-3vZ8wU .

5.5 Educational Discussions and Panel

During the whole training, the lectures and the exercises were interactive with the participants posing a lot of questions to the tutors. During the last training day a panel was organised about the lessons learned by the experiment or work package leaders in the DOPAS Project. Each panel member provided a 1-2 slide introduction on what they considered as the most important lessons learned from their experiment or work package. After this, the floor was open for the participants' questions. Around 40 minutes were reserved for the starting presentations and another 35 minutes for the audience's questions. The following questions were given in advance for the panel members for preparing their summaries:

- What do you consider the major challenges concerning the working methods in the implementation of the experiments? in the implementation of plugs or seals for the disposal facility?
- What working methods would you also adopt in the future? What worked very well? How can you learn from the experiments and improve the efficiency, cost and safety of future working methods?
- Measurements, quality assurance, approvals by regulator, ...
- How did you carry out method tests? What could be improved in the method tests? What type of standard tests was available and what tests would still need to be developed? (E.g. concrete casting mock-ups, contact grouting; earth radar for casting, reinforcements).
- Practical procurement experiences? Suggestions for improvement?
- Major lessons learned yourself, your unit and your organisation, the DOPAS consortium?

The participants' questions focussed on the practical emplacement of the bentonite and shotcrete materials and to the related working environment concerns like dust control measures (e.g. need for filtering dust) and need for sufficient amount of ventilation in the underground facilities; and on the capability of the plugs to resist the needed pressure in the case of the different plug experiments especially in crystalline rock. The sources for challenges in the experiments and in the real repository conditions (e.g. rock conditions) and the measures to overcome them (e.g. the location selection by using the Rock Suitability Classification, RSC) were asked, too. The operational capacity to construct the total number of plugs needed per annum and the time needed to construct the plugs was of interest to the participants. The panel closed with the closing summaries by the panellists. The discussion information from the panel was not recorded, but the final documentation of the DOPAS

Project includes the lessons learned for the interested reader (see Chapter 10 for further sources).

5.6 Safety Instructions

During the training, exercises were carried out in an underground laboratory and in a nuclear facility. A safety induction to the rules on conduct and on the safety procedures to ensure the visitor's safety is mandatory for location access. Such instruction was given both at Josef URC before entering underground and at the ÚJV Řež a.s. prior entering the laboratory facilities. Such instructions are not included into the training materials as they are always repeated upon entry and they are continuously updated.

5.7 Assessment and Feedback

The training process included several assessment targets and means of assessment. The types of assessment used included peer feedback and assessment, tutor feedback, guidance and assessment, first impression collection ("the blank A4"), group self-assessment against preset criteria (see section 4.1), a formal assessment via a questionnaire and the tutors' evaluation. Assessment was continuous and integrated into the exercises, too.

In the beginning of the training workshop, the participants were given the formal feedback questionnaire as a part of the training materials, which they were asked reply on a continuous basis during the training week. This feedback questionnaire made up the formal assessment of the training. The participants returned their forms a week after the training latest. The tutors present on Day 5 made their own assessment about the training using suitable questions of this same questionnaire.

Feedback collected immediately at the end the training included the very first sentiments of the participants by asking them to

- "Write down several adjectives (3-5) that you believe describe the DOPAS Training Workshop 2015".

Then they were asked to describe or complement the following sentences on a blank piece of paper:

- Now I know about ...
- I did not feel I understood the following content....
- I would have liked to have ...
- After this training workshop I would like to learn more about...

This evaluation was followed by a group evaluation on how well the objectives the participants had set for the training were fulfilled.

The objectives from the first training day included:

- Input/output for other demonstration experiment.
- Understanding the difference and reasons for them.
- Geotechnical monitoring.
- Short- and long-term monitoring.
- Hands-on experience.

Based on the evaluation with the exception of geotechnical monitoring, the participants felt that they had achieved their objectives. Some participants desired to have more practical training on geotechnical monitoring, which was not included into the training programme except on presentation level.

In addition, the participants included evaluation into their exercise reports submitted for the tutors' assessment after the training workshop.

Final tutor feedback was given to the participants on their exercise reports. A summary of their formal feedback on the training course was distributed to them, too. After two weeks of the training implementation a feedback meeting for the planning group was organised via teleconferencing to discuss the collected feedback and the tutors' views on the training workshop.

A summary of types of tools used for feedback collection and the different types feedback received are included in **Appendix II-4**.

The formal feedback questionnaire included nine assessment areas. The average scores on these assessment areas are given in the **Table II-2**. The score scale ranged from 1 to 5 (very poor – poor - average – good - very good).

Table II-2. Overall participants' assessment of the DOPAS Training Workshop 2015

Assessment areas	Average score given by participants (n =12)
1. Selection of learning units and topics	4.6/5
2. The coverage of learning units and topic presentations	4.4/5
3. The order of learning units and topic presentations	4.3/5
4. Tutors (expertise, tutoring)	4.7/5
5. Training materials	4.8/5
6. Activities	4.8/5
7. Exercises	4.7/5
8. Practical arrangements	4.8/5
9. Time keeping/Schedule	4.7/5

The tutors themselves also expected the assessment results to fall between the scores 4 and 5.

6 Training Aids

This chapter lists the type of learning aids and needs for the lectures, exercises, for the presentation the other activities and group work. The topic details are given in the detailed training plan/list of contents in **Appendix II-1**.

Advance materials distributed in electronic format included:

- Participation confirmation and guide for participants (including logistics and location map).
- Training programme.
- Training materials including lectures and presentations, excluding exercise solutions.
- Suitable other background material like design basis development workflow poster from WP2.
- List of commonly used abbreviations in geological disposal and in the DOPAS Project.
- Feedback questionnaire.

Printed or hard copy materials included:

- Programme and maps for transport (print outs).
- Name tags for participants and tutors.
- Table name tags for participants, tutors/panellists.
- List of contact information during the week.
- Participant lists for daily signing (for the diploma).
- Flip chart with paper/ white board.
- Plain DIN A4 sized paper, notes paper, painter's tape.
- Post-it notes, exercise templates, pens, pencils, markers.
- Exercise materials.
- Discussion question lists for tutors/facilitators.

Information and communications technology and software included:

- Video projector and screen.
- Internet/wireless connection/s (including YouTube).
- Desktop/ portable computer/s for tutors and participants.
- MS PowerPoint, MS Word, MS Excel for tutors and participants.
- Digital camera or mobile phone camera (for documentation).
- Datalogger and wireless data transmission for data collection from sensors.
- Processing software and database on server.
- Gnuplot, text editor.
- Calculators.

Exercise materials, visuals and videos included:

- Videoclips from the experiment implementation stages.
- Videos related to geological disposal time scales (YouTube).
- Movie DVD: "Into Eternity" and DVD player, silver screen.
- Examples of various sensors, measurement components, cables, and data logger(s).
- Workshop for sensor preparation: tools for preparation of probes, thermometers (analogue and digital), cables, circuit plans, resins.
- Cement/concrete samples prepared for uni-axial testing in laboratory.
- Materials and equipment (e.g. pH meter, pH electrodes, accuracy scales, material mixers, distilled water and other solutions)

- provided for material weighting, mixing and for pH measurements.
- Samples of different host rocks (mica gneiss, granite, salt) and of various salt based concrete materials and of bentonite pellets.

Protective gear:

- For underground: helmets, boots, reflection vests, belts, lamps.
- For laboratory: laboratory coats.

Selecting a room with the possibility to modify the layout of tables and chairs is recommended for the presentations, the exercises, and the panel.

7 Instructions for the Tutors

The planning group was given a short induction to the learning approach during the first planning meeting. Further, the tutors were given instructions on how to evaluate the learning outcomes of the participants. These prior instructions gave guidance for the preparation of the training materials and for practical logistics, too. The tutors had several roles during the training. They acted as lecturers, exercise tutors, guides, session chairs, panellists, facilitators, and organisers questioning and clarifying during the training. They were provided a PowerPoint template for their lecture presentations. Alternatively the tutors had the option to use their own organisation's templates, providing the general guidelines regarding the presentation were complied to. A list of applicable abbreviations was prepared to avoid opening up the same common abbreviations in all of the presentations. **Appendix II-5** includes the instructions related to the training without the detailed local logistics information, which applied only to the training in the Czech Republic. The task checklist used for the training process is included in Appendix I-2.

8 Learning Outcomes

The five learning outcomes (LOs) defined for the training were:

- To understand (K)[7] the process/es of designing a full-scale experiment from a set of requirements related to the performance of a plug or a seal as a repository component in geological disposal.
- To be able to contrast (S) the differences of such processes resulting from the different boundary conditions e.g. from the host rock environments (clay, crystalline rock, and salt), the experimental settings (above ground, underground experimental facilities vs. real repository conditions), and other site and disposal concept specific features.
- To comprehend (K) the linking of different experiment project's related subprojects and tasks and their inputs and outputs as a part of the experiment implementation.

[7] K = Knowledge, S = Skills, C = Competence as used in ECVET (European Commission, 2012)

- To acquire (S) hands-on experiences in experimenting with materials' testing and monitoring techniques needed in an experiment.
- To know how (C) the individual experiments and their outputs contribute to the overall demonstration planning and demonstration programmes for safety of the waste management programmes at the different stages of repository development.

The learning outcomes were described mainly from the point of view of a young professional having limited experience in working with plugging and sealing related tasks or in underground conditions. The learning outcomes in general were evaluated by the tutors to equal EQF[8] levels four to five.

In addition to these training workshop's learning outcomes, the DOPAS Project had organized expert staff exchanges to the FSS experiment, to the EPSP experiment and to the POPLU experiment at specific stages of the experiment implementation. The targets of the visits at the different experiments during the staff exchanges were:

- During the FSS visit, the experimental work on the filling of the bentonite core at the above ground facility.
- During the EPSP visit, the experimental work in the shotcreting practices.
- During the POPLU visit, the experimental work including the preparatory work for reinforcement structures and instrumentation prior casting of the plug.

The learning outcomes defined by the personnel participating in the staff exchanges included a wide range of learning outcomes related to knowledge, skills and competence. The level of the learning outcomes varied from EQF 4-6.

Table II-3 includes a general summary of the identified learning outcomes. More details are included in **Appendix II-6** and in Appendix II-1. It is important to keep in mind that despite the amount of the learning outcomes listed, these learning outcomes are derived only from a limited view to the full-scale experiments and therefore the listing, too, is limited.

In planning a future training, this type of learning outcomes could also be included into the practical exercises of the training at a suitable training location.

[8] EQF = European Qualification Framework (see Appendix II-5 for more details on the levels 4-6)

Table II-3. Learning Outcomes identified in terms of KSC (Knowledge, Skills, Competence) on a general level

Knowledge	**Descriptions**
	Nuclear waste management R&D programmes overview
	DOPAS Project overview
	Requirements, functions and design basis of plugs and seals
	Underground sealing/closure structures and technical solutions for them (design and construction)
	Site location selection methods for the structure/s
	Mechanical stability of host rock
	Underground hydrochemistry
	Clay and concrete barriers
	Clay material knowledge (incl. swelling pressures)
	Concrete material knowledge (incl. thermal and mechanical processes)
	Material handling technologies and logistics for clay and concrete materials
	Monitoring and performance confirmation
	Constraints and boundary conditions including working environment and work safety
Skills	**Descriptions**
	Critical evaluation of design and implementation
	Specialised planning and organisation for full-scale experiments
	Understanding about the used technical solutions (including used materials and handling techniques)
	Specifying and managing requirement hierarchies and their link to design
	Grouting works/installation
	Concrete recipe development and method testing
	Installation of sensors and monitoring devices
Competence	**Descriptions**
	Peer discussions
	Peer review
	Peer collaboration and joint development
	Observations and benchmarking
	Work safety practices, boundary conditions and constraints

9 Other Materials

Other materials produced during the planning and for implementation of the DOPAS Training Workshop were:

- DOPAS Training Workshop 2015 brochure for advertising the training (**Appendix II-7**).
- Instructions for course logistics including block bookings for hotels for the participants and for the tutors (as a part of the tutor instruction). This part of material is not included into the Appendix II-5 as it was timely only for this specific training.

- Detailed collected feedback from feedback forms and their compilation (only the summary of the feedback is included into this report).
- Final exercise reports on Exercises 2-5 by the two groups in the training. This exercise material is available ONLY for future training course TUTORS on request from the DOPAS Project Coordinator at Posiva.

10 Final Observations

DOPAS Training Workshop 2015 was implemented at a time of the DOPAS Project when one more year of the project activities was still ahead. E.g. the POPLU plug casting had just been initiated and in general the performance assessment of the experiments had not been completed. The planning group concluded in the feedback meeting in September 2015 that based on the experiences and on the participant feedback from the training workshop the training plan was successful and would required only minor modifications if repeated immediately.

Since the implementation of the training workshop, an extensive amount of new information is provided by the DOPAS Project and this is reported in the DOPAS Project's D6.4 Final Project Summary Report (DOPAS, 2016), in the Work package summary reports (D2.4, D3.30, D4.4 and D5.10), in the Experiment Summary Reports (D4.3 DOMPLU, D4.5 POPLU, D4.7 EPSP, D4.8 FSS), and in the DOPAS 2016 Seminar presentations and extended abstracts. These reports and documents contain additional information on analysis results, the lessons learned, the conclusions and suggestions for future work in the field of the plugs and seals reported during the final year of the DOPAS Project.

For anyone planning to take advantage of the DOPAS Project experiences in training, it is recommended to review the updated documents and publications and to complement the DOPAS Training Workshop 2015 training materials produced with the latest state-of-the-art results from the DOPAS Project.

Appendix II-8 includes general overview of the development work in the DOPAS Project resulting from the expert elicitation of the Work package 3 and 4 summary reports. The figures in this Appendix can be useful as a part of the general orientation of future training about the full-scale experiments on plugs and seals (see DOPAS 2016, D6.4 for more detailed explanation of the Appendix figures).

This DOPAS Training Workshop 2015 was planned to take advantage of both experience and theory. Replicating the hands-on experiences of this training would in principle require access to an underground facility infrastructure suited for the experimentation, access to a suitable workshop and laboratory premises and software and data collection instruments. Such facilities are accessible for use at the Josef Underground Laboratory and Research Centre and based on an agreement with the Czech Technical University (http://ceg.fsv.cvut.cz/en). The Josef facility has served as a successful education and training infrastructure also for several other training and educational events like for the IAEA and for the Petrus network.

For further information, please visit the DOPAS Project website at http://www.posiva.fi/en/dopas.

11 References

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APPENDICES

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
Recommended extent of the full completed training: 4 ECTS					
DAY 1	**Location: Prague CTU**		Chair of the day: Jacques Wendling	Organisation and Tutor names	Activity type
14.9.2015	Time	Duration (min)			
Orientation to the Training Workshop (5.)					
	09:00-09:30	30	Welcome; Introduction to the training workshop programme and CTU - CEG	CTU/Radek Vasicek	presentation
	09:30-10:00	30	Introduction to DOPAS project and to Posiva	Posiva/Marjatta Palmu	presentation
	10:00-10:45	45	Icebreaker, course objectives and concept of time	Posiva/Marjatta Palmu and all	participant's objective setting and activity
	10:45-11:00	15	***Coffee break***		
Learning Unit 1: From Requirements to design basis of plugs and seals					
1.1 Understanding requirements management and their application for plugs and seals design basis					
	11:00-11:45	20+25	The role of plugs and seals. Different timelines, different host rocks (case of clay and crystalline repository concepts). Introduction to Andra and SKB.	Andra/Jacques Wendling incl. Nagra content, SKB/Pär Grahm	lecture/s
1.2 Requirements - understanding and applying them					
	11:45-12:00	15	Sources of requirements. Participants' reflection activity	Andra/Posiva/SKB	participant's reflection activity
	12:00-13:00	60	***Lunch break***		
	13:05-13:25	20	Generic introduction to requirements management (hierarchy in engineering, V-model)	Posiva/Marjatta Palmu	lecture
	13:25-14:00	30	The Design Basis development work flow for Plugs and Seals	SKB/Pär Grahm	lecture
	14:00-14:20	20	***Coffee break***		
1.3 Developing a design basis for an experiment					
	14:20-14:50	30	Case example of EPSP experiment	SURAO/Marketa Dvorakova	presentation
	14:50-15:20	30	Scoping the DOMPLU experiment (case DOMPLU) to meet the requirements and challenges - a project management perspective. Moving from the initial design to an experiment in place.	SKB/Pär Grahm	Brief intro to DOMPLU and lecture
	15:20-16:25	15 + 50 incl. break	**Exercise 1:** Group work on WBS method in scoping an experiment or a technical development project	Participants & Pär Grahm	Intro to exercise and partipants' work

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
	16:25-16:30	*5*	***Short break for presentation setup***		
	16:30-17:00	15+10	Presentation of Exercise 1 results on structuring a technical development project and feedback. Summary by tutor moved to DAY2	Participant groups and SKB/Pär Grahm	exercise report and feedback to exercises
	17:00		***End of Day 1***		

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
DAY 2	**Location: Josef**	Duration	Chair of the day: Jiri Svoboda , afternoon: Dean Gentles	Organisation and Tutor names	Activity type
15.9.2015	Time	min			
	7:45-9:00	75	***Transfer from Prague to Josef***	Cars leaving from hotels Krystal and Diplomat	
Orientation to Josef (6.)					
	09:00-11:40	160	Practicalities and advice to studying and acting in Josef - Safety instructions	CTU/Radek Vasicek	instruction
			Presentation of Josef, Josef Geology and the EPSP experiment in Josef	CTU/Radek Vasicek, Michal Roll & Jiri Svoboda	presentation and videos
			Visit to the EPSP experiment in Josef (90 min)	CTU/Radek Vasicek & Jiri Svoboda	site visit, participants' notes
			Coffee break (included in the above)		
	11.45-11:55	10	Introduction/division to groups for the week's student exercises and related reporting (2-5)	Posiva/Marjatta Palmu, CTU/Radek Vasicek	instruction
Learning Unit 2: Preparation of an in-situ or full-scale plug or sealing experiment					
Material no	**2.1 How to come up with a coherent demonstrator program for plugs and seals?**				
	12:00-13:00	60	***Lunch break (time fixed due to Josef)***		
	13:00-14:10	70	Theoretical basis to Andra's interative safety assessment process and the last iteration cycle	Andra/Jacques Wendling	Lecture and interaction with participants
			Cases from the safety assessment iteration cycle in Andra's demonstrator programme in clay. The role and implementation of FSS experiment in DOPAS project	Andra/Jacques Wendling	Comprehensive review of outcome and interaction with participants to find out Andra's approach during the last round of iteration of the S.A.
2.2 The role of instrumentation and monitoring in an experiment					
	14:10-14:25	15	***Coffee break***		
	14:25-15:25	60	The role of instrumentation and monitoring in an experiment	CTU/Svoboda	lecture, examples of sensors
	15:30-19:00	210	Two groups 1+2 **:** **Exercise 2** Preparing and installing analogue and digital thermometers in Josef	CTU/Svoboda	Guided participant activities in Josef; reporting in two groups
	19:20-20:30	70	*Picnic at Josef*	CTU	
	20:30-22:00	60	***Return to Prague*** ***End of Day 2***		

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
DAY 3	Location: REZ	Duration	Chair of the day: Morning: Marjatta Palmu, Afternoon: Andre Rübel	Organisation and Tutor names	Activity type
16.9.2015	Time Leave DIPLOMAT 7:15 and take train 7.48 Praha-Podbaba railway station	20	***7:48 Train from Prague to Rez***	400m walk from Diplomat hotel to Dejvicka tram stop (no 1 or 18), take 3 stops (final stop), duration 4min, every 5 min	**Need your ID with you (preregistrations done by 1.9.2015)**
Learning Unit 3: Design of a seal for an experiment/demonstrator within the broader context of RD&D programmes; Safety assessment and Performance assessment of closure as design input					
3.1 How to move from initial design in an iterative manner to the final experiment design and construction (to as built) and assess the outcome. What is the state of the art in the demonstrator programs today? What questions still need to be addressed?					
	08:25-08:35	10	Safety instructions for working in UJV Rez and short introduction to UJV ReZ Chemistry of Fuel Cycle and Waste Management Department	UJV Rez/Vaclava Havlova	instruction and presentation
	08:35-9:25	45	Andra's scientific programme and the main questions to be replied for the next report (DAC) and after submission of DAC	Andra/Jacques Wendling	lecture
	9:25-9:40	20	***Coffee break***		
	9:40-10:30	50	Plugs as a part of the demonstration programmes in Nordic countries (YJH and FUD and stages in licencing) incl. alternative plugs	Posiva/Petri Koho (incl. SKB program points)	perpective lecture (crystalline rock environment, different management process)
	3.2 Behavior of plug components and materials				
	10:30-10:50	20	The use of individual tests to complement existing material and process knowledge (case of REM metric experiment)	Case by Andra/Jacques Wendling	lecture on a case example
		10	***Short break***		
	11:00-11:40	40	The role of pH in the Czech plug system and a summary on the use of the work in the Czech safety assessment/case - influence of pH	UJV/Petr Vecernik	lecture and demonstration
	11:40-11:50	20	Group division and instructions for <u>Exercises 3-4</u>	UJV/Petr Vecernik	instruction

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
	12:00-13:00	60	***Lunch break***		
	13:10-15:20	40	**Exercise 3:** Stress test of concrete and	UJV/Petr Vecernik	guided exercise
		90	**Exercise 4:** Interaction of concrete with bentonite in parallel (incl. coffee)	Participants and UJV/ Katerina Videnska & Dagmar Trpkosova	guided exercise
	15:20-15:40	20	Group discussion on the exercise 3-4 results	Participants and UJV/Petr Vecernik	participants' activity
	15:50		Departure from UJV Rez to station		
	16.22-16:50	20	***16:22 Train to Prague to SURAO info centre (Dlazdena 6, 110 00 Prague)***		
	17:00-17:50	20	Presentation of SURAO public involvement and information activities	SURAO/Lucie Steinerova	presentation
		30	Presentation of the Czech siting programme	SURAO/Lukas Vondrovic	presentation
	18:00 - until 20:20	76+60	*Movie night in Prague at SURAO with related discussions*	Movie - Into eternity (Marjatta Palmu - discussion moderation)	SURAO info center
			End of Day 3		

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
DAY 4	Location: Josef	Duration	Chair of the day: Pär Grahm and Petri Koho	Organisation and Tutor names	Activity type
17.9.2015	Time				
	7:45-8:50	60	***Transfer from Prague to Josef***	Cars leaving from hotels Diplomat & Krystal	3 cars reserved
3. 3 Introduction to Safety Assessment and the role of Safety case (Learning Unit 3)					
	9:00-10:40	90+10 coffee break	Integration of experimental work and process modelling in safety assessment and safety case; Time perspective considerations; summarising the current theoretical and iterative approach. Modelling vs. technical testing and demonstrating. About GRS.	GRS/Andre Rübel	lecture providing SA basis, repeating and reflecting on the previous day: tests and cases, time visualisation
4. Learning Unit 4: Construction feasibility of a plugging experiment					
4.1 Practical underground work concerns in setting up an in-situ or full-scale experiment					
	10:50-11:10	20	Risk management for large-scale experiments and work underground	SKB/Pär Grahm	lecture
	11:10-11:55	40	Case example of POPLU experiment (start slot location + RSC and design; moving into real repository construction, as built vs. design)	Posiva/Petri Koho	lecture/presentation
	12:00-13:00	60	***Lunch break***		
	13:10-14:00	50	<u>**Exercise 5**</u> Two groups: Identifying and prioritizing risks for full-scale experiments G1: DOMPLU and G2: POPLU	Participants and tutors Pelle and Petri	group exercise, presentation last day
	14:00-14:40	40	Feasibility of a seal in a clay rich host environment. How to adapt the technological process including alternative concept/s (Risk identification and management perspective incl.)	Andra/ Regis Foin	lecture
	14:40-15:00	20	***Coffee break***		
3.4 Monitoring for performance assessment of experiment components (Thermal processes) - Learning Unit 3					
	15:00-16:45	105	<u>**Exercise 2 continues**</u>: EPSP data and its handling/calculations from the underground thermal sensor monitoring	CTU/Svoboda	guided exercise, potential time for reports
	17:20-19:00	60	*Culture at the Cathedral*	CTU/Svoboda	
	19:00-20:00	60	***Return to Prague***	CTU	to hotels with minibuses
	20:00 =>		*Dinner at own cost at Kulatak restaurant*		
			End of Day 4		

DOPAS Training workshop 14-18 September 2015 in Czech Republic				**Final implemented programme 18 September 2015**	
DAY 5	Location: Prague CTU	Duration	Chair of the day: Radek Vasicek	Organisation and Tutor names	Activity type
18.9.2015	Time				
	4.3 How to further apply the lessons learned for the future (Learning Unit 4)				
	8:35-9:25	50	Preparing for ELSA experiment (not yet an in-situ experiment)	GRS/Andre Rübel	lecture/ presentation with link and summary view
	9:25-9:50	20	***Coffee break***		
	9:50-10:45	55	How the lessons learned can be applied to programmes not yet in demonstration stage - Case of RWM incl. co present.	RWM/Dean Gentles	lecture with summary view, too
	10:45-10:50	5	***Short layout arrangement break***		
4.2 Working methods underground and for experiments (Learning Unit 4)					
	10:50-12:05	40 min + 35 min	Panel on experiences, constraints and lessons learned (5 -10 min intro by each, Q&A, discussions)	SKB/Pär Grahm + Posiva/Petri Koho; CTU/J.S. SURAO/Marketa D.; GRS/Andre, RWM/Dean; Andra/ Regis Foin, + moderator & chair Marjatta & Radek	interactive panel
	12:10-13:10		***Lunch break***		
	13:10-14:30	80	Reporting of exercises 2-5 by participants; final reports due 2 October 2015	6 group presentation of participants. Exercise 2, both groups each 15 min with commenting; for Exercise 3 only one and Exercise 4 only one, each 10 min including commenting, Exercise 5 both groups 10 min each (Tutors: UJV, CTU, Posiva including commenting)	participants' activity, interactive feedback
	14:30-14:40		***Coffee break***		
	14:40-14:45	5	Instructions for returning exercise reports	Posiva/Marjatta Palmu	instruction
	14:45-15:45	60	Summary, assessment and feedback discussion	Posiva/Marjatta Palmu, CTU/Radek Vasicek	teaching and assessment discussion
Closing of Training Workshop					
	16:10-16.40	30	Tutors' summary feedback discussion after closing (max. 30 min)	Radek, Petri, Marjatta, Dean	review of implementation
Tasks done after workshop			**Permission for Into Eternity movie screening: provided by Magicfilms DK via email**		
			Participants' feedback forms returned by 23 September 2015 in electronic format (n =12)		
			Videoconference for tutor'sfeedback held on 24 September 2015 2-4 pm CET		
			Participants' exercise reports received 2 October 2015 (homework done)		
			Review and approval of participants' reports (Exerc. 2-5), by 11.10.2015		

DOPAS Training Workshop 2015

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DOPAS Training Workshop 2015 - To do list version 11.9.2015

Tips:

DOPAS TRAINING WORKSHOP 2015
[14-18.9.2015]

Produce the content plan for the workshop

- Overall content and schedule (R: Resources needed)
  - Content lectures and exercises,
  - Division of content between tutors
  - Tutors
    - Names of UJV tutors
      - Need confirmation of a tutor from UJV for DAY5 afternoon Petr
    - Confirmation of SURAO tutors (ok other than Marketa)
    - Hotel booking from block: reserve by 24 August
  - Time allocation and scheduling of content
- Specific content checklist for tutors (R: Resources needed)
  - Tutor Guide produced by Marjatta
    - v6 update needed
  - Includes a general list of abbreviations
  - Corrections or additions to be provided by all by 23 June (done)
- Telemeeting on 29 June 2015 afternoon 12:30-15:00 (R: Resources needed)
  - Content check and agreement (done)
  - Review meeting on 28 August in Helsinki
    - Decision on review meeting in August/Sept. (Andra proposal, doodle by 15 July - prefer 28 August) done
    - action list sent out
  - Minutes/notes no 3 send out for comments and approved
    - produce final minutes
  - Approval of minutes from meetings 1-2 (done)
- Individual tutors' specific content - bullet list (R: Resources needed)
  - By 23 June 2015 Additions or corrections to content list for approval by each tutor (partly pending)
  - ok Dean, Jiri, Marketa,
  - Jacques, Andre, Marjatta, UJV, Petri - ok
- Detailed content by each tutor for review (R: Resources needed)
  - Deadline for training materials on 25 August 2015 (two working days prior review)
  - All tutors to work on their own pace on the materials
    - Every tutor posts on Projectplace "Training materials" folder
  - Marjatta to produce a ppt-template for those wishing to use it (not mandatory, see Tutor Guide) - on projectplace
  - Marjatta to produce "Conditions of use"
- Face to face review meeting, changes to training materials (R: Resources needed)
  - Decision on review meeting in August/Sept. (28 August)
- Database upload of materials and distribution to participants by 8.9.2015 done (R: Resources needed)
  - Final versions of material need to be by 6 September
  - User and password for each participant latest on 7.9.2015(Jiri)
- Feedback meeting on Training Workshop (R: Resources needed)
  - Date 24.9. agreed for teleconferencing
  - Agreement on report feedback to participants
  - Participant feedback return date 23.9.
    - Compilation needed

Publish workshop brochure and open registration, confirm participation

- Brochure out 5.6.2015 (R: Resources needed)
  - brochure
  - registration form
  - selection criteria
  - confirmation letter and advice
- Dissemination of brochure (on-going) (R: Resources needed)
  - Webpage (updated)
  - EC events database (submitted, pending publication)
  - various mailing lists (see excel for details)
  - ENEN association website and database
  - IGD-TP website (pending)
  - Projectplace posts submitted
  - Repeat advertisement (PP in July)
- Consortium registration by 26.6.2015 (R: Resources needed)
  - Preliminary level of interest for the course received - 2 registered
- Final registration date by 10.8.2015 (R: Resources needed)
  - Compilation of main participant list
  - Compilation of reserve list (if oversubscribed)
  - Registration status by 13.7. - four in total plus two expr. of interest
  - Final registrations 12 persons
- Confirmation to participants by 17.8.2015 (R: Resources needed)
  - Confirmation e-mail
    - ok Jenny
    - ok Iveta
    - ok Rocio
    - ok Marvin
    - ok Taina
    - ok Anna
    - ok Karel
    - ok Jiri (cancelled) Zdenka
    - ok Eszter
    - ok Balu
    - ok Poly (cancelled) Agnes
    - ok Krzysztof
- Last minute changes of participants by 10.9.2015 (R: Resources needed)
  - Confirmation e-mail
    - 3.9.2015 Agnes
  - Name badge changes - no
  - New Table name badges - no
  - Changes to Participation list with contacts - done
  - Changes to Participation list (daily) for signing - done
- Final participant related materials
  - Name badges
    - ok (Marjatta)
  - Participation list with contacts
    - done (Marjatta)
  - Participation list (daily) for signing
    - done (Marjatta)
  - Table name badges
    - ok (Marjatta)
  - Sending contact information with permission to all
  - Background information of participants
    - Mail to forward
    - Compile
  - Feedback form (Marjatta, discuss with Jiri/Radek about electronic form?)

Practical organisation, logistics

- Local transport to Josef and Rez (R: Resources needed)
  - 3 cars reserved for day 2 and day 4
    - Radek (done)
  - local train, tickets and instructions incl. timetable
  - local transport from SURAO to hotels (to be decided)
  - Marjatta to get local transport tickets on site
- Hotel block bookings (R: Resources needed)
  - DIPLOMAT
    - 15 rooms in a block (Radek, done)
    - Reserve latest 24.8.2015
    - 11 stay in Diplomat
  - KRYSTAL
    - 12 rooms in a block (Radek, done)
    - Reserve latest 24.8.2015
    - 5 stay at Krystal
  - One stays at Fusion, comes to Diplomat
- Training locations (R: Resources needed)
  - CTU
    - Lunches day 1 and day 5
    - Coffees/tea x 2 day 1 and day 5
  - Josef URC
    - Lunches (reserved) day 2 and day 4 from 12-13 hrs
    - Coffees/tea x 2 day 2 and day 4
  - UJV/REZ
    - Lunch day 3
    - Coffee/tea x 2 day 3
  - SURAO information centre
    - to be organised on site - Lucie/Marketta
- Training materials distribution (R: Resources needed)
  - CTU
    - website with password
      - Jiri to send user and password - done
  - Upload for Distribution - CTU done, internal site
  - Final submission date to database 7.9.2015
  - Database material ready 8.9.2015
  - Last updates on 11 September 2015 and during course
- Training aids (R: Resources needed)
  - CTU (Radek & al.)
    - Videoprojector, computer
    - Handouts (instructions) on Day 1
    - White A4 paper, markers, detachable tape
    - Notepaper, pens, tbd...
    - Flip charts with paper
  - Josef URC (Radek & al.)
    - Videoprojector, computer
    - Notepaper, pens, tbd...
    - Flip charts with paper
    - Equipment/workgear needed for the tunnel visit and exercise
    - own shoes (notified)
  - UJV/REZ
    - Protective workgear for laboratory? Lucie checks, ok
    - Videoprojector, computer (UJV organises)
    - Flip charts with paper (UJV organises)
    - Preregistration ID data by 1 Sept. 2015 and ID with each for access to facility (all visitors on day 16.9.2015 - tutors and participants)
      - List sent to Radek (ok), all data available
  - SURAO information centre
    - White A4, flip chart/s
    - Videoprojector, computer, DVD player
    - DVD - Into eternity
      - Discussion questions
      - Hardcopy (ok, Marjatta)
      - Official permission to showok (Marjatta)
    - Snacks, refreshments for movie night
  - Daily participant list for signing
  - Daily agendas needed for chairs
- Exercise and reporting instructions (R: Resources needed)
  - CTU
    - Reporting instruction handout given at CTU (marjatta & radek)
  - Josef URC
    - Detailed exercise instruction for exercise 2a on Day 2
    - Detailed exercise instruction for exercise 2b on Day 4
  - UJV/REZ
    - Detailed exercise instructions for exercises 3-4 on Day 3 for the laboratory
  - SKB at Josef
    - Detailed exercise instructions for exercise 5 on Day 4
  - Deadline for submitting final reports by 2 October 2015
  - Information on exercises (Marjatta & Radek)
  - Agreement on exercise report reviewers ok
  - Review and feedback on exercise 2-4 reports ok
- Training certificate (R: Resources needed)
  - Certificate templates for completion and for participants only
  - Signed by Posiva (Johanna Hansen, Marjatta Palmu) & CTU Radek Vasicek. With DOPAS and company logos
    - need print outs and Radek's signature
  - Daily participant list for signing required for completion and reports from exercises
    - chairs given list
  - ETCS recommendation letter
  - Send certificates to participants after receipt of exercise reports

List of contents DOPAS Training Workshop 2015
by learning units and followed by general content items

General information[1] for DAY 1

- **ID Number: D1 0** List of abbreviations, DOPAS Training materials conditions for use

1 Learning Unit 1: From requirements to the design basis of plugs and seals (DAY 1)

1.1 Understanding requirements management and their application for plugs and seals design basis (TOPIC 1); D1

The role of plugs and seals in geological disposal. Different timelines, different host rocks (case of clay and crystalline repository concepts) - Duration: 20+20 minutes by Jacques Wendling and Pär Grahm.

Starting point of the lectures:

What is a plug and what is a seal? (An interactive question to start with), Where are they used and for what purpose? How do they differ? Immediate Answer: Closure of repository or its parts and why we need closure? The rest of the questions should be addressed in the following two lectures.

[1] The ID numbers refer to the numbers of the training material Powerpoint presentations D indicating the training day number and the first number indicating the Learning Unit number (1-4) or other activities (5-11).

1.1.1 The Purpose of Plugs and Seals in Clay - Jacques WENDLING (J.W.), ANDRA (20 min)

- **ID Numbers: D1 1.1.1a; D1 1.1.1b**
- Rapid summary of the role of seals in Andra's repository (10-15 min)

  E.g. Andra's concept for safe disposal (pictures, figures) - concept of isolating and containing the high level waste and potential other waste types in Cígéo, the pillars on which the "passive" and "retrievable" disposal concept of Andra is based, special characteristics of the chosen host rock environment, the layout and underground structures (=openings) that need to be closed and when; the purpose, lifetime and challenges related to closure in clay, different types of closure elements in the French concept (plugs and seals). Explanation of DOS and DAC.
  - Main global function of the repository [The concept of geological disposal for isolation and containment of waste (the safety concept)]
  - Role of the host rock
  - Role of the excavations => need of a sealing system
    - Different type of seals, but more or less same design
- Time scale affected to the functions (5 min)
  - In relation with the activity of the wastes (describe also the type of waste/s to be disposed off)
  - Repository includes HLW => several million years
  - Seals favourable characteristics should last the same duration => limited to 1 M years in practice
  - In a case of the seal's function is less than 1 M years than something else needs to take over the safety function of the seal like in the case Finnish and German case the backfill maintains or takes over the safety function
    - Different functions of the seals - a function time of less than 1 Million year. In the Finnish case the function is not needed afterwards

- In the German case 50 000 years, but then something else takes over the function of the seal when the seal is not included
- Foreseen time when the geological disposal facility will finally be closed

- Specificities linked to Nagra's concept (eventually 5 min)
  - Waste types in the repository e.g. codisposal or only HLW/SF
  - ALL plug and seal types,
  - General layout of repository,
  - Underground structures/openings to be closed,
  - Lifetime of seal and repository,
  - What takes over the safety function after the seal's lifetime is over?,
  - Pilot monitoring?, role of closure in such a case,
  - Other Nagra specifics) e.g. A comparison of the Nagra concept - describing the level in which it is similar to the French concept and different. Explanation of especially about the differences and the different uses of plugs and seals in Nagra's concept (in Opalinius clay)

Learning aid: If possible, please take a sample piece of BURE clay with you to pass around the material among the students.
Presentation needs: a videoprojector and computer with MS Powerpoint, whiteboard and markers (or Flipchart and markers)

1.1.2 The Purpose of Plugs and Seals in Crystalline Rock - Pär Grahm (P.G.), SKB (20 min)

- **ID Number: D1 1.1.2**
- Posiva's (and SKB's) concept for safe disposal (for the isolation and containment of radionuclides), waste types to be disposed off (spent fuel, direct disposal)
- The pillars that make up for passive safety of the repository, the concept of safety function
- The KBS-3 multibarrier concept and the components of the concept

- The influence of the host rock environment (crystalline rock) plugs and seal especially
- Disposal facility (construction and closure in phases) - overall layout, types of underground structures (=openings) that need to be closed (different type of tunnels, shafts, auxiliary rooms, investigation boreholes); the lifetime of the repository and when (after how long) it will be closed
- The different types of plugs and seals needed (case: ONKALO, SFL)
- Role/s of closure of a repository, types of plugs and seals, their function, the function of the deposition end tunnel plug, design lifetime needed, contribution to the backfill safety function; mechanical and hydraulic performance, temperature during curing of concrete, against prevailing loads; function of the different types of materials in the plug (concrete, clay ...)

Learning aid: Take a sample piece of ONKALO mica gneiss and potentially Äspö granite with you to pass around among the students (not a big piece).
Presentation needs: a videoprojector and computer with MS Powerpoint

- Further discussion about why closure is required?
  (If you ask this from the audience, then at least following things should start to pop-up and lead to the question of requirements: closure is needed because the waste is hazardous for a long time; closure isolates from the environment, how well does it isolate?, closure restores the disturbed environment close to its original state (need to establish an environmental baseline); closure makes it more difficult to access the repository with purpose or unintentionally; plugging enhances the performance of the other barriers like backfill (in KBS-3 especially); ....) => moving to the students´ reflective exercise

1.2 Requirements - understanding and applying them (TOPIC 2)

including the (K) understanding of requirements management systems and their applications to plugs and seals and (S) developing a basis and (S) scoping an experiment from a project management perspective.

1.2.1 Sources of requirements. Student reflection activity - Marjatta Palmu (PMP) POSIVA, P.G., J.W. (20 min)

- Ask the students based on the previous to talk with their neighbour for about 5 - 7 minutes about what is a requirement in general and what is their source? Where do they come from for the plugs and seals? (Answers should include things that you have presented in the presentations (safety requires), protection of humans and the environment, avoidance of harm or hazards to human and the environment; regulators, potentially society, standards, international organisations (EU, IAEA, etc.)
- Student replies can be marked on a flip chart as they respond (to keep for later reference during the day)

Presentation needs: flip chart with paper and couple of markers

1.2.2 Requirements management as a system (general introduction) - PMP (20 min)

- **ID Number: D1 5.2.2 (About Posiva) and D1 1.2.2** (updated)
- Starting point from the discussion: How does one translate these identified requirements into practical designs and solutions?
- Explain the V-model of requirements coming from systems engineering and software engineering introduced more widely by IEEE Computer Society in the end of 1970's
- The requirements side structure, hierarchy of the system and the verification and validation at each hierarchy level;
- Description of the generic content of the different levels of requirements, their main content and from where each level is derived from (to be covered in more detail in the following case presentations)
    - Stakeholder requirements (owners, authorities, society, ...)
    - System requirements (the safety concept, safety function)

    - Subsystem requirements (from the system and the safety functions of the subsystem)
- How to write and interpret requirements (format of a requirement, traceability to source, potential attributes, workshops and review)
- Setting a baseline and change management due to the iteration cycle;
- The use of software to manage requirements has become essential for both managing the attributes, links between requirements and changes to requirements
- Use figure of a generic model and applications especially in waste management in the Nordic programme (sources e.g. OECD/NEA workshop and other presentations, STUK's current development work with Fortum),
    - Give an example of requirements coming from stakeholder requirement to specification (example from Posiva) and simplified examples of individual component verifications (from SKB's canister lab)
- Related concepts are configuration management (applied in nuclear field), functional analysis (originally only in JW's presentation), and requirements engineering. The Japanese QFD (Quality Function Deployment) - one of the quality tools also applies a similar approach.

Requirements management learning outcomes after this learning session is over:
- Identify and list major sources of requirements for geological disposal and for closure
- Understand and ability to describe the major elements of the general concept of requirements management (various elements of it) and its objectives orally or in written form/figures
- Discuss the collection of requirements and their different hierarchy.

Presentation needs: a videoprojector and computer with MS Powerpoint

1.2.3 The Design Basis (TOPIC 3) development work flow for Plugs and Seals - Application of requirements management system to plugs and seals and developing a design basis from them. - P.G. (30 min)

- **ID Number: D1 1.2.3, D1 1.2.4** (Poster updated to DOPAS Seminar 2016 version, originally IGD Geodisposal conference poster)
- Explain what was done in DOPAS WP2 to come up with the workflow description (use WP2 slide material) for plugs and seals from requirements to conceptual design, basic design and detailed design bases.
  - from policy decisions to stakeholder requirements
  - constraints by waste types and host rocks
  - plug system requirements and safety functions (case KBS-3 mentioned, details explained later)
  - loads for the subsystem to resist, design and material understanding
  - modelling of performance, coming up with the conceptual design
- Continue to run through the (work flow poster for Geodisposal conference, updated) starting from conceptual design to basic design and to design basis for a plug, emphasize the DOMPLU and KBS-3 example and refer to the fact that Andra carries this out in a bit different way that is explained later by J.W.

Learning aids: Attach the work flow conference poster **(ID Number D1 1.2.4)** to the learning materials distributed to the participants
Presentation needs: a videoprojector and computer with MS Powerpoint, flipchart/whiteboard and markers

1.3 Developing a design basis for an experiment (TOPIC 3 continues to cover the work flow)

1.3.1 Case Example of the Czech experiment EPSP - Marketa Dvorakova (M.D.), SÚRAO (30 min)

- **ID Number: D1 1.3.1**
- Reasons and safety concept of the Czech experiment, types of wastes for disposal, the plans for different types of plugs and seals in the repository (types of underground openings)
- The objectives of the experiment and existing requirements, task division between different partners
- How the experiment was planned (the requirements) and what was the outcome of the planning in terms of design
- Explain the features of the different system/subsystem components of the EPSP
- What modelling including parameters (M, H, T?), material and other pre-understanding and knowledge was needed for the design and implementation
- (remember that the participants will see the experiment in practice in Josef)
- What is the current state of the experiment, related risks, and expected outcomes from the experiment (also in terms of parameters), how is the success of the experiment judged/assessed?

Presentation needs: a videoprojector and computer with MS Powerpoint

1.3.2 Scoping the DOMPLU experiment (TOPIC 3). Moving from the initial design to an experiment in place - P.G. (30 min)

- **ID Number: D1 1.3.2**
- Scoping an experiment for a project plan to address (all or some) requirements by using work breakdown structure (WBS) of project management.

- The subprojects in an experiment project - what is included in the project plan, how to transfer the design into an experiment in place; what is included in the implementation/construction of the experiment e.g.
    - modelling
    - design - as a whole and individual components; material selections
    - location, measurements, design adaptation
    - instrumentation and data handling
    - procurement
    - method tests, assemblies and related testing, construction of the plug and related components and auxiliary structures, measurements
    - quality assurance, work safety, documentation
    - data collection and analysis
    - ....
    - dismantling (life time of the experiment?)

Presentation needs: a videoprojector and computer with MS Powerpoint; flipchart + markers

1.3.3 EXERCISE 1: Group work on WBS method in scoping an experiment or a technical development project - P.G. (15 min+ 50 min +15 min+10 min) - Closing DAY 1

ID Number: D1 1.3.2 full version

Introducing the Exercise (15 min)

- Explain the use of WBS and project management approach to designing an experiment based on the previous process information (as an example a project structure template could be shown) - if desired, such a template could be given in an electronic form in advance with the lecture materials) (15 min)
- Students work on the exercise incl. preparing the presentation of the results (50 min)

- Presenting the exercise results (students) - in two-three groups or more, tutor to decide (smaller groups work faster) - a total of 15 min.
- Summary and feedback on exercise by the tutor P.G. (10 min)

Presentation and exercise needs: Flipcharts or Whiteboards, post-it notes, markers and pens

2 Learning Unit 2: Preparation of an in-situ or full-scale plug or sealing experiment (DAY 2)

2.1 How to come up with a coherent demonstration program for plugs and seals? (DAY 2 - TOPIC 4)

Includes presenting the development of a coherent demonstrator programme (K[2]) for plugs and seals, the role of instrumentation and monitoring in such an experiment including a hands-on exercise (S) in Josef Underground laboratory.

2.1.1 Theoretical basis to Andra's iterative safety assessment process and the latest safety assessment round - J. W. (45 min) - DAY 2 morning before lunch

- **ID Number: D2 2.1**
- Theoretical basis of Andra's iteration cycle type procedure for safety assessment (45 min, before lunch)
    - Initial knowledge/design
    - Functional analysis
    - Disposal System Specifications

[2] K; S, C refer to Knowledge, Skills, Competence - see D7.2 report and its Appendix II-6 on Learning Outcomes and the Appendix II-5 Guide for Tutors for more details.

- Eventual evolution of design : technological development and tests
- Phenomenological analysis
- Use of all the previous points for
  - Risk analysis during operational period
  - Qualitative safety assessment during post closure period
- Performance assessment
- Safety calculations
- Review
- Analysis of the outcomes of the review to define a new program of knowledge acquisition and/or technological development
- Beginning of a new iteration cycle

2.1.2 Actual case example about the last round of safety assessment iteration in Andra's demonstrator programme in clay (FSS,) - Explicit description of the last iteration cycle - J.W. (35 min) - DAY 2 after lunch

- **ID Number: D2 2.1** continues
- Lecture type up to review of outcomes
- Interactions with the students to find out what was Andra's response
- Description of the real actual program for seals in terms of experimental, demonstrator and simulation program
- Focus on FSS (and REM, the two) experiments inside DOPAS, REM in more detail later.

<u>Presentation needs for both</u>: a videoprojector and computer with MS Powerpoint; whiteboard or flipchart with markers

2.2 The role of instrumentation and monitoring in an experiment - Jiri Svoboda J.S. (60 min) - DAY 2 (TOPIC 5)

- **ID Number: D2 2.2**
- The role of instrumentation in an experiment (can be also more generic) , several uses
- How to select what parameters to measure?
- What type of sensors and instruments are available and implemented in DOPAS (and in EPSP as a case example)? - pressure, temperature, volume, strain, stress, pH, leakage, ... show in practice
- How to select your instruments? How to collect data? How to process data? - in relation to EPSP
  - Introduction (10 min)
    - Why monitoring
    - Measurement chain
    - What is sensor
    - Analogue vs digital
    - How to get data out
    - Data collection, storage, presentation
  - Why and how in the experiment (10min)
    - Why monitoring
    - What to measure
    - How to measure
    - How often measure
    - What to do with measured data (data interpretation) ?
    - Typical failures
  - Common sensor types and their principles (15min)
    - Deformation (strain)
    - Pressure
    - Temperature
    - ...
  - EPSP – how it is done... (25min)

- Overall EPSP
- What is measured, why and where
- Sensor selection
- Technology used
  - Sensors
  - Data loggers
- DAQ + Measurement sytem
- Online demo

- Short note about Exercise 2 (monitoring and data path – same system as for EPSP)

Learning aids: examples of various sensors, measurement components, cables, data logger(s), internet / wireless network
Presentation needs: computer, projector, PowerPoint, flipchart/whiteboard, markers

2.2.1 EXERCISE 2: Installing thermometers in Josef (Jiri Svoboda, 240 min) - DAY 2 (afternoon, last lecture /exercise of the day)

- **ID Number: D2 2.2.1**
- Please list major steps of installation and what is needed to do this.
  - Introduction into exercise and experiment used (15min presentation)
  - Short demonstration of sensor used (5min)
  - Manufacturing of probe (assembly, testing, sealing) (75 min)
    Probe consisting of several thermometers will be manufactured by each group.
- *Break + getting ready/equipped into underground + transfer into underground (30min)*
  - Probe installation into the rock in the underground (45 min)
  - Connection to data logger and measurement network (20min)

- Heater start & first measurements (30min)
- *Clean-up & Transfer out (20min)*

- All the work will be under supervision and assistance of CTU staff. Certain parts to be done by CTU staff (as borehole drilling) or by the students at their own risk.
- The data will be processed on DAY 4
- The experimental setup in the underground has to be prepared before exercise. E.g. current experimental setup at Josef URL will be refurbished for the exercise.
  - *type of sensors, the purpose of the sensors, expected outputs*
  - *practical installation work*
  - *what needs to be considered in advance (plan for the sensor locations?, tools needed? instructions for installment*
  - *actual installation, problem solving during installation (e.g. electrical connection)*
  - *sensor intactness, sensor testing (quality assurance against breakage, replacement of faulty sensors, use of duplicate sensors)*
  - *connections to measurement units , activities related to the measurement units*
  - *data input and output checks, test readings?*
  - *Two options - thermometers with heater tube; other one just the installment into curing concrete*
  - *sensors connected to network, need student computers for the exercises*
- Some information given on how the exercise will continue on Day 4. What needs to be taken with them to Josef by the students (computers, etc.)

<u>Learning aids</u>: material for probe manufacturing (sensors, cable, protective tube, …)
<u>Equipment and tool, instruction needs</u>: electrical workshop, data logger(s), experimental setup (in the underground), drilling machine, computers

Computers (students can take their computers underground, but not necessary)? In such a case: the tolerance of the equipment that is required for taking them underground needs to be informed to the students - also for insurance coverage) - not needed, but can be taken at own risk (generally no problems as Josef does not have a water problem)

3 Learning Unit 3: Design of a seal for an experiment/ demonstrator within the broader context of RD&D programmes (DAY 3 - DAY 4)

How to move from initial design in an iterative manner to the final experiment design and construction (to the as built state) and assess the outcome?

Designing (K) a sealing component for an experiment or demonstrator and the role of safety assessment and performance assessment (K) of closure as a design input
Introducing the use of individual tests e.g. metric test as a means to contribute material and process understanding and to the performance assessment (K, S)

This unit addresses how to move from the initial design in an iterative manner to the final experiment design and construction and how to assess the outcomes (K). Further the learning unit addresses the behaviour of plug component materials (K) and provides practical materials' related testing exercises in a laboratory setting (S, C).

- includes the handling and interpretation process of data acquired (S, C) from the Josef Gallery hands-on monitoring exercise.
- includes introduction to laboratory and other types of tests to increase understanding of materials and processes in disposal
- includes an introduction to safety assessment (K) and the role of safety case taking into consideration the differences in the time perspectives (K).

3.1 What is the state of the art in the demonstrator (RD&D) programs today? (DAY 3) TOPIC 6

3.1.1 Andra's scientific programme and its current state. The main questions replied to for the next safety assessment report (DAC 2017) and after the submission of DAC? J.W. (45 min) - DAY 3

- **ID Number: D3 3.1.1**
- Andra's actual scientific program (10 min)
  - Includes experiments, demonstrators, simulation
  - Long lasting experiment (REM: 20+ years) and demonstrator (FSS 3 years)
  - Not all data available for DOS (2015) and DAC (2017) dossiers
- Main questions to be addressed before the DAC (15 min)
  - Not possible to go further than FSS in terms of technological feasibility
  - Possibility to go further in terms of scientific knowledge (REM, SET, NSC, BHN, … : all Bure URL experiments directly linked to seals)
- Main questions to be addresses after the DAC (15 min)
  - Technological issues : Scale 1 in real situation : pilot industrial phase in CIGEO before introducing waste packages
  - Observation issues : long lasting measures (up to 100-150 years) in real pilot plant context to confirm numerical simulation on this time scale (gain of an order of magnitude compared to today available data)
  - Scientific issues : Bure URL long lasting experiments, including REM (part of DOPAS)
- Nagra's view points related to similar main questions to be added to this:
  - e.g. the approach to R&D plan/programme (what type of plan, when updated, how does it address demonstrators;
  - where does the DOPAS experiments fit into, what are Nagra's next steps in terms of closure demonstrators/experiments after the DOPAS project => towards licensing a facility

Presentation needs: a videoprojector and computer with MS Powerpoint; whiteboard or flipchart with markers; slides from Nagra

3.1.2 Plugs as a part of the demonstration programmes in Nordic countries (YJH and FUD and in the stages of licensing) - including alternatives - Petri Koho, KHPT (50 min) with some slides from P.G.) DAY 3

- **ID Number: D3 3.1.2**
- Posiva's scientific programme YJH (origin Posiva 2000-14) and the role of closure and the specific role of deposition tunnel end plug in safety
- Explanation of the similar Swedish FUD programme,
- Joint work on plugs SKB-Posiva; What has been done historically in-situ and in demonstrations for closure (e.g. Prototype repository, Canadian shaft sealing),
- What is the influence of the host rock (crystalline rock) for the experiment, what about the site related constraints (repository site/URL; regulator's role on quality assurance...), influence of other components in the concept (like need for new materials e.g. Self compacting concrete (SSC), related method tests, a table on comparison of the properties of the developed concretes vs. normal concrete), discussion about the functions of the concrete in comparing the properties, low pH concrete and its development); challenges of monitoring (e.g. do we make a hole in the plug or not? how much does it disturb the system), stray materials, challenges in instrumentation => also influencing the distances between the demo tunnel and design considerations
- Why now both DOMPLU and POPLU experiments? What is now needed for the licensing (Posiva's RTD programme for closing open questions towards operating licence; feedback from construction license application) => FISST, Yhteistoimintakoe (YT-test),
- Future cooperation areas between SKB and Posiva
- SKB's future plans

Presentation needs: a videoprojector and computer with MS Powerpoint; whiteboard or flipchart with markers

3.2 Behaviour of plug components and materials (DAY 3) - TOPIC 7

3.2.1 The use of individual tests to complement existing material and process knowledge (case of REM metric experiment)

Andra's contribution in terms of REM experiment and how to integrate the results in the safety procedure (DAC) - **J.W. (20 min)**

- **ID Number: D3 3.2.1**
- REM experiment (15 min)
  - Why REM?
  - REM description including instrumentation (to be decides where FSS instrumentation, too, relates to material)
  - Simulation of resaturation
  - First results at 09-2015
- How to use the future result in terms of safety procedure (5 min)
  - Seals concepts at Andra (rapid repetition)
  - Permeability of the core
  - Swelling pressure of the core
  - Resaturation time of the core

<u>Presentation needs: a videoprojector and computer with MS Powerpoint; whiteboard or flipchart with markers</u>

3.2.2 Instructions for laboratory Exercises 3-4 on material behaviour, Petr Večernik, Katerina Videnska and Dagmar Trpkosova - ÚJV 3 DAY

- Division into laboratory groups if needed (4 people in each group; depends on the number of students)
- General instructions for both exercises given and the basis of the exercises

3.2.3 <u>EXERCISE 3:</u> Stress test of concrete (ÚJV team)

- **ID Number: D3 3.2.3** (See **Appendix II-3** in DOPAS D7.2 report by Palmu & al.)
- Types of samples (forms, properties)
- Types of tests
- Standards and measurement procedure
- Calculations
- Outcome of tests and result interpretation (calculation)
- Verification of material properties

<u>Learning aids:</u> cement/concrete samples, laboratory equipment, lab coats, note sheets, pencil, calculator
<u>Presentation needs:</u> computer, Powerpoint, projector, flipchart/whiteboard and markers

3.2.4 About ÚJV and the role of pH in the Czech plug system and a summary on the use of the work in the Czech safety assessment/case (demonstrator programme), ÚJV team - DAY 3

- **ID Numbers: D3 3.0 and D3 3.2.4**
- pH in concrete and in the plug components - types of interaction (chemical influencing the mechanical properties of bentonite?), Influencing factors on pH level

- Testing methods used for material selection, variation in pH and its influence - practical examples
- pH follow-up on site after the construction,
- Countermeasures against unfavourable pH influences

Presentation needs: computer, Powerpoint, projector, flipchart/whiteboard and markers

3.2.5 EXERCISE 4: Interaction of concrete with bentonite, ÚJV team - DAY3

- **ID Number: D3 3.2.5** (See **Appendix II-3** in DOPAS D7.2 report by Palmu & al.)
- Purpose of testing, types of interaction between concrete and bentonite, Influencing factors
- Methods of study of interaction (standard methods, work instructions)
- Outcomes of the test
- Impact of the interactions
- Observation of interacted samples; description of observations
- Discussion of exercise results (can be combined with the presentation to follow).

Learning aids: fine grain cement, concrete and bentonite materials, laboratory equipment, accuracy scales, laboratory coats, note sheets, pencil, pen, calculator, pH meter, pH electrodes, material mixers, solution (distilled water)
Presentation needs: computer, Powerpoint, projector

3.3 Introduction to Safety Assessment and Integration of the experimental work and process modelling in the safety assessment/ safety case - André Rübel (A.R.), GRS (90 min) DAY 4 morning - (TOPIC 8)

- **ID Number: D4 3.3**
- What is safety? ("a teaser" for educational discussion as a starter)

- Discussion on how can safety be proven (show compliance with the regulation, no future dose in the very long run)
- Timescale of evolution of geology
- Time scale of evolution of life forms and change in human behaviour
- Dose concept
- Today humans as measure (with some variations)

- Quantitative analysis of repository needed
  - Proof of safety
  - Calculation of quantifying parameters
  - Comparison with regulatory limits
  - Main message: Safety Assessment is no prognosis of future human radiation exposure
  - Improvement of system understanding
  - Optimisation of repository concept
- Challenges that require simplification
  - Large scale problem
  - Heterogeneous system
  - Long time scale
  - Spatial and temporal variable properties
  - Complex interaction between different processes
  - Large uncertainties
- Procedure for model development
  - Site description (geology, hydrogeology, hydrology, repository concept)
  - Site evolution
  - FEP Catalogue
  - Scenario development (expected evolution, division by probability)
  - Calculation model
  - Process model (part of the system and/or short term)
  - Integrated long term safety assessment model (full system, full assessment period of 1 Mio. years)

- Consequence analysis
- Types of process models (with examples of questions and processes regarding plugs and seals) - DOPAS related
  - Hydraulical (H)
  - Mechanical (M)
  - Thermal (T)
  - Others
  - Coupling of processes
  - Codes used in DOPAS
  - Possible example from DOPAS (refer to the REM test, another example, too)
- Safety assessment
  - Types of indicators (safety/performance)
  - System decomposition into compartments (near-field, far-field, biosphere)
  - Examples for simplification from process towards integrated model
  - Dealing with uncertainties
  - Types of uncertainties
  - Monte Carlo methods
  - Sensitivity analysis
  - Plugs and seals in integrated models
  - GRS integrated simulations as example from DOPAS

Learning aids: conceptualisation of time (teaser cartoon, use of the previous outcomes of discussion and the movie screened on Day 3, Marjatta to provide)
Presentation needs: computer, Powerpoint, projector, flipchart/whiteboard and markers?

3.4 Monitoring for performance assessment of experiment components (Thermal processes) - Exercise 2 continues - J.S. CTU (105 min) - DAY 4 afternoon, last exercise of the day) - (belongs to TOPICS 5 & 8)

- **ID Number: D4 3.4 (continuation of EXERCISE 2 (D2 2.2.1))**
- Raw data collection (measured data and sensor data)
- Sensor data calibration data explanation
- Processing sample data using spreadsheet
- Collection of processed data of several sensors
- Graphic analysis of several sensors
- Comparison of results
- Conclusion

Learning aids: access to measurement system, computers, excel, gnuplot, text editor, wifi
Presentation needs: computers and excel (participants need these, too), projector, powerpoint, gnuplot, flipchart/whiteboard, markers

4 Learning Unit 4: Construction Feasibility of a plugging experiment (DAY 4 morning and noon, early afternoon + DAY 5 morning)

4.1 Practical underground work concerns in setting up an in-situ or full-scale experiment (TOPIC 9)

Includes the practical (S) and technical concerns related to the construction work and work methods in setting up an in-situ or full-scale experiment (K). Experiment and work related risks are identified and discussed as a part of this learning unit. (S, C)

4.1.1 Risk management for large-scale experiments and work underground - P.G. (20 min)

- **ID Number: D4 4.1.1**
- The process of risk management - identification, prevention, mitigation, recovery
- Special features of risk management of large scale experiments and underground work
- Practicalities related to risk management

Presentation needs: computers and projector, Powerpoint, flipchart/whiteboard, markers

4.1.2 Case example of POPLU experiment (recipe development, method tests and casting, start slot location + RSC and design; moving into real repository construction, as built vs. design) - KHPT (40 min)

- **ID Number: D4 4.1.2**
- Experience of the POPLU experiment
  - o POPLU case a form of a story from the beginning to today and what is planned ahead, participants to identify and contrast with the original risk management plan an realised risks in the exercise, do not emphasize especially the risks, since the participants are asked to identify them in their Exercise 5.

Learning aids: use of videos, other visuals
Presentation needs: computers and projector, powerpoint, flipchart/whiteboard, markers

4.1.3 EXERCISE 5 Two groups: Identifying and prioritizing risks for full-scale experiments G1: DOMPLU and G2: POPLU (DAY 4 afternoon)

- **ID Number: D4 4.1.3**
- Instructions for handling and reporting the Exercise 5

Learning aids: do we wish to provide a risk identification template as a structural tool for the students? (no, open tabletop exercise on flipcharts using partial brainstorming)
Presentation needs: computers and projector, Powerpoint, flipchart/whiteboard, markers

4.1.4 Feasibility of a seal in a clay rich host environment. How to adapt the technological process including alternative concept/s - Régis Foin (R.F.) Andra (40 min) - DAY 4 afternoon

ID Number: D4 4.1.4
Including the presentation of the alternative concept (hydraulic cuts and SET demonstrator and explaining how the risks of the experiment were identified and how the alternative concept is a way to manage or mitigate risks (i.e risk identification and management perspective included in presenting these topics)

- Preparation of the emplacement (10 min)
  - Feasibility of the hydraulic cuts
  - Feasibility of the concrete liner dismantling
- Containment walls realization (12 min)
  - Fabrication of low pH concrete and shotcrete
  - Low pH concrete emplacement
  - Low pH shotcrete emplacement
  - Final grouting
- Swelling clay core realization
  - Nominal solution with concrete liner dismantling (10 min)
    - Fabrication of the admixture
    - Transport and storage
    - Quality verification
    - Filling operations
  - Alternative solution with hydraulic cuts (5 min)

        - Fabrication of components
        - Specific filling of hydraulic cuts
    - Safety aspects (3 min)

Learning aids: bentonite pellet samples
Presentation needs: computers and projector, MS-Powerpoint, flipchart/whiteboard, markers

4.2 Working methods underground and for experiments (DAY 5 morning) - TOPIC 9 continues

4.2.1 Lessons learned from the experiments until today (K) - PANEL on experiences, constraints and lessons learned - SKB (P.G.), Posiva (KHPT), Andra (Régis), RWM (Dean), GRS (André), CTU (Jíri), SÚRAO (Marketa) representatives (75 min)

- **ID Number: D5 4.2.1**
- First around 5-10 minute introductions to DOMPLU, POPLU underground working methods (especially slot, casting, cover against rock fall, ...), CTU/SURAO (shotcreting the plug part), FSS construction of the plug (10 min), ELSA related methods (more testing methods) - some of this may be repetition as a summary
- Round table discussions on prequestions and by students - 30-40 min for discussion and questions
    - What do you consider the major challenges concerning the working methods?
    - What working methods would you also adopt in the future? What worked very well?
    - Measurements, quality assurance, approvals by regulator, ...
    - How did you carry out method tests? What could be improved in the method tests? What type of standard tests was available and what tests would still need to be developed? (examples: concrete mock-ups for casting, contact grouting; earth radar for casting, reinforcements),
    - Practical procurement experiences? Suggestions for improvement?
    - Major lessons learned?
    - Closing summaries from each experiment (DOMPLU, POPLU, EPSP, FSS).

<u>Presentation needs:</u> computers and projector, powerpoint, flipchart/whiteboard, markers, table and name cards for the panel table - layout arrangement, facilitator (PMP or other volunteer)

4.3 How to further apply the lessons learned for the future - DAY 5, TOPIC 10

4.3.1 The use the DOPAS experiences in a waste management programme not yet in the demonstration stage or without a site (K, S) - Case of RWM - Dean Gentles (D.G.) RWM (75 min) - DAY 5 morning

- **ID Number: D4 4.3.1**
- List of content to be provided (a summarising perspective in the presentation taking inputs related to the four learning units)
- current pre-design for three different geologies, how they have been designed
- plugs and seals in the system,
- take the learning from the experiments, the different requirements
- assumptions in the RWM designs
- lessons learned from the experiments of DOPAS and how they are incorporated in RWM design

<u>Presentation needs:</u> computers and projector, MS-Powerpoint, flipchart/whiteboard, markers

4.3.2 Preparing for ELSA experiment - A.R. (45 min) DAY 5 morning

ID Number: D4 4.3.2

Further a case summary is provided in how these activities are implemented in the preparation of a full-scale experiment to be implemented following the four existing DOPAS experiments (K, S) for the ELSA shaft sealing that is not yet an in-situ experiment.

- Safety concept of repository in salt (major difference in the concept compared with others)
  - Some words about Gorleben as potential site in Germany for 30 years
  - Specifics of as a host rock - Salt as the dry, impermeable host rock, timescale 10-50 000 years
  - Objective to avoid the contact of external waters with the waste
  - The Shafts/Drifts as potential pathways for inflowing waters
  - When and under which conditions the convergence and compaction of salt backfill reaches low permeability → resulting in a long-term barrier (include also an explanation of the potential compaction (precompaction, further compaction activities?) and other phases that the backfill structure must undergo)
  - Additional barrier needed for time until compaction state is reached (approx.. 10.000 years) → sealing structures like for shafts
- The Concept of shaft sealing for Gorleben = ELSA concept and related material and host environment understanding (Be aware of the site specificity of the concept)
  - Reasoning behind the use of different materials for the sealing structure
  - Geochemical stability of different materials in the host rock environment
- Work in Phase 2 (in DOPAS) in preparing for ELSA continuation
  - Test of additional materials (bitumen) as a component of the structure
  - Selection of methods for pre-compaction of crushed salt
  - Geochemical stability of salt and sorel concrete (explain the specificities of these types concretes, contract with potentially the other concretes in the other experiments especially if they differ also in other than geochemical and mechanical aspects)
  - Mechanical stability of salt concretes
- Future phases for ELSA
  - Multiple experiments for different sealing elements vs. one large experiment (decision still to be taken? or all?)

- Summary on besides the work done in the phase 2, what other contributions has the other work in the DOPAS project given to the German programme, has is created ideas on the planning of the next phase of the work (see your previous bullet point) - the changes in the German R&D plan reflected by the legislation, not all yet decided

Learning aids: salt and sorel concrete samples, salt host rock
Presentation needs: computers and projector, PowerPoint, flipchart/whiteboard, markers

5 Orientation to the Training Workshop (DAY 1 morning)

5.1 Welcome & Introduction to the training workshop programme - Radek Vasicek (R.V.), CTU (30 min)

- **ID Numbers: D1 5.1.1 and D1 5.1.2**
- Welcome, short introduction to CTU and self, and to the locations where the course will be held
- Run through the programme, logistics (of the day and the week)
- Whom to turn to in case of need of information
- Introduction of tutors present, short round of introductions of the participants: name, country and organisation (more detailed will be done in the icebreaker)
- Link to the document storage and the passwords (reminder)
- Other matters, e.g. wifi access, emergency procedures, ...

Learning aids: programme and maps for transport print outs, name tags for participants, table name tags, list of contact information, partipant lists for signing (daily)

5.2 Introduction to DOPAS Project - PMP (30 min)

- **ID Number: D1 5.2.1**
- General presentation
- Partners, timing, objectives
- Concept of DOPAS
- Different experiments and work packages matrix
- Where are we now, figures of experiments
- Where to find more information
- Euratom support

Presentation needs: computers and projector, powerpoint, flipchart/whiteboard, markers, YouTube from Posiva site on time ("meeting" the Coordinator)

5.3 Icebreaker, course objectives and concept of time - PMP (45 min) - DAY 1

- D1 - See **Appendix II-4** in D7.2 report
- Instructions to select your pair to be given (use of short words).
- Introduce yourself to your pair, discuss your objectives for the training
- Join with another pair, introduce your pair to the others, discuss your objectives, write different objectives - each on single white A4 paper in block letters, post them on the wall. Look at what others have posted, group similar objectives together. Then spend the remaining time to discuss what time means to you, to your work, to disposal and to the society. From which perspective should you look at time?
- Finally prepare to introduce the group members to the others and your objectives and your thoughts about the concept of time.

Presentation aids: plain A4 white paper, group division copies, markers, painters tape, camera for documentation of results / pictures; use of a "puzzle" to find your pair in the beginning (requires participants to take contact with each others in the very beginning).

6 Orientation to Josef URC and Underground Laboratory - R.V. & J.S. (110+15 min) (DAY 2 morning)

6.1 Practicalities and advice to studying and acting in Josef (R.V.)

- ID Numbers: D2 6.1a-b Safety instructions (not provided, site specific, always repeated by host)

- History, location in Czech Republic, practical site logistics above ground
- Required protective gear, work safety rules, behavioral rules inside Josef and in entering Josef
- Contact persons in case of questions
- What to do in case of emergency
- Other

6.2 Presentation of Josef Geology and the EPSP experiment, Michal Roll and J.S. (50 min with the previous)

- **ID Numbers: D2 6.2a-c**
- Complementary information to Marketa's presentation
- Videos from the previous work stages of the EPSP, pictures in timely order following the steps of the experiment setup process from the location improvement, construction of different components and installation of instrumentation, and about what can now be seen on the location

6.3 Visit to the EPSP experiment location (60 min) with relevant explanations by CTU - R.V. & J.S. & M. R. & Lucie Hausmannova

6.4 Introduction to the week's exercises and division of the participants into groups (2) for preparing and reporting Exercises 2-5 on Day 5 (PMP & Radek, 15 min)

- **ID Numbers: D2 6.4** (see also D7.2 report)

6.5 Picnic (DAY 2 closing of the day) - appr. 2 hrs

7 Introducing SÚRAO's programme on siting and deep geological repository (K), and information activities to the general public (K, S). - DAY 3 afternoon - total 60 min

7.1 SÚRAO's site selection programme - Lukas Vondrovic, SÚRAO

- **ID Numbers: D3 7.1a**
- Introduction to SURAO and the site selection programme
  - The disposal strategy for heat-generating nuclear waste in the Czech Republic assumes the direct disposal of spent fuel in steel-based canisters in crystalline host rock at a depth of 500m.
  - The total waste package inventory will be approximately 6000 containers with spent nuclear fuel and 3000 concrete containers with other radioactive waste.
  - The operational phase of the repository will be 80 years or so and the opening of the repository is planned for 2065.
- Potential host rock and locations, disposal concept
  - Following initial screening of a number of localities in the early 1990s, RAWRA/SURAO (The Czech Radioactive Waste Authority) defined 7 areas (Fig. 1) to be subjected to further multidisciplinary investigation.
  - The localities were chosen based on the Swedish concept due to similarities between the geological conditions of that country and the Czech Republic. Six of the localities are located in granitic rock (with a crystallization age of between 515-320Ma) and one is made up of high-grade metamorphic rock (migmatites, granulites). All the potential sites are located in geologically stable environments with a minimum of faults and high levels of predictability in terms of the rock environment.
- Stages of the siting programme, timing, activities
  - SURAO, in its capacity as the national waste repository authority, runs three key projects which are focused on the site selection process.

- The first of the projects is dedicated to scientific support for safety assessment evaluation purposes and includes the construction of synthetic geosphere models (e.g. hydrogeological models, structural-geology models, geotechnical models etc.) and the evaluation of the localities in terms of various criteria (e.g. safety, socioeconomic, political etc.). The result will consist of the creation of detailed safety assessment reports for each potential locality.
- The second project concerns the engineering aspects of the future repository, the stability of the engineered barriers and an initial feasibility study.
- Both of these projects require primary data that will be provided by the third project called “Exploration of 7 localities, phases I, II, III” which is a classical terrain-based project focused on obtaining primary geological data.
    - Phase I (2014-2016) involves the gathering of surface-based data only (e.g. geological mapping, hydrogeological analysis, geophysics etc.) and will result in a reduction of the number of potential localities to 3 or 4.
    - Phase II (2017-2019) will involve deep borehole drilling for the verification of the geophysical data, and further complex geological investigation work, following which the number of candidate localities will be reduced to 2.
    - Phase III (2020-2025) will focus on providing data based upon which the government will select a final site in 2025.
    - In addition, important primary data for the Exploration project will be provided by RAWRA’s underground generic research program.

7.2 SURAO's deep geological repository programme - L Kovacik, SÚRAO

- **ID Numbers: D3 7.1b**
- Disposal concept and the timing of implementation
- Work on the individual engineered barriers
- The Czech safety case for the deep repository
- Budget and provisions for funding

- EPSP as part of the Czech programme

7.3 SURAO's information activities to the general public (incl. presenting the information centre) - Lucie Steinerova, SURAO - DAY 3

- **ID Numbers: D3 7.2**
- Public outreach and governance principles related to the site selection
- Public attitudes towards geological disposal
- Examples of interest from SURAO's information activities

8 Movie night: Into eternity and discussion on the movie - PMP, DAY 3 evening, around 3 hrs at SURAO information centre

Discussion questions on the movie:

- Your impressions about the movie? Have you seen it before/seen it for the first time?
- What did the director try to convey to the audience? How did he succeed?
- What did you like about the way of presenting the xxx (concept of time? the difficulty of knowing about the future? the way of communicating about the repository? handling of uncertainty?)
- What would you have changed in the way of presenting xxx? Why?
- Could this movie provide support for the deep repository? Would it make you uneasy about the repository?
- Did this meet what you expect from a documentary? Yes/No - Why?
- Can you separate the movie as an artwork from making a statement?
- Other comments?

Perpectives on the movie: What is known of ONKALO, final disposal after thousands of years? Is it revealing itself slowly like the moose in the film? Are the people excavating it? Metaphores for the future? Humans thinking they would find something of value behind the "final curtain?" How can information be preserved about the repository? Should it be preserved?

Learning aids: Movie copy the movie DVD e.g. from web shops or producer, permission to present from Magic Hour Films, and DVD player (or computer and speakers) and projector needed. Magic Hour Films is able to provide the movie in several language versions on request.

9 Josef Cathedral visit (DAY 4 closing of the day) - appr. 1 - 1.5 hrs

Some small snack after visit and return to Prague
(Group dinner in Prague decided on the spot)

10 Exercise reporting by participants (K, S, C) - DAY 5

10.1 Presentation and commenting of the exercises 2-5 to the participants and tutors (who are present - (75 min)

- The group exercise final reports are available for potential trainers at request from the DOPAS Project coordinator (only).
- Exercise 2 is presented by both groups time 15 min each including commenting. Exercise 3, 4 max 10 min per exercise including discussion,
- Exercise 5 presented by both groups max. 10 min each including discussion

10.2 Instructions for returning exercises - R.V. & PMP (15 min)

- Instructions for reporting - format, length, content expected, delivery date by 2 October 2015.
- Returned exercises qualify for a completion certificate, otherwise only participation to training workshop certificate

11 Assessment, feedback and summary of training workshop (C) - PMP & tutors present (60 min) DAY 5

- **ID Number: D5 11 and Appendix II-4 in D7.2 report.**
- Review the frame of the DOPAS project and the workshop's relation to it
- Feedback questionnaire collection from students, time to fill out (or email) - needs to be prepared (electronic?)
- Ask students to reply to open questions on a blank piece of paper

Now I know about ...

I did not feel I understood the following content ....

I would have liked to have ...

After this training workshop I would like to learn more about...

- Direct assessment on the attainment of the goals set by the participants in the beginning of the training workshop - PowerPoint, discussion with the students
- **Repeat important delivery dates, delivery addresses for exercises and mailing addresses for certificates**

<u>Learning aids:</u> plain A4 papers, pens, feedback forms printed,

Presentation needs: objectives from day one on ppt, photos

12 Closing

13 Tutors' tasks after workshop

- Review of the exercises (DL from participants 2 October 2015) - agreement on the division of exercises (TBD)
- Signing of certificates (TBD)
- Feedback meeting from the training workshop (via telecon on 24 September or 14 October as a back-up)
- Review of the Workshop deliverable D7.2 for the EC (date TBD)

DOPAS Training Workshop 2015 (DOPAS TWS 2015) Training Materials Summary
Please visit the DOPAS training materials for download in slide pdf -format at the DOPAS website http://www.posiva.fi/en/dopas . This Appendix provides the main lecture slide summaries for the purpose of material overview and to assist in the material selection and downloading.

DAY1

Day and ID#	File content
D1 5.2.1	DOPAS Project: General presentation
D1 1.1.1b	The role of plugs and seals in clay (Andra)
D1 1.1.2	Purpose of plugs and seals in crystalline rock (SKB)
D1 1.2.2	DOPAS Requirements Management (Posiva)
D1 1.2.3	Design basis development work flow for plugs and seals (SKB)
D1 1.3.1	Case example of EPSP Experiment (SURAO)
D1 1.3.2post	Scoping the DOMPLU Experiment - post-exercise (SKB)

DAY2

D2 6.2a	Introduction to Josef © CTU
D2 6.2b	Josef Geology © CTU
D2 6.2c	The EPSP Experiment in Josef (CTU)
D2 2.1	Theoretical basis to Andra's safety assessment process and case from the iteration cycle of Andra's demonstration programme
D2 2.2	The role of instrumentation and monitoring in an experiment (CTU)
D2 2.2.1	Exercise 2 - monitoring

DAY3

D3 3.1.1	Andra's scientific programme today and its next stage (Andra)
D3 3.1.2	Plugs as a part of demonstration programmes in Nordic countries (Posiva)
D3 3.2.1	Use of individual tests - Case REM metric test (Andra)
D3.3.2.4	The role of pH in the Czech plug system (UJV)
D3 7.1	Czech siting programme (SURAO)
D3 7.2	Public involvement (SURAO)

DAY4

D4 3.3	Integration experimental work and process modelling in safety assessment (GRS)
D4 4.1.1	Risk management for large-scale experiments and work underground (SKB)
D4 4.1.2	Case example of POPLU experiment (Posiva)
D4 4.1.4	Feasibility of a seal in a clay rich host environment (Andra)

DAY5

D5 4.3.2	Preparing for ELSA experiment (GRS)
D5 4.3.1	How the lessons learned can be applied to less advanced programmes? (RWM)

DOPAS Training Workshop 2015

A General Overview Of DOPAS Project

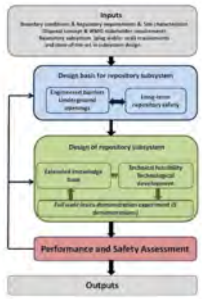
Marjatta Palmu
on behalf of consortium
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

5.2.1

DOPAS (2012-2016) in general
Full-scale demonstration of plugs and seals

- DOPAS is about full-scale demonstrations of plugs in underground and above ground with 4 year duration
  - for the feasibility of construction and for the performance assessment of the plugs selected for the demonstrations
- 14 partners, 8 countries, 5 experiments
- 18.5 million euro budget with Euratom FP7 support



2

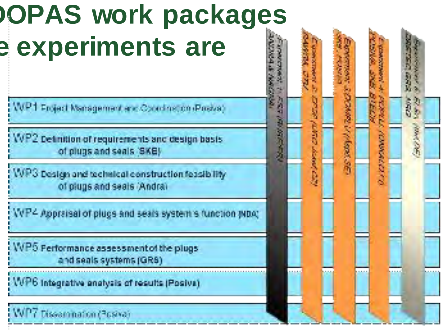
One context for DOPAS – meet our coordinator
http://www.posiva.fi/en/media/time_travel_to_final_disposal#.VeKm53yVmM

3

Seven DOPAS work packages and five experiments are

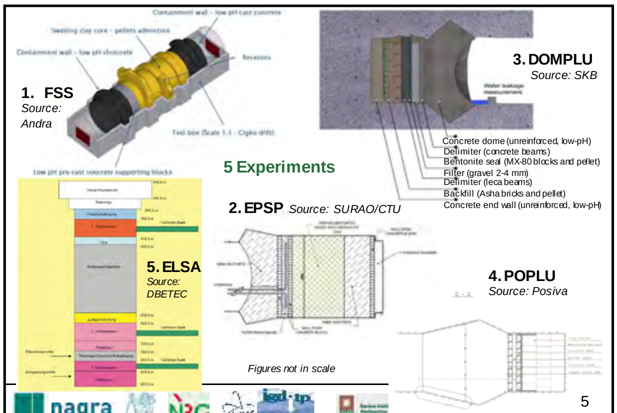
implemented partly or fully in underground or above ground conditions.

Results can be used for planning of L/ILW and Spent Nuclear Fuel repositories.



This training workshop is a part of the WP7 Dissemination.

4



5

1. FSS STATUS (Andra & Nagra)

- FSS installing and emplacement actions done by September 2014, seal intended for clay.
- Clever dismantling finished by at end of August 2015.

7

2. EPSP STATUS (SURAO, CTU & UJV)

- Plug location host rock improvement was done during 2014
- Construction of plug elements (e.g. shotcreting) started in Autumn 2014
- Bentonite saturation on-going in August-September 2015

Photos© SURAO & CTU

Crystalline host rock of Josef Underground Laboratory

9

3. DOMPLU STATUS (SKB & Posiva)

- Wire sawed plug slot produced in crystalline rock
- Dome plug was casted in March 2013, cooling system installed
- Data freeze for DOPAS reporting in September 2014
- Plug's performance is currently monitored

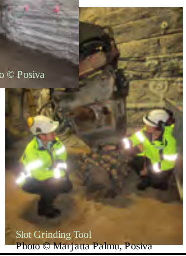
Photos: SKB

11

4. POPLU status (Posiva, SKB, VTT & B+TECH)

- Plug location selection using repository criteria
- Slot excavation produced with boring, wedging and grinding method
- Plug installing and emplacement activities in 2015
- The first concrete casting is completed in July 2015, second casting on going this week

POPLU Slot location. Photo © Posiva



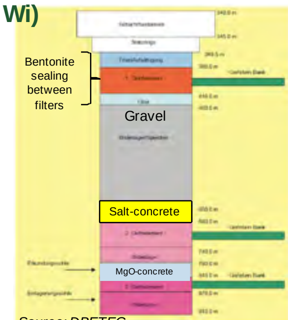
Slot Grinding Tool
Photo © Marjatta Palmu, Posiva

13

5. ELSA shaft seal experiment in Germany GRS+DBETEC and BMWi)

ELSA related background laboratory and modelling work for LAVA, LASA and THM ton on-going preparing for a future full-scale sealing demonstration. Gorleben shaft depth is over 900m. Foreseen seal lifetime couple of hundred thousands years.

© DBETEC and TUBAF



Source: DBETEC

14

Work carried out in different scales e.g. to define:

Photo: SURAO

All other photos: ANDRA

- are the densities high enough?
- what emplacement challenges exist?
- what's the efficiency of methods?
- how to quality assurance and control?

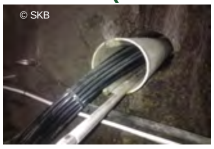
15

The main outcomes of the DOPAS project will be the full scale demonstrators

- Establishing and using requirements for plugs and seals experiments in different European countries and producing a generic view taking into consideration the influences of national and general factors respectively.
  - The context and safety concept behind each experiment influences the intended lifetime of the plugs and seals during the repository lifetime from short to very long-term as presented later.
- Establishing design basis for different types of tested plugs and seals.
- Developing designs, working methods and materials for such plugs for deposition tunnels, drifts and for various shaft seals.
- Developing strategies for demonstration of design compliance with design basis.

16

Plug behaviour instrumentation example (monitoring performance)



17

Novel and added information and knowledge has been gained about

- How to locate suitable places for plugs.
- What densities can be achieved for bentonite components, dismantling large concrete/bentonite structures, and related logistics concerns.
- How to construct plugs under regulatory oversight, repository requirements and strict work safety rules:
  - e.g. approval and modification of materials, handling logistics, public procurement and all supporting activities like method tests, and addressing work safety constraints
- How to monitor the plug and seal behaviour
  - plans ready for POPLU (ONKALO) and EPSP (JOSEF)
  - on-going monitoring for DOMPLU (ÄSPÖ)
- And about how well the requirements are fulfilled by the implemented experiment designs.

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DOPAS 2016 Seminar

- First announcement to be published
- Call for abstracts: Summer 2015
- **Deadline for abstracts: November 2015**

- Author notification: January 2016
- Final programme: February 2016
- Extended abstract submission: March 2016

- **DOPAS 2016 Seminar: 25-27 May 2016 in Turku, Finland**
- Proceedings published: August 2016

Visit:
http://www.posiva.fi/en/dopas/dopas_2016_seminar


Photo © J. Hansen, Posiva


Source: Posiva

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Acknowledgements

- **The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013 under Grant Agreement no 323273, the DOPAS Project**
- **More information can be found on the DOPAS website: www.posiva.fi/en/dopas**
- **DOPAS partners (see below) are thanked for their contributions to this presentation**

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Further reading for you. All public deliverables of the project are and will be available at:
www.posiva.fi/en/dopas

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DOPAS Training workshop 2015

Learning Unit 1 : From Requirement to design basis of plugs and seals

Understanding requirements management and their application for plugs and seals

The role of plugs and seals. Different timelines, different host rocks (case of clay repository concept)

Jacques WENDLING (Andra/DRD/EAP)
D1 1.1.1
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Summary

Radioactivity and its use in France

Radioactive wastes in France and how to manage them

Deep underground repository and role of seals in france

Other country focusing on Clay type host rock : Switzerland

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Principal types of Use of Radioactivity in France


Electricity production


Defense


Industry


Research

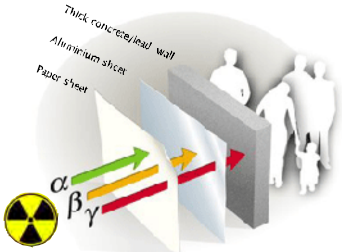

Medicine


Amount of radioactive waste produced in France annually per inhabitant

2 Kg/year

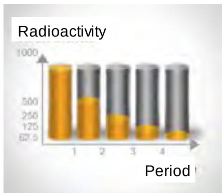
Radioactivity is a natural phenomena (1/2)

linked to unstable atoms which transforms into slable ones by emiting different types of rays (α, β, γ) more or less dangerous



Radioactivity is a natural phenomena (1/2)

Which decreases more or less rapidly with time



The ½ life period is the duration after which half of the amount of radioactivity of a single radionuclide has naturally disappeared by disintegration

- Iodine 131 : 8 days
- Cobalt 60 : 5 years
- Tritium : 12.3 years
- Césium 137 : 30.1 years

- Carbone 14 : 5 700 years
- Plutonium 239 : 24 000 years
- Choride 36 : 360 000 years
- Iodine 129 : 17 million years
- Uranium 238 : 4.5 billions years

Radioactive wastes in France and how to manage them

What to do with these radionuclides before they become harmless ?

France has choosen a long term solution for all types of wastes implying a multi barrier concept including :

A waste container
- Transport
- Exploitation phase

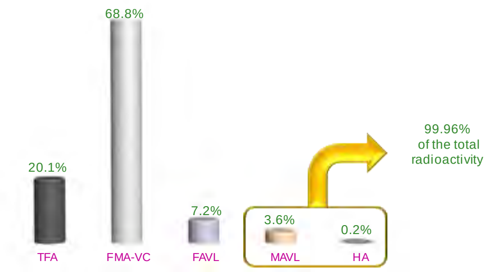
An engineered barrier system (EBS)
- Exploitation phase
- Institutional phase

A geological media
- Long term safety

Classification of radionuclides for storage in France

	Waste containing mainly RN with Very Short ½ life period < 100 days	Waste containing mainly RN with Short ½ Life (VC) period ≤ 31 years	Waste containing mainly RN with Long ½ Life (VL) period > 31 years
Very low activity (TFA)	Industrial storage during radioactive decrease	Recycling or dedicated surface storage (Cires, in activity)	
Low Activity (FA)		Surface repository (CSA, in activity)	Subsurface repository (in study)
Intermediate Activity (MA)			Deep geological repository (Cigéo, in study)
High Activity (HA)	No RN in this category	Deep geological repository (Cigéo, in study)	

Total volume of radionuclids wastes per categories



End of 2013 the total volume of radionuclids waste was around 1 500 000 m^3

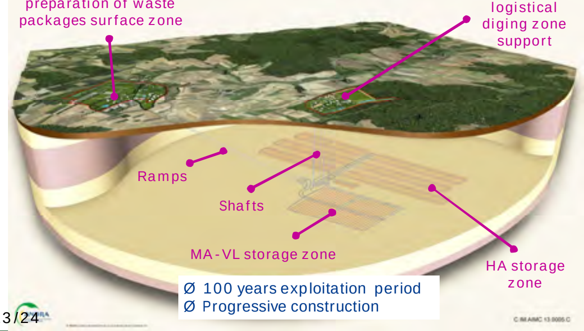
Ø 90% of the total amount (volume) of RN has already a long term management solution (repository in activity)

A solution is actually studied for High Level Wastes and Intermediate Level Long Lived Wastes

Cigeo : Deep underground clay host rock geological repository

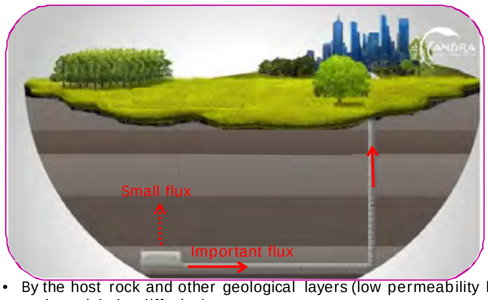
- Deep underground (500 m): to protect from (limit) human intrusion and natural disasters on surface
- Clay host rock: very low permeability and favorable for RN « trapping » (high cation sorption)
- Geological repository: stable over very long period of time (far beyond human possibilities)

Principle of Cigeo repository 2014 architectural design



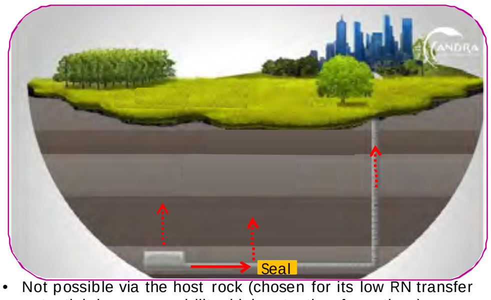
Ø 100 years exploitation period
Ø Progressive construction

Radionuclides are migrating toward the surface



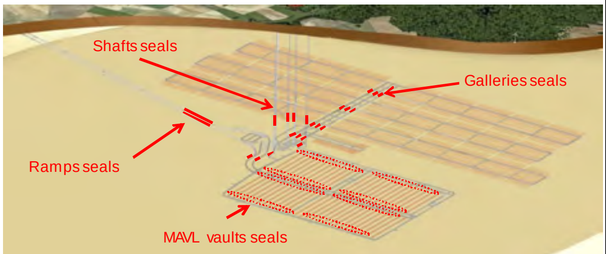
- By the host rock and other geological layers (low permeability host rock: mainly by diffusion)
- Using the excavated gallery network (high permeability: mainly by convection)

How to limit the migration toward the surface ?



- Not possible via the host rock (chosen for its low RN transfer potential: low permeability, high retention for cations)
- Possible in the gallery network: try to come back to the natural (host rock) propeties: "clay type seals"

Actual foreseen emplacement of seals in Cigeo



Seals have to last as long as needed to prevent RN to come to the surface.
Limited at 1 My in practice (duration of the SA calculations)

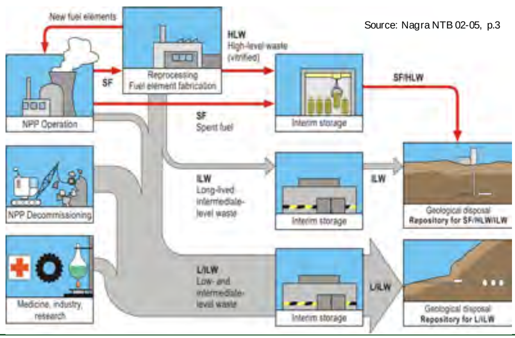
Other country focusing on Clay type host rock

Example of Switzerland

If not otherwise stated, the following material is extracted from Nagra 08-07-2015

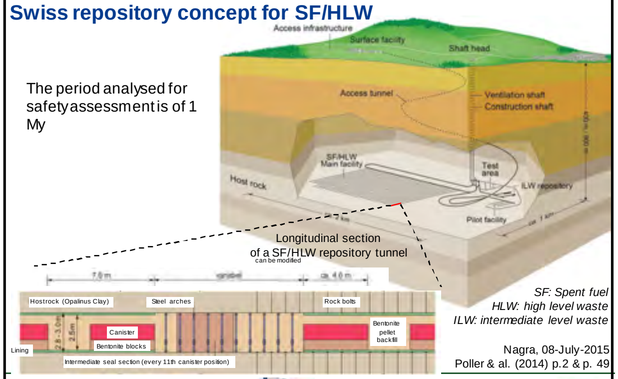
Elements of Swiss Waste Management Concept

Source: Nagra NTB 02-05, p.3



Swiss repository concept for SF/HLW

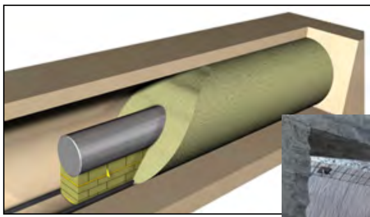
The period analysed for safety assessment is of 1 My



SF: Spent fuel
HLW: high level waste
ILW: intermediate level waste

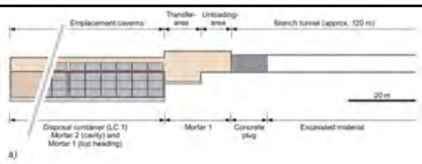
Nagra, 08-July-2015
Poller & al. (2014) p.2 & p. 49

Swiss example : Emplacement tunnel of the SF/HLW repository



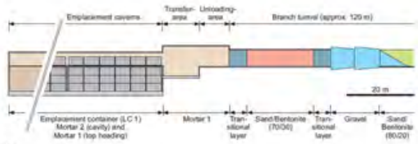
Nagra, 08-07-2015

In-tunnel emplacement concept with canister emplaced in tunnel on bentonite blocks, backfilled with granulated bentonite.

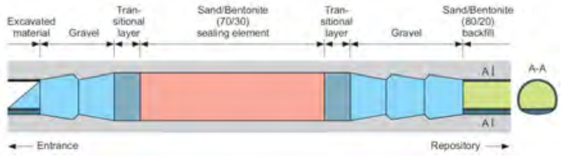


Swiss example : L/ILW emplacement cavern without (a) / with (b) Engineered Gas Transport System (EGTS)

Nagra, 08-07-2015

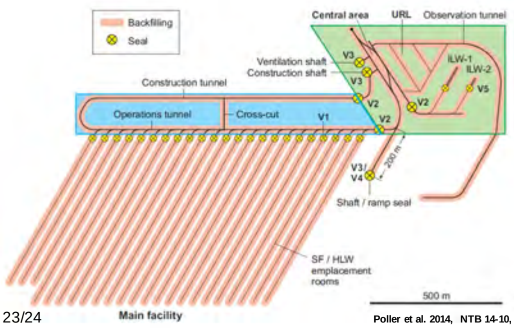


Swiss example : Generic possible layout of a gallery seal



Source: Nagra

Layout of the backfilled/sealed Swiss SF/HLW repository



Poller et al. 2014, NTB 14-10, p. A-21

Thank you

References related to Nagra's concept

Nagra. 2002. Projekt Opalinuston, Konzept für die Anlage und den Betrieb eines geologischen Tiefenlagers – Entsorgungsnachweis für abgebrannte Brennelemente, verglaste hochaktive sowie langlebige mittelaktive Abfälle.Technischer Bericht NTB 02-02

Poller & al. 2014. Modelling of Radionuclide Transport along the Underground Access Structures of Deep Geological Repositories. Nagra. Technical report NTB 14-10. August 2014. ISSN 1015-2636.

Nagra. 2002. Project Opalinus Clay. Safety Report. Demonstration of disposal feasibility for spent fuel, vitrified high-level waste and other long-lived intermediate-level waste. Nagra Technical Report NTB 05-02.

Nagra reports available at *http://www.nagra.ch/de/cat/publikationen/technischeberichte-ntbs/ntbs-2001-2013/downloadcenter.htm*

DOPAS Training Workshop 2015

DOPAS

D1 1.1.2
The Purpose of Plugs and Seals in Crystalline Rock

Pär Grahm, SKB
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

update 2016

Well, who is "Pelle"?

- B.Sc. Mechanical engineering (1993)
- B.Sc. Energy systems and environment (1995)

Experience:
- 2 years Consultant/Designer
- 11 years Oskarshamn NPP (Project Manager)
  - Design, licensing and construction of a repository for Low-Level Waste
  - Re-licensing of NPP including power upgrades of unit 2 and 3
  - Advanced security upgrade of the NPP site (checkpoints, S-systems, UPS)
- 6 years SKB (Project Manager, Team Manager)
  - Technical development of Engineered Barrier Systems (several projects)
  - DOPAS experiment leader

Now, say something about SKB…

Outline of this lecture

- Waste types to be disposed
- The KBS-3 system
- Engineered Barriers Systems (EBS) for passive safety of the repository
- Host rocks (European geologies, focus on crystalline rock)
- The Swedish and Finnish repositories for Spent Fuel
- Different types of plugs and seals needed
- Closure of a repository

Different waste types – different solutions

Waste from Operation and Decommissioning

Spent Nuclear Fuel

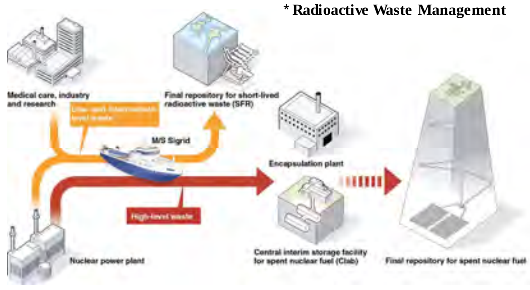
Long Lived Waste categories:
- Spent Fuel
- Control rods
- Reactor vessel (PWR)
- Core components
- Legacy waste (Transuranic waste, TRUW)

Low - & Intermediate Level Waste (L&ILW)

High Level Waste (HLW)

The Swedish RWM*-system (SKB's mission)

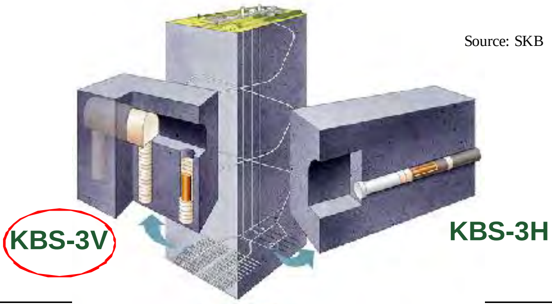
* Radioactive Waste Management



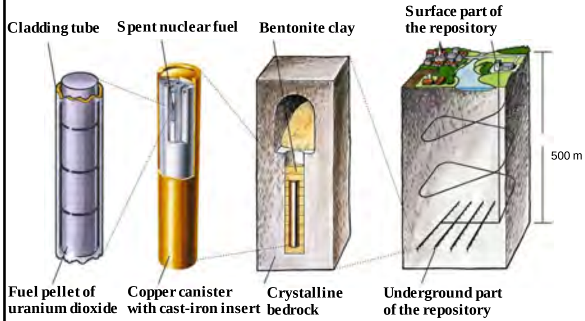
©

The Swedish and Finnish repository concept for Spent Nuclear Fuel

Source: SKB ©



KBS-3V - Engineered Barrier Systems

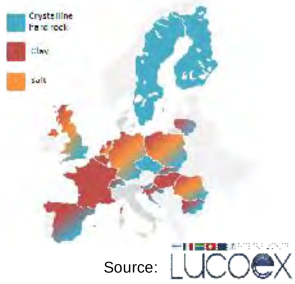


European geology

http://portal.onegeology.org/

https://en.wikipedia.org/wiki/Geology_of_Europe#/media/File:Europe_geological_map-en.jpg

Schematic of suitable host rock in Europe for deep geological repository



Source: LUCOEX

Country	Geological inventory for deep geological repository
Belgium	Clay
Bulgaria	Clay, Crystalline rock
Croatia	
Denmark	
Czech Republic	Crystalline rock
Finland	Crystalline rock
France	Clay
Germany	Clay, Crystalline rock, Salt
Hungary	Clay
Italy	
Lithuania	Clay, Crystalline rock
The Netherlands	Clay, Salt
Poland	Clay, Crystalline rock, Salt
Romania	Clay, Crystalline rock, Salt
Slovakia	Clay, Crystalline rock
Slovenia	Clay, Crystalline rock
Spain	Clay, Crystalline rock
Sweden	Crystalline rock
Switzerland	Clay, Crystalline rock
United Kingdom	Clay, Crystalline rock, Salt

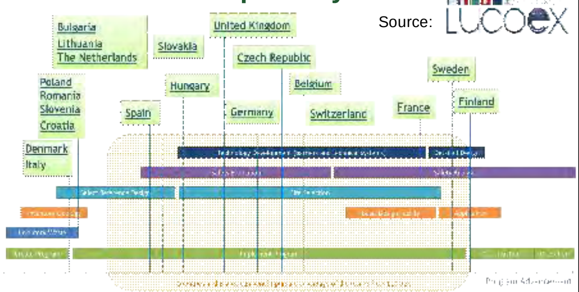
Countries with planned start year for operation

Source: LUCOEX

Country	Year for start of operation of deep geological repository
Belgium	
Bulgaria	
Croatia	
Denmark	
Czech Republic	2065
Finland	2022
France	2025
Germany	2035
Hungary	2064
Italy	
Lithuania	
The Netherlands	
Poland	
Romania	2055
Slovakia	
Slovenia	2065
Spain	
Sweden	2029
Switzerland	2050
United Kingdom	

How far the member states have come in their repository work

Source: LUCOEX



Choice of geology (to be made..)

- **Belgium, Bulgaria, France, Germany, Hungary, Lithuania, the Netherlands, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland and United Kingdom consider clay as an option for host rock.**
- **Bulgaria, Czech Republic, Finland, Germany, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain, Switzerland and United Kingdom consider crystalline rock as an option for host rock.**

Source: LUCOEX

Crystalline rock

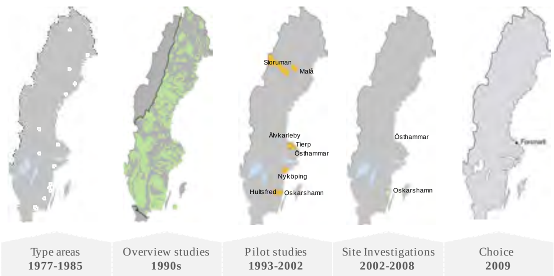
Photos by SKB

- **Site investigations - Rock type and fracture zones are studied from drill cores**



Finding a site in Sweden…

Source: SKB



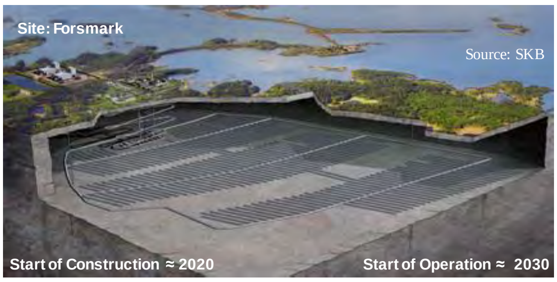
SKB has chosen Forsmark

- **The rock in Forsmark offers much better prerequisites for long-term safe disposal and facilitates implementation**
  - o The rock is homogenous and has only sparsely fractured water-carrying fractures at repository depth
  - o Good thermal conductivity allows the repository to take up less space
  - o Less rock mass and material for backfill
- **Buildings above ground can be built within the existing industrial area**
  - o Access to infrastructure
  - o Limits environmental impact

Source: SKB

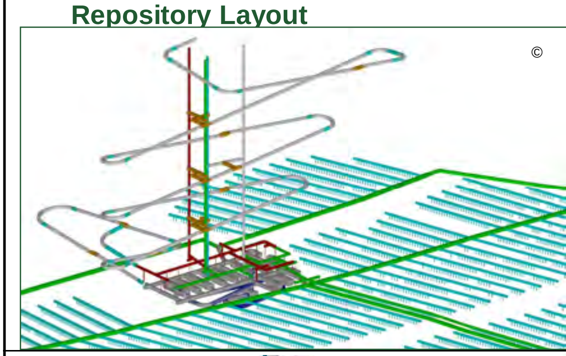
The Spent Fuel Repository

- **Principle outline of the deposition area -470 m (licensing ongoing)**
- **Each deposition tunnel will be sealed by an end plug**



©

Repository Layout



Spent Fuel Repository – Construction phase

- After 3 years

- After 6 years

Spent Fuel Repository in the future

Construction around 10 years

Operation around 40 years

Site after closure

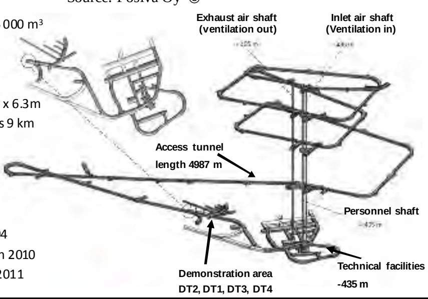
20

Finland: ONKALO layout and technical spec.

Status: 3 July 2015
Source: Posiva Oy ©

Technical specifications
- Excavation volume 365 000 m³
- Access tunnel
  - Length 5 km
  - Inclination 1:10
  - Dimensions 5.5m x 6.3m
- Total tunnels and shafts 9 km
- Shaft diameters 3.5m and 4.5 m
- Shaft depths -435m

Schedule
- Start of excavation 2004
- Research level -420m in 2010
- Excavation finished in 2011



Layout for the first years of operation in 2020's

Source: Posiva Oy

© Posiva

Extended disposal facility around 2120's

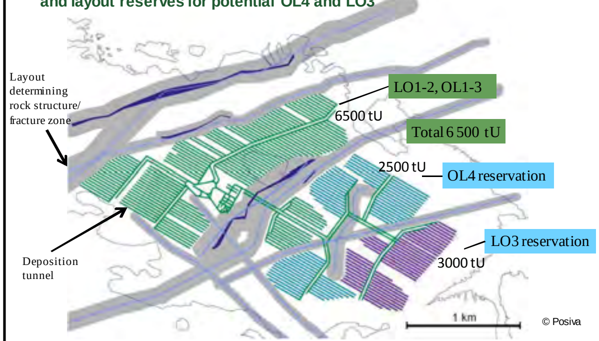
- Repository capacity is 6500 tU*) (about 3325 canisters)
- Depth of the tunnel system -420-455 m and the footprint is about 2 km²
- Construction and operating time approximately 100 years
- The total excavation volume about 2 million m³
- Total length of tunnels ~ 60-70 km

© Posiva

*) This presented layout includes reserve for OL4, too
adapted from Posiva 2013. WR 2012-66, p. 51, 53)

Scope of Posiva's construction license application for 6500 tU (LO1-2 & OL1-3)

and layout reserves for potential OL4 and LO3



Source: adapted from Posiva 2008. EIA08, p.52

Backfilling of deposition tunnels

©
Source: SKB

Deposition tunnel end plugs

Plugs are secondary barriers during the operational phase of the repository (≈ 100 years) with following functions:

- Confine the backfill
- Support saturation of the backfill
- Provide a barrier against water flow that may cause harmful erosion of the bentonite in buffer and backfill

© Source: SKB TR-10-12

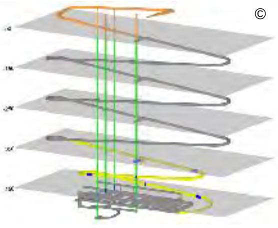
Closure of a repository

Source: SKB TR-12-08 (Fig. 2-5)

©

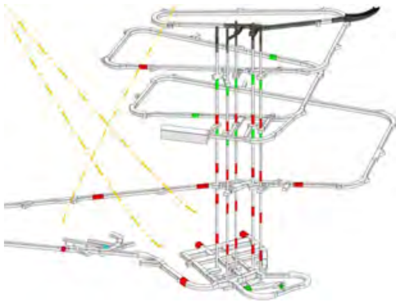
Plugs and Seals are installed at predefined locations to cut off hydraulic paths and/or to give mechanical support to structures.

- Seal deposition areas
- Seal the bottom level ramp (to 100 m above repository level)
- Seal shafts
- Seal boreholes
- Top seal



Grey colour represents crushed rock, yellow bentonite-filled sections, green crushed rock that has been optimised for low hydraulic conductivity, blue installation plugs of concrete and brown top seal of rock backfill with injected concrete.

Closure of a repository



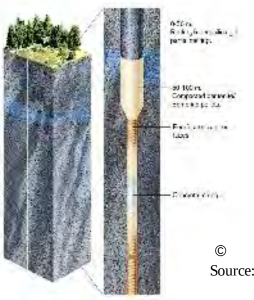
Generic Closure Design (c) Posiva Oy by Saanio&Riekkola (not in scale)

©

Legend:

BOREHOLE PLUG
INTRUSION OBSTRUCTING PLUG
HYDRAULIC PLUG
MECHANICAL PLUG
DEPOSITION TUNNEL END PLUG (HYDRO-MECHANICAL PLUG)

Sealing of investigation boreholes



©
Source: SKB TR-12-08 (Fig. 4-1)

The road ahead – Building a repository for spent nuclear fuel

- Detailed design of EBS; Canister, buffer, backfill and plugs
- Detailed design of installation process and quality control
- Development of installation equipment
- Manufacturing of EBS components
- Integrated testing of installation

DOPAS Training Workshop 2015

Requirements Management
General Introduction

Marjatta Palmu, Posiva Oy
14 September 2015

D1 1.2.2

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

update 2016

Sources of Requirements

- Highest level requirements are derived from policy decisions and strategies, legislation and other regulations, owners, other major stakeholders
- System requirements are derived from safety objectives to be fulfilled and related safety functions of subsystems and components
- Design requirements are also derived from standards and rules, and from industry conventions
- Forming statements about what a system, component (design of a component) has to do (shall…), how does it need to perform, and what it must be like (its characteristics e.g. not harmful…), what type of conditions it needs to tolerate, what it cannot be?

Source: adopted from DOPAS D2.4

2

Expected Learning Outcomes from Topic 1.2

- Identify and list major sources of requirements for geological disposal and for closure
- Understand and be able to describe the major elements of the general concept of requirements management (various elements of it) and its objectives orally or in written form/figures
- Discuss the collection of identified requirements and their different hierarchy
- Understand how requirements are applied in the design of plugs and seals using iteration cycles in interaction with compliance management

3

List of contents (1)

- What is a requirement, what makes a requirement?
- How to write and interpret requirements;
- What does one do after requirements have been identified?
- Models for requirements management – describing the different levels of the requirements, their content and source/links
- Setting a baseline for requirements and managing change
- Tools to assist in the management; Related concepts, and short examples

- How does one translate identified requirements into practical designs and solutions? Some case examples and DOPAS experiment examples to follow in today's other presentations.

4

What is a requirement?

- an objective or a need of an end-user
- expressed in general with the verb "shall"
- requirement itself <u>is not the solution </u>to the objective or need

What makes a requirement?

- a single statement with defined attributes,
  - an absolute requirement (applies always), "shall" verb in the statement
  - target (requirement sets a target, but can be optimised or negotiated)
  - expectation or expression of need (requires modification into a requirement)
- preferably numerical
- requirements can further be
  - functional
  - non-functional requirements
  - constraints/boundary conditions
- have different priorities in relation to each other

5

Writing requirements

Requirements need to be
- **correct (use a competent team)**
- **consistent (cross check)**
- **complete (need has to be covered)**
- **realistic (technical feasibility)**
- **necessary**
- **verifiable**
- **traceable to source (change management and updates)**
- **can be prioritized in connection with other requirements**

Expressing priorities
- **shall (absolute)**
- **should (iterate, negotiate)**
- **nice to have (optimisation)**
- **may**

6

Requirement attributes (examples)

Source	Who has placed the requirement, origin?
Lifecycle stage	In which lifecycle stage does the requirement apply
Justification	Reason, why this requirement is needed
Priority	In relation to other requirements (e.g. classification)
Urgency	At which stage of the system design or engineering is the requirement based information (when is it needed for the work)
Verifiable	Can the compliance to the requirement be tested, verified or validated (important to consider when writing a requirement)
Approved	Has the requirement been approved as part of the design basis
Inspected	Inspection status
Value	Target/validation value
Range of values	Acceptable range of values or tolerances for a numerical requirement
Safety	Is the requirement safety or production critical?
Other comments	Other necessary complementary comments
Open issues	Open questions prior a requirement can be accepted

Overall disposal system objectives or requirements

- **Safety** and **robustness** of system
  - The disposal system has to ensure that the waste is secure and that human beings and the environment are protected from the effects of radiation for the time period of about one million years during which the wastes (especially spent fuel) pose unusual hazard
  - Robust: Performance may not be unduly affected by residual uncertainties from realistic future scenarios regarding its evolution ...
- **Reduction** of **likelihood** and **consequences of human intrusion**
  - Measures should be taken to minimize the risk of human intrusion. Should intrusion nevertheless occur, the repository should be designed in such a manner that degradation of performance after intrusion is limited.

=> Safety functions of disposal system = functional objectives with key relevance to long-term safety and security (to comply with the requirements).

Source: adapted from Nagra 2005. NTB-05-02, p. 34

What to do after requirements are identified?

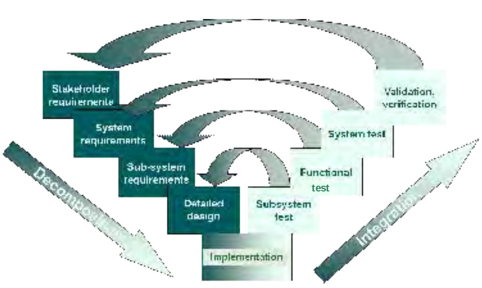
- Requirements themselves form a complex information structure, that increases in complexity as the disposal project advances to specification level.
- Within this system the number of relationships increases and adds further to complexity and knowledge management challenges.
- Simultaneously the requirement changes need to be managed and the status of the requirements updated according to each project stage.
- Requirements change in an iterative manner (iteration cycle)
- As a starting point for managing requirements (i.e. setting up a requirements management system (RMS)) the first baseline of requirements needs to be set. The changes are compared against this baseline and traced with the assistance of a requirements management tool in most cases.

Requirements Management (RM)

- a way of including the customer's voice into the design process by
  - stating what a system is supposed to do
  - instead of how it is supposed to do it.
- according to Hoffman & al. (2004) :

  "**Requirements management** is the structuring and administration of information from elicitation, derivation, analysis, coordination, versioning and tracking requirements during the complete product lifecycle"
- The origin of requirements management is in Systems Engineering
- An alternative concept meaning almost the same "Configuration Management"

A system of requirements – V-model



A hierarchical system to link higher level requirements into lower level requirements for operationalization => designing functionality to meet the identified needs with **practical solutions from alternative options**, and verifying these against the set (of) requirements

Example source: Posiva

Requirements

- make a hierarchy of increasing detail when moving from the top level requirements to the component level specifications.
- They are developed in an iterative manner and
- intended to ensure traceability and control the impact of changes.
- They shall/ cannot be in conflict with each others (links between requirements need to be identified).
- The source/s of a requirement needs to be identified in a transparent, traceable manner (especially the underlying assumptions) – e.g. numbering of requirements, level of requirement, and further attributes of each requirement.

Source: adopted from DOPAS D2.4

Requirements Management (RM)

- In the disposal system's requirements management
  - approval,
  - inspection,
  - prioritization and
  - verification of compliance of solutions to requirements

  make a crucial part of the RM system.
- Requirement attributes are used for the purpose as part of the Requirement Management Tools. RM Tools are software databases assisting in managing the complex requirement infrastructure.

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The hierarchy levels in Posiva's V-model (VAHA)

Figure 9-1. General structure of backfill requirements.

- Stakeholder requirements (Level 1) [SHR]
- System requirement (Level 2)
- Subsystem requirement (Level 3) – Backfill (incl. plug)
- Design requirement (Level 4)
- Design specification (Level 5)

Source: POSIVA 2012-03, pp.113-118

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A set of examples contributing to Level 3 performance targets (incomplete set)

- Hydraulic isolation (Level 4)
  - *The plugs shall isolate the deposition tunnels hydraulically during the operational phase of the repository.*
  - *solution?*
- EBS compatibility
  - *The chemical composition of the backfill and plugs shall not jeopardise the performance of [other barriers] the buffer, canister or bedrock.*
  - *solution?*
- Ability of plugs to keep backfill in place
  - *The plugs shall keep the backfill in place during the operational phase.*
  - *solution?*

Source: POSIVA 2012-03, pp.113-118

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RM Tools to manage requirements

Complex information structure

16

Suitable software (RM tool) is necessary (1)

- The work on draft documenting and managing the requirements often starts with e.g. MS Excel, but for keeping track of all requirements and their links and managing changes and their impact, a requirements database is most useful.
- Tool is needed because in the development process, the requirements are becoming more detailed at the lower requirements levels and finally when translated into specifications their relations become more complex and numerous. The requirements also change and the requirements need to be handled, their status updated and traced. (e.g. Hoffmann & al. 2004).
- In a recent project, the Finnish Radiation and Nuclear Safety Authority STUK is developing a RMS to include the current Finnish Nuclear Safety Guides (45 YVL-guides in total):
  - Related Data Volume: approximately **9500 requirements with 19 attributes** including defined value/s for each of these requirements!
  - This volume represents only the regulatory requirements!

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Suitable software (RM tool) is necessary (2)

- Comparisons between databases/tools are available on the web, popular software includes e.g. comprehensive enterprise software like SAP or dedicated software like DOORS (IBM).
- Custom-made Access® or other database based software also exist.
- One link to the current software listing is available at http://www.capterra.com/requirements-management-software/

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Related concepts to systems engineering and RMS

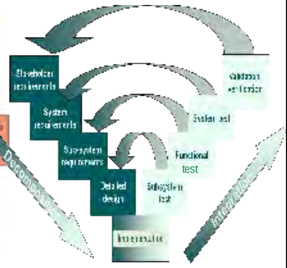
- **Configuration management** (overall architecture of the disposal system for design) a process including verification and validation of selected design bases and designs. Looks at the V-model over the whole project's lifetime.
- **Functional analysis** – also originating from systems engineering (Andra's presentation)
- **Requirements engineering** – related to RM
- **Quality Function Deployment (QFD)** – "House of Quality" for customer driven product development – use of ratings to come up with the optimum solutions in terms of conformance, performance and image. Developed by Japanese Y. Akao since 1960s.

Some V-model application examples

Canister quality assurance

Code verifications

It's all about iteration

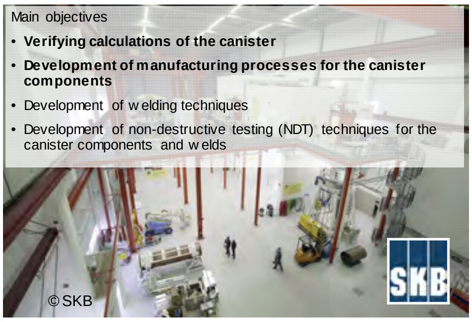


Source: Posiva

© Nagra

Examples from the SKB's Canister laboratory

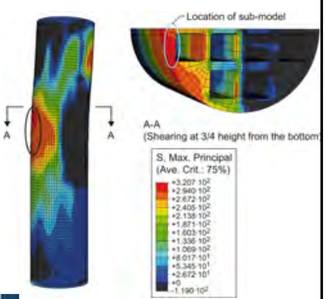
Main objectives
- **Verifying calculations of the canister**
- **Development of manufacturing processes for the canister components**
- Development of welding techniques
- Development of non-destructive testing (NDT) techniques for the canister components and welds



Verifying calculations of the canister

- **Shear load case = highest demands / functional demands/ requirements/**
  - **Global load analyses**
  - **Local load analyses**
  - **Highest strains close to the surface**
  - **Give high demands on acceptable defects**

A means of verifying compliance with the requirements



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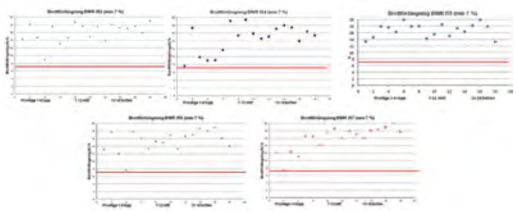
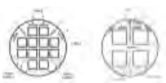
Elongation of insert material – Process quality improvement

- Improve the casting process for minimizing deviations of mechanical properties in insert – improved process control increases confidence in sampling results





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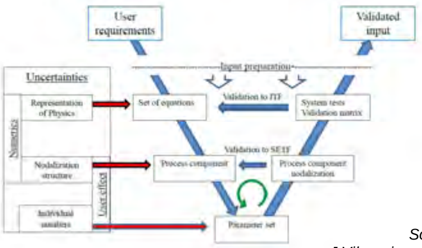
A recent dissertation: VVER-440 Thermal Hydraulics as a Computer Code Validation Challenge

Novel Method for Code Input Validation,
V-model approach



ITF = Integral Test Facility
SETF = Separate Effect Test Facility

Source: J.Vihavainen 2014, Fig.14, p. 51

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List of recommended further reading:

- OECD/NEA. 2004. Engineered Barrier Systems (EBS): Design Requirements and Constraints – Workshop Proceedings, Turku, Finland 26-29 August 2003. available on https://www.oecd-nea.org/rwm/public-documents/ (nea-4548)
- OECD/NEA: 2003. Engineered Barrier Systems (EBS) in the Context of the Entire Safety Case - Workshop Proceedings, Oxford, United Kingdom 25-27 September 2002. available on https://www.oecd-nea.org/rwm/public-documents/ (nea-4308)
- NASA. 1995. Systems Engineering Handbook. SP-610S. e.g. on http://web.stanford.edu/class/cee243/NASASE.pdf or newer version (2007)

Web resource:

Rational DOORS
https://www.youtube.com/watch?v=qYK7_g4Fy44 (12 min demo)
http://www-03.ibm.com/software/products/en/ratidoor

This presentation provides also a short introduction to the V-model.

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DOPAS Training Workshop 2015

DOPAS

D1 1.2.3
Design basis workflow for Plugs and Seals

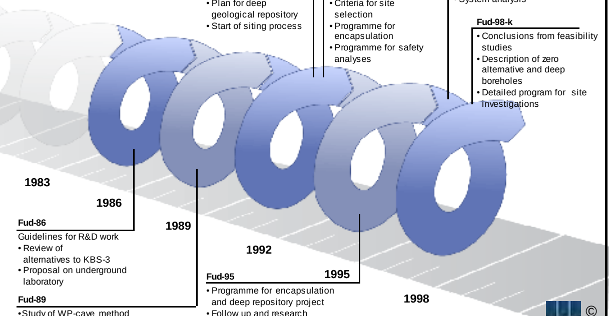
Pär Grahm, SKB
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project. update 2016

Outline of this lecture

- From policy decisions to stakeholder requirements
- Constraints by waste types and host rocks
- Plug system requirements (KBS-3V example)
- Modelling and testing of performance, coming up with the conceptual design
- A Design Basis Workflow (as developed by DOPAS)

Continuous knowledge building



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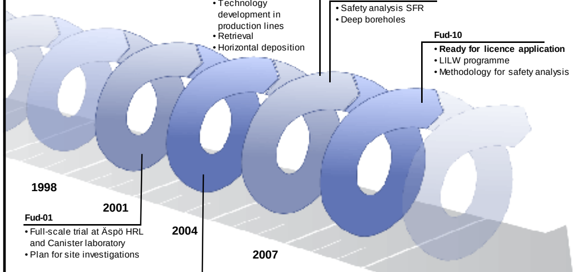
Continuous knowledge building



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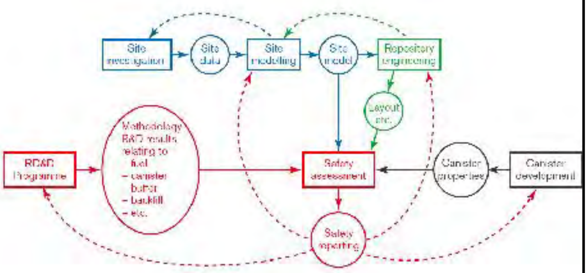
Research, technology and review


Research cooperation

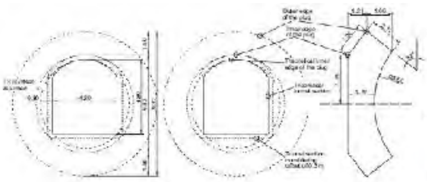

Technology development and full scale tests

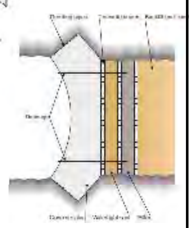
Regularly review

Iterative development of EBS design



The reference conceptual plug design





- Published in SKB TR-10-16
- The reference plug design allows modifications according to SKB R-11-04

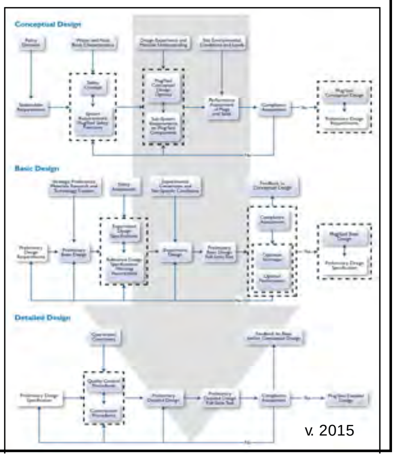
Design requirements for KBS-3V plugs

- The plug strength must be sufficient to withstand the pressure that occurs during the sealing phase (Requirement DRP22)
- The plug must withstand thermal loads caused by the rock and concrete expansion during the sealing phase (Requirement DRP30)
- The plug must be sufficiently tight to prevent erosion of the backfill and buffer materials out of the deposition tunnel (Requirement DRP26)
- The time until the plug is installed and can achieve its functions may not be longer than the time it takes for the pellet-filled part of the deposition tunnel volume to be filled with water (Requirement DRP21)
- The design working life is 100 years, therefore all requirements on the plug during the sealing phase shall be met for 100 years.
- The frequency of malfunction of the plug causing retrieval of installed backfill shall be 10^{-3} or less per installed plug.

Note. The list is not complete!

The DOPAS Design Basis Workflow

- Illustrates the iterative development of the design basis, undertaken in parallel with the development of conceptual, basic and detailed designs.
- Dashed boxes are used to show activities undertaken in parallel.

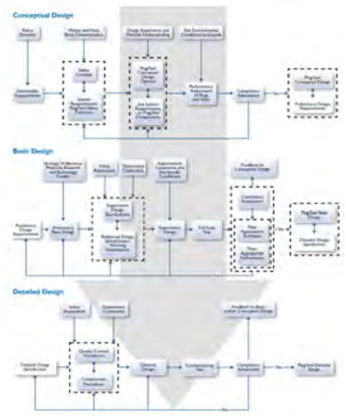


v. 2015

The DOPAS Design Basis Workflow

- Illustrates the iterative development of the design basis, undertaken in parallel with the development of conceptual, basic and detailed designs.
- Dashed boxes are used to show activities undertaken in parallel.

This version of the work flow in 2016. This is the final version in Deliverable D2.4.



Conceptual design

- Conceptual designs describe the general layout of a repository structure, including the different repository components and how they are arranged, and the type of material used for each component (e.g., concrete, bentonite, gravel). In a conceptual design, the environmental conditions (including rock characteristics) are presented in generic terms, for example by describing the nature of the processes occurring rather than quantifying the processes. The performance of the components and the overall structure are described qualitatively.

Basic design

- In a basic design, the components in the conceptual design are described in more detail with an approximate quantitative specification of geometry and material parameters. The properties of the environmental conditions are presented in detail, which requires characterisation of the site or elaboration of the assumptions underpinning the design. Performance is described quantitatively.

Detailed Design

- In a detailed design, the concept is presented in such detail that it can be constructed, i.e. it provides precise information on all aspects of the structure's components.

Experiments in DOPAS

- The full-scale demonstration experiments undertaken in the DOPAS Project have addressed specific objectives, for example; technological feasibility (FSS), performance (DOMPLU), alternative design options (POPLU), and materials research in support of preliminary basic design (EPSP and ELSA).
- Results of full-scale tests provide further support to design decisions, especially optimisation issues.
- Design requirements may be revised based on learning from the experiments.
- The outcome of a satisfactory compliance assessment is selection of a basic design.

DOPAS

Thanks for listening!

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DOPAS TRAINING WORKSHOP 2015

1.3.1 Case Example of EPSP Experiment

Marketa Dvorakova
SURAO
14.9.2015

Outline of the Lecture

- EPSP Project Goals
- Requirements on the EPSP Plug
- Design of the EPSP Experiment
  - Plug design
  - Instrumentation
  - Experiment test planning
- Implementation of the EPSP Experiment
  - Geological conditions – mapping in the niche
  - Tunnel reshaping
  - Improvement of the rock mass
  - Plug construction
  - Data collection and construction of the mathematical models

EPSP Project Goals

- Construction of an experimental plug
- Focus on fundamental understanding of materials and technology
- Experimental niche reshaping
- Improvement of the rock mass in the experimental niche by polyurethane resin
- Instrumentation and performance assessment
- Evaluate the use of fibre reinforced sprayed concrete for the concrete plugs and sprayed bentonite pellets composed of Czech bentonite for the bentonite zone

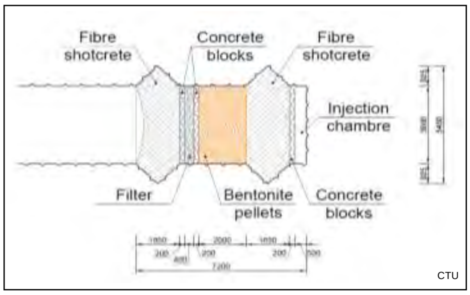
Requirements on the EPSP plug

- The strength of EPSP shall be consistent with withstanding a pressure of 7 MPa to simulate the maximum pressure expected to be developed by the bentonite buffer in the deposition tunnels
- Design working life for the plug components is 150 years
- The bentonite zone shall use Czech bentonite (Bentonite B75) as this is the candidate buffer material in the reference concept
- A concrete recipe with a relatively low pH shall be used
- Fibre shotcrete shall be used for the inner and outer concrete plugs to limit crack formation
- The temperature in the concrete plugs during the cement curing shall be controlled in order to limit shrinkage and crack formation

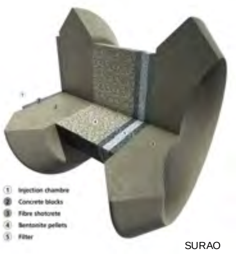
Design of the EPSP experiment

- The technical design of the plug was the responsibility of the Centre of Experimental Geotechnics of the Czech Technical University (CTU), Prague and was based on a structural proposal contained in Reference Design 2011 (SURAO, 2011)
- The EPSP experiment is the first detailed work on plugs and seals
- Experience from KBS-3H study (SKB and Posiva)

Plug design



Plug Design



SURAO

- Pressurisation Chamber

The chamber will serve as primary point for pressurisation media injection

- Inner and Outer plug

Concrete plugs are designed to hold the other components of EPSP in place

- Bentonite Emplacement

The bentonite pellets are going to be emplaced between the inner plug and filter

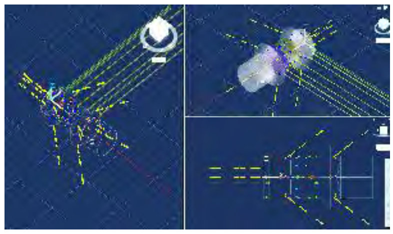
- Filter

The filter will serve as collection point of water, which could leak through the EPSP

7

Instrumentation

- Monitoring of: temperature, contact stress, deformation, pore pressure, moisture, swelling pressure distribution, ...



CTU

8

Experiment Test Planning

- The plug will be tested by means of injecting air/water suspension into a pressurizing chamber, followed by the monitoring of the performance of the plug
- Up to 2 MPa
- Monitoring of key processes (water, stress, temperature)
- Collecting data
- Modeling of the whole plug system
- Analysis

9

Implementation of the EPSP experiment

10

Geological conditions – mapping in the niche

- The EPSP experiment is being conducted at the Josef Regional URC which is located near the town of Dobříš in the Čelina-Mokrsko former gold mining area. The host rock comprises Sázava-type granitoids of the Variscan age (Morávek et al., 1992)

CTU

11

Tunnel Reshaping

The hydraulic wedge splitting was used in combination with non-detonating (GBT) splitting.

Using those technologies, the profile of the niche has been adjusted and recesses for concrete plugs excavated.

Experimental niche after reshaping works

© SURAO

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Improvement of the Rock Mass

- Once the reshaping has been finished the rock improvement started. The rock properties have been improved by means of grouting. The resin has been used to lower the rock permeability in order to allow higher pressures to be applied on the plug and to limit unnecessary leakages into rock mass.
- Grouting of the contact zone between rock and concrete plug

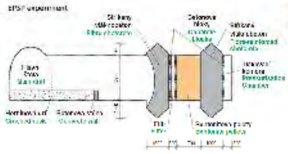
SURAO

Grouting: 5 m around EPSP
Polyurethane resin (WEBAC)
Hydraulic conductivity $< 10^{-8}$ m/s

Plug Construction

CONCRETE
- Glass fibre shotcrete
- Lower pH

CTU



TUNEL MAGAZIN

BENTONITE
- Czech Ca-Mg bentonite
- Dry density around 1.4 Mg/m3
- Hydraulic conductivity $< 10^{-12}$ m/s
- Swelling pressure > 2 MPa

Data Collection and Construction of the Mathematical Models

- The behaviour of the plug will be comprehensively monitored throughout the duration of the experiment.
- The final assessment of the experiment will involve the use of numerical analysis and modelling techniques.
- Finally, it is envisaged that the successful completion of the EPSP experiment will contribute towards demonstrating how sealing plug systems behave under real conditions

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- SÚRAO (2011). Update of the Reference Project of a Deep Geological Repository in a Hypothetical Locality. Accompanying Report. Report EGP 5014-F-120055.
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DOPAS Training Workshop 2015

DOPAS

D1 1.3.2
Scoping the DOMPLU experiment at Äspö HRL

Pär Grahm, SKB
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

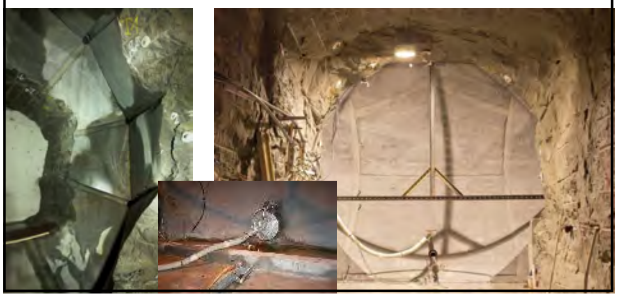
Outline of this lecture

1. Information about the DOMPLU experiment
   - Objectives (partially based on requirements)
   - Experimental layout
   - Photos from installation
   - Example of results and conclusions
2. Scoping a technical development project
   - Useful tool: Work Breakdown Structure (WBS)
   - Group work: Create a WBS for the DOMPLU full scale experiment

Part 1 – Information about DOMPLU

The DOMPLU experiment

- DOMPLU is a full-scale test of the plug system in realistic conditions at Äspö HRL (-450 m) with 4 MPa water pressure in the deposition tunnel.



Acknowledgement

- DOMPLU is conducted as a joint project between SKB and Posiva. Correspondingly, SKB takes part of Posiva's plug project POPLU in ONKALO.
- Both DOMPLU and POPLU are part of the Full-Scale Demonstration Of Plugs And Seals (DOPAS) project.

The research leading to these results has recieved funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013 under grant agreement no 323273, the DOPAS project.
More info can be found at the Dopas website: www.posiva.fi/dopas

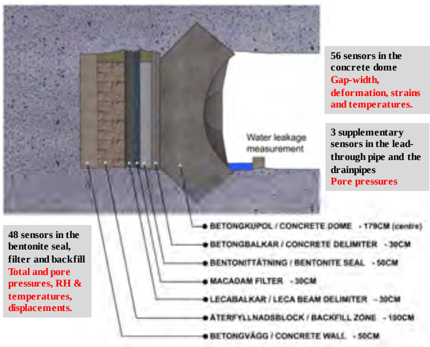
DOMPLU objectives (major)

- Construction of a dome plug system according to design specifications (SKB TR-10-16) in the license application.
- Improve the plug design and verify quality control of installation and commissioning in full-scale.
- Control water tightness of the plug. Recent analyses allow a maximum leakage of <0.1 l/min past the plug. (SKB TR-14-22, in preparation)

Preparations before full-scale

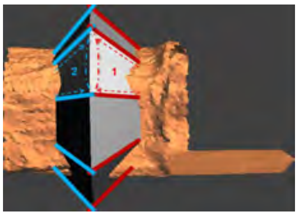
- Laboratory tests of plug component materials:
  - Filter/Drainage (gravel in different fractions, geotextiles, LECA)
  - Bentonite Seal, MX-80 blocks and pellets
  - Low-pH Concrete, recipe B200 (SKB R-09-07)
- Analytical and Numerical calculations for design purposes and full-scale test predictions
  - Hydro-Mechanical modelling of Bentonite Seal – Filter - Backfill
  - Thermal and structural responses of the Concrete Dome
- Downscaled (1:10) tests of the plug system (6 trial cycles)
- Äspö HRL field-tests (slot excavation, contact grouting)
- Pilot borehole core characterisation and water injections

DOMPLU layout



Monitoring of leakage
On-line scale

Slot excavation by wire sawing



- Symmetrical octagon design (16 cuts, ⌀ 8.8 m)
- Safety scaffold structure for workers protection

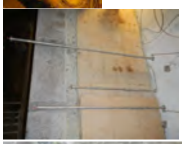
The excavated slot

- Model composed of laser scanning data

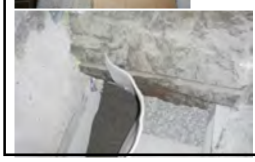
- View of the excavated slot for casing of the concrete dome

Installation 1 (3)

- 3 lead-through pipes for sensor cabling and water inlet pipes



- Backfill blocks/pellets and LECA beams
- Gravel filter, bentonite seal (MX-80 blocks/pellets) and concrete beams

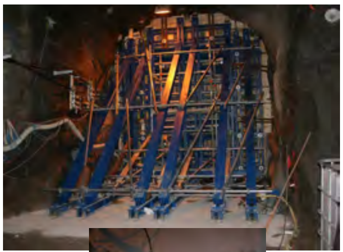


Installation 2 (3)

- Grouting tubes (3 sections)
- Geotextile (2 layers)

- Concrete sensors
- Cooling system

Installation 3 (3)



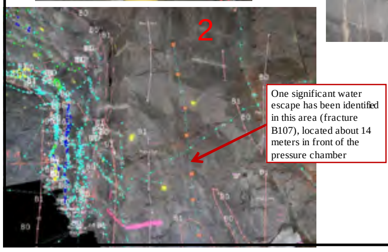
- Formwork (by Doka)
- Casting (94 m^3 B200)
  - § Non-reinforced structure
- Chillers (redundant)

DOMPLU in operation

- Monitoring have been carried out since March 2013.
- Full water pressure 4 MPa was reached in February 2014.
- Data freeze for the DOPAS project: September 30, 2014.

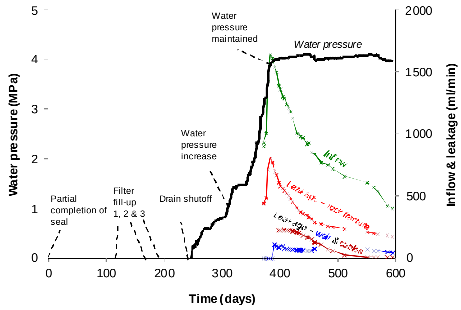
- On-line leakage measurements.
- Plastic sheet reduces effects of tunnel ventilation and evaporation.

Water escapes



1. Cables
2. Rock fracture
3. Plug/Rock interface

Water inflow and leakage trends



September 30, 2014: The measured leakage past the plug (in weir) was 0.04 l/min at 4 MPa water pressure (this was about 11% of the inflow)

Conclusions (in selection)

- In general, plug construction was successful and workers safety aspects were handled in a good way. Learnings: Formwork can be redesigned, installations at tunnel ceiling can be improved.
- Initially, all sensors worked well. A few sensors failed during contact grouting and other sensors have failed due to water pressure increase.
- Sensors data correspond very well to predictive calculations.
- The plug is tighter than the rock!
- The leakage past the plug (collected in the weir) is well below 0.1 l/min and the trend is decreasing. Seal is not yet saturated.

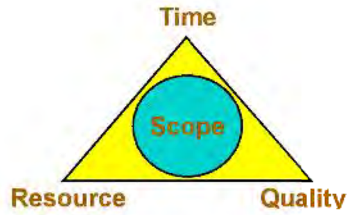
DOMPLU coming work

- Technical reporting. DOPAS deliverable D4.3
- DOMPLU results will lead to a "light update" of the basic design of deposition tunnel plugs in the Spent Fuel Repository.
- Operation and monitoring of DOMPLU will continue at 4 MPa water pressure, at least until late 2016
- DOMPLU will be opened and retrieved in 2017. A final load test (close to the design load of 9 MPa) is a unique opportunity to verify the design of the concrete dome and the numerical models used.

DOMPLU publications

- SKB P-13-37 System design of Dome plug. Creep properties at high stress levels of concrete for deposition tunnel plugs. (published)
- SKB P-13-38 System design of Dome plug. Mechanical properties of rock-concrete interface (published)
- SKB P-14-26 Experience of low-pH concrete mix B200. Material properties from laboratory tests and full-scale castings (in preparation)
- SKB R-14-24 System design of Dome Plug. Experiences from wire sawing of a slot abutment for the KBS-3V deposition tunnel plug (in preparation)
- SKB R-14-25 System design of Dome Plug. Preparatory modelling and tests of the sealing and draining components (in preparation)
- KTH TRITA-BKN147 Instrumentation and Evaluation of the Concrete Dome Plug.
- **SKB TR-14-23 System design and full-scale testing of the Dome Plug for KBS-3V deposition tunnels. Main report** (in preparation)

Part 2 – Scope Management



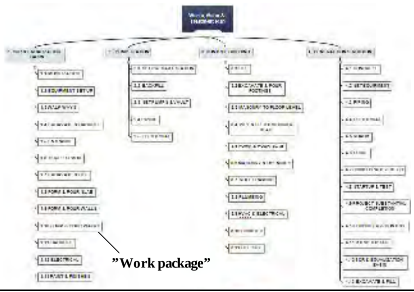
Determining the scope

- **An essential part of the project planning is to define a scope statement.**
- **Correct and proper breakdown of the scope is essential for a successful project (i.e. to fulfil the project objectives and meet the Client's expectation on the deliveries).**
- **Subdivision of major project deliveries should be done in a Work Breakdown Structure (WBS). ***

*
- ISO 21500 Guidance on project management
- ISO 10006 Guideline to Quality in project management
- PMBOK Guide (Project Management Institute)

What is a WBS?

- **A hierarchically-structured grouping of project elements:**



- **Defines total scope**
- **Deliverable–oriented**
- **Schematic**
- **Id-No. on each work package**
- **Can be used for each project phase**

Why use WBS?

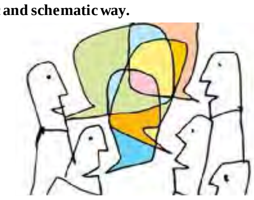
- **Advantages with a Work Breakdown Structure:**
  - § Gives a common understanding of what to do
  - § Improves the accuracy of cost, time, and resource estimations
  - § Gives a baseline for performance measurement and control
  - § Facilitates clear assignment of responsibilities

- **A good WBS makes it easier to keep control of the scope!**
  - § Regular follow-up of WBS work packages
  - § Checkpoint for limitations
  - § Any changes of scope to be approved by the Client.
  - § Use project change forms!

How to create a WBS (some tips)

- **Identification of work packages**
  - § Engage people with various background and competence (include specialists).
  - § Brainstorm on blank paper. For instance, use Post-it notes and pen.
  - § Use experiences and lessons learned from similar projects.
  - § Arrange the work packages in a strategic and schematic way.

- **Verification of scope**
  - ü Summarise and discuss in the project team
  - ü Use a reference group for review and further input
  - ü Formal approval by the Client



Group work - WBS

- Create a WBS for the DOMPLU full scale experiment
- Focus on the project phase <u>Installation</u> (including monitoring)
- Use information in the previous presentation (DOMPLU layout, and photos from installation)
- Ask experts (if necessary ;)

Group work – WBS

- 1.Project Management
- 2. Planning
- 3. Design, modelling and pre-tests
- 4. Purchase & Manufacturing
- 5. Installation & Monitoring
  - 5.1
    - 5.1.1
    - 5.1.2
    - 5.1.3
  - 5.2
  - 5.3
- 6. Reporting
- 7. Closing

Presentation of group work

An example

- 5. Installation & Monitoring
  - 5.1 Rock excavation
    - 5.1.1 Drilling slim holes
    - 5.1.2 Drilling large holes
    - 5.1.3 Wire sawing
    - 5.1.4 Blasting
    - 5.1.5 Cleaning of tunnel
    - 5.1.6 Measuring rock surfaces
  - 5.2 Preparatory civil work
    - 5.2.1 Weirs
    - 5.2.2 Foundations
    - 5.2.3 Back wall
    - 5.2.4 Lead-through pipes
    - 5.2.5 Service
    - 5.2.6 Geodetic survey
    - 5.2.7 Filling of boreholes
  - 5.3 Backfill
    - 5.3.1 Block emplacement
    - 5.3.2 Pellets
    - 5.3.3 Sensors
    - 5.3.4 Water inlet pipes
    - 5.3.5 Lead-through pipes casing
  - 5.4 Filter
    - 5.4.1 LECA delimiter
    - 5.4.2 Gravel
    - 5.4.3 Drainage (and de-air) pipes
    - 5.4.3 Water inlet pipes
    - 5.4.4 Sensors
  - 5.5 Concrete delimiter
    - 5.5.1 Beam emplacement
    - 5.5.2 Mortar
    - 5.5.3 Geotextile 2 pcs
  - 5.6 Bentonite seal
    - 5.6.1 Block emplacement
    - 5.6.2 Pellets
    - 5.6.3 Sensors
  - 5.7 Concrete dome
    - 5.7.1 Cleaning of slot
    - 5.7.2 Injection grout tubes
    - 5.7.3 Cooling system
    - 5.7.4 Sensors
    - 5.7.5 Formwork
    - 5.7.6 Casting
    - 5.7.7 Cooling
  - 5.8 Water systems
    - 5.8.1 Pressurisation
    - 5.8.2 Leakage measurement
    - 5.8.3 Commisioning
    - 5.8.4 Service and control

DOPAS

Thank you for a great team work!

www.posiva.fi/en/dopas

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Conditions for use of this training material

DOPAS Training Workshop 2015
Participants and Tutors

DAY 2

Photo: (c) Marjatta Palmu

DOPAS
Training Workshop 2015

The Josef Underground Facility

Radek Vašíček
Centre of Experimental Geotechnics,
Faculty of Civil Engineering, CTU in Prague
15 September 2015 D2 6.2a

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Content

- The Josef: Brief history and site description
- Education & training
- Research & development projects
- Public welcome

2

The Josef facility

- Operated, managed, financed… by Centre of Experimental Geotechnics (CEG) as integral part of the Faculty of Civil Engineering, CTU in Prague
- Facility is not old but you can hear several names of it…
- *The Josef Underground laboratory, The Josef gallery, The Josef ~~mine~~, URC Josef…*

3

The Josef facility

Underground Educational Facility
since 2007
&
Underground Research Centre
since 2011


4

The Josef facility

http://www.mapy.cz

60km south from Prague

5

The Josef facility: brief history

- Underground exploration works for the mining of gold
- Gold exploitation commenced in the Middle Ages – the peak of production reached in the 14th century
- Interest was renewed in the 1980s
- The excavation of the Josef Gallery commenced in 1981
- Exploration ceased in the mid 1980s

120t Au

Photo by P. Morávek

6

Since 1980's is there:

- Underground:
  - The main drift 1 835m with profile 14 – 16m²
  - Total length of the other drifts 6 018m, profile 9m²
  - Height of the overlying strata 30 – 180m
  - About 20km of core drills
- Adequate surface area with administrative building – newly renovated

The Josef facility: geology – More by Michal Roll 6.2b...

- The locality is characterised by rich veining and a complicated tectonic structure.
- Most of the underground areas are not lined.

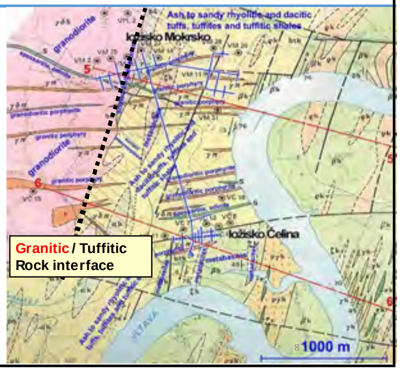


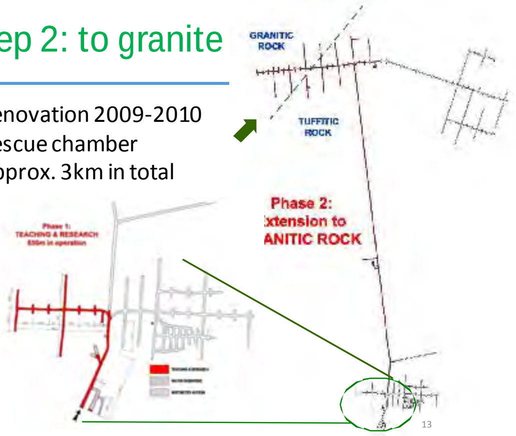
Photo by P. Morávek
Geological map: Morávek et. al., 1991

Step 1: 650m in tuffs

Regular teaching & research works since Sept 2007

Step 2: to granite

- Renovation 2009-2010
- Rescue chamber
- Approx. 3km in total

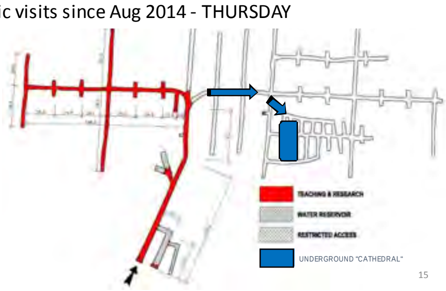


Step 3: Underground Research Centre

- Surface facility
- Research, training and marketing
- After 4 years of preparation
- Opened 2011

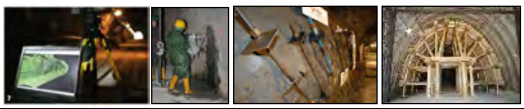
Step 4:
2 floors + large room at Čelina–east

- Renovation of galleries at 2 levels above „zero“ (20 and 40m) and adaptation of large cavern - underground „cathedral“
- Public visits since Aug 2014 - THURSDAY



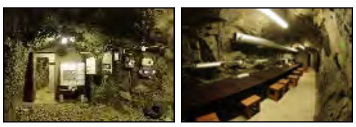
Education & Training: CTU

- Faculty of Civil Engineering
- Starting in 2007 with 3 departments
  - Centre of Experimental Geotechnics
  - Dept. of Geotechnics
  - Dept. of Special Geodesy
- geology, rock mechanics, underground structures, field testing, environmental engineering, mining, geodesy, the „disposal“ aspects
- Practical exercises in 20 courses, 300 students / year



Education & Training: national

- Since 2010 - ’’Inter University Laboratory“
- Related to the construction and operation of:
  - Underground gas storage tanks,
  - spent nuclear fuel disposal in deep repository
  - the potential underground storage of CO_2
- Supported by Ministry of Youth, Education and Sport
- FCE CTU and 4 other Czech universities



Education & Training: national

Inter University Laboratory

- CTU: CEG and Faculty of Nuclear Sciences and Physical Eng.
  geotechnics, radiochemistry
- University of Chemistry and Technology Prague
  analytical chemistry, radioanalytics
- Masaryk University - Faculty of Science
  geochemistry, tectonics, hydrogeology, mining mapping
- Technical University Liberec - Faculty of Mechatronics
  numerical modelling, nanotechnology, transport processes

Education & Training: memberships

- European Nuclear Education Network (ENEN ass.; CTU – FNSPE, FCE)
- 2009: Recognized as IAEA training site - Member of the "Underground Research Facilities Network" (URF)
- 2009: ITC School of underground waste management (n/a)
- 2010: Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP)
- 2011: The Competence Maintenance, Education and Training group – the group of IGD-TP

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Education & Training: projects

2006 – 2008: ENEN II

- Networking of European nuclear education, training and knowledge management (from national to European level)
- Nuclear engineering, radioprotection and radwaste management, geological disposal

2009 – 2012: PETRUS II - „Towards an European training market and professional qualification in Geological Disposal"

- Geological disposal only, sharing of teaching capacities, knowledge and experience, students
- 18 participants (7 Universities, 6 WMOs…)

2013 – 2016: PETRUS III - „Implementing sustainable E&T programmes in the field of Radioactive Wastes Disposal"

- Master Programme implementation, focus on PhD and professional development
- 20 participants (9 Universities, 6 WMOs…)

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Education & Training: practical courses at Josef

- 1 – 3 weeks
- with help of SURAO and other institutions
- geotechnical laboratory, in-situ tests and experiments and more…
- June 2011: 1st course "Fundamentals of Geological Disposal"; by CTU, ITC and IAEA
- September 2013: another IAEA practical course (+ Cardiff Uni)
- September 2011, 2012, 2014: 2-3 weeks practical courses on RADWASTE disposal (CTU + SURAO; FR, ES, CZ, FI)
- Now J

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Research & Development: general

- Following Swedish concept KBS3 of the deep repository
  - granitic rock + bentonite buffer and backfill
  - SÚRAO, other national – MIT/ TACR, MYES, GACR…
  - Intl. - EURATOM, Norwegian funds…
- Several issues on buffer & backfill (and plugs)
  - THMC parameters, material selection, long term stability, technologies…

SKB, Illustrator: Jan Rojmar

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Research & Development: CEG focus

Geotechnical problems related to the repository being solved at Josef by CEG

- Swelling clays behaviour
  - Laboratory investigations and specifics of laboratory methods
  - Technological aspects (sprayed clays)
  - Long term stability
- Gas permeability of rock massive
- Large scale in-situ tests
  (buffer, backfill, plugs…)

Research & Development: cooperation

Other problems in geological disposal and other fields

– in cooperation

- Geochemistry and mineralogical stability of bentonite and interaction with the rock environment
- Tracer tests (fluorescent, radioactive – PAMIRE…)
- Dynamic fracturation of rock
- Underground energy storage and geothermal energy
- SÚRAO, ÚJV Řež a. s., VŠCHT, TUL, ČGS, Charles Uni, IsaTech, Geomedia, Arcadis a. s., Progeo…

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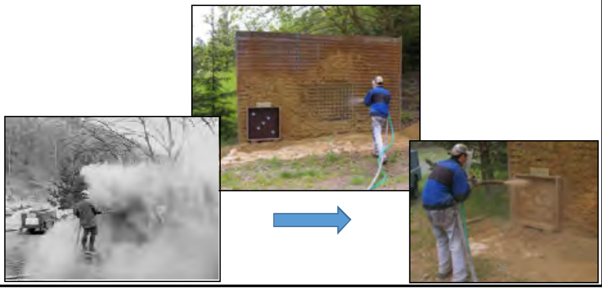
R&D example: TIMODAZ

- ''Thermal Impact on the Damaged Zone Around a Radioactive Waste Disposal in Clay Host Rocks"
- 6.FP EU, 2007-2010
- WP4.3 Lining stability under thermal load

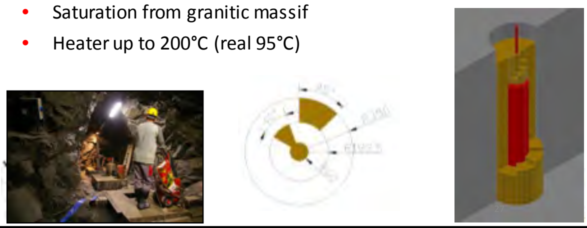
R&D example: Shotclay

- The Development of Sprayed Backfill Technology
- SURAO, 2008 - 2009



R&D example: Mock-Up-Josef

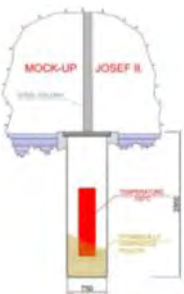
- SURAO, 2011 - 2015
- Real (1:2) model of disposal cell according to SKB – KBS3V
- 0.75m diameter, 2.25m depth in granite (2.8m total)
- Czech Ca-Mg bentonite, Blocks ρ_d=1.65g/cm^3
- Saturation from granitic massif
- Heater up to 200°C (real 95°C)



R&D example: Mock-Up-Josef

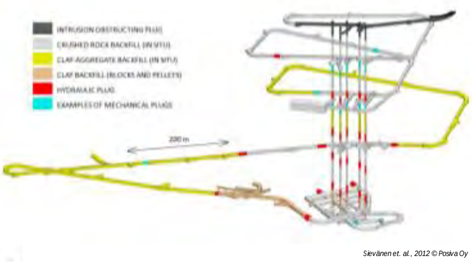
R&D example: Mock-Up-Josef II

- Under preparation 2 similar experiments
- Buffer – compacted pellets
- Bentonit 75 - as in EPSP/ MX80
- Temperature above 100°C (150°C?)
- Artificial saturation allowed



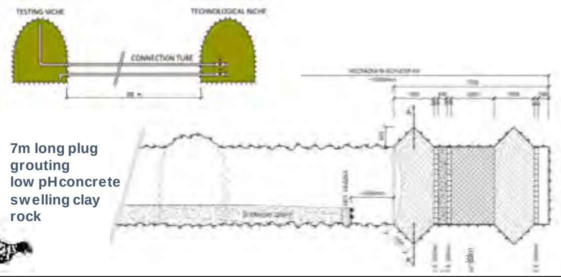
R&D example: DOPAS – this workshop J EPSP - More by Jiri

Repository sealing plugs – FP7



R&D example: DOPAS - EPSP

- **Experimental Pressure and Sealing and Plug**
- CTU together with SÚRAO and ÚJV Řež a. s.



- 7m long plug
- grouting
- low pHconcrete
- swelling clay
- rock

R&D example: DOPAS - EPSP

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Space for… marketing

- Minova/ Orica drilling and bolting tool – all in one

33

Space for … fire experiment - Sept 2008

19.10.2016

34

Space for… testing of vehicles

- Škoda auto a. s. & Faculty of transportation, CTU

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Public welcome

- Regular visiting days, Open days
- Group visits on request (public, high schools)
- SURAO guests (public) from potential DGR localities
- Three circuits for visitors in the underground
- Intl. road bike competition (next 8 May 2016)
- and…

Public welcome

New attraction: Underground „cathedral“ - THURSDAY

- chamber 10*26*40m, 3D on youtube
- Vertical quartz veins, up to 40cm thick
- Viewpoints and balconies at 3 levels (0, +20m, +40m)
- Darkness, music, lightshow and more…

Conclusion

The Josef site is:

- not far from Prague, situated in lovely area,
- A good example of the place where radwaste waste cannot be disposed (gold deposit, shallow, fractured rock, water regime,…)
- With more than 18 finished, 14 ongoing and 6 submitted projects very good „playground“ for universities and research institutions in geological disposal and other fields
- A nice place for education & training (continuing activities of 4 Czech universities, PETRUS, IAEA URF net…)
- Open to public…

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List of references

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- Sievänen, U., Karvonen, T. H., Dixon, D., Hansen, J. & Jalonen T. Closure Production Line 2012 – Design, production and initial state of underground disposal facility closure. POSIVA 2012-19. Posiva Oy, Eurajoki. ISBN 978-951-652-200-8.
- *SKB, Illustrator: Jan Rojmar, available online [10.9.2015]:* http://www.posiva.fi/en/final_disposal/basics_of_the_final_disposal

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Conditions for use of this training material

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DOPAS Training Workshop 2015, 14 – 18 September 2015
The Josef Underground Research Centre
Faculty of Civil Engineering, Czech Technical University in Prague

The Josef gallery - Geology

Michal Roll
D2 6.2b

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Geographic position (1)

Příbram region =

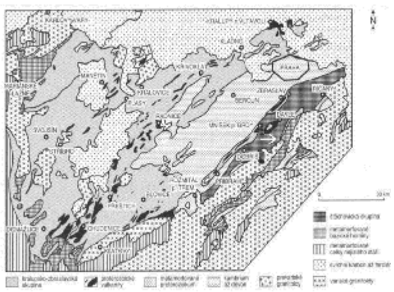
Bassement sediments

vs.

Central Bohemian plutonic complex

http://pruvodce.geol.cechy.sci.muni.cz/regionalni_geol/barrandien.htm
http://www.mcz-krbykamna.cz/cms.php?id_cms=6

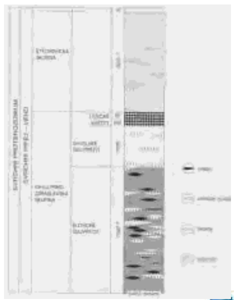
Geographic position (2)



http://pruvodce.geol.cechy.sci.muni.cz/regionalni_geol/barrandien.htm
http://www.mcz-krbykamna.cz/cms.php?id_cms=6

Jílové zone

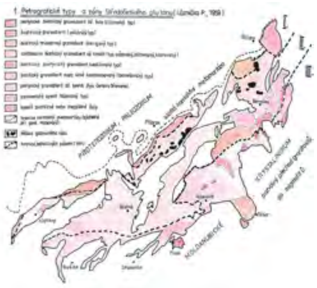
- Kralupsko-Zbraslavská group
- Davle formation
- Jílové zone
- Direction SW-NE, in length ~ 70 km
- Clay schists, siltstones, greywacke
- Andesite, dacite, ryolite and their pyroclastics
- Age ~ 600 million years



http://pruvodce.geol.cechy.sci.muni.cz/regionalni_geol/barrandien.htm

Central Bohemian plutonic complex

- Complicated structure
- X0 – X00 sectional plutons
- Amphibol-biotitic granodiorite even tonalite
- Age 350 – 330 million years



http://departments.fsv.cvut.cz/k135/wwwold/webkurzy/obrazky/str_pluton.gif

Vein-rock types

Albitic granite

Spessartite

http://www.geologie.uni-frankfurt.de/gesteine/Gesteine-Seiten/Bild27.html
http://petrol.sci.muni.cz/poznavanihornin/magmatity/alkalickozivcovygranit.htm

Mineralogy

- Deposits Čelina a Mokrsko
- Au-mineralization and Scheelite mineralization
- Mesothermal type, Q-veins, direction W-E.
- Avarage grade 2 g/t, decreases with depth
- Another ore minerals: pyrite, pyrhotine, molybdenite aurostibite and antimony
- Another gangue minerals: calcite, baryte

http://www.hofmann.estranky.cz/fotoalbum/mineraly/mineral--scheelit/scheelit-medoveho-zbarveni.html

http://www.muzeum-pribram.cz/cz/akce/detail/zlato-u-celiny/37/

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DOPAS Training Workshop 2015

D2 6.2c EPSP Experiment

Jiri Svoboda, CTU in Prague
September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

DOPAS Project

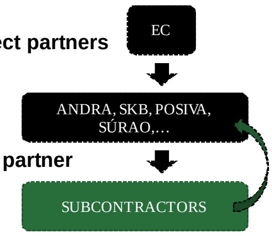
- EURATOM FP7 project
- 2012-2016
- 14 partners
- 8 countries
- 4 big experiments à EPSP

- In CZ: SÚRAO, CTU in Prague, ÚJV Řež, a.s.

2

DOPAS Project

- Originally agencies as project partners
- Others as subcontracting



- At submission time CTU as partner

- Negotiation – EC requests no subcontracting à new partners

3

DOPAS Project

Funding of CZ part:

- CTU in Prague – EC; Ministry of education, youth and sports
- SÚRAO – EC + nuclear account
- ÚJV Řež, a.s. – EC + SÚRAO

- Public money from different sources – lot of rules to follow, public tenders/procurement process

4

DOPAS EPSP

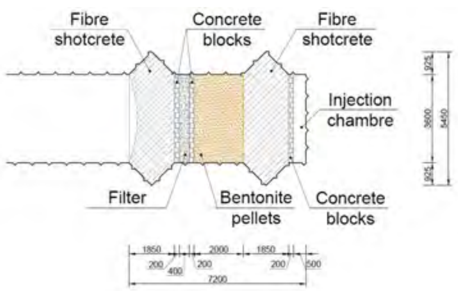
Main roles and responsibilities of partners within EPSP in-situ experiment:

- SÚRAO
  - Geology mapping, mineralogy
  - Rock improvement, boreholes, instrumented rock bolts
- CTU
  - Design of EPSP
  - Construction works & technology
  - Monitoring
  - Run of the experiment

Note: Laboratory and other works are not included in this list. Only in-situ works listed.

5

EPSP



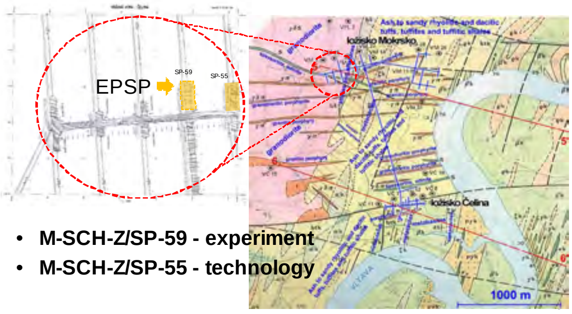
6

EPSP works

- Preparation of niche
- Construction – phase 1 (subcontracting)
  - Rock reshaping & improvement
  - Instrumented rock bolts
  - *Plug contact grouting*
- Construction – phase 2 (subcontracting)
  - Construction works (shotcrete, support structures, filter,…)
  - Technology
- Bentonite sealing
- Monitoring

7

EPSP



- M-SCH-Z/SP-59 - experiment
- M-SCH-Z/SP-55 - technology

Preparation of niches (CTU)

- Clean up of the floor (lot of material removed)
- General clean-up
- Electricity
- Water
- Network
- Concrete floor for technology (2014)
- *Expected/delivered: beginning 2013*

9

Public procurement kicks in…

…lowest price is not always the best thing

10

Construction works – phase 1 (SÚRAO)

- SÚRAO
  - Part of state
  - Internal rules
  - Public procurement law
- Mapping of geology
- Rock improvement & reshaping – public tender
  - Tender expected I.Q 2013 à II./III.Q 2013
  - Works expected to finish April 2014 (according to agreement with contractor) à September 2014

à all spare time consumed…

11

Construction works – phase 2 (CTU)

- CTU
  - Public university
  - Internal rules
  - Public procurement law – public money
- Building works & technology
  - *Works could start only once phase 1 is finished*
  - Works expected to start at the end of 2013 à October 2014
  - First public tender (I.Q 2014) had to be cancelled and a new one had to be performed

12

Bentonite sealing

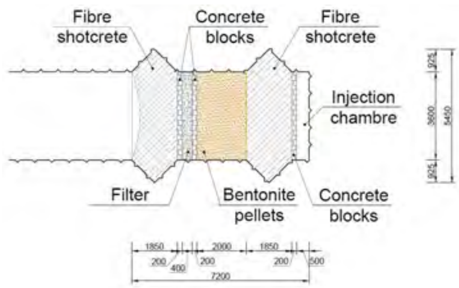
- Originally planned as part of Phase 2 subcontracting
- Work was performed by CTU
  - Tighter control on quality
  - CTU has already developed technology for that
  - More cost effective
  - Reduces complexity of tender process
  - European Commission (EC) prefers the works to be done by project partners

Monitoring

- Originally planned as part of Phase 2 subcontracting
- Work was performed by CTU
  - Tighter control on quality
  - More cost effective
  - Saves a lot of time – monitoring has been partially prepared ahead (while Phase 1 has been running)
  - Reduces complexity of tender process
  - EC prefers the work to be done by partners

Back to technical…

EPSP



EPSP components

- Pressurisation chamber
- Inner shotcrete plug
- Bentonite sealing
- Filter
- Outer shotcrete plug
- Separation walls

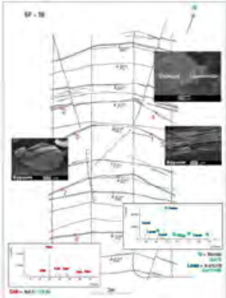
- Technology
- Monitoring

EPSP works

- Preparation of niche
- Construction – phase 1 (subcontracting)
  - Rock reshaping & improvement
  - Instrumented rock bolts
  - *Plug contact grouting*
- Construction – phase 2 (subcontracting)
  - Construction works (shotcrete, support structures, filter,…)
  - Technology
- Bentonite sealing
- Monitoring

Geology

- Detail mapping of selected niche



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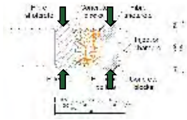
Niche reshaping

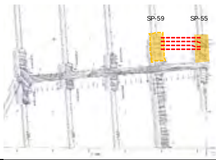
- No blasting used
- Hydraulic wedge splitting
- Gas expansion - GBT Non-Detonating Safety Power Cartridge



20

Connecting boreholes

- Connecting boreholes
  - Instrumentation – 5 boreholes
  - Pressurisation & extraction
    - § 4 – injection chamber
    - § 4 – filter



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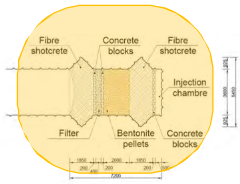
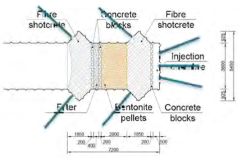
Grouting

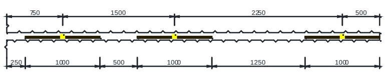
- Improvement of rock mass
- Polyurethane resin (WEBAC)
- 5m envelope around experiment



Rock bolts installation

- Rock response monitoring
- GeoKon Rebar
- Boreholes origin
  - Front face – 4
  - First plug – 4
  - Second plug – 4
- 3 sensors in each borehole
- “Hard” resin used to glue bars in





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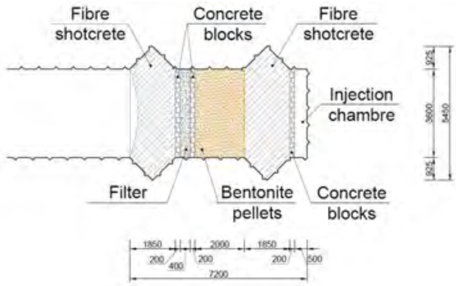
EPSP



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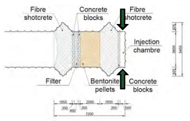
Pressurisation chamber adjustment

- Installation of pressurisation tubes
- Reduction of chamber volume
- Waterproofing
- Installation of sensors
- Erection of separation wall
- Ultimate test of technology and logistics for the plug construction
  - Size constraints on equipment
  - Long distance for concrete transport in the underground
  - Limited power supply



Pressurisation chamber

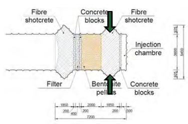
Pressurisation chamber

Pressurisation chamber

Separation wall

Inner glass fibre shotcrete plug

- Erected in nonstop run in 23h (November 12th/13th 2014)
- 38m^3 of concrete used



- Shotcrete (wet mix)
- Low pH
- Glass fibers

- Concrete produced in Prague (1 – 1½h transport time)
- At portals concrete transferred into small trucks (two small trucks alternating – 2km drive one way, 40 minutes turnaround)

Shotcrete

- Cement CEM II / B – M (S-LL) 42,5 N
- Microsilica SIKA FUME
- Sand&gravel 0-4 & 4-8 Dobřín
- Plasticiser SIKA 1035CZ
- Retardant SIKA VZ1
- Accelerator SIKA Sigunit L93 AF
- Glass fibres – crack HP (Sklocement Beneš)

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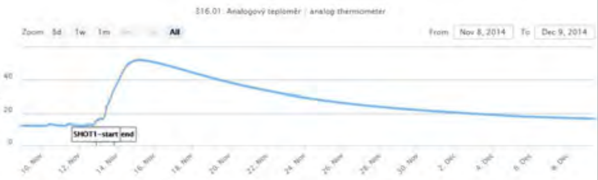
Shotcrete

- Workability: 12h
- Low dust evolution
- Maximum temperature inside plug < 55 degr. C



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33

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Plug test

- December 3rd 2014
- Water pumped into pressurisation chamber
- Excessive leakage on the contact between the plug and rock

à Contact grouting

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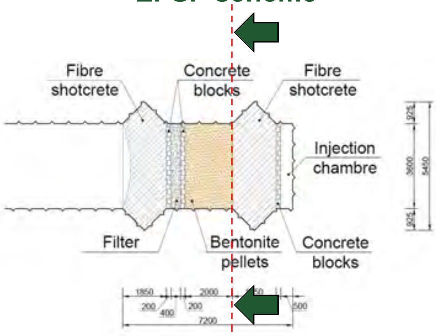
EPSP scheme



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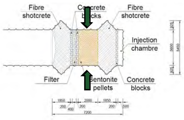
Bentonite sealing

- Main sealing element
- Pellets (Czech Ca-Mg bentonite)
- Emplacement:
  - Dynamically compacted (vibration desk)
  - Shot clay technology
- Target overall dry density over 1400kg/m3



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Pellets

- Bentonite B 75 in powder form….
- Two technological compaction processes were selected from the range of commercial technologies available:
- The roller compaction through the disk die.
- The compaction by the roll press.

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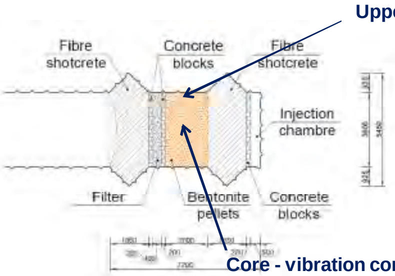
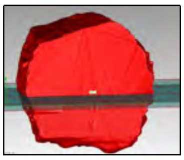
Bentonite emplacement

- Total volume of sealing section 23.7m^3

Upper vault – shotclay (5%)





Core - vibration compacted (95%)

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Bentonite emplacement

- Emplacement started on June 5th 2015

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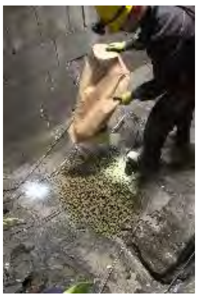
Bentonite emplacement



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Bentonite emplacement

- "Fresh" pellets
- Vibration compacted

42

Bentonite emplacement

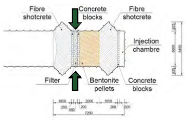
- Upper parts

Bentonite emplacement

- Emplacement done in 9 days between June 5th and 15th 2015
- Total amount of material used 39.9 tons
- Volume of sealing section 23.7m³
- Average density 1684kg/m³
- Average dry density 1427kg/m³

Filter

- Collection of water
- Possible alternative place for pressurisation

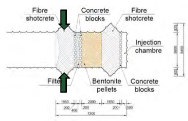


- Drain at bottom
- Connected to the SP-55 via cased boreholes

- Erected step by step to support bentonite emplacement

Outer plug

- “Copy” of inner plug



- Structural element
- Same dimensions as inner plug
- Same material as inner plug

- Erected June 19th/20th 2015

Outer plug

Outer plug

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DOPAS

www.posiva.fi/en/dopas

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

DOPAS Training Workshop 2015

Learning Unit 2 : Preparation of an in-situ or full-scale plug or sealing experiment

How to come up with a coherent demonstrator program for plugs and seals

Theoretical basis to Andra's iterative safety assessment process and the latest safety assessment round including the role of FSS and REM experiments in DOPAS project

Jacques WENDLING (Andra/DRD/EAP)
D2 2.1 15 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Summary

General history of deep underground repository in France
- The 1997-2005 period : feasibility phase
- The 2006-2015 period : the Cigéo Project

General procedure for safety assessment analysis
- The FA (Functional Analysis)
- The PARS (Phenomenological analysis of Repository Situations)
- The QSA (Qualitative Safety Analysis)

The actual loop
- Major milestones in terms of safety loops
- Actual general planning
- Main planned experiences

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General history of deep underground repository in France

- The 1991-2005 period (the feasibility phase)
- The 2006-2012 period, the Cigéo project today

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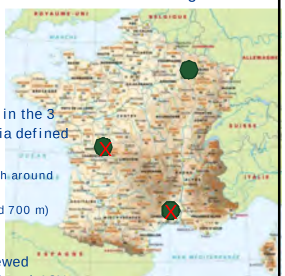
The 1991-2005 period: siting

1992-1994: Site screening for U/G research laboratories
- Consultation mission led by Member of Parliament Christian Bataille
- Site selection on the basis of voluntary sites
  - 2 types of rocks, 3 areas preselected :
    - Granite: Vienne
    - Clay: Gard, Meuse/Haute-Marne

1994-1996: Above/ground geological survey in the 3 preselected areas, with regard to safety criteria defined by ASN (in basic safety rule 1991)
- 150 m thick clay layer in Meuse/Haute-Marne, depth around 500 m
- Thick high strength clay layer in Gard (depth around 700 m)
- Granite under sedimentary cover in Vienne



- 1996: Licence application for 3 URLs, reviewed 1997-1998 by CNE (National review board) and ASN
- 1998: URL licenced in Meuse/Haute-Marne

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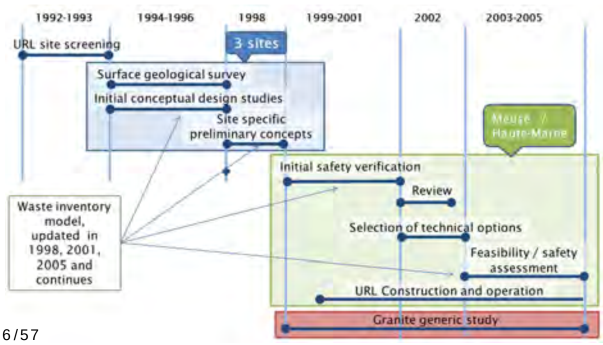
The 1991-2005 period: From generic to site specific concepts



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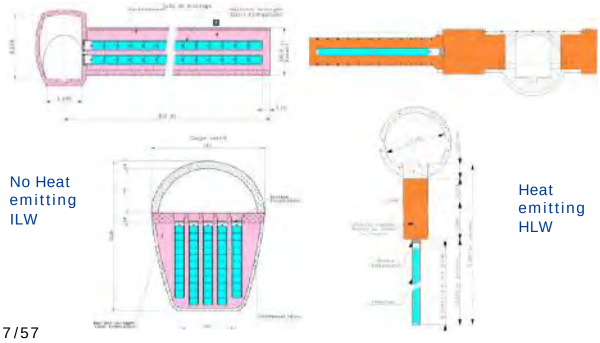
The 1991-2005 period: Andra's preliminary concepts in 1998-2001



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The 1991-2005 period: organisation

Basically two sub phases:

- Up to 2001, this is a very Research intensive phase, and the functional approach is shared between the project team and the safety department to guide the concept related work and structure the safety analysis.
- Between 2001 and 2005, in view of the 2005 milestone, there is a strong need to structure the overall approach:
  - The FA is developed by the project team for use both:
    - *By the safety department to work on the safety analysis (see the level 2 Dossier 2005 document "safety evaluation")*
    - *By the design team to describe very clearly the functions allocated to each of the main components (see the level 2 Dossier 2005 document "architecture and management of the geological disposal").*
  - The PARS is developed by the Research department (see the level 2 Dossier 2005 document "phenomenological evolution of the geological disposal"). The results are used for safety evaluations (quantitative).
  - The QSA combines both above approaches to define safety scenarios.

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General history of deep underground repository in France

- The 1991-2005 period (the feasibility phase)
- The 2006-2012 period, the Cigéo project today

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The 2006-2015 period: French HLW-ILW management scheme

2006 Act

UOX fuel reprocessing, Pu+U recycling (MOX, URe)

- Heat decrease storage of final HLW
  - Disposal of HLW
    - § from 2025 for older HLW
    - § after 60-90 y. for currently produced HLW
  - Vitrified fission products and minor actinides
  - Experimental/special spent fuel
- Interim storage of final ILW
  - Disposal of ILW from 2025, with a view to making the best use of storage capacities
  - Fuel tubes, nozzels...
  - Maintenance/dismantling waste
  - Waste from liquid effluent treatment
- Interim storage of reusable matter (MOX SF)
  - Reuse in GenIV reactors? Processing of minor actinides?
    - Prospective studies of GenIV waste disposal
  - Heat decrease storage + disposal?
    - As a precaution, direct disposal of spent fuel has been explored.

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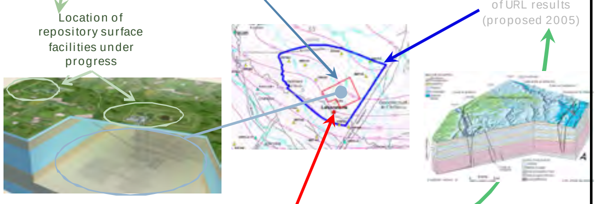
The 2006-2015 period: Stepwise siting combining geology/industrial/local integration criteria on a concertation basis



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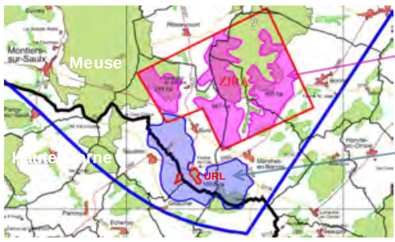
The 2006-2015 period: Stepwise siting combining geology/industrial/local integration criteria on a concertation basis

ØAndra has set up a new dialogue phase to implement the surface facilities:

- ü Meuse and Haute-Marne wish a sustainable partnership for hosting Cigéo.
- ü The selected site will be validated for the DAC (2017)



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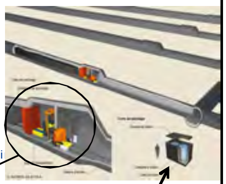
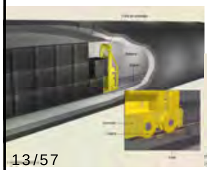
The 2006-2015 period: ILW disposal cells

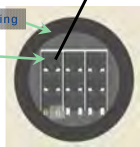
ILW disposal cells are 500 m long horizontal tunnels located at the median of the host clay layer:

- Thick concrete lining to limit long term deformations;
- Ventilation of ILW repository cells as long as they are not closed.

Emplacement/retrieval processes and equipments are beei developed and prototyped:



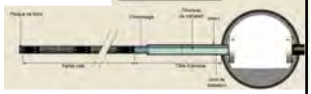




The 2006-2015 period: HLW disposal cells

HLW will be disposed of in lined horizontal micro-tunnels (80-100 m long : 0,8 m in diameter):

- Heat conduction in clay
  - Ømax. temp in clay rock: 90 °C
- Steel liner
- Cell length to be optimized with regard to technological limits and cost
- Emplacement/retrieval equipments tested in worst conditions.



The 2006-2015 period: Organisation (I)

2006-2010: towards the optimization of the repository concepts

- 2006-2007: Feedback from 2006 reviews
- 2007-2009: New iteration between design/knowledge/safety
- 2009: Safety/reversibility options, reviewed in 2010

The previous methodologies (Functional Analysis, PARS, QSA,...) are maintained:

- For working on these different documents, the 2009 dossier in particular (this document is used to support the more detailed siting of Cigeo)
- For continuing the concept development work (iteration between design/knowledge/safety),

The responsibilities remain (compared to the previous period)

The 2006-2012 period: Organisation (II)

2010-2012 : The Cigéo Project has entered its industrial design phase:

- 2011: Completion of project requirements (next slide), waste inventory and delivery planning;
- 2012: Signature of the Cigéo system prime-contracting agreement between Andra and the "Gaiya group" (Technip, Ingérop)
- 2013: Signature of subsystem contracting agreements (conventional surface facilities, nuclear surface facilities, nuclear processes, underground facility).

This implies significant changes to the organisation and the project requirements document is used for the industrial development

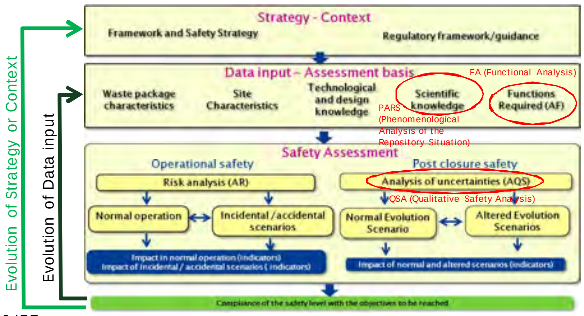
Period 2006-2015: Cigéo Project requirements

In 2011, the results of 20 years of R&D have made it possible to issue detailed project technical requirements.

- Postclosure Safety
  - Protect humans and the environment from radioactivity and toxicity of waste
  - Oppose groundwater flow
  - Limit the release of radionuclides and immobilize them whithin repository
  - Delay and mitigate the migration of radionuclides
  - Preservation of the favorable properties of host clay
- Nuclear safety and security in operation
  - Contain radioactive substances, protect people against exposure to ionizing radiation, control of nuclear criticality, remove the thermal power, vent gases
  - Failures and internal and external hazards risk management
- Waste emplacement and retrievability
  - Receive, prepare and emplace waste packages
  - Close the repository
  - Allow retrieval of the waste packages
- Control, monitor, observation
- Sustainable development, corporate and social responsibility
- Project governance

The safety approach procedure

Safety approach : a global approach with key steps



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Safety approach : FA (Functional Analysis)

Functional analysis is a method for describing a system or a product.

This method was seen as being the basis for developing « well adapted » products (initially in a military environment), based on the belief that the well adapted product must be user needs "driven" and that functions were probably the best way of describing the needs.

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Safety approach : FA (Functional Analysis)

The basic approach is the identification of the expected functions of the object in view of developing a satisfactory answer to the user needs:

- *Needs* : a product is developed to satisfy needs
- *User* : person or organisation for which the product or system is conceived and who uses at least one of its functions at one point in time
- *Function* : Intended effect of a system, sub system, product
- *Product* : a solution to needs through the satisfaction of the functions

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Safety approach : FA (Functional Analysis)

The starting point is, once the scope has been well defined, the function identification

This initial identification can be based on:
- User needs analysis
- Previous systems
- Brainstorming
- Environmental analysis
- ...

The top level, or main functions, must then be broken down based on the why?/how? Rule

The result:
- First level functions
- Functional tree
- Criteria
- Performance levels
- Flexibility

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Safety approach : FA (Functional Analysis)

This approach has advantages:
- A simple methodology
- The description of needs is more durable than the description of the technical solutions
- Useful for correct management of costs

Functional analysis can be applied to different objects:
- Systems, such as space systems
- Products, such as standard industrial products
- Software packages
- Organisations

Results:
- A Coherent system, a valid product for a given market or use, a coherent and bug free software package, ...
- The best solution:
  - From a performance/cost point of view (product)
  - With respect to competition (product)
  - For system integration (system)
  - For the organisation (Enterprise Resource Planning)

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Safety approach : FA (Functional Analysis)

A few rules

In such a functional expression of needs there is no reference at first to the technical solution.

This allows the user of the method to focus on needs before going into the technical details.

It therefore stimulates the user of the method to optimize the product and find the best proposal in view of the needs.

The amount of detail of the analysis is to be set according to the time left before the system is required:
- Feasibility study : overall needs analysis
- Conception phase : sub system analysis
- Detailed design : component analysis

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Safety approach : FA (Functional Analysis)

How to apply to waste management

The functional approach is well suited to:

- The long time frames of radionuclides repository projects, since the initial functional break down is a lasting description
- The few relevant past systems from which to benefit and the need to break new grounds
- The need to demonstrate to stake holders, safety authorities, … that the solution we put forward is fully justified by allowing to trace from high level functionalities to detailed requirements, at the component level (a traceable link between the product (or system) and the solution)

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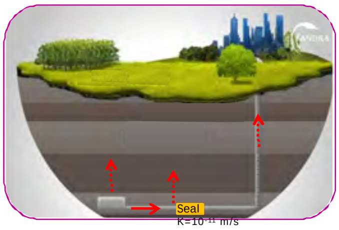
Safety approach : FA (Functional Analysis)

Seal example



Initial need/question: How to limit the migration toward the surface ?

- Not possible via the host rock, chosen for its low permeability
- Possible in the highly permeable gallery network

➡ Put a component in the gallery network to try to come back to the natural (host rock) properties: “low permeability seals”
Performance needed by the seals ? Trial and error hydraulic numerical simulations to find a suitable value : let's say 10^{-11} m/s

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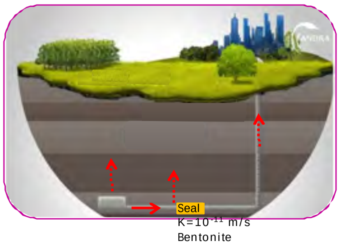
Safety approach : FA (Functional Analysis)

Seal example



Sub question: How to achieve such a low permeability ?

- Very low permeability of the seal itself
- Recompression of the EDZ around it to reduce its permeability

➡ Use of a swelling clay (bentonite)

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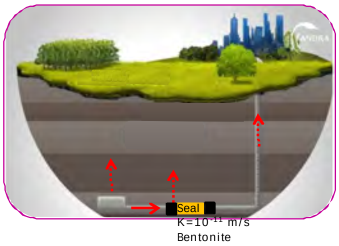
Safety approach : FA (Functional Analysis)

Seal example



Sub question: How to maintain the swelling pressure of the clay ?

- Swelling clays are developing a swelling pressure if their volume is constrained during resaturation

➡ Use of concrete walls to maintain the volume of the bentonite core

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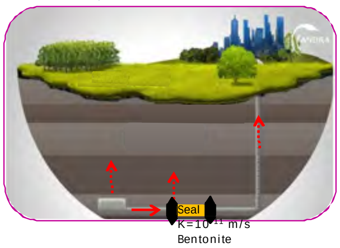
Safety approach : FA (Functional Analysis)

Seal example



Sub question: How to maintain the concrete wall during the swelling of the clay?

- The concrete walls must be calibrated so has to be able to support the mechanical contraints due to the swelling of the clay core

➡ Anchor the concrete walls into the host rock

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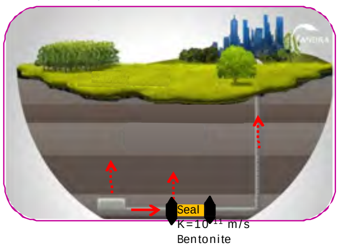
Safety approach : FA (Functional Analysis)

Seal example



Initial need/question: How to limit the migration toward the surface ?

- The bentonite core is the main component to the function
- The recompacted EDZ is a contributor to the function
- The concrete walls have no direct contribution to the function but are a necessary support.

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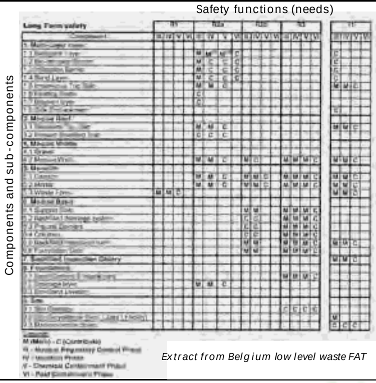
Safety approach : FA (Functional Analysis)

The final result is a table component-functions

FAT : Function Allocation Table



Extract from Belgium low level waste FAT

Safety approach : FA (Functional Analysis)

Some references

BS EN 1325:2014, Value Management. Vocabulary. Terms and definitions

- Value analysis, Functional analysis, Vocabulary, Management, Management techniques, Enterprises, Organizations, Personnel, Performance, Terminology, Definitions

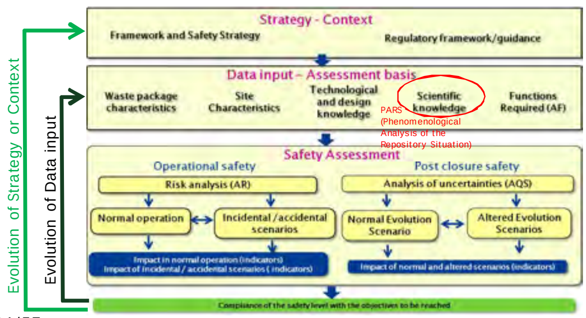
Some systems orientated project management standards (XPX 50-400 series)

Functional analysis is quoted in IAEA (and NEA) documents

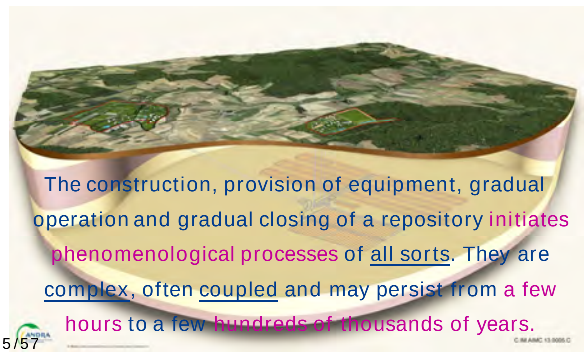
- Safety Assessment Methodologies for Near Surface Disposal Facilities (ISAM methodology)

PARS (Phenomenological Analysis of the Repository Situations)

Safety approach : PARS (Phenomenological Analysis of Repository Situations)



Safety approach : PARS (Phenomenological Analysis of Repository Situations)



The construction, provision of equipment, gradual operation and gradual closing of a repository initiates phenomenological processes of all sorts. They are complex, often coupled and may persist from a few hours to a few hundreds of thousands of years.

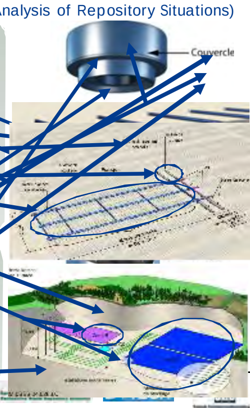
Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Multiple components

- Primary matrix (waste)
- Primary container
- Disposal package
- Cells and cell equipment
- Connecting drifts and their structural components, shafts, etc.
- Modules and seals
- Zone
- Geological medium

Multiple materials

- Glass (e.g.: waste)
- Metal
- Concrete
- Ceramic (e.g.: skids)
- Structure clay (bentonite)
- Clay from the site



Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Multi-physical

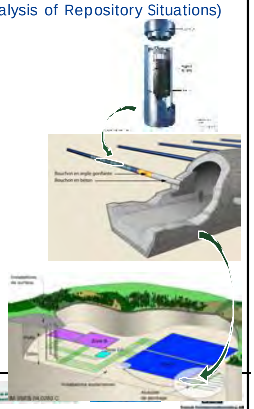
Thermal (T), Hydraulic-Gas (H), Mechanical (M), Chemical (C), Radiological (R)
Solute transfer in porous media (Tr).

à Multiple physical processes interacting unilaterally/bilaterally
à With high and low coupling levels
à Either concomitantly or sequentially

Multiple spatial scales

- centimetres to metres: waste
- metres to decametres: cell
- hectometres to kilometres: repository
- several kilometres: geological medium

à Management of > 7 orders of magnitude in space



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Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Management of :
à 6 orders of magnitude in time
à 7 orders of magnitude in space

Need to structure the knowledge/uncertainties to
à isolate/frame phenomenological situations
à to organize the knowledge restitution (source, verification, hypothesis and simplifications... traceability)
à to prepare the data bases for numerical simulations

"Phenomenological Analyse of Repository Situations (PARS)"

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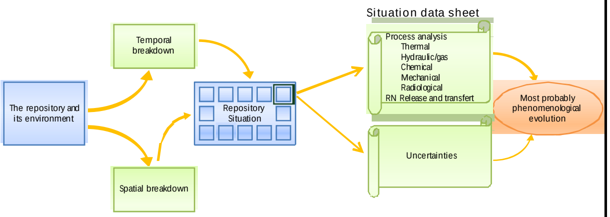
Safety approach : PARS (Phenomenological Analysis of Repository Situations)

The complexity of the system requires that it be broken down into subsystems

è *Spatial/temporal segmentation of the evolution of the repository into "situations"*



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Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Spatial/temporal segmentation è ± 80 situations

		Operation (Years 0 – 50 – 100)	Post-closure (Years 1000 – 5000 – 10000 – 50000 – 100000 – 1000000)
Surface installation		1	54
Underground structures	Shaft	4, 6, 5	65, 61, 66
	Connection and service drifts	3, 7, 8	62, 59
	B CE/DT waste repository zone	10, 42, 47, 48, 43, 44, 45, 46	66, 76, 64, 70, 79
	B BB waste repository zone	49, 50, 51, 52, 53	
	Vitrified waste repository zone	11, 18, 25, 24, 19, 20, 21, 22, 23	67, 75, 57, 68, 80
	UOX spent fuel repository zone	12, 26, 32, 33, 27, 28, 29, 30, 31	68, 77, 71, 72, 82
	MOX spent fuel repository zone	13, 34, 41, 40, 35, 36, 37, 38, 39	69, 78, 73, 74, 83
Geological medium farfield	Callovo-Oxfordian clay	14	14, 81
	Dogger carbonate	9	9, 63
	Oxfordian limestone	15	15
	Kimmeridgian marls	16	16, 60
	Tithonian: Barrois limestone	17	17
Surface environment		2	55

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Safety approach : PARS (Phenomenological Analysis of Repository Situations)

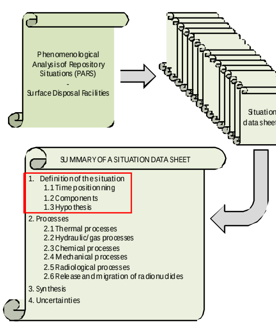
Situation data sheets structured in four parts :

q Chapter 1 : Definition of the situation

This chapter deal with the presentation of the current situation. It includes:

- *Time positioning :*
  - à *Beginning/ending time of the situation*
  - à *Positioning of the situation within the situation matrix*
- *Components*
  - à *Presentation of the "components tree" highlighting natural and engineering components which are concerned*
  - à *Description of components (from engineering studies) : materials, dimensioning, functions...*
- *hypothesis*
  - à *Trace back assumptions at the current state of art (design hypothesis, neglected couplings,...)*

Size : ~ 2 or 3 pages (including figures)



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Safety approach : PARS (Phenomenological Analysis of Repository Situations)

Situation data sheets structured in four parts :

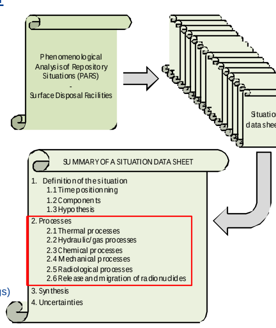
q Chapter 2 : Description of processes

This chapter deal with the description of THMCR processes (including couplings) which affect components over the space/time.

- Description of processes (nature, level of couplings, sequencing,...)
- Quantification of processes (order of magnitude, characteristic timescales,
  - à Beginning/ending time of the situation
  - à Positioning of the situation within the situation matrix

Factually, without value judgment or safety consideration

Size : unlimited. Depends on :
- the number of processes involved and the necessity of describing/quantifying them (includ. couplings)
- the current level of knowledge



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Safety approach : PARS (Phenomenological Analysis of Repository Situations)

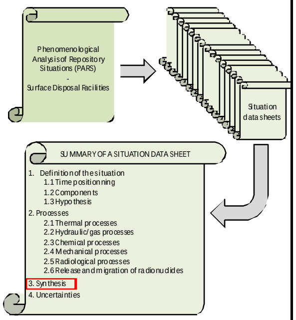
Situation data sheets structured in four parts :

q Chapter 3 : Synthesis

This chapter deal with the synthesis of the phenomenological state specifying:

- *Major phenomena (order of magnitude, characteristic timescale)*
- *And/or phenomena which drive the evolution of the disposal.*

Size : ~ 1 page



Safety approach : PARS (Phenomenological Analysis of Repository Situations)

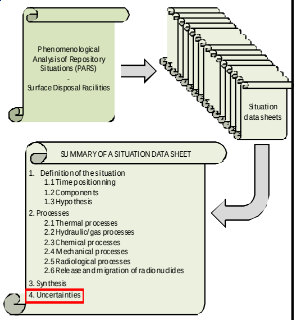
Situation data sheets structured in four parts :

q Chapter 4 : Uncertainties

This chapter deal with the identification of uncertainties of all sort:

- *Characterization / lack of knowledge*
- *Qualitative uncertainties (processes, coupling effects,...)*
- *Quantitative uncertainties (uncertainties on parameters, natural variability, approximations/simplifications,...)*
- *Identification of bifurcation: Could the story of the phenomenological evolution be different? Is there an alternative evolution possible ?*

Size : unlimited : depends on the level of knowledge and the current state of art.



Safety approach : PARS (Phenomenological Analysis of Repository Situations)

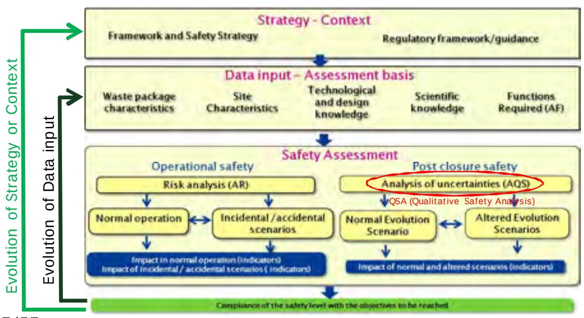
Writing requirements

To make a description base on factual and clearly referenced scientific arguments (with regard to the current knowledge):

- Identifying the source of information (simulation, experiment, analogues, expert opinion,...)
- Showing references in a systematic way (traceability)
- Crossing as much as possible different sources of information to make the description robust and consistent
- Adopting a rigorous style, factually, without making any safety or value judgment
- Stepping back towards the origin of information by focusing on their representativeness (samples, full scale experiments / modelling,...)

QSA : Qualitative Safety Analysis

Safety approach : QSA (Qualitative Safety Analysis)



Safety approach : QSA (Qualitative Safety Analysis)

Managing uncertainties and events

To explore possible dysfunctions

- Inventory of all uncertainties
  - *Scientific and technological knowledge*
- Examine if uncertainties can:
  - *Affect the ability of a component to fulfil a safety function and its associated performance(s),*
  - *Have an influence on the ability of another component to fulfil a safety function and its associated performance(s),*
  - *Modify the environment of the component in such a way that it can influence the manner in which the component fulfils its functions.*

Proposes Management of Uncertainties

- By design measures:
  - *Specific or generic measures*
- By the definition of calculation cases in scenarios:
  - *Through conservative choices or sensitivity analysis in the normal evolution scenario (NES)*
  - *Through the definition of calculations cases in an altered evolution scenario (AES), including sensitivity analyses*

Safety approach : QSA (Qualitative Safety Analysis)

- Base of the methodology
  - Integrated and structured approach for the treatment of uncertainties
    - their impact on safety functions and
    - how they are managed
- A two steps method
  - Analysis of uncertainties component per component
  - Global analysis (of all functions) and identification of failure mode (including combination of uncertainties)

Safety approach : QSA (Qualitative Safety Analysis)

Component

FAT — Safety functions

PARS — Scientific knowledge on processes

- Analysis for each uncertainty:
  - *Examine if it can affect the capacity of the component to fulfil (contribute to) a safety function,*
  - *Examine if it can have an influence on the ability of another component to fulfil a safety function,*
  - *Examine if it can modify the environment of the component in such a way that it can influence the manner in which the component fulfils its functions.*

Safety approach : QSA (Qualitative Safety Analysis)

According to 2008 regulatory guidance, need to evaluate normal and altered scenarios

The normal-evolution and altered scenarios describe the spatial-temporal combination of FEPs and models in line with safety functions based on QSA results:

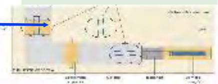
- Verification of the performance of the safety functions and robustness of the design by relying on relevant indicators (dose and other complementary indicators)
  - *uncertainties leading to a certain number of hypotheses for calculation purposes.*
- Normal Evolution Scenario (NES)
  - *Covers all features/events/process coupled or not considered as sufficiently certain or probable*
  - *Is a verification step in the design and acquisition of knowledge by presenting an integrated view of disposal components with the expected function*
- Altered Evolution Scenarios (AES)
  - *Describes "uncertain" or "conventional" situations corresponding to two main categories:*
    - *Failure of one or more safety functions of disposal*
    - *Human intrusion (after monitoring period)*

Safety approach : QSA (Qualitative Safety Analysis)

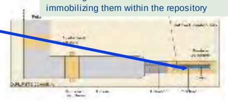
Illustration of AES based on the QSA (2005 Dossier)

- "Seal-failure" scenario
  - Failure of shaft or drift seals, or of all seals.
  - Sensitivity studies at the containment parameters of the EDZ, seals, etc.
- "Package-failure" scenario
  - Failure of all or part of overpack for ILW waste or of spent-fuel containers.
  - Sensitivity study to test the influence of the hydraulic transient.
- "Borehole" scenario
  - Different locations, one or two boreholes.
  - Sensitivity studies to the containment performances of the EDZ, of packages, etc.
- "What-if" scenario

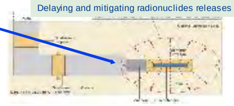
Preventing water circulation



Limitating radionuclide release and immobilizing them within the repository



Delaying and mitigating radionuclides releases



The actual safety loop

Major milestones in terms of safety loops

The 1991 Waste Act

- Creation of « Andra » as a public independant body
- 3 research areas for High Level Long-lived Waste: P/T; long term storage; geologic disposal

1996: Licence application for 3 URLs (clay; granite)

1998: Government decision to licence the Meuse/Haute-Marne URL licence,

1st SA → 2001: Intermediate Clay report, first NEA peer review…

2nd SA → 2005: Feasibility /safety assessment of safe geological disposal in Meuse/Haute-Marne clay layer, reviewed 2005-2006

The 2006 Programme Act: Reduce/avoid the burden on future generations

- Reduce volume and harmfulness of wastes
- Reference option for final waste that can no longer be treated: geological repository with respect to reversibility (100 y at least)
- Continue research on P/T (CEA) and interim storage (Andra) on a complementary basis.

3rd SA → 2009: Safety, reversibility and design options, reviewed 2010

2010-2012: Launch of the industrial design phase

2013: Public debate

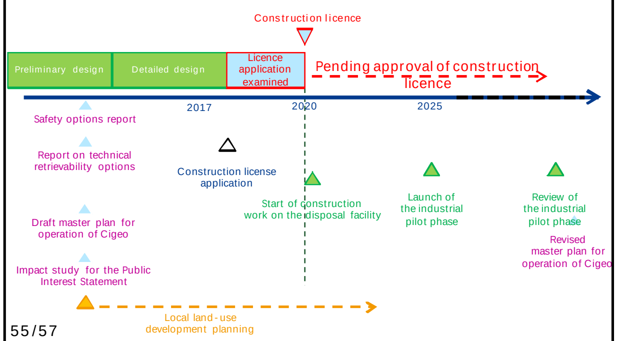
4th SA → *2015-17: DOS (Safety Opiions) and Licence application*

Actual loop

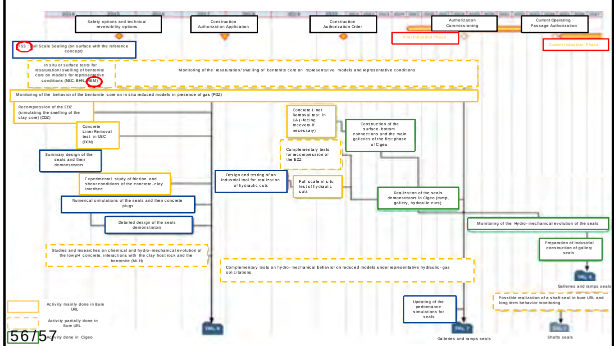
Around 2018-2019: Law defining reversibility conditions

2029: Beginning of operation

The current schedule



The actual RD&D development plan for seals



Thank you

DOPAS Training Workshop 2015

D2 2.2 The role of instrumentation and monitoring in an experiment

Jiri Svoboda, CTU in Prague

September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Contents (1)

Contents (2)

Introduction

Monitoring in general with respect to DGR

Why monitoring?

- Monitoring - Continuous or periodic measurement of radiological and other parameters or determination of the status of a structure, system or component.

  (IAEA Glossary 2007)
- In short – A way to know what happens in the repository
- Monitoring
  - Before anything starts
  - During construction phase
  - During disposal operation
  - After closure

Sensors

- A sensor is a device that measures a physical quantity and converts it into a signal, which can be read by an observer or by an instrument.

  For example, a mercury-in-glass thermometer converts the measured temperature into expansion and contraction of a liquid that can be read on a calibrated glass tube.

  A thermocouple converts temperature into an output voltage, which can be read by a voltmeter.

  For accuracy, most sensors are calibrated against known standards.

  (Wikipedia)

Analogue vs digital

"People are analogue, computers are digital"

- Every sensor in principle is analogue
- Analogue signals are hard to transmit and work with without degradation at every step of transmitting or processing
- Digital signal e.g. 1s and 0s is THE language computers speak and can be transmitted over long distances without information loss

7

Analogue vs digital

- Quality of signal (measurement)
  - Analogue - S/N ratio (dB)
  - Digital - Resolution (bits)
- Conversion from analogue to digital is done by A/D convertor.
- Digital sensor means that conversion from analogue to digital is done by some electronics inside sensor.

8

How to get data out?

- Signal
  - Analogue
  - Digital
- Cables – metallic, optic
  - Cheap and reliable
  - Not a good option after closure – cables can create preferential paths for water
- Wireless (radio; point to point link or mesh network)
  - Rock is not good for electromagnetic waves propagation
  - Custom made equipment, slow transmition, power source problems, limited lifetime

9

Data collection, storage and presentation

- Data acquisition system
  - Collects readings from sensors via data loggers
  - Stores readings into database (or elsewhere)
- Database (or other storage)
  - Stores all collected data for further processing
    - § Primary data from sensors
  - Calculated values
  - Other info (sensors calibration etc.)
- User front end
  - Takes data from database and processes them to the form suitable for user

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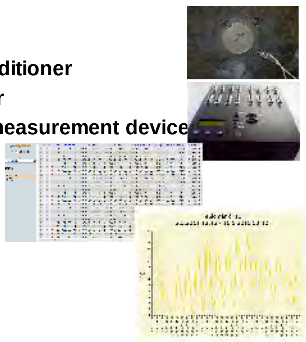
Measurement chain

- Sensor itself
- Amplifier/conditioner
- A/D convertor
- Data logger/measurement device
- Database
- UI front end
- User



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Disposal specific

- Cables are not welcome after closure
- Very long distance to the surface (not easy to use wireless)
- NO access for service after disposal closure
- Where to get power for sensors and devices after closure?
- How to get data (measurements) out?
- Extremely long time span.

12

What about the experiments?

The role of the instrumentation in the experiments

13

Why (not) to use instrumentation?

- Instrumentation is our "eyes" into what happens inside of our experiments

Observer effect

- Our instrumentation and/or process of measurement will have an impact on our experiment.

  Even non-invasive methods do have an impact.

  Example: Chemical interaction between sensors and environment (corrosion,..). Preferential paths along cabling. Heat production. Gradient creation.

14

What to measure?

- Purpose of the experiment is a starting point – raison d'être of the instrumentation is to gather necessary supporting evidence
- Identification of key processes
  à What parameters to measure
- Identification of key places
  à Where to measure
- Minimalist vs maximalist approach (I can but should I?)
  - Do not disturb the experiment!
  - I want to know everything!
- Always try measure all parameters, which could influence the measurement itself (e.g. temperature)

15

How to measure?

- Required parameters to measure drive the sensor selection
  - Phenomena
  - Range
  - Accuracy
  - Speed
- Diversify your portfolio
- Try to use several sensors of different type and principle for same parameter
- Check your sensor in advance
- Practical considerations
  - Will it fit into space? Will it impact the experiment? Will it survive? How much it costs?...

16

How often to measure?

- Highly depends on your application. However

You can throw away only things you have (measured)

and even very slow processes can have a fast sudden change.

- Practical considerations
  - Measurement itself can disturb the system (for example – the act of measurement heats up the sensor a bit)
  - Some measurements are slow by nature
  - You have to be able to handle the data flow

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How often to measure?

- *PLACEHOLDER SLIDE – example of interval/frequency of measurement importance (external poster in Josef gallery)*

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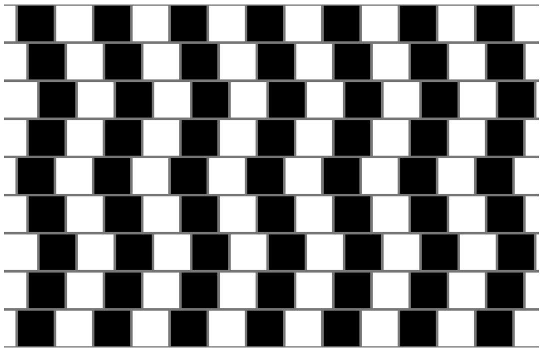
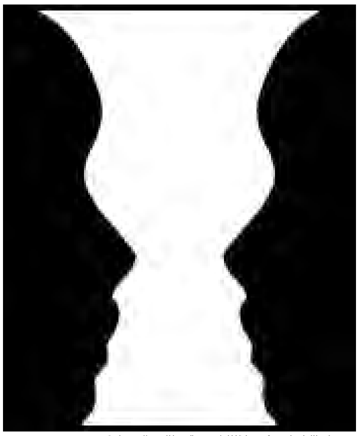
Data interpretation

- The measured data are useless without interpretation
- Do you trust your sensors?

Let’s try it…



© https://en.wikipedia.org/wiki/List_of_optical_illusions



© https://en.wikipedia.org/wiki/List_of_optical_illusions

Data interpretation

- The measured data are useless without interpretation
- Do you trust your sensors?
- Data validation
- Safety checks
- Cross checking
- Analytical tools

Typical failures

- Water
- Mechanical damage
  - Installation
  - Overload
- Electrical problems
  - Ground loops
- Durability and temporal stability

Typical failures - corrosion

Cables & Sensors

- Pressure cell

Thermometer

- Cables

Mechanical damage

26
25-

Common sensor types

What could be on my shopping list…

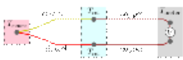
Principles of the sensors

- "Electromagnetic" sensors – change of electro magnetic properties and/or generation of electricity
  - Voltage/current
  - Resistivity
  - Inductivity
  - Hall effect*
- Vibrating wire sensors – change of oscillation frequency (pitch) by changing of wire tension
- Fiber optic
- …

*) **Hall effect** is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. It was discovered by Edwin Hall in 1879. (Source: Wikipedia)

Temperature

- Thermocouples
  - E,J,K,M,N,T
  - B,R,S
  - C,D,G
  - P
  - …



K-type thermocouple (chromel-alumel) – © Wikipedia.org

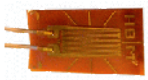
IEC 584-1
EN 60584-1

- Resistance temperature detectors (RTD)
- Thermistors
  - PTC
  - NTC

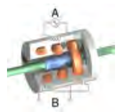
https://en.wikipedia.org/wiki/Thermocouple
https://en.wikipedia.org/wiki/Resistance_thermometer
https://en.wikipedia.org/wiki/Thermistor

Strain (deformation)

- Resistive strain gauges
  - Metallic



  - Piezoresistors
- Linear variable displacement transducer (LVDT)



©https://en.wikipedia.org/wiki/Linear_variable_differential_transformer

- Vibrating wire strain gauges

https://en.wikipedia.org/wiki/Strain_gauge

Force (pressure)

- There are no "direct" force/pressure sensors with electric output. The force/pressure is usually measured as deformation of elastic element.

- Membrane
- Rod
- Cantilever
- …

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Water content and humidity

- Relative humidity
  – Capacitive sensors
  – Thermocouple psychrometry

- Water content
  – Time Domain Reflectometry (TDR): Dielectric constant
  – Frequency Domain (FD): Capacitance and Frequency Domain Reflectometry
  – Amplitude Domain Reflectometry (ADR): Impedance
  – Time Domain Transmission (TDT)
  – Resistance blocks
  – Heat discipation

TDR – electromagnetic pulse propagation speed is measured -> dielectric constant
FD – capacince is measured based (oscillator freq is measured – rods in sample make capacitor)

32

EPSP experiment

Monitoring implementation

33

EPSP overall

- Experiment objectives (as stated in DoW)
  – systematic test and application of Czech based materials and technologies;
  – comparison with the results produced for the consortium members of this project;
  – development and testing of new construction techniques such as sprayed bentonite;
  – application of low pH concrete or shotcrete as structural and sealing materials for the plug;
  – comprehensive monitoring program, which will be pre-assessed during planning phase, of plug and surrounding rock as one basis for its modelling and performance assessment activities.

34

Monitoring

- Identification of key processes
- Identification of key places in experiment

- Selection of suitable sensors
- Selection of installation places

- DAQ & Measurement system

à Project of monitoring (DOPAS deliverable D3.18)

35

EPSP monitoring timeline

- Preparatory phase
- Construction work up to the completion of the inner plug
- Testing of the inner plug
- Completion of the construction of the experiment (bentonite emplacement, filter, outer plug)
- Trial operation
- The main experimental program

36

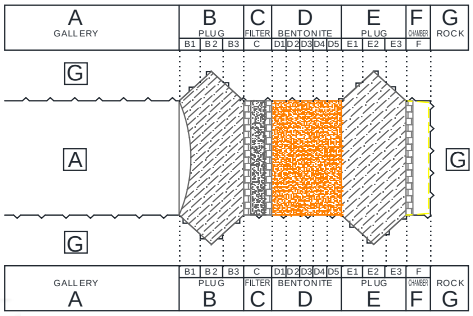
What, why and where?

- Construction phase – focus on concrete structures
  - Temperature evolution
  - Deformations (shrinkage)
- Experimental program – focus on EPSP performance
  - Water movement monitoring
  - Bentonite monitoring
  - Structural response of EPSP and host rock

37

What, why and where

- Profiles



38

What, why and where

- Water movement inside the experiment is monitored in terms of water in-/outflow, water content distribution within the bentonite seal and water (pore) pressure distribution.
- The mechanical response of the plug is monitored by means of strain gauges installed at key locations in the concrete plugs and instrumented rock bolts positioned within the rock. Moreover, contact stress measurement is deployed between the rock and the plug.

39

What, why and where

- Temperature distribution is monitored since it is important not only during the construction stage (hydration heat) but also during the loading of the experiment as a reference base for sensor compensation.
- The swelling pressure of bentonite sealing is monitored using pressure cells.

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Sensors

- Water (moisture movement)
  - RH sensors (E+E 071)
  - TDR sensors (DECAGON 5TE)
  - Outflow from drain

- Stress state
  - Piezometers (GeoKon – 4500SHX-10MPa)
  - Pressure cells (GeoKon - 4810X-10MPa)

- Temperature sensors
  - Dedicated analogue and digital sensors (DS18B20 and LM35DZ)
  - Compensation thermometers inside other sensors (thermistors)

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Sensors

- Mechanical response of experiment
  - VW strain gauges (GeoKon 4200A-2)

- Response of rock mass
  - Instrumented rock bolts (VW) (GeoKon 4911-4X)
- Technology
  - Amount, flow rate, pressure of pressurisation media
  - Status of technology
  - Energy consumption

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Data Loggers

- **Campbell scientific CR1000 and AVW200**
  - Vibrating wire sensors
  - Thermometers
  - TDR (via SDI-12)


- **In-house built data loggers**
  - Temperature sensors
  - Humidity sensors (optionally)

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Data Loggers

- **Directly connected (via convertors)**
  - Humidity sensors


- **GeoKon**
  - VW sensors
  - Thermistors

- **In-house on-line measurement system**

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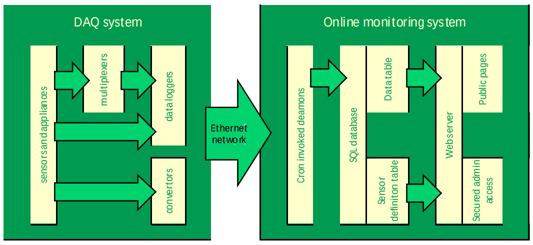
Sensor protection

- **Sensors and cables protected by stainless steel casing**


45

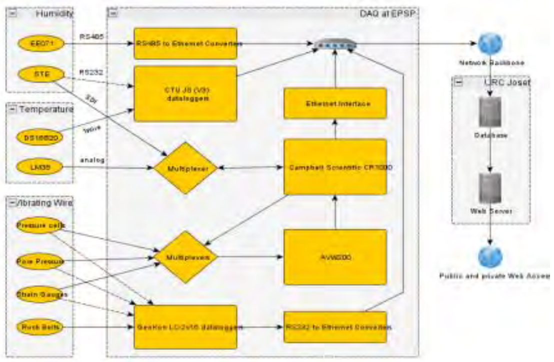
DAQ* + measurement system



*) data acquisition

46

DAQ + measurement system



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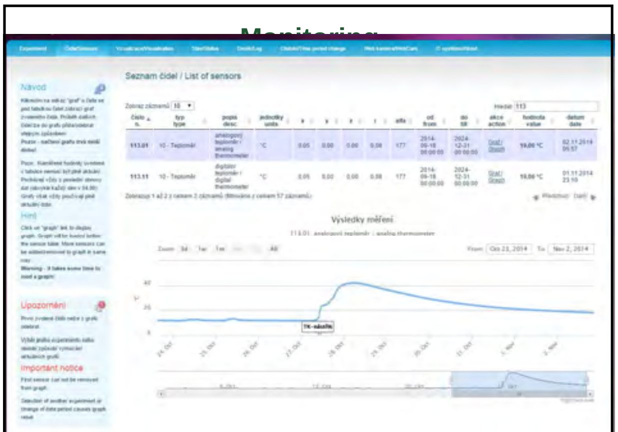
Monitoring



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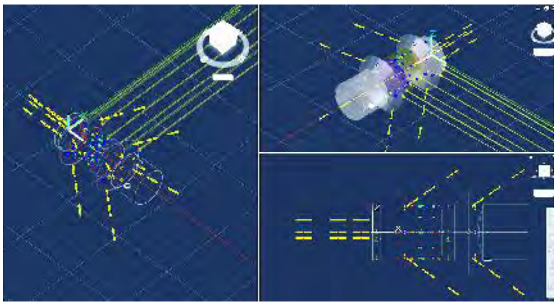
Monitoring – 3D model



Sensor selection process

- Sensors with good track record used where possible
- "New" sensors
  - References
  - Sample sensors tested in advance

References

- IAEA glossary http://www-pub.iaea.org/MTCD/publications/PDF/Pub1290_web.pdf
- DOPAS Deliverables
  - D2.1 Design Basis and Criteria Report
  - D3.15 Detail design of EPSP plug
  - D3.17 Interim results of EPSP laboratory testing
  - D3.18 Testing plan for EPSP instrumentation and monitoring

List of recommended further reading:

- Modern Project deliverables (http://www.modern-fp7.eu/)
  - State of art is good start http://www.modern-fp7.eu/fileadmin/modern/docs/Deliverables/MoDeRn_D2.2.2_State_of_art_report.pdf

Note: There is new MODERN2020 project (http://www.modern2020.eu/ - should be online by the end of 2015)

- Wikipedia articles about sensors:
  - https://en.wikipedia.org/wiki/Thermocouple
  - https://en.wikipedia.org/wiki/Resistance_thermometer
  - https://en.wikipedia.org/wiki/Thermistor
  - https://en.wikipedia.org/wiki/Strain_gauge
  - https://en.wikipedia.org/wiki/Linear_variable_differential_transformer

List of recommended further reading:

- GeoKon Manual library (manuals include theoretical background) - http://www.geokon.com/Manuals
  - Vibrating wire and other sensors
- Decagon – www.decagon.com
  - TDR and other soil sensors
  - Education section http://www.decagon.com/education/

Conditions for use of this training material

DOPAS Training Workshop 2015

Exercise 2

Jiri Svoboda, CTU in Prague
September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Day 2

- **Introduction into exercise and experiment used (15min presentation)**
- **Short demonstration of sensor used (5min)**
- **Manufacturing of probe (assembly, testing, sealing) (75 min)**
  Probe consisting of several thermometers will be manufactured by each group.
- **Break + getting ready/equipped into underground + transfer into underground (30min)**

2

Day 2 (cont.)

- **Probe installation into the rock in the underground (45 min)**
- **Connection to data logger and measurement network (20min)**
- **Heater start & first measurements (30min)**
- **Clean-up & Transfer out (20min)**

3

Day 4

- **Raw data processing (Excel)**
  - **Raw sensor data from database**
  - **Sensor calibration data**
  - **Processing data in excel**
    - **Raw à Values**
    - **Validity checks**
    - **Plotting**
- **Processed data analysis (GnuPlot) - Option**
  - **Processed data**
  - **Plotting multiple sensors for cross analysis**

4

www.posiva.fi/en/dopas

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DOPAS Training Workshop 2015
Participants and Tutors

Photo: (c) Marjatta Palmu

DAY 3

DOPAS Training workshop 2015

Learning Unit 3 : Design of a seal for an experiment/demonstrator within the broader context of RD&D programmes

Safety assessment and performance assessment of closure as design input

How to move from initial design in an iterative manner to the final experiment design and construction (to as build) and assess the outcome

Andra's scientific programme and the main questions to be replied for the next report (DAC) and after submission of DAC

Jacques WENDLING (Andra/DRD/EAP)
D3 3.1.1 16 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Summary

Conditions for use of this training material

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Introduction and Context

The 1991 Waste Act
- Creation of « Andra » as a public independant body
- 3 research areas for High Level Long-lived Waste: P/T; long term storage; geologic disposal

1996: Licence application for 3 URLs (clay; granite)
1998: Government decision to licence the Meuse/Haute-Marne URL licence,
1st SA → 2001: Intermediate Clay report, first NEA peer review…
2nd SA → 2005: Feasibility /safety assessment of safe geological disposal in Meuse/Haute-Marne clay layer, reviewed 2005-2006

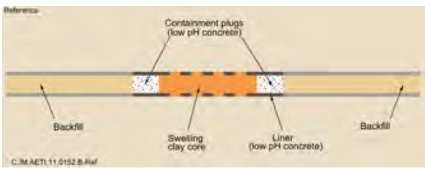
The 2006 Programme Act: Reduce/avoid the burden on future generations
- Reduce volume and harmfulness of wastes
- Reference option <u>for final waste that can no longer be treated</u>: geological repository with respect to reversibility (100 y at least)
- Continue research on P/T (CEA) and interim storage (Andra) on a complementary basis.

3rd SA → 2009: Safety, reversibility and design options, reviewed 2010
2010-2012: Launch of the industrial design phase

2013: Public debate
4th SA → *2015-17: DOS (Safety Options) and Licence application*
Actual loop
Around 2018-2019: Law defining reversibility conditions
2025: Operation

The actual seal concept: reference

Multi-component system :
- Bentonite core
  - Low permeability
  - Recompression of the EDZ (lower its permeability)
- Partial removal of the concrete liner to ensure a good bentonite/EDZ interface
- Concrete containment plugs to ensure mechanical stability of the bentonite core

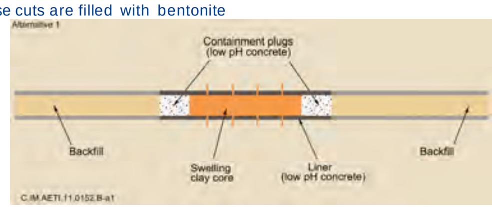


The actual seal concept: alternative

For the moment there is still significant uncertainties on the possibility to reduce the EDZ permeability by recompression through the swelling of the bentonite core.

Thus an alternative concept for the seal is studied, including hydraulic cuts of the EDZ

These cuts are filled with bentonite



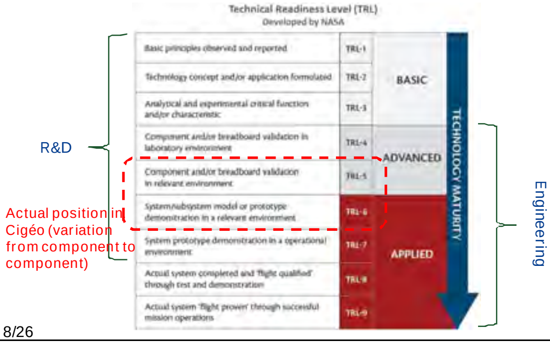
The main scientific questions

Long term evolution of the (low pH) concrete
- Chemical evolution in contact with clay (bentonite/argilites)
- Effect of corrosion of the metal reinforcement in concrete components

Long term evolution of the EDZ HM characteristics
- Gas effects near resaturation
- Mechanical behavior after recompression by the swelling of the bentonite core
- Mechanical behavior after mechanical rupture of the concrete lining

Rehydration of the bentonite plug
- Order of magnitude of the resaturation time
- Effect of gas on the resaturation

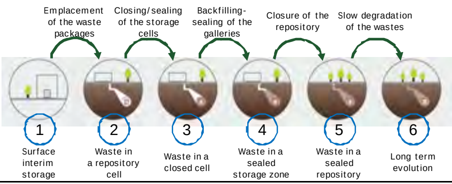
Main Technological Challenges: the TRL scale



Main Technological Challenges: Retrievability

Why
- To retrieve waste packages
- Abilility to reverse the decisions taken today

How
- Machines, packages, cells designed to allow the withdrawal of the waste packages
- Progressive and changeable closing schedule to leave the choice to next generations
- Appointments every 10 years with civil society to prepare the decisions



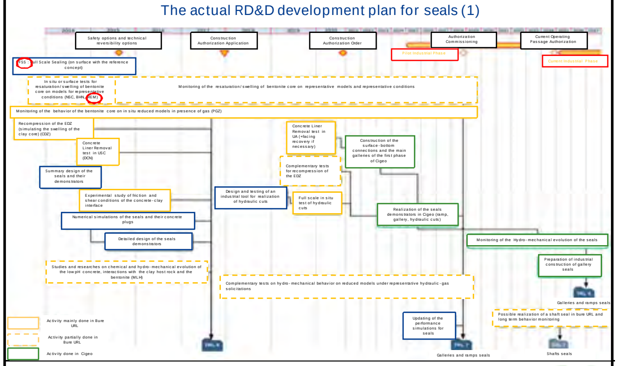
Main demonstrators in the actual program

Having a full spatial scale seal (10 m Ø, 60 m long) demonstrator with measurement during the whole resaturation time (several 1 000 years at least) and in a representative environment (URL) is impossible.

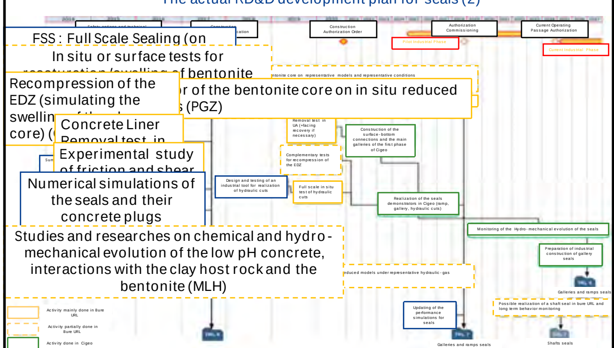
→ Andra has chosen to develop several complementary demonstrators covering the whole problematic by parts

They are all part of the RD&D program and are completed by a numerical simulations program

Introduction and Context
The actual RD&D development plan for seals (1)



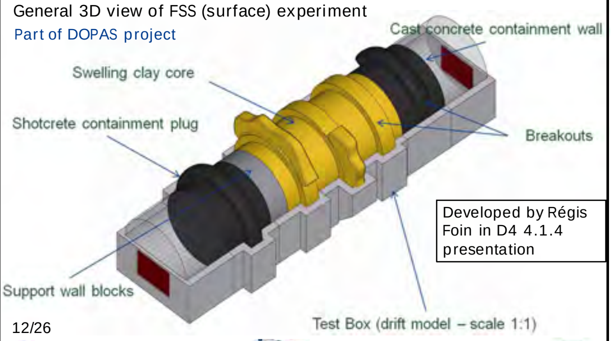
Introduction and Context
The actual RD&D development plan for seals (2)



Main demonstrators in the actual program

General 3D view of FSS (surface) experiment

Part of DOPAS project



Developed by Régis Foin in D4 4.1.4 presentation

Main demonstrators in the actual program

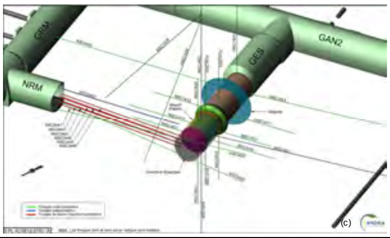
REM (surface) experiment, part of DOPAS Project : metric scale FSS bentonite mixture resaturation

Developed by Jacques Wendling on the D3 3.2.1 presentation

Main demonstrators in the actual program

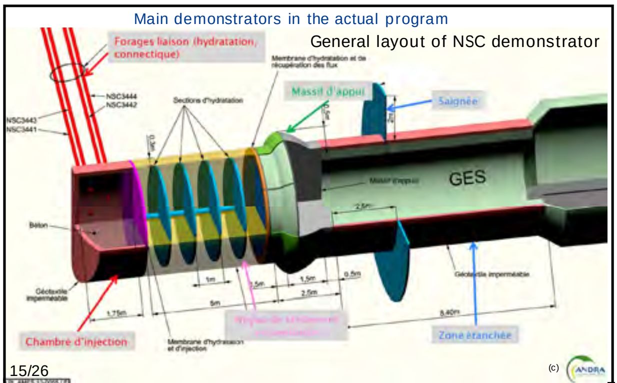
NSC demonstrator (out of DOPAS Project scope)

This underground URL ½ scale experiment aims to evaluate the hydraulic performance of a seal bentonite core and its near field (EDZ) by evaluating the water pathways in the system and its equivalent permeability.



Main demonstrators in the actual program

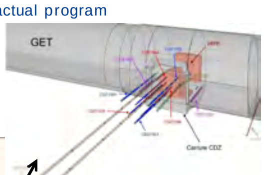
General layout of NSC demonstrator

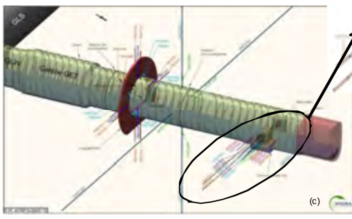


Main demonstrators in the actual program

CDZ demonstrator : recompression of the EDZ

Outside of the DOPAS Project scope





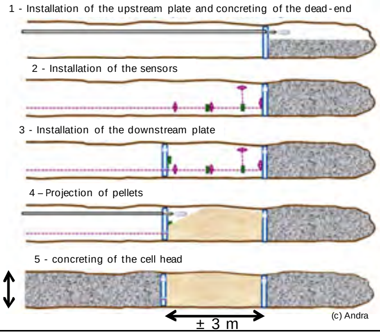
View of the hydraulic cylinder used for CDZ

Main demonstrators in the actual program

BHN demonstrator

- Underground (Bure URL)
- Natural resaturation of FSS bentonite mixture

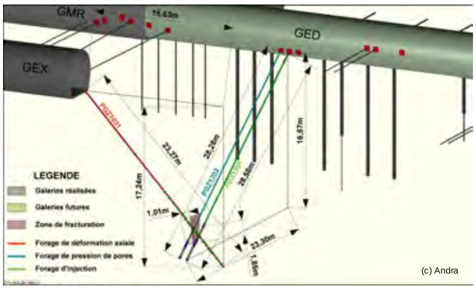
Out of the DOPAS Project scope



Main demonstrators in the actual program

PGZ experiment : in-situ borehole gas injection test

Out of the DOPAS Project scope



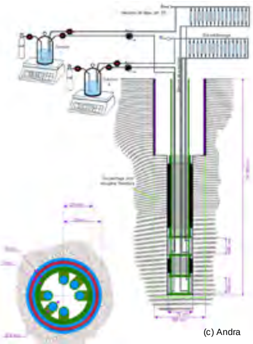
18/26

The main demonstrators in the actual program

MLH experimentation

- In situ borehole chemical experimentation.
- Analysis of the evolution with time of chemical composition of a synthetic concrete water in contact with the clay host rock

Out of the DOPAS Project scope



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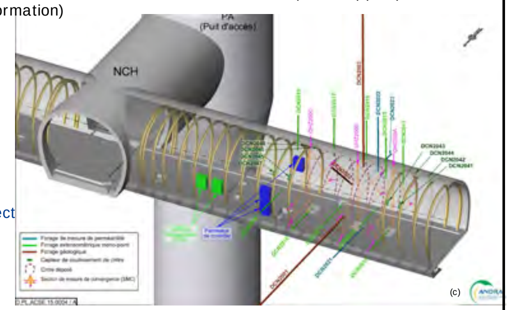
Main demonstrators in the actual program

DCN experimentation : concrete liner removal test (in the upper part of the host rock formation)

Out of the DOPAS Project scope



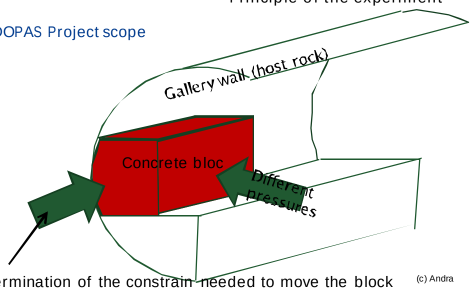
20/26

Main demonstrators in the actual program

Experimental study of friction and shear conditions of the concrete-clay interface

Out of the DOPAS Project scope

Principle of the experiment



Determination of the constrain needed to move the block

(c) Andra

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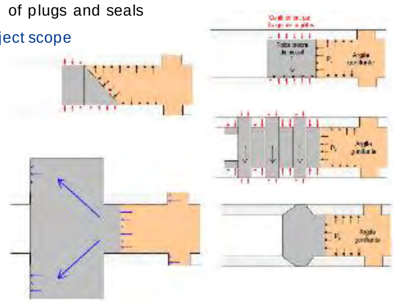
Main demonstrators in the actual program

Numerical simulations of plugs and seals

Out of the DOPAS Project scope

Numerical test of different forms for the concrete containment plug

Examples



(c) Andra

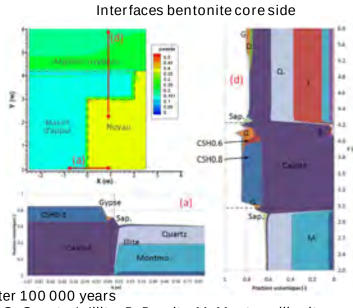
22/26

Main demonstrators in the actual program

Reactive transport 2D numerical simulations of the interfaces in a seal

Out of the DOPAS Project scope

Interfaces bentonite core side



Example of porosity after 100 000 years

G: Gypse, D: Dolomite, Q: Quartz, I: Illite, B: Brucite, M: Montmorillonite, Sap: Saponite

(c) Andra

23/26

Main demonstrators in the actual program

Alternative concept : hydraulic cut TSS demonstrators

- Ø Surface experiment
- Ø Focused on technical feasibility (robot emplacing the bentonite blocks in the cuts

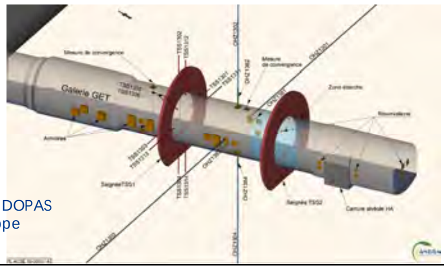
Out of the DOPAS Project scope

24/26

Main demonstrators in the actual program

Alternative concept : hydraulic cuts SET demonstrators

- Ø In the URL
- Ø Focused on hydraulic performance of the cuts



Out of the DOPAS Project scope

25/26

Thank You

26/26

DOPAS

DOPAS Training Workshop 2015

Plugs as a Part of the Demonstration Programmes in Nordic Countries

Petri Koho, Posiva

16th September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

D3 3.1.2

Outline of the Lecture

- Nuclear Waste Management in Finland
- Nuclear Waste Management Programme
- Concept Development Programme
- Safety Functions of the Closure of Deposition Tunnels
- Requirements for the Deposition Tunnel End Plug
- Previous Full-Scale Plug Tests
- Current Plug Designs; Two different designs
- Experimental Design
- Forthcoming Development Work and Roadmap to Operation

Nuclear Waste Management in Finland

- According to the Nuclear Energy Act, all nuclear waste generated in Finland must be handled, stored and permanently disposed of in Finland
- Nuclear waste is not allowed to be exported or imported
- As producers of nuclear waste, Teollisuuden Voima Oyj (TVO) and Fortum Power and Heat Oy (Fortum) are responsible for implementing the management of nuclear waste
- The disposal of spent fuel from Olkiluoto and Loviisa nuclear power plants is implemented by Posiva Oy established by TVO and Fortum in 1995

Nuclear Waste Management in Finland

Nuclear Waste Management Programme

- The Ministry of Employment and the Economy (abbreviated as TEM in Finnish) decides on the principles to be followed in nuclear waste management in Finland
- The legislation provides that the parties with the nuclear waste management obligation must provide the ministry with regular reports on how they have planned to implement the measures included in nuclear waste management and their preparations
- Up to 2008, these reports were submitted to the ministry annually
- Since 2009, the reports have been submitted at three-year intervals, and it must describe in detail the measures for the next three-year period and also present an outline of the plans for the subsequent three-year period (3+3)
- TVO and Fortum as producers of nuclear waste are responsible for producing the report, but they have given the task to Posiva

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Nuclear Waste Management Programme

- In addition to the annual nuclear waste management reports, the parties with the nuclear waste management obligation have been preparing three-year plans for nuclear waste management in Olkiluoto and Loviisa since 2003
- The plans (TKS-2003, TKS-2006 and TKS-2009) have included the plans for future research, development and planning work, as well as an assessment of the status of nuclear waste management, in particular with respect to the preparations for final disposal of spent nuclear fuel
- Nuclear Waste Management Programme YJH-2012 was the first overall plan to combine the reporting, containing
  - low and intermediate waste repositories
  - interim storage of spent nuclear fuel
  - final disposal of spent nuclear fuel
  - planning of decommissioning

Nuclear Waste Management Programme

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YJH-2012
Nuclear Waste Management
at Olkiluoto and Loviisa Power Plants:
Review of Current Status and Future Plans for 2013-2015

Posiva Oy

May 2013

- YJH-2012 can be found from Posiva's website
- http://www.posiva.fi/en/databank/publications/nuclear_waste_management_plans_and_annual_reports_(yjh_reports)
- YJH-2015 programme is currently under preparation to describe in detail the measures to be taken from 2016 to 2018 (update: available)
- The programme was delivered to TEM by the end of September 2015

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SKB's FUD Programme – Research, Technology and Review

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Research cooperation

Technology development and full scale tests

Regularly review

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SKB's FUD Programme – Continuous Knowledge Building

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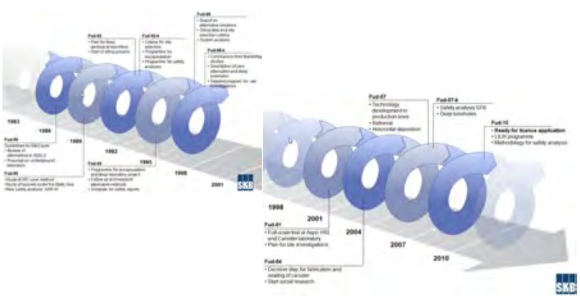

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Concept Development Programme

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- Based on the request of the Finnish Radiation and Nuclear Safety Authority (STUK), Posiva has collected the plans to solve open issues relating to the final disposal concept and the descriptions for testing and demonstration of the functionality of the disposal concept to Final Disposal Concept Development Programme
- The programme lists the requirements placed on each factor involved in the final disposal process, such as spent fuel, disposal canister, buffer, deposition tunnel backfill and end plug, and rock facilities
- The programme also presents plans for implementing full-scale testing in the underground rock characterisation facility ONKALO
- The programme describes the issues that are still open as well as the tests to be performed in order to solve them
  - Research, development and testing of the engineered barrier system
  - Deposition tunnel backfill and end plug
  - POPLU – full-scale deposition tunnel end plug test

Role of the Deposition Tunnel End Plug

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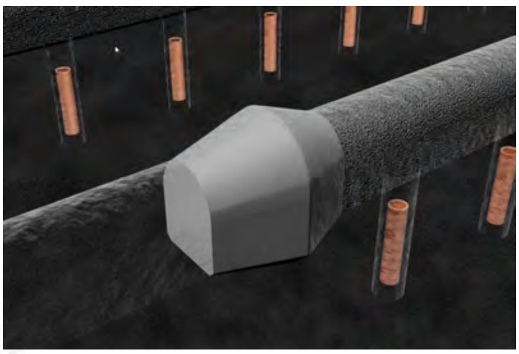

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Role of the Deposition Tunnel End Plug and Safety Functions

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- The long-term safety principles set out for the KBS-3 method are based on the use of a multi-barrier disposal system consisting of engineered barriers and host rock
- The roles of the barriers in establishing the required long-term safety of the repository constitute the safety functions of the barriers
- The closing structures of the deposition tunnels consist of backfill and end plugs with the following safety functions
  - Contribute to favourable and predictable mechanical, geochemical and hydrogeological conditions for the buffer and canisters,
  - Limit and retard radionuclide releases in the possible event of canister failure, and
  - Contribute to the mechanical stability of the rock adjacent to the deposition tunnels
- The safety functions are implemented in the proposed design through a set of technical design requirements, based on performance targets defined for the engineered barriers that they should meet in the long-term to provide the safety level needed

Requirements for the Deposition Tunnel End Plug

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- The technical design requirements of the engineered barriers are expressions of performance targets in a form that can be tested or otherwise proven at the stage of implementation through observations and measurements
- Design specifications are detailed specifications determined for the design based on the performance targets and design requirements
- The design specifications for the deposition tunnel end plug reflect the design of the plug that aims to provide sufficient structural stiffness and water tightness to ensure that the system performs as intended
- In the Concept Development Programme the fulfilment of the requirements set for the deposition tunnel end plug is discussed and the plan to show the fulfilment through development and testing is given
  - Þ POPLU and DOMPLU deposition tunnel end plug tests

Previous Full-Scale Plug Tests

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- The need for a plug at the entrance of a deposition tunnel was recognised at an early stage of the KBS-method
- Different plug designs have been tested in previous full-scale experiments
  - Stripa mine tunnel plugging experiment in the 1980s
  - Backfill and Plug Test in 1999 - 2005 at Äspö HRL
  - Prototype Repository from 2001 onwards at Äspö HRL
  - Compartment plug test for the horizontal emplacement concept in 2005 at Äspö HRL and Grimsel
  - Tunnel Seal Experiment (TSX) in 1998 - 2004 at AECL's URL
  - Enhanced Sealing Project (ESP) from 2009 onwards at AECL's URL

Backfill and Plug Test

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- An O-ring made of bentonite blocks was introduced into the plug design after the Stripa Experiment
- The O-ring did not perform as intended, as leakage of water was found to be quite high
- The test was made as a preparation for the Prototype Repository (Euratom project)

Prototype Repository

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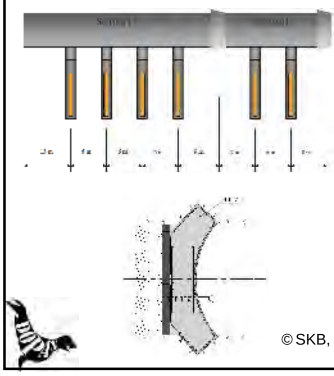

- The Prototype Repository incorporated two plugs
- Unlike the previous experiments, both concrete plugs were cast with self-compacting concrete (SCC)
- Plug 2 was comprehensively instrumented to investigate its mechanical response to the pressure load
- Both plugs were contact grouted through pre-installed grouting tubes

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Tunnel Seal Experiment (TSX)

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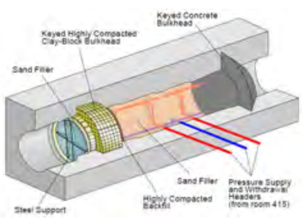

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- The concrete bulkhead was made of unreinforced low-heat high-performance concrete (LHHPC)
- The experiment also included a bulkhead composed of highly compacted sand-bentonite blocks
- The clay bulkhead provided an effective barrier to water transport and demonstrated the ability to close off existing flow paths and to self-seal
- The TSX also highlighted the importance of keeping joints and interfaces to a minimum and the effectiveness of contact grouting to reduce seepage between the concrete bulkhead and rock

Enhanced Sealing Project (ESP)

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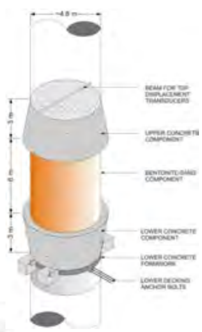

- The ESP consists of an instrumented, full-scale shaft seal, designed to permanently seal the access shaft to Atomic Energy of Canada Limited's (AECL's) URL
- The project was undertaken as part of the permanent closure of AECL's URL
- The seal consists of two concrete segments that sandwich a bentonite-clay-based unit limiting the mixing of deeper saline groundwater with shallower less-saline groundwater on a hydraulically active fracture zone
- The monitoring results are indicative of a system where the clay is effectively isolating the regions above and below the fracture feature

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Current End Plug Reference Design

- The previous full-scale experiments have contributed into the development of the reference deposition tunnel end plug design
- The experiments have for example shown that the requirement of water tightness in combination with a concrete plug subjected to high pressure is a challenge
- The current reference design is the same for SKB and Posiva, and was developed based on a concept where the plug is divided into separate layers; filter, bentonite seal and low-pH reinforced concrete dome, each layer separated with delimiters
- The purpose of the bentonite seal is to aid in the water tightness of the plug by sealing water leakage paths through small cracks in the concrete plug or between the concrete and the rock surface

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Posiva's Current Reference: Dome plug (Posiva 2012-18) (= SKB Reference design, TR-10-16)

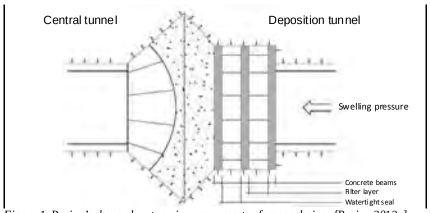

Figure 1. Posiva's dome plug, top view, as current reference design. [Posiva 2012a]

© Posiva, 2012-18

- Filter: 750 mm crushed rock or permeable blocks, installed density ≥ 1900 kg/m³
- Seal: 750 mm compacted MX-80, dry density ~1400 kg/m³
- Delimiters: 300 mm wide (x 3) of concrete beams

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Current End Plug Experiment Designs

- The design of the plugs constructed and tested in the POPLU and DOMPLU experiments differ from the reference design
- The plug design used in the DOMPLU experiment is similar to the reference design with some modifications
  - use of unreinforced concrete instead of reinforced concrete for the concrete dome
  - two of the concrete delimiters have been replaced with other materials
  - the thickness of the watertight seal is 500 mm
  - the installed dry density of the filter is 1400 kg/m³
- The modifications intent to test the performance of new materials planned to potentially be introduced as the reference design in the future, or to facilitate experiment implementation

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Current End Plug Experiment Designs

- The POPLU design is based on a different concept to that of the reference design
  - POPLU is a wedge-shaped low-pH reinforced concrete structure
- The idea is to demonstrate the performance of a simpler plug design that can potentially be used in a drier tunnel without high water inflows; such as the conditions in ONKALO
- By providing evidence that a simpler concrete structure with less components will perform as required, the plugging process could become more straightforward to implement
- After POPLU and DOMPLU experiments, there may be two options for the deposition tunnel end plug available during the implementation stage and possibly the wedge design might replace the dome design as Posiva's reference design

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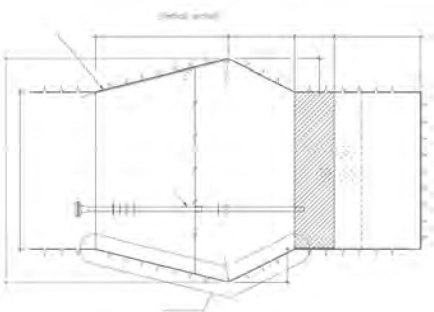
Posiva Wedge Design



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Full-Scale End Plug Experiments

- If the developed plug design deviates from the previously tested plugs, the new concept must be tested in order to verify that it works in realistic conditions
- Performing the test in full-scale gives input on the construction feasibility of the design
- A full-scale test will also give valuable input on the water tightness of the plug in real or simulated water inflow conditions
- The experiences from full-scale experiments are very valuable to the design of future full-scale tests
  - e.g. Full-Scale In-Situ System Test (FISST)

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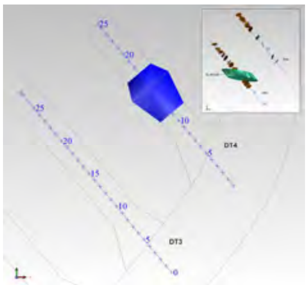
Experimental Design



- Finding a suitable location for the experiment in crystalline rock requires the identification of suitable bedrock volumes to host the experiment
  – the criteria to select the bedrock volume is set so that it promotes the fulfilment of the requirements set for the experiment
- For POPLU, the Rock Suitability Classification (RSC) -system developed by Posiva was applied
  – it was used to verify the suitability of the plug demonstration tunnel locations and to select the location for the plug within the tunnels
- Also, the stability of the new demonstration tunnels was verified based on the objectives of the POPLU experiment (10 MPa)

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Experimental Design

- When performing experiments at the future repository there are more things to be considered compared to the URL
- These items include for example
  – regulatory authority control
  – safety classifications
  – possible method tests
  – quality control practices
  – approval cycles by the authority
  – foreign materials control
- It is of course beneficial to note all the above items when performing experiments at the URL to gain experience and maximum benefit from the experiment for the future
- It is highly important to decide in the planning phase of the experiment what are the items considered in the experiment e.g. approval cycles by the authority must be noted in the schedule

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Experimental Design

- Foreign materials control is an important aspect of the experimental design especially at the future repository such as ONKALO
  – Even if the materials used in the test components will be later removed from the site prior to repository operation, they have the potential to leave traces to the surrounding groundwater and bedrock environment
  – These traces could have an impact the to long-term performance and safety of the whole repository
  – It is thus very important to use materials that have been evaluated and allowed to use by the foreign materials approval
  – Any new materials introduced to the experiment must have the foreign materials approval before use in the experiment

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Experimental Design

- When the objective of the experiment is to develop components to repository operation, it must be evaluated that the components do not have harmful effects to the other components in the concept
  – High calcium content affects adversely to the swelling properties of bentonite
    => low-pH concrete and contact grout
  – Organics promote radionuclide transport when released
    => use of e.g. plastics is strictly limited
- When performing experiments at an URL it is also important to use the same materials as e.g. in real operational-phase plugs, to see that the initial state of the plug will be achieved with approved materials
- In the planning phase of the experiment the approval time and possible iteration rounds of new materials and the costs related to that must be noted, e.g. testing of concrete materials is time consuming

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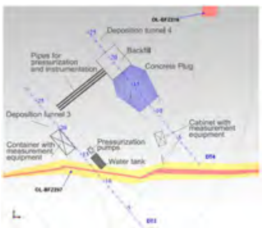
Experimental Design

- Monitoring of the experiment is useful for observing the behaviour and performance of the experiment
- Monitoring can however disturb the system so that the initial state of the component is not achieved
- It must be planned in the experimental design how and in what extent the monitoring of the experiment is done
- In the POPLU experiment e.g. following are needed for monitoring
  - 81 sensors
  - monitoring tunnel
  - tunnel-to-tunnel lead-throughs
  - plug lead-throughs
- An example of the challenges in end plug monitoring is how to separate the three different types of leakage
  - through the concrete plug
  - in the contact between the concrete plug and the rock
  - passing the plug through the rock



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Forthcoming Development Work and Roadmap to Operation

- POPLU and DOMPLU test results and experiences provide input for the plug development work
- Feedback by STUK to the reference design presented in the Construction Licence Application is taken note in the update of the Concept Development Programme and thus implemented in the development work
- Any modifications or iterations to the end plug design will be tested in the Full-Scale In-Situ System test (FISST)
- New evaluation round of the design is made after FISST and possible changes to the design are tested in the Joint Operating Test (JOT)
- The end plug design used in JOT is the design that has been approved for the actual repository operations
- The conclusions of JOT are needed for the Operating Licence

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SKB: Continued Development

- A new RD&D plan (FUD 2016)
- Buffer & backfill; Continued system tests e.g. manufacturing of clay components, verification of installation processes, handling of groundwater inflow during installation, quality management etc.
- Plugs; Opening and retrieval of DOMPLU in 2017
- Integrated system test at Äspö Hard Rock Laboratory 2018-2019; Excavation of 100 m tunnel, drilling of deposition holes, plug slot excavation, deposition of two full-scale dummy canisters, installation of buffer and backfill, plugging of the deposition tunnel

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SKB: Continued Development

- Governmental decision for the Swedish Spent Fuel Repository at Forsmark is expected in 2018. License conditions will be given in late 2019. (Note that the application was submitted in 2011!)
- Start of repository construction (ramp) in mid 2020
- Fully integrated system tests at the deposition area around 2027-2028
- Final functional testing from 2029
- Trial operation starts around 2031

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Posiva's publications can be found at http://www.posiva.fi/en/databank

SKB's publications can be found at http://www.skb.com/publications

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Abbreviations

TVO	Teollisuuden Voima Oyj
TEM	Työ- ja elinkeinoministeriö, Ministry of Employment and the Economy in Finland
STUK	Säteilyturvakeskus, Radiation and Nuclear Safety Authority in Finland
POPLU	Full-scale deposition tunnel end plug test at ONKALO
DOMPLU	Full-scale deposition tunnel end plug test at Äspö HRL
HRL	Hard Rock Laboratory
URL	Underground Research Laboratory
AECL	Atomic Energy of Canada Limited
FISST	Posiva's Full-Scale In-Situ System test
JOT	Posiva's Joint Operating Test

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DOPAS

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The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

DOPAS Training Workshop 2015

Learning Unit 3 : Design of a seal for an experiment/demonstrator within the broader context of RD&D programs

Safety assessment and performance assessment of closure as design input

How to move from initial design in an iterative manner to the final experiment design and construction (to as build) and assess the outcome

The use of individual tests to complement existing material and process knowledge (case of REM metric experiment)

Jacques WENDLING (Andra/DRD/EAP)
D3 3.2.1 16 September 2015

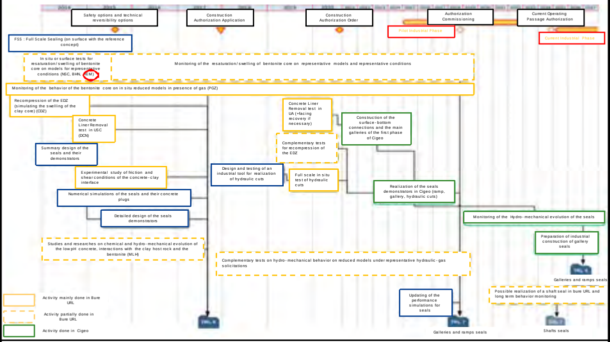
The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Summary

- Background and context
- Aims of the experiment
- Experimental layout
- First results

Conditions for use of this training material

Background and Context (1/2)
Cigéo 2015-2035 PDP



Background and Context (2/2)

Plugs and seals demonstrator program

- Technical feasibility
  - Surface demonstrators
    - FSS "Scale one technical feasibility for a drift plug" (DOPAS WP3)
      - Test of concrete formulations
      - Test of pellets/powder bentonite formulation
      - Test of filling of the plug by the bentonite mixture
    - TSS and SET "hydraulic cut-offs"
      - Test of filling the hydraulic cut-offs with bentonite blocks
  - Underground demonstrators (Bure URL)
    - DCN "removal of tunnel lining segments"
    - BHN "natural resaturation at metric scale"
- Phenomenological understanding consolidation
  - Surface demonstrators
    - REM "metric scale resaturation" test (DOPAS WP5)
      - FSS pellets/powder mixture
      - Near to natural resaturation
  - Underground demonstrators (Bure URL)
    - NSC "1/2 scale grift plug"
      - Bentonite blocks
      - Artificial resaturation

Pellets and powder

Blocks

REM : aims of the experiment

Complete the database on powder / pellets mixture resaturation
- Most experiment done with forced resaturation (flow several orders of magnitude higher than in natural media)
- At decimetric scales

Ä Metric scale experiment with "as near as possible from site" resaturation

Same density as for FSS

Consolidate the physical representation of the HM behavior of powder/pellets mixture
- Improve the numerical representation of the rheological behavior of such a mixture
- Improve the numerical representation of the hydraulic behavior of such a mixture

Ä Implementation of a high number of HM sensors (not possible in-situ)

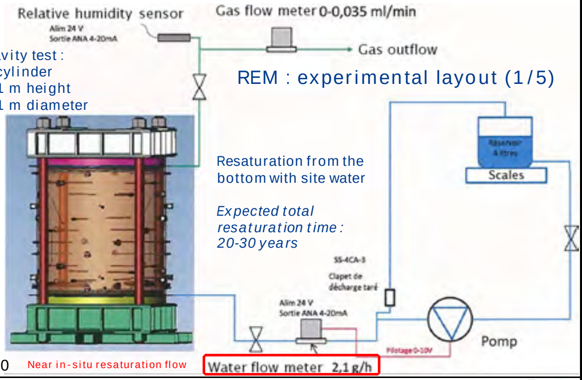
Numerical HM simulation / benchmarking

Help provide (partial) demonstration of powder mixture "natural" resaturation for the DAC (2017)

Help design (and optimize) the seals and plugs for the Cigéo project

REM : experimental layout (1/5)

Cavity test :
- cylinder
- 1 m height
- 1 m diameter



Resaturation from the bottom with site water

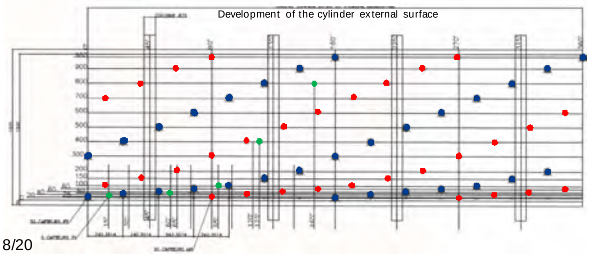
Expected total resaturation time : 20-30 years

Near in-situ resaturation flow

7/20

REM : experimental layout (2/5)

Sensors
- 30 for total (swelling) pressure (+ 4 on top)
- 30 for relative humidity
- 5 for interstitial (water) pressure
- 4 for strength (on bolts)



8/20

REM : experimental layout (3/5)

REM emplacement and filling (Sept. 2014)

View of the test cavity during its cleaning

Total pressure sensors

Relative humidity sensor installed

9/20

REM : experimental layout (4/5)

REM emplacement and filling (Sept. 2014)

10/20

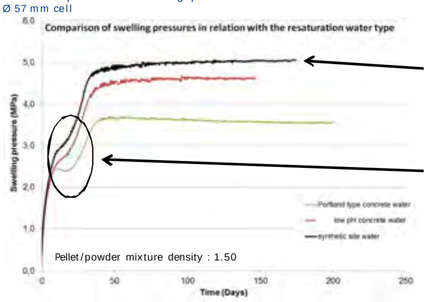
REM : experimental layout (5/5)

Satellite experiments (Ø 57 mm and Ø 240 mm cells)
- Resaturation with leached concrete water
  - "Portland type" leached concrete water
  - Low pH concrete water (the same as the one used for FSS)
- Measure of swelling pressure
  - Radial resaturation
- Measure of permeability
  - Radial resaturation
  - Axial permeability measurement
- Expected resaturation time
  - < 100 d for Ø 57 mm cell
  - < 500 d for Ø 240 mm cell

11/20

REM : on-going work and first results

Satellite experiment : swelling pressure in relation with different resaturation water type
Ø 57 mm cell



Swelling pressure higher than expected from the ESDRED (Euratom FP6) results, mainly linked to the very low water content of the bentonite used to generate the pellets/powder

With site water (and to a lesser extent with low pH concrete water) the « double porosity » behavior is not present during the resaturation phase

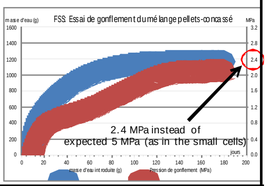
12/20

REM : ongoing work and first results

Satellite experiment : Ø 240 mm cell

- First used to determine the swelling pressure for FSS
  - Beginning of resaturation end of April 2014
  - Expected swelling pressure not reached
  - The piston was stuck
  - Repair of the piston (end of September 2014)
  - Beginning of new experiment (October 2014)
  - New swelling pressure results for FSS (February 2015)

- Use for REM (4 to 5 month delay)
  - Installation of sensors to measure (March 2015)
    - total pressure
    - Relative humidity
  - Beginning of experiment (March 2015)
  - Results obtained in July 2015 : swelling pressure of around 3.3 MPa
  - Density of the bentonite pellets/powder mixture was not exactly the same as the one used for the small diameter cell



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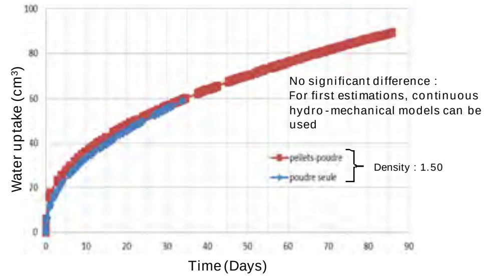
REM : ongoing work and first results

Satellite experiment : water uptake for powder and pellets/powder mixture



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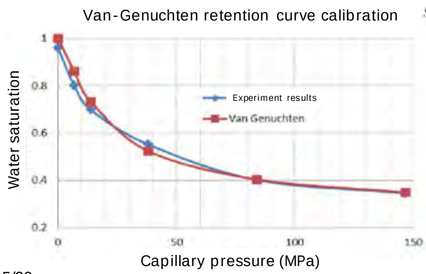
REM : ongoing work and first results

REM first hydraulic (no mechanic) numerical simulation



$$S_{r,w} = S_{res} + \frac{S_{max} - S_{res}}{\left[1 + \left(\frac{P_{cap}}{P_r}\right)^n\right]^m}$$

$$S_{max} = 1$$

$$S_{res} = 0.25$$

$$m = 0.486085$$

$$n = 1.88$$

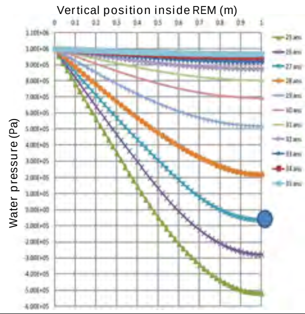
$$P_r = 14 \times 10^6 \, Pa$$

15/20

REM : ongoing work and first results

REM first hydraulic (no mechanic) numerical simulation

Expected resaturation time :
25-30 years



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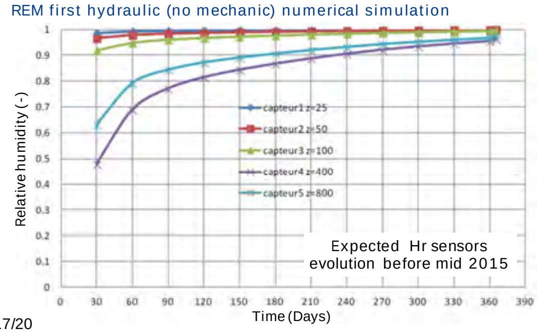
REM : ongoing work and first results

REM first hydraulic (no mechanic) numerical simulation



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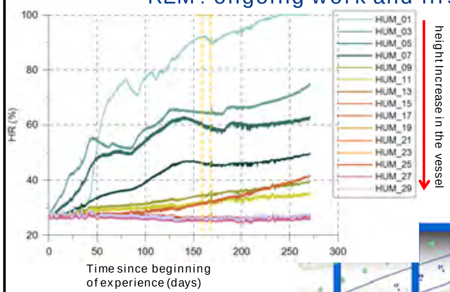
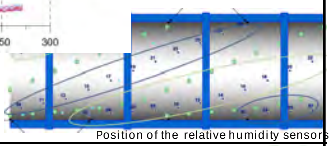
REM : ongoing work and first results



Relative humidity measurement since the beginning of the experiment



Position of the relative humidity sensors

18/20

REM : general achievement (within DOPAS)

Experimental results (REM + satellite experiment)

- Evolution of the resaturation in time during 1.5 years
  - Expected resaturation of around several centimeters
  - Evolution of the relative humidity over the whole volume of the cell
- Evolution of the swelling pressure during 1.5 years over the whole volume of the cell

- *The experiment will be maintained at least for 10 years to see the evolution of resaturation and to help develop a specific rheological model*

Numerical simulations

- Simulation of the resaturation period
  - Evolution of the saturation (relative humidity) over the whole cell
  - Evolution of the swelling pressure over the whole cell

- *Development of a specific rheological behavior*
- *First benchmark*
  - *To compare simulations predictions and experimental results*
  - *To compare results of different simulations / codes*

Thank You

DOPAS

DOPAS Training Workshop 2015

14-18 September 2015
Day 3

Material Reference: D3
Content Reference: 3.2.4

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

ÚJV Řež, a. s.

The role of pH in the Czech plug system and a summary of assumed pH influence in the Czech safety case

Petr Večerník, Jenny Gondolli, Václava Havlová

DOPAS Training Workshop
16 September 2015

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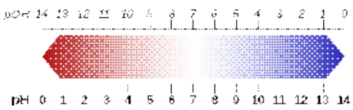
pH - background and measurement

pH
- numeric scale used to specify the acidity or alkalinity of an aqueous solution
- the negative of the logarithm to base 10 of the activity of the hydrogen ion

$$pH = -\log_{10}(a_{H^+})$$

- values range: 0-14
  pH < 7 - acidic, pH = 7 - neutral, pH > 7 - alkaline / basic



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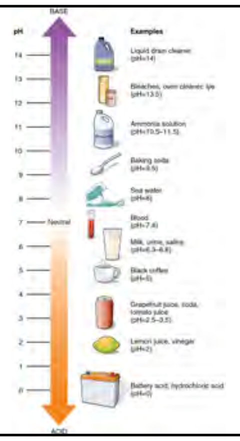

3

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pH - background and measurement

pH measurement
- an indicative – pH indicators
  their color changes with pH

- precise – pH electrode

4

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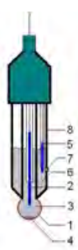
pH - background and measurement

pH electrode
- combines the glass and reference electrodes into one body



1 - a sensing part of electrode, a bulb made from a specific glass
2 - internal electrode, usually silver chloride electrode or calomel electrode
3 - internal solution, usually a pH=7 buffered solution of 0.1 mol/L KCl
4 - when using the AgCl electrode, a small amount of AgCl can precipitate
5 - reference electrode, usually the same type as 2
6 - reference internal solution, usually 0.1 mol/L KCl
7 - junction with studied solution - frit usually made from ceramics
8 - body of electrode, made from non-conductive glass or plastics

5

pH - background and measurement

pH meter
- consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading
- measuring of electric potential – transfer to pH values
- laboratory or field/in-situ devices

pH buffers
- for calibration
- available for all pH range
  in laboratory: pH = 7, 9, 11 and 13

Cement and concrete composition, behaviour, alkaline plume, pH

Cement
- hydraulic binder, i.e. a finely ground inorganic material which, when mixed with water forms a paste, which sets and hardens by means of hydration reactions and processes, and which retains its strength and stability even under water after hardening.

(EN 197-1:2000)

Paste – is obtained by mixing cement and water.

Mortar – is obtained by mixing cement, water and sand.

Concrete – is obtained by mixing cement, water, sand, and coarser aggregates (and other components).

Cement and concrete composition, behaviour, alkaline plume, pH

- Can exist as natural product
  - at Maqarin and Khuysham Matruk (Jordan) natural cements were produced in situ by combustion of a bituminous marl (an organic-rich clay, biomicrite) 10^5 to 10^6 years ago
- Man-made material
  - in 1824 Joseph Aspdin took out a patent on Portland cement, a material he produced by burning powdered limestone and clay
  - in 1845 Isaac Johnson made the first modern Portland cement by firing a blend of chalk and clay at high temperature (1400-1500°C), similar to those used today

Cement and concrete composition, behaviour, alkaline plume, pH

- Production
  - raw mix obtained by blending a calcareous material (limestone) with a small amount of an argillaceous one (clay or shale). These materials are crushed to a very fine powder (<200 µm) and then blended in the correct proportions.
  - this blended raw material is heated in a rotary kiln where it reaches a temperature of about 1400-1500 °C. The material formed in the kiln is described as clinker.
  - to produce Portland cement, the clinker is ground together with a small amount of gypsum to control the setting properties.

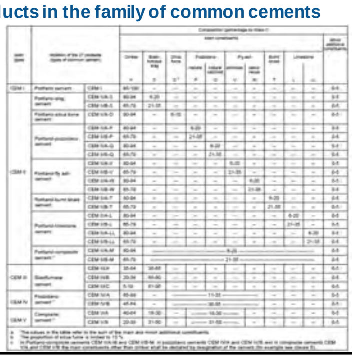
Cement and concrete composition, behaviour, alkaline plume, pH

- 5 main cement types:
  - CEM I – Portland cement
  - CEM II – Portland-composite cement
  - CEM III – Blastfurnace cement
  - CEM IV – Pozzolanic cement
  - CEM V – Composite cement
- Cement chemistry notation

C = CaO	S = SiO_2	A = Al_2O_3	Ŝ = SO_3	F = Fe_2O_3
H = H_2O	M = MgO	T = TiO_2	K = K_2O	N = Na_2O

Cement and concrete composition, behaviour, alkaline plume, pH

- 27 products in the family of common cements (EN 197-1:2000)



Cement and concrete composition, behaviour, alkaline plume, pH

- **hydration of C_3S and C_2S**

calcium silicates + water → calcium silicate hydrate + portlandite

Dissolution:

$Ca_3SiO_5 + 3\ H_2O \rightarrow 3\ Ca^{2+} + H_2SiO_4^{2-} + 4\ OH^-$

$Ca_2SiO_4 + 2\ H_2O \rightarrow 2\ Ca^{2+} + H_2SiO_4^{2-} + 2\ OH^-$

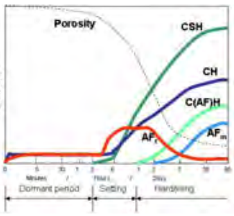
Precipitation:

$x\ Ca^{2+} + H_2SiO_4^{2-} + 2(x\text{-}1)\ OH^- \rightarrow (CaO)_x(SiO_2)(H_2O)_y$

$Ca^{2+} + 2\ OH^- \rightarrow Ca(OH)_2$

To sum up:

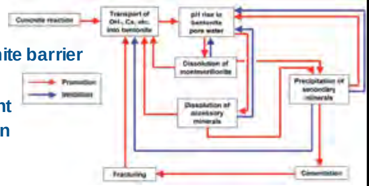
$C_3S, C_2S + H_2O \rightarrow C\text{-}S\text{-}H + Ca(OH)_2$



Source: ITC School (2008), Eurajoki, Finland © Posiva & CAU DIT COUMES C.: Basics of cement chemistry

Cement and concrete composition, behaviour, alkaline plume, pH

- **Cement water composition**
  - highly basic (pH = 12.5-13.5)
  - main components: OH^-, Ca^{2+}, K^+, Na^+, SiO_3^{2-}, SO_4^{2-}
- **Alkaline plume**
  - can influence bentonite barrier
  - some of the important processes involved in bentonite alteration



ITC School (2008), Eurajoki, Finland © Posiva:
R. Alexander: Applications and long-term safety and performance aspects II: a new natural analogue of bentonite alteration by low alkali cement leachates

Influence of alkaline plume on bentonite properties

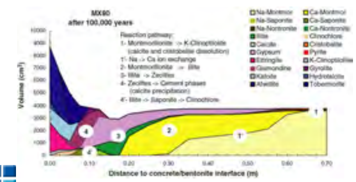
- **Effect of alkaline plume**
  - Effect of pH – influencing stability fields of various mineral phases
  - Effect of chemical composition – degradation products of concrete (especially alkaline waters rich in Na, K, Ca)

⬇

- Change in composition of bentonite porewater
- Accessory minerals dissolution
- New mineral phases formation and mineral transformation (both as a result of concrete degradation and bentonite alteration)
- Clogging of bentonite pore space by the newly-formed minerals

Influence of alkaline plume on bentonite properties

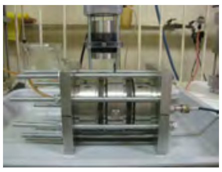
- **Effect of alkaline plume**
  - Long term processes – reaction paths and products depend on the concrete type, bentonite ionic form and accessory minerals presence
  - Important factors – temperature, time, volume of materials in the interaction, diffusion coefficients of species in bentonite
  - Modeling of long-term alteration and its spatial range in bentonite – important for the prediction of spatial range and alteration rate



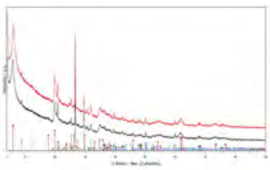
Example of modeling – Composition of a clay barrier after 100,000 years of interaction with an effective diffusion coefficient of $10^{-11}\ m^2.s^{-1}$ (from Gaucher and Blanc, 2006)

Influence of alkaline plume on bentonite properties

- **Small scale laboratory and physical models**
  - Spatial range depends on concrete type, used bentonite and time
  - Laboratory conditions often far from the repository conditions (high-pH solutions (e.g. NaOH), high temperature, low amount of bentonite® to obtain alteration products)
  - Physical models and URL experiments close to real conditions are very time-consuming, amount of alteration products may be very low



Physical Interaction Model of the EPSP plug (project DOPAS)

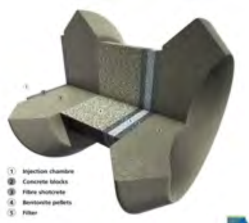


Bentonite RTG diffraction patterns after 20 months (red line) and after 26 months (black line) of bentonite 75 interaction with OPC in underground laboratory Josef conditions (from project FR-TI1/362)

Concrete mixtures for EPSP

- **Concrete plugs in EPSP are constructed of sprayed fibre concrete**
- **Low-pH concrete mixtures were developed in cooperation on the experimental basis of ÚJV and subcontractor**
- **Two mixtures were tested in experimental niche in URL Josef**
- **Composition:**
  - cement CEM II/B-M,
  - micro silica,
  - aggregates 0-4 & 4-8,
  - glass fibres,
  - plasticiser,
  - retardant and accelerator.

Exact recipe of the mixture is the internal know-how of the subcontracting company



3D model of EPSP (DOPAS Project)

Concrete mixtures for EPSP

- **Material properties of concrete plug were projected to fulfill following limits (with norms or procedures of testing):**

- leachate pH < 11.7	(Alonso et al. (2012) - SKB R-12-02)
- compressibility strength > 30 MPa	(ČSN EN 12390-3)
- flexural strengths > 3 MPa	(ČSN EN 14488-3)
- hydraulic conductivity < 10^{-8} m/s	(ČSN CEN ISO/TS 17892-11)
- fibre content > 3 kg/m^3	(ČSN EN 14488-7)

- **Control measurements have confirmed fulfillment of limits and conditions**

pH of the leachate = 11.4-11.5
compression strength: 44.4 MPa
flexural strengths: 5.8 MPa

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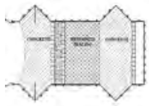
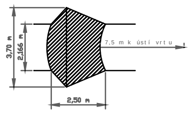
Role of the plug in the Czech DGR concept

- **Concrete plugs of disposal boreholes (horizontal disposal concept)**
  - Simple mechanical plug, main role is to seal the disposal borehole
- **Concrete plugs of galleries (both concepts)**
  - Combined mechanical/hydraulic plug
  - Prototype plug for Czech deep geological repository



Prototype of combined pressure sealing plug, realized as EPSP in Josef underground laboratory (DOPAS Project)



Reinforced concrete plug for the disposal borehole sealing (from Update of Czech Reference Programme, 2012)

- **Main role of plugs – closure of filled boreholes or galleries, mechanical function**

19

Role of other concrete materials in the Czech DGR concept

- **Concrete waste package for HLW**
  - Waste isolation, main waste package for HLW disposal in the repository
- **Concrete filling of HLW caverns**
  - Filling of empty space in HLW caverns after waste packages disposal, final sealing of the caverns
- **Concrete groutings**
  - Usage when necessary
- **Concrete plugs for deep boreholes**
  - Usage when necessary
- **Concrete obstruction plug (whole repository closure)**

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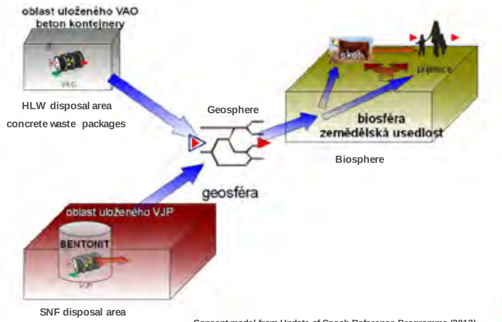
HLW disposal
Concrete containers in separate compartment



Concept model from Update of Czech Reference Programme (2012)

21

R&D on the topic of radionuclide behaviour under cement matrix conditions

- **Scientific support of safety assessment of Czech deep geological repository (DGR) project (2014-2018)**
  - Behaviour of cement matrixes being used for solidification in ÚJV (for institutional waste), in Bratrství and Richard ILW repositories (pH, leaching stability, strength properties)
  - Radionuclide solubility and migration through the material under leachate conditions
- **CEBAMA Euratom H2020 Project (2015-2019)**
  - Long term interaction with bentonite
  - Change of migration properties due to interaction

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- **All presented pictures and photographs (provided they are not otherwise copyrighted) are for non-commercial use only**

- **References**

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  - Alexander R.: Applications and long-term safety and performance aspects II: a new natural analogue of bentonite alteration by low alkali cement leachates
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- ČSN EN 14488-3: Testing sprayed concrete - Part 3: Flexural strength (first peak, ultimate and residual) of fibre reinforced beam specimens
- ČSN CEN ISO/TS 17892-11: Geotechnical investigation and testing - Laboratory testing of soil - Part 11: Determination of permeability by constant and falling head
- ČSN EN 14488-7: Testing sprayed concrete - Part 7: Fibre content of fibre reinforced concrete

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DOPAS Training Workshop 2015

Siting in the Czech Republic

Lukáš Vondrovic

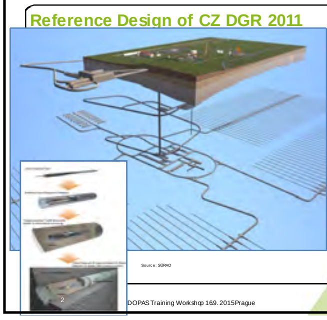
16 September 2015

D3 7.1

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

Reference Design of CZ DGR 2011



Source: SÚRAO

- The basic fuel back end concept consists of the **direct disposal of spent fuel** in **steel based canisters** in **a crystalline host rock**
- Depth: 500 - 600 m
- Operation period **2065 – 2140**

Site Selection Programme for Final DGR Site 2015 - 2025

- Near surface geological survey of preselected sites (7) – now
- Evaluation of primary data from sites and selection of the most suitable sites on the basis of preliminary safety
- Evaluation and other socioeconomic, political and environmental criteria (2016)
- Geological survey of selected sites with deep boreholes (2018 – 2019)
- Evaluation of sites and selection of 2 candidate sites for Government decision (2019/2020)
- Detailed characterisation at 2 candidate sites (2020 – 2024)
- Evaluation of the candidate sites and selection of the final site (2025)

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

Sites

- 7 sites
- Proposed exploration areas
- Located in the crystalline rocks 515 - 320 Ma
- Crystalline = granites and metamorphic rock

Advantages:
strength, homogeneous composition,
low permeability, stable environment

Source: SÚRAO

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

Rocks

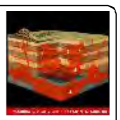
Granite

Plutonic rock origin from depth 5-10 km

Main minerals: quartz, felds, mica, amphibole

More precisely: granite, granodiorite, syenite, durbachite

Source: Isogeo



Source: www.geology.com

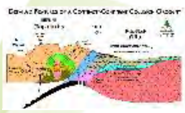
Granulite / migmatites

Metamorphic rocks HT-MP condition 20 km depth

Granulites: feldspar, garnet, quartz

Migmatites: quartz, felds, micas

Source: Isogeo



Source: www.geology.com

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

Sites

Čertovka

Granite, 515 Ma Tis pluton, reflected the Cambro-ordovician extension

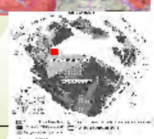
Teplá-Barrandian Unit (west)

East part sediments of the Žihle basin (sandstones, arkose)

Proposed exploration area: 29 km²

Source: SÚRAO

Source: SÚRAO



Source: SÚRAO

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

SÚRAO

Sites

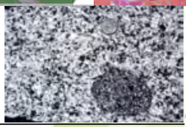
Březový potok

Granodiorite, 350 Ma, reflecting subduction processes

Central Bohemian plutonic complex

Moldanubian Unit

Proposed exploration area: 23 km²



Geological Disposal of Spent Nuclear Fuel in the Czech Republic

SÚRAO

Sites

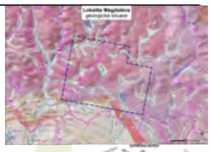
Magdaléna

Syenite, 340 Ma, mixing of the earth crust and mantle material

Central Bohemian plutonic complex

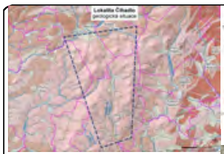
Moldanubian Unit

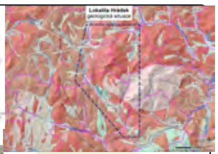
Proposed exploration area: 23,5 km²

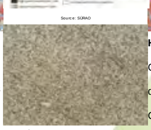


Geological Disposal of Spent Nuclear Fuel in the Czech Republic

SÚRAO







Čihadlo

Granite, 328 Ma Klenov pluton

Decompressional melting of deep seated rocks

Central Moldanubian Plutonic Complex

Moldanubian unit

Proposed exploration area: 24 km²

Hrádek

Granite, 330 Ma

decompressional melting of deep seated rocks

Central Moldanubian Plutonic Complex

Proposed exploration area: 25 km²

Geological Disposal of Spent Nuclear Fuel in the Czech Republic

SÚRAO

Sites

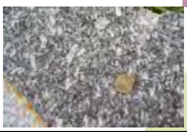
Horka

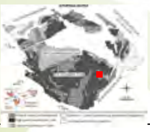
Durbachite, 340 Ma Třebíc pluton,

Mixing of the earth crust and mantle material

Moldanubian Unit

Proposed exploration area: 28 km²





Geological Disposal of Spent Nuclear Fuel in the Czech Republic

SÚRAO

Sites

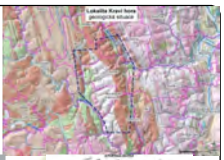
Kraví Hora

Granulite/migmatite 340 Ma

High-grade rock, continental collision

Moldanubian Unit

Proposed exploration area: 18 km²



Exploration programme stage I

SÚRAO

- Near surface geology
- Narrowing the numbers of potential localities
- **Aims:**
- Geological map (3D model)
- Verification of faults and brittle structures
- Hydrogeological model
- Define possible block in level of repository

Exploration programme stage I

SÚRAO

Geological mapping

Synthesis of all exploration methods

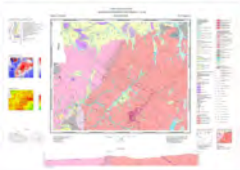
3D visualization of geological pattern

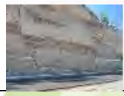
Visualization:

Rock types

Ductile and brittle structures

Geological pattern in the depth





Exploration programme stage I

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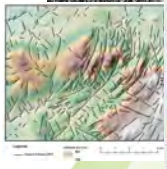
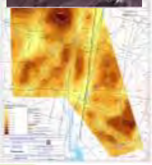
Remote sensing

Satellite and radar image

3D topographical model

Defining the brittle fractures





Exploration programme stage I

SÚRAO

Geophysics

Study of „fields“

Definition of: faults, rock types, geological boundaries

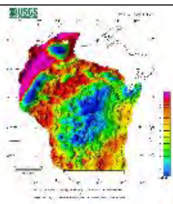
Fields:

Gravity
Regional structures, depth evolution

Electric
Local faults

Magnetic
Faults, rock types

Seismic
Geological boundaries, faults



Exploration programme stage I

SÚRAO

Site selection

Criteria:

- Project
- Safety (geology)
- Environmental
- Socio-economic

Generic research for DGR

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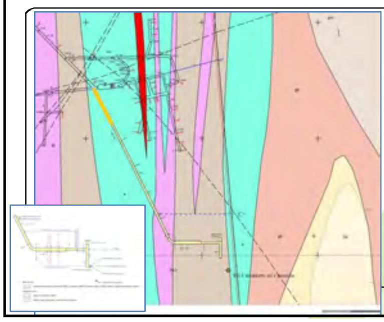


URF Bukov

- Crystalline rocks – gneisses, migmatites with sequences of fractures
- Depth – 600 m below surface
- Construction - 2013 – 2016
  - 1st research project parallel with construction – Pilot Rock Characterisation / Site Descriptive Model
- Operation until 2025 …??)
- Research projects
  - Long-term properties of canister materials in reducing conditions
  - Rockmatrix diffusion properties in crystalline rocks
  - T-H-M-C properties of the rock

Generic research for DGR

SÚRAO

Bedřichov Water Supply Tunnel

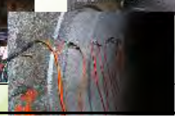
Construction period:
§ 1981-83

Tunnel profile:
§ Circular 3,6m diameter

Building technology:
§ drill and blast 1705 m,
§ TBM 890 m

Tunnel depth:
§ max. 140 m

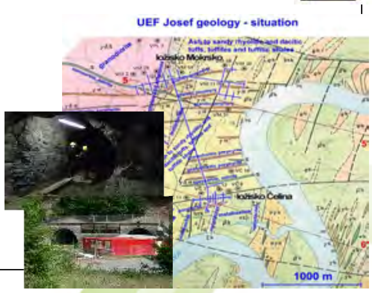
Uncovered granite:
§ total 1397 m
§ TBM section 787 m



Demonstration research for DGR

Josef Gallery

- Operated by CTU
- Demonstrations projects
- Training activities
- Supported by ministries and SÚRAO



Thank you for your attention

Fig. 7. Example of how the surface facility for access to the geological repository might also look

vondrovic@surao.cz

www.surao.cz

DOPAS

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project. Included images are for non commercial use

DOPAS
Training Workshop 2015

Communications and Public Involvement in the Czech Republic

Lucie Steinerová
September 16th 2015

D3 7.2

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Implementing Public Participation Approaches

Lucie Steinerova
Communications Manager

SÚRAO

Welcome in the Czech Republic!

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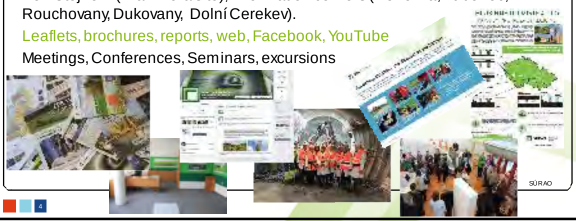
Communications activities

Media servis – every day responsibility

Information centres: Prague, Richard, Litoměřice IC, Jáchymov, Bystřice nad Pernštejnem (Kraví Hora site), information corners (Rohozná, Lubenec, Rouchovany, Dukovany, Dolní Cerekev).

Leaflets, brochures, reports, web, Facebook, YouTube

Meetings, Conferences, Seminars, excursions



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Involvement in the regions with operated repositories

Based on Atomic law

Municipalities with operated repositories (Jáchymov, Rouchovany, Litoměřice) has a member in Board of SÚRAO

- Each of them receives grant 3 million CZ Crowns from Atomic Account
- Close cooperation
- International experience

Incentives during geological research for DGR

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Communication and information tools

6

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Social science in the DGR siting process

2005 - 2009 technical work stopped

- Need for a new approach – participation, openess, dialogue
- Opinion surveys showed:
  - Support to nuclear energy – support to the idea of final solution of the fuel cycle
  - NIMBY
  - Need for more information
  - Need of a fair dialogue
  - Low level of trust
- International experience
- ARGONA project (Euratom) – application of a RISCOM model into the Czech case
  - First stakeholders groups – „Reference group"

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Public involvement

By the ARGONA project - first public hearing in May 2009

- **2007-2009: ARGONA Project (Euratom)** – first Reference Group for Stakeholders
  - ® **first Czech public hearing in May 2009**
- **November 2009:** National conference – „**Deliberation - Way to the Deep Geological Repository**"
  - under the auspices of the minister of industry and trade
  - ® **first Czech „round table" discussion across all stakeholders**
- **June 2010:** „**round table**" discussion how to establish transparency and open dialogue with all stakeholders
  - about establishing „Working group for Dialogue" independent discussion forum for set up transparency site selection with involving public
- **November 25th, 2010: ® first meeting of the Working Group for Dialogue** (delegates of state administration, local communities, local NGO, Czech NGOs, both Czech Parliaments Chambers, representative of SÚRAO)
- **2011-2013: IPPA Project (Euratom)**
  - Implementing Public Participation Approaches
  - End Users Conference, September 2013, Prague
- **Since 2012: FSC** – Forum on Stakeholder Confidence (NEA/OECD)
  - Facilitates the sharing of experience in addressing the societal dimension of RWM
  - FSC Meeting, October 2012, Prague + Carlsbad

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Working group on Dialogue about DGR

Established in November 2010

- To ensure mutual and meaningful dialogue on the DGR siting process
- Enforcement of municipalities in the process of DGR siting Þ proposals for legislative changes

Implementer is one of its members

Established as an advisory group of Ministry of Industry and Trade

2014 WG transformed under Governmental Council for Energy and Raw Material Strategy

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Full scale stakehoders group

33 members in 2015

Organization / Institution	Number of members
Municipalities	2 of each site
Ministry of Trade and Industry	1
Ministry of Environment	1
State Office for Nuclear Safety	1
Radioactive Waste Repository Authority	1
Representatives of local NGOs (from localities)	1 of each site
NGOs (nationwide)	2
Parliament of the Czech Republic (Chamber of Deputies + Senate)	2
Expert – sociologist	1
Expert – selected by representatives of municipalities	1
Legislative expert	1

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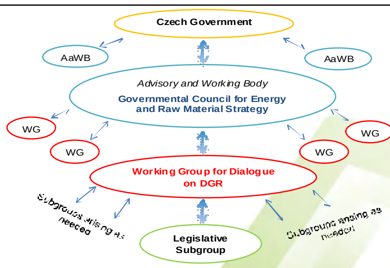

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New goals of the Working Group

- Involvement in the preparation of the new Act on the Deep Geological Repository
- Discussion on the criteria for the site selection for DGR
- Debate on the Concept of Radioactive Waste and Spent Nuclear Fuel
- Extension of tools to inform and for the equitable distribution of compensation in the localities
- Establishing cooperation with foreign organizations of similar type as the WG for Dialog
- Collection of information and its distribution among the public
- Funding for these activities

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- Information on the WG activities from the international point of view at
- www.argonaproject.eu (2007- 2009) www.ippaproject.eu (2011-2014)

- SÚRAO is a member of FSC – Forum on Stakeholder Confidence OECD/NEA https://www.oecd-nea.org/fsc/

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Experience from abroad

Czech stakeholders group is based on Swedish experience

- Stakeholders group with a clear role in the transparent process - CR 5 years experience – beginners
  Adjusted to the domestic framework – legal framework, history, culture, socioeconomic background

- Hungary – information committees model – each site one commitee

- France – information and stakeholders groups with strict roles defined in law

- Belgium – Partnership – local groups in precisely defined parnership with the implementer (MONA, STOLA)

- Finland – site municipality communicates directly with the implementer

- NO SYSTEM OF COMMUNICATION CAN BE COPIED, BUT WE ALL CAN LEARN FROM EACH OTHER

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Thank you for your attention

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www.surao.cz

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DOPAS Training Workshop 2015
Participants and Tutors

Photo: (c) Marjatta Palmu

DAY 4

DOPAS TRAINING WORKSHOP 2015

Integration of Experimental Work and Process Modelling in Safety Assessment

André Rübel (GRS)

D4 3.3
17 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Introduction of GRS

Who is GRS?

- The Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) is a non-profit organisation which deals with technical-scientific research and provides expertise
- GRS was established as a business in January 1977. The headquarters are in Cologne, other sites include: Berlin, Braunschweig and Garching
- GRS is only financed by contracts and the present annual volume of contracts is worth 57 million €
- Main customers are:
  - The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
  - The Federal Ministry of Economic Affairs and Energy (BMWi)
  - The Federal Ministry of Education and Research (BMBF)
  - The Federal Foreign Office (AA)
  - The Federal Agency for Radiation Protection (BfS)
  - The European Commission

Major activities

- Research and development
  - Reactor safety
  - Radiation protection
  - Waste disposal
  - Environmental protection
- Analyses, assessments and expert opinions
- Scientific-technical services and support

Repository Safety Research Division
↳ Safety Analyses Department

What is safety?

Calvin and Hobbes are playing in the sandbox. Calvin builds a town out of sand. Hobbes is digging a hole.
Conversation:

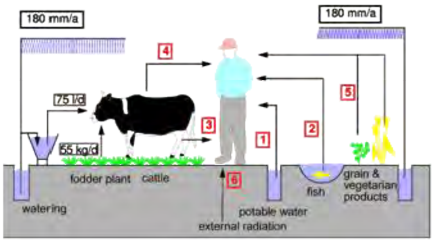
Picture 1:	C: Here's a little town. H: Here's a steam shovel scooping out a giant hole.
Picture 2:	C: Here comes the bulldozer, pushing thousands of barrels of toxic nuclear waste into the giant hole.
Picture 3:	C: Over the years, these dangerous poisons seep into underground waterways.
Picture 4:	C: The cancer rate of the nearby little town triples. H: If you want me, I'll be under the bed.

Comic not included in presentation for copyright reasons.

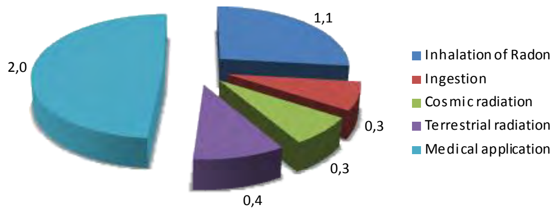
Bill Watterson, Calvin & Hobbes of June 9,1987

Safety assessment poses four key questions
- What might happen?
- When might it happen?
- What is the likelihood?
- What are the consequences?

Radionuclide exposure pathways



Mean radiation exposition of population in Germany



Mean natural radiation exposition: 2.1 mSv/a

Data from BfS

Past, present and future

Climate
Durability of constructions
Geology
Human behaviour

1 000 000 a — 100 000 a — 10 000 a — 1 000 a — 100 a — present

Pictures: Wikimedia Commons

Challenges

Large scale system

Heterogeneous system properties

Spatial and temporal variable system properties

Complex interaction between different processes

Manifold of uncertainties

System is regarded for very long timescales

Safety assessment approach

Long-term safety assessment

Major element of the Safety Case

- Quantitative Analysis of the long-term development of the repository
  - Full repository system
  - Compartments and geotechnical components
- Aims
  - Assessment of repository safety
    - Calculation of indicators related to humans
    - Comparison of results with regulatory limits
  - Increase of system understanding
  - Optimisation of repository concept

No prognosis of the radiation exposition of future population!

Approach

§ Site description
- Geology
- Hydrogeology
- Hydrology (regional/local)
- Biosphere

§ Repository concept

§ Geoscientific long-term prognosis of site

§ Description of processes
- Experimental results
- Process modelling
- Natural analogues

Many programmes use a FEP-catalogue

Scientific knowledge basis

Description of all relevant
§ Features
§ Events
§ Processes

Approach

Scenario

Scientific knowledge basis — Description of all relevant Features, Events, Processes

Scenario Development — Description of site evolution

Use of scenarios

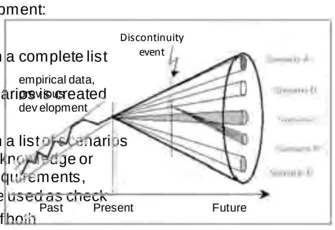
A scenario is a synthetic description of an event or series of actions and events
Create visions of possible future evolutions that have a potential impact on the safety of the repository under consideration of experience, knowledge and probability

Scenario development:

§ Bottom-up
- Starting from a complete list of FEPs, a list of scenarios is created

§ Top-down
- Starting from a list of scenarios collected by knowledge or regulatory requirements, FEP-lists are used as check

§ Combination of both



Graphic: Modified after Wikimedia Commons

Approach

Scenario

§ Description of site evolution
- expected evolution
- probable evolution
- less probable evolutions
- what-if cases

§ Stylized scenarios

Scientific knowledge basis — Description of all relevant Features, Events, Processes

Scenario Development — Description of site evolution

Approach

Model

§ Includes various simplifications to reduce complexity of
- Geometry
- Processes

§ Process Models

§ Integrated Models

Scientific knowledge basis — Description of all relevant Features, Events, Processes

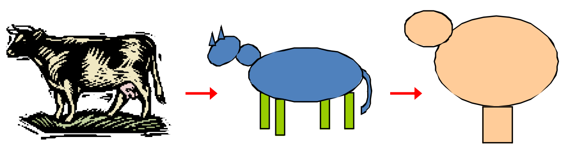
Scenario Development — Description of probable and less probable evolutions including what-if cases

Assessment Model — Representation of scenario

Simplifications to handle complexity in modelling

§ Not all processes in real system can be described
§ Computing time too high for thousands of simulations over Mio. of years

Realistic Model | **Process-Level Model** | **Integrated Model**



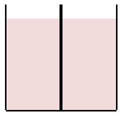
Observation by experiment

Mechanistic understanding
§ High detail of description
§ Long computing time
- Subsystems
- Short timespan
- Few simulations

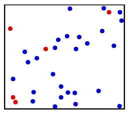
Abstraction describing behaviour
§ Lower detail of description
§ Short computing time
- Total system
- Full timespan
- Large amount of simulations

Example

Observation (Experiment) | **Mechanistic Model (Process-Level Model)** | **Phenomenological Model (Integrated Model)**



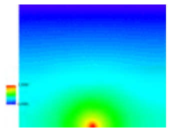
Transport by diffusion



Brownian Motion

$$\frac{\partial \rho}{\partial t} = \frac{\partial^2 \rho}{\partial x^2} \times \int_{-\infty}^{+\infty} \frac{\Delta^2}{2\tau} f(\Delta)\, d\Delta +$$

higher order even moments



Fick's law

$$J = -D \frac{\partial c}{\partial x}$$

Animation: Wikimedia Commons

Qualitative temporal evolution of uncertainty of processes

Transient period | Disposal system stability | Geosphere evolution

Uncertainty range

Time [a]

100 1 000 10 000 100 000 1 000 000

Quantify by predictions with process models

Quantify by predictions with integrated models

Approach

Consequence Analysis

Calculation of indicators
- Safety indicators
  - Comparison with regulatory limit yields safety statement (dose / risk)
- Performance indicators
  - increase of system understanding
  - optimisation of repository concept
- Iterative process

Scientific knowledge basis — Description of all relevant Features, Events, Processes

Scenario Development — Description of probable and less probable evolutions including what-if cases

Assessment Model — Representation of scenario

Consequence Analysis — Calculation of indicators and comparison with limits

Approach

Scientific knowledge basis — Description of all relevant Features, Events, Processes

Scenario Development — Description of probable and less probable evolutions including what-if cases

Assessment Model — Representation of scenario

Consequence Analysis — Calculation of indicators and comparison with limits

Meet criteria?

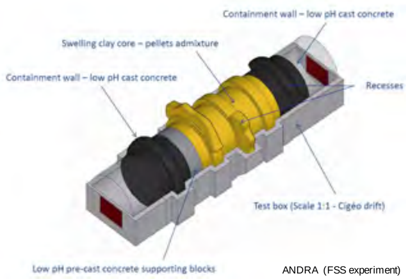
Yes

No / optimisation

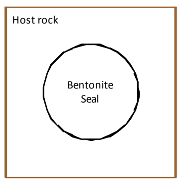
Iteration

Process modelling of sealings

Coupling of processes – Example: Resaturation of a clay sealing



ANDRA (FSS experiment)



Coupling of processes – Example: Resaturation of a clay sealing

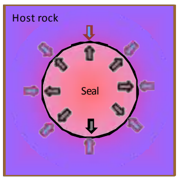
Thermal, **H**ydraulic, **M**echanical **C**hemical Processes

Inflow of water from host rock (H)
Change of thermal conductivity ð (T)

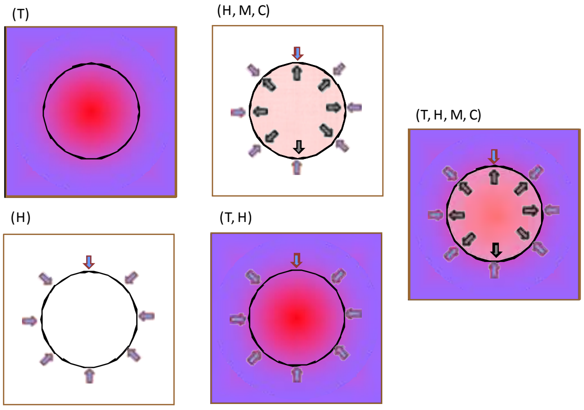
Rise of temperature (T)
Expansion of water ð (H)

(H) ð Uptake of water by Bentonite which is not in chemical equilibrium (C)
Change of Bentonite composition
Change of Bentonite permeability ð (H)

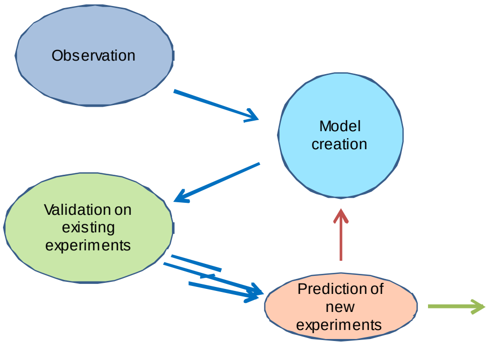
(H, C) ð Swelling of Bentonite (M)
Increase of swelling pressure
Change of permeability of EDZ ð (M, H)



Decoupling of processes – Example: Resaturation of a clay sealing



Validity of models



Process-level modelling codes used in DOPAS

§ Commercial:
- Particle Flow Code (PFC™) (M) http://www.itascacg.com/software/pfc
- 3DEC™ (M) http://www.itascacg.com/software/3dec
- ALGOR (M) http://www.algor.com
- FEFLOW (H) http://www.mikepoweredbydhi.com/products/feflow

§ Research (Free):
- EQ3/6 (C) https://missions.llnl.gov/energy/technologies/geochemistry
- PhreeqC (C) http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc
- Code_Bright (T,H,M) https://www.etcg.upc.edu/recerca/webs/code_bright
- OpenGeoSys (H) http://www.opengeosys.org

§ Company owned:
- CLOE (H,M)

Remark: Codes might have additional capabilities (THMC) that haven't been used in DOPAS

Processes modelled in DOPAS

§ Hydraulic modelling
- Temporal evolution of seal permeability
- Flow rates of fluid through the seal with time
- Temporal evolution of the pore saturation
- Pore pressure of fluids in the seal

§ Hydraulic / Mechanical modelling
- Temporal evolution of the sealing porosity
- Total pressure of the seal

§ Mechanical modelling
- Mechanical stress and load of the seal

§ Chemical Modelling
- Mineral phase changes in sealing material

Integrated performance assessment modelling of sealings

Integrated performance assessment modelling

- No total system performance assessment is performed in DOPAS

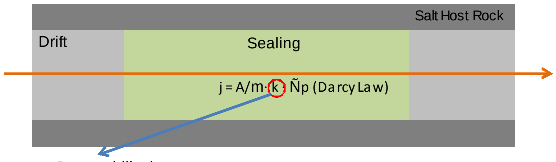
...but

- Development of integrated performance assessment models
  - Using experimental results
  - Using process modelling
- Modelling of sub system (sealing) using integrated assessment code

Aim:

- Better representation of sealing in integrated assessment code
- Reduction of uncertainty

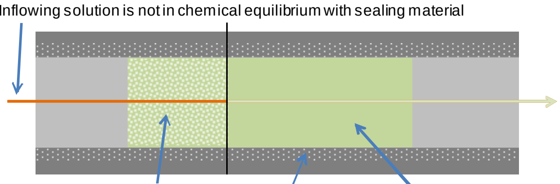
Sealing in integrated PA: So far…



Permeability: k
- uniform average value across cross section of sealing
- stepwise constant in time
- conservative values are used to match assumptions

Sealing in integrated PA: Closer to reality?

Inflowing solution is not in chemical equilibrium with sealing material



Sealing material is disturbed
→ permeability is increasing

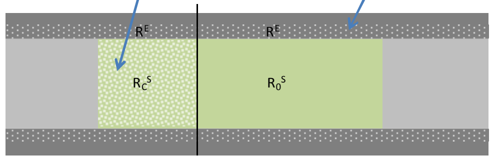
Original sealing material

Excavation disturbed Zone (EDZ) around sealing with increased permeability

Sealing in integrated PA: New!

Corroded Sealing
k = f(j,k) from experiments

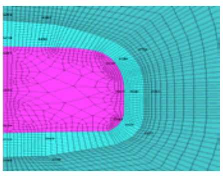
EDZ: k = f(t)



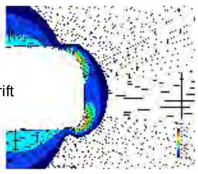
$$R = R_C + R_0 = \frac{R_C^E R_C^S}{R_C^E + R_C^S} + \frac{R_0^E R_0^S}{R_0^E + R_0^S} = \frac{R_C^E R_C^S \left(R_0^E + R_0^S\right) + R_0^E R_0^S \left(R_C^E + R_C^S\right)}{\left(R_C^E + R_C^S\right) \times \left(R_0^E + R_0^S\right)}$$

$$R_0^S = \frac{m_C L_0}{A^S k_0^S},\ R_0^E = \frac{m_C L_0}{A^E k_0^E},\ R_C^S = \frac{m_0 L_C}{A^S k_C^S},\ R_C^E = \frac{m_0 L_C}{A^E k_C^E}$$

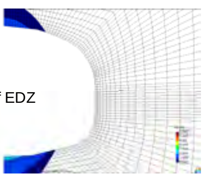
Process modelling (I): Mechanical modelling of EDZ (drift seal)



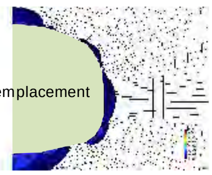
Open drift



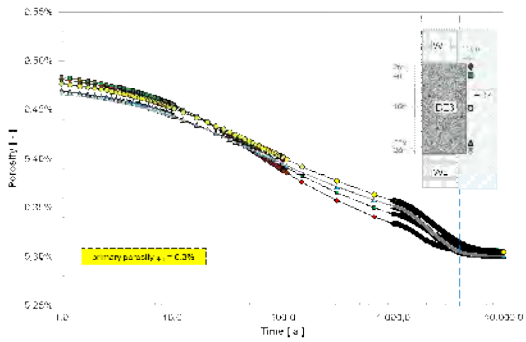
Cutting of EDZ



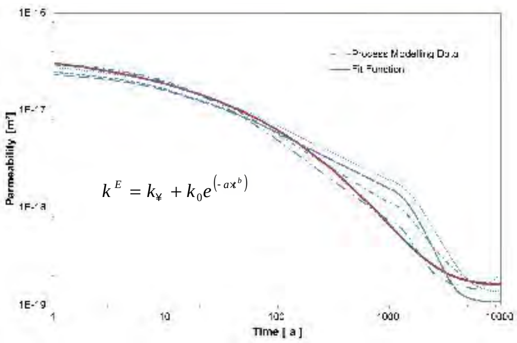
After seal emplacement



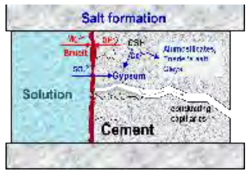
Process modelling (I): Mechanical modelling of EDZ (shaft seal)



EDZ behaviour used in integrated model

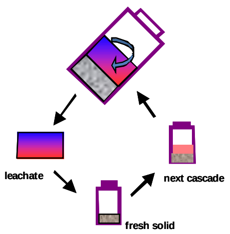


Process modelling (II): Geochemical modelling of material dissolution

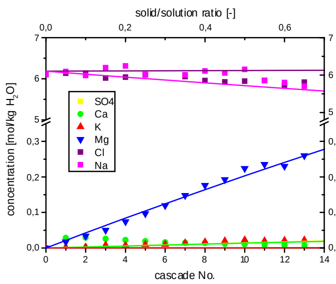


Process modelling (II): Geochemical modelling of material dissolution

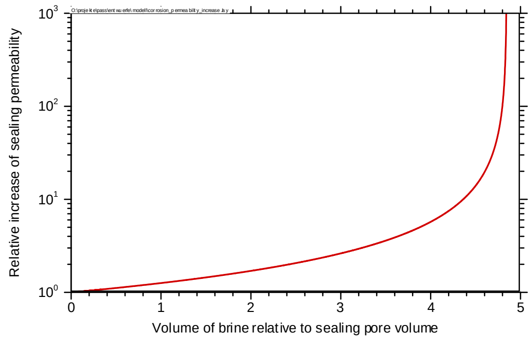
Experiment



Process modelling on experimental data



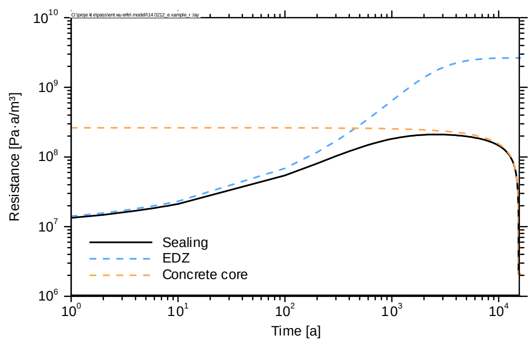
Material behaviour used in integrated model



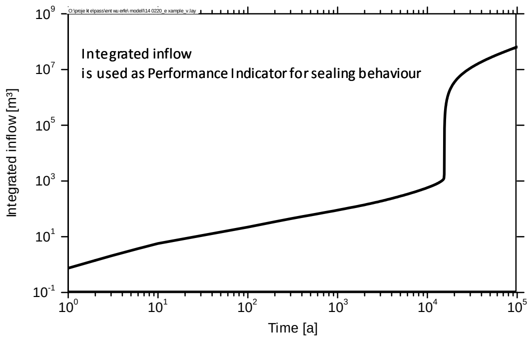
Integrated model: Illustrative example calculation

Parameter		Value
Length of the sealing	[m]	30
Diameter of the sealing	[m]	7
Hydraulic pressure at sealing	[MPa]	10
Viscosity of brine m	[Pa s]	$5.3\cdot10^{-3}$
Porosity of salt concrete material f	[-]	0.2
Initial permeability of salt concrete material	[m²]	$5\cdot10^{-19}$
Permeability of corroded salt concrete material	[m²]	$1\cdot10^{-14}$
Corrosion capacity of the brine $k_{L,V}$	[l/l]	1
Extension of the EDZ	[m]	1
EDZ initial permeability k_0	[m²]	$4.5\cdot10^{-17}$
EDZ long-term permeability k_∞	[m²]	$1.6\cdot10^{-19}$
EDZ fitting parameter a	[-]	0.4
EDZ fitting parameter b	[-]	0.35

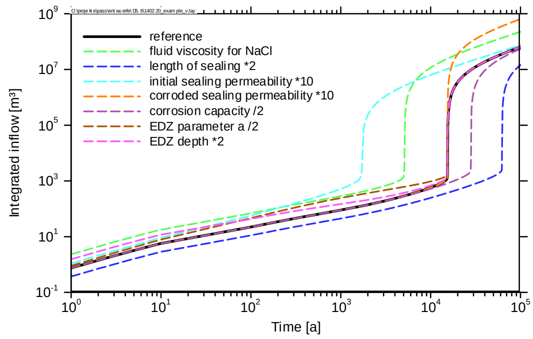
Integrated model: Hydraulic resistance of a sealing



Integrated model: Integrated inflow



Integrated model: Parameter variations



Managing Uncertainties

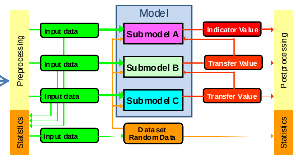
Type of uncertainties

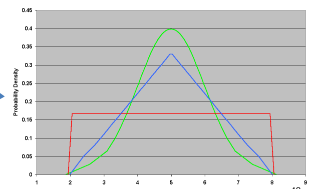
- Epistemic
  - Knowledge based
  - Reducible
    - Parameter uncertainties
    - Model uncertainties
- Aleatoric
  - Random
  - Irreducible
    - Scenario uncertainties

Managing Uncertainties

- Mitigation
  - Reduce by better characterisation
- Argument
  - Qualitative argument
  - Uncertainty not important
- Assessment
  - Estimate/quantify uncertainty

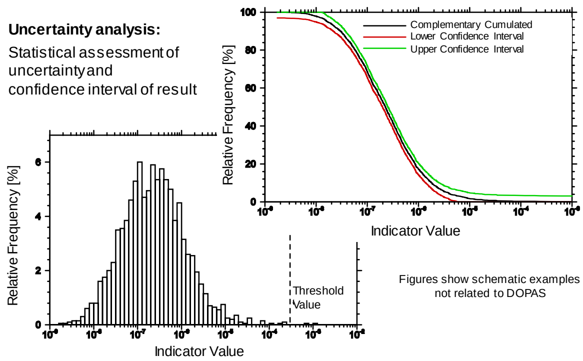
  - Probabilistic Assessment
  - Monte Carlo Simulations
    - Large number of runs
    - Probabilistic varied parameters





Probabilistic Monte-Carlo-Analysis of large number of simulations

Uncertainty analysis:
Statistical assessment of uncertainty and confidence interval of result



Figures show schematic examples not related to DOPAS

Probabilistic Monte-Carlo-Analysis of large number of simulations

Sensitivity analysis

- Identification of parameters which contribute most to uncertainty
- Arbitrary example not related to DOPAS:

	Parameter	Spearman Test	Rank Correlation	FAST	EFAST
1	Initial permeability	1	1	1	1
2	Mg-content of solution	2	2	2	2
3	...	3	3	3	3
4	...	4	4	4	4
5	...	6	6	6	6
6	...	5	5	5	11

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§ References for further reading:

- For further reading look at the final reports of the Integrated Project PAMINA which was part of the 6th framework programme of the European Commission. The material van be found here: http://www.ip-pamina.eu
- An overview can be found in the

"*European Handbook of the state-of-the-art of safety assessments of geological repositories*"

which can be downloaded here: http://www.ip-pamina.eu/downloads/pamina1.1.4.pdf

Acknowledgement

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DOPAS
Training Workshop 2015

D4 4.1.1
Risk management for large-scale experiments and work underground

Pär Grahm, SKB
14 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Scope of this lecture

- The process of risk management (PMBOK Guide®)
  Planning - Identification – Assessment – Response development – Control
- Practicalities related to risk management
- Special features of risk management of large-scale experiments and underground work

Why care about risks?

- Ensure to follow legal requirements
- Avoid people getting injured
- Protect the environment
- Control of costs
- Keep confidence in the project
- Trust in the business (a company threat)
- Use lessons learned
  (making the same mistakes again and again is insanity..).

What is a project risk?

1. Cumulative effect of the probability of uncertain occurrences that may positively or negatively affect project objectives.
2. Degree of exposure to negative events and their probable consequences (opposite of opportunity). Characterized by three factors: risk event, risk probability, and amount at stake.

Ref. Project Management Terms. by J. LeRoy Ward

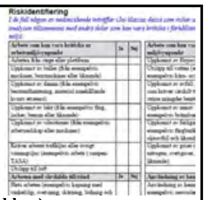
Five Risk Management processes

1. Planning
2. Identification
3. Analysis and assessment of risks
4. Risk response development
5. Control and follow-up

1. Planning (according to SKB)

- Risk analysis is initiated in the early project planning, as soon as the scope of the project has been defined.
- Risks must be continuously reviewed during a project.
- Before start of work-activities in the field (underground) a detailed risk analysis must be performed and documented. The basis for this analysis is the work plans.
- Involve different professional categories when the risk analysis is carried out.
- Clarify responsibilities for the work.
- Pre-job brief (where contractors participate)!

2. Identification of risks



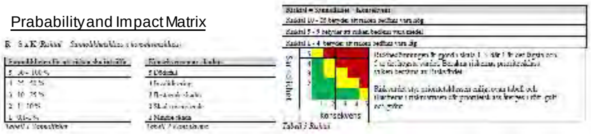
- Where do we start? How is it done?

- Review the project plan
- Review the defined scope statement (WBS)
- Use a checklist (if available)
- Search for experience (involve staff and stakeholders)
- Brainstorming, interviews, rout cause analysis, group discussions etc.

- The identified risks are documented in a separate "risk register" which will also include the triggers that indicate the occurrence of the event that took place.
- Categorize risks for better focus.

3. Analysis and assessment of risks

- Prioritize risks for further analysis or action by assessing and combining the probability of occurrence of the risk and its impact.
- Use a pre-defined template, example from SKB:



- The risk register can be used for further quantitative analysis such as economic uncertainty of project budget.

4. Risk response development

- A risk that has been assessed as "High risk" or "Medium risk" shall always have a response action!
  - Avoid
  - Transfer
  - Mitigate
  - Accept (actively/passively)
- A risk that has been assessed as "Low risk" needs no response action but remains in the risk register for control.
- Responsibility for each risk response is delegated, including a time plan to allow follow-up.

5. Control and follow-up of risks

- Use the risk register in project meetings, for communication with stakeholders and status reporting.
- The Project Manager (or delegated work responsible person) should always include in the project meeting agenda the task of re-evaluation of the prioritized risks.
- Some risks perhaps need to be handled on a company level.
- Close the risk when the work package is completed.
- Don't forget to identify new risks!

General concerns for work underground

- Falling stones
- Fire (smoke)
- Evacuation of staff
- Logistics
- Narrow spaces (loss of breathing air)
- Falling (trap doors, holes, uneven/slippery floor)
- Lifting and transporting heavy items
- Lack of visibility
- Foreign materials (effect of chemicals etc.)

Special risk features for large-scale experiments underground

- Important to have knowledge about the site and experimental conditions:
  - Groundwater inflows and its chemical composition
  - Fractures in the rock
  - Geodetic measurements
- High water pressure conditions
- Challenges in logistics (installations, transports, timing)
- Management of primary data from sensors

Case example of POPLU

- Presentation by Mr. Petri Koho

Group exercise (no 5) on Risk Management

- Identifying and prioritizing risks for full-scale experiments
  - G1: DOMPLU
  - G2: POPLU
- Instructions:
  - Practice step 2 "Identification" and Step 3 "Assessment"
  - Focus on risks during installation of the full-scale test
  - No need to identify "administrative risks" such as purchasing, contracting or lack of resources.
  - Check DOMPLU and POPLU presentations for information about project objectives and technical installations.

DOPAS

Thank you!

www.posiva.fi/en/dopas

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

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DOPAS Training Workshop 2015

Case Example of POPLU Experiment

Petri Koho, Posiva
17th September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

D4 4.1.2

2

Outline of the Lecture

- POPLU Project Objectives and Expectations
- Design of the POPLU Experiment
  - Rock Suitability Classification of Demonstrations Tunnels and Plug Location
  - Plug Design and Concrete Development
  - Instrumentation and Test Planning
- Implementation of the POPLU Experiment
  - Tunnel Excavation and Plug Slot Production
  - Plug Construction and Concrete Method Tests
  - Instrumentation Installation
- Forthcoming Activities

3

POPLU Project Objectives

Addressing YJH-2012:

- Construction of full-scale deposition tunnel end plug (demonstration, workmanship, quality control)
- Detailed structural design, including concrete recipe development for plug
- Tunnel excavation development, *(wire-sawing technique)*
- Producing quality manual for quality control practices and risk mitigation for plug
- Instrumentation and performance monitoring (mechanical load transfer, concrete shrinkage, water tightness), including models

POPLU is linked to SKB's full-scale dome plug test (DOMPLU)

4

Plug Performance Expectations (VAHA)

- The plugs shall isolate the deposition tunnels hydraulically during the operational phase of the repository. (L3-BAC-9)
- The chemical composition of the backfill and plugs shall not jeopardise the performance of the buffer, canister or bedrock. (L3-BAC-13)
- The plugs shall keep the backfill in place during the operational phase. (L3-BAC-18)
- The plugs shall consist of materials that have a good hydraulic isolation capacity and that will not undergo large volume changes in the long term. (L4-BAC-2)
- The plugs shall be designed to maintain their hydraulic isolation capacity at least as long as the central tunnels are open. (L4-BAC-6)
- The plug shall be designed to withstand the sum of the swelling pressure of the backfill and the hydrostatic pressure of the groundwater at the repository depth. (L4-BAC-13)
- The plugs must be designed to maintain a backfilling function even after their hydraulic isolation capacity has been lost. (L4-BAC-14)
- Backfill and plug materials shall be selected so as to limit the contents of harmful substances (organics, oxidising compounds, sulphur and nitrogen compounds) and microbial activity. (L4-BAC-18)

5

Additional Initial Plug Expectations

- Plug should endure 7.5 MPa total pressure (4.5 MPa water pressure, 3 MPa expected swelling pressure)
- Design working life for the plug is 100 years
- The plug has a high water tightness (comparable to DOMPLU)
- Hydraulically conductive fractures shall not intersect the entire length of the plug
- Smooth/flat excavated rock surfaces at plug abutment (requirements to be determined), discontinuous excavation damage zone (EDZ)
- Low pH-concrete to be used
- May use steel and/or fibre reinforcement in concrete
- Filter and seal layers can be incorporated if necessary
- All material shall be checked and approved by the safety analysis team

(green = applicable to POPLU test, red = not applicable to POPLU test)

6

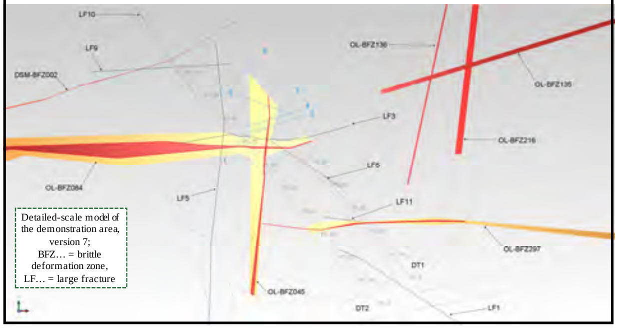
Design of the POPLU Experiment – Tunnel and Plug Slot Location Planning

- The Rock Suitability Classification (RSC) -system was used to select the locations of the two demonstrations tunnels needed for the POPLU experiment and the location of the plug within the tunnels
- The RSC-system has been developed by Posiva to evaluate natural properties of the repository host rock for the purpose of locating suitable rock volumes for the various parts of the repository e.g. hosting a deposition tunnel
- The criteria are based on requirements stemming from aspects of long-term safety, related to the functioning of the bedrock as a natural barrier as well as to ensuring proper conditions for the functioning of the EBS-system
- The criteria mostly deal with
  - Chemical composition of the groundwater
  - Groundwater flow
  - Mechanical stability of the host rock

Rock Suitability Classification for POPLU – The Starting Situation

7

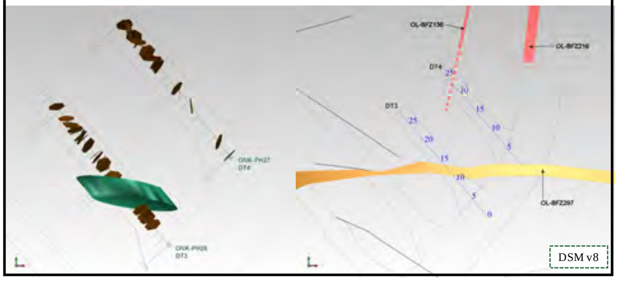
The area immediately northeast of the existing demonstration tunnels 1 and 2 was considered a possible location for the POPLU experiment on the basis of investigations and detailed-scale modelling of bedrock structures carried out earlier, during the construction of the two demonstration tunnels.



Rock Suitability Classification for POPLU – Pilot Hole Investigations

8

- To further verify the suitability of the selected location, a pilot hole was drilled within the profile of each planned tunnel
- The pilot hole drilling was done at the end of November 2012
- Posiva's standard set of drill hole investigations was carried out in the holes



Rock Suitability Classification for POPLU – 1st Suitability Classification (”deposition tunnel”)

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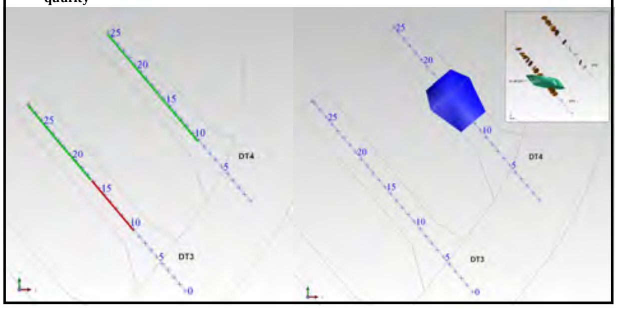
- The first suitability classification was carried out in February 2013
- Chainage 9.00 - 16.20 m of the demonstration tunnel 3 was classified unsuitable for a plug
- In all other locations the criteria set for bedrock hosting a plug were determined to be fulfilled
- It was suggested, that chainage 11 - 17 m in DT4 would preliminarily be chosen for the location of the POPLU plug, as the tunnel section in question would likely be the best in rock quality



Structural Design of POPLU Experiment

10

- The structural analysis and detailed design of the POPLU experiment commenced in Autumn 2012
- In addition to the concrete plug component and stainless steel reinforcement it contained the design of
  - Backwall
  - Filter layer
  - Tunnel-to-tunnel and plug lead-through pipes
- The basis of the structural design were
  - 100 years design service life; material requirements, crack control
  - 7.5 MPa pressure behind the plug; leak tightness, structural strength
  - Temperature differences
- Leak tightness of the concrete plug component is ensured by
  - 3 strips of bentonite tape around the plug circumference
  - 6 injection loops around the plug circumference

Structural Design of POPLU Experiment

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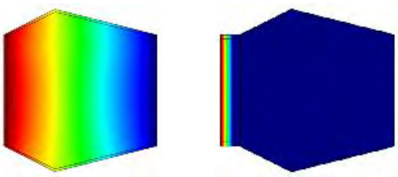
- Water tightness of the POPLU design was modelled with different seal layer material options and configurations
- The modelling showed that adding a clay component to the plug design increases the water tightness of the design (learned also from the previous full-scale experiments and DOMPLU)
- No clay component was added to the POPLU design as the idea of the POPLU experiment is to demonstrate the performance and water tightness of a plug design with no additional component layers



Structural Design of POPLU Experiment

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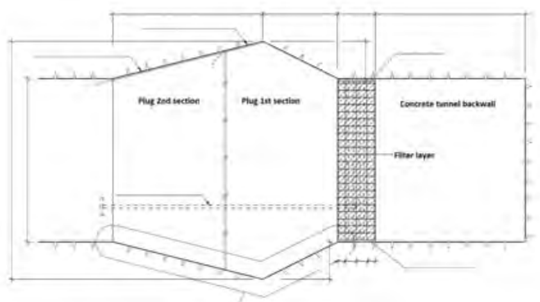

Concrete plug component: length 6 m, width 6 m, height 7 m
Filter layer: length 1 m, width 4 m, height 5 m
Backwall: length 3 m, width 4 m, height 5 m

Low-pH Concrete Recipe Development

13

- The concrete recipe development for the POPLU experiment commenced in Autumn 2012
- Objectives set for the concrete development
  - Low amounts of cement for low PH
  - Minimal shrinkage
  - Workability: Self compacting concrete (SCC)
  - Low permeability
- Three different concrete mix designs were developed
- Mix designs were modified versions of Swedish plug concrete and Canadian plug concrete (from previous full-scale experiments)
- Two concrete mix designs were chosen to large scale (factory) testing
- The concrete mix for POPLU was selected based on the results of the factory testing and recommendation from foreign materials approval
- Cement based low-pH injection grout is under development for contact grouting

Low-pH Concrete Recipe Development

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	POPLU Target	POPLU Concrete	"Normal concrete"
Compressive strength, MPa	> 50	79.5	50
Split tensile strength, MPa	3.2	4.5	3.2
Modulus of elasticity, GPa	34	34.2	34
Autogenous shrinkage, mm/m	(min)	0.15	0.1
Drying shrinkage, mm/m	(min)	0.22	0.6
Water tightness, mm	max 50	5.0	25
Chloride diffusivity, m^2/s	(min)	$2.8*10^{-12}$	$10\text{-}20*10^{-12}$
pH of leachate at 90 days (reference/Groundwater)	< 11	11.4 / 10.3	>12,5

POPLU Instrumentation Planning

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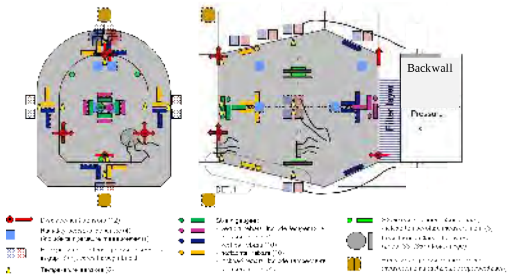

Values to be measured: temperature, humidity, strain, displacement, pressure, and water leakage.

POPLU Instrumentation – Sensors

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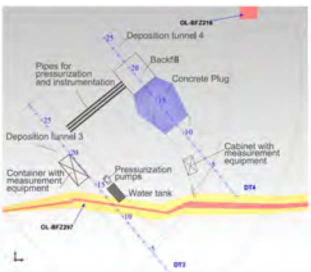
	Code	Front part FP	Seam SE	Back part BP	Filter layer FL	Back wall BW	*Total*
Strain gauges	SG	16	3	13			*32*
Thermocouples (single)	TCI	6		2		(4)	*8 (12)*
Total pressure sensors	TP	2		5	4		*11*
Pore pressure sensors	PP	2		5	4		*11*
Rel. Humidity sensor (Fuktcom)	RHF	2		2		(1)	*4 (5)*
Rel. Humidity sensor (Aitemin)	RHA	2		1		(2)	*3 (5)*
Displacement sensors (LVDT)	DS				3		*3*
Displacement sensors (Omega)	DSO	9					*9*
	Total	**39**	**3**	**28**	**11**	**(7)**	**81 (88)**

POPLU Pressurisation Test Planning

17



- Primary test criteria of POPLU is water tightness (no leakage, measured on front face of the plug)
- Use of 70 sensors in concrete plug component to evaluate the changes in values during pressurisation
- Water pressurisation system to fill filter layer behind the plug and induce loading corresponding to groundwater pressure
  - pressurisation up to 4.2 MPa
  - pressurisation time of 11 weeks
  - pressurisation adjusted based on response from leakage and sensors

Implementation of the POPLU Experiment – Tunnel Excavation and Plug Slot Production

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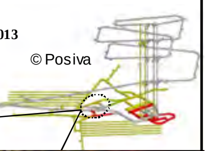
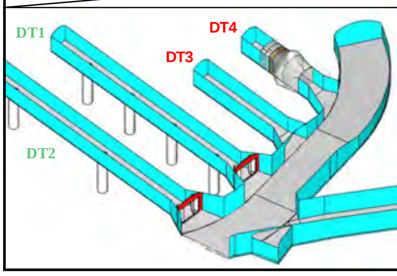
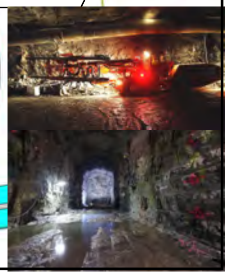
- Tunnel excavation commenced at -420 m level in September 2013
- Excavation was finished in December 2013
  - DT4 was excavated first, then DT3
- The method used for excavation was drill and blast
- The tunnels were excavated to fulfil the same requirements as the previous demonstration tunnels (DT1 and DT2)







Rock Suitability Classification for POPLU – 2nd Suitability Classification (”deposition tunnel”)

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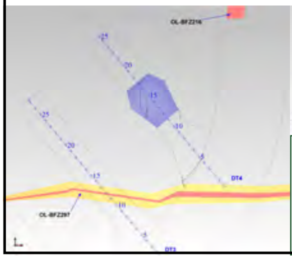
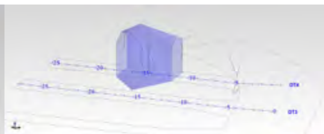
- The second suitability classification was carried out in October 2013
- Once the excavation had reached chainage 17.2 m (slightly past the end of the prospective plug location), the detailed-scale model was updated using the data obtained from the tunnel
- Based on the tunnel observations (and the detailed-scale model), no hydrogeological (L5-ROC-59) or brittle deformation (L5-ROC-60) zones are present in the assessed tunnel section or the suggested plug location
- Also, no fractures are present - hydraulically conductive (L5-ROC-80) or not - that would intersect the entire length of the plug





It was concluded that the criteria set for the plug location are fulfilled in the demonstration tunnel 4 in general and that the suggested chainage 11 - 17 m is suitable for the plug location.

POPLU Slot Production – Drilling-Wedging-Grinding

20

June 2014 – February 2015

POPLU Slot Production – Laser Scan of the Ready Slot

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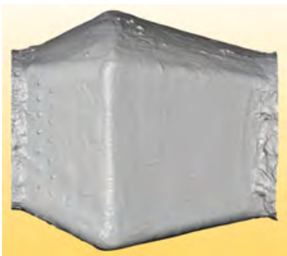

POPLU Construction – Method Tests

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- The transfer of the selected concrete mix design to construction was started in July 2014 by performing the 1st method test
- In total three method tests have been casted at ONKALO to test the concrete
  - aggregate size
  - temperature
  - chemical dosages
  - working methods
- Method test for contact grouting is under development

POPLU – Method Tests

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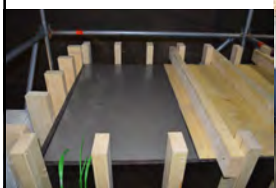

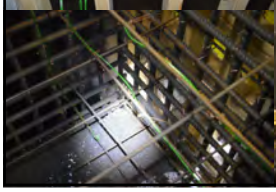

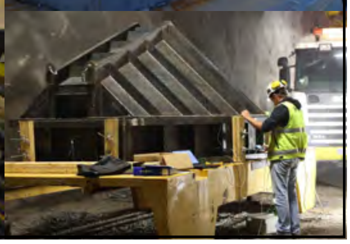

POPLU Construction

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February 2015 – December 2015

POPLU Construction

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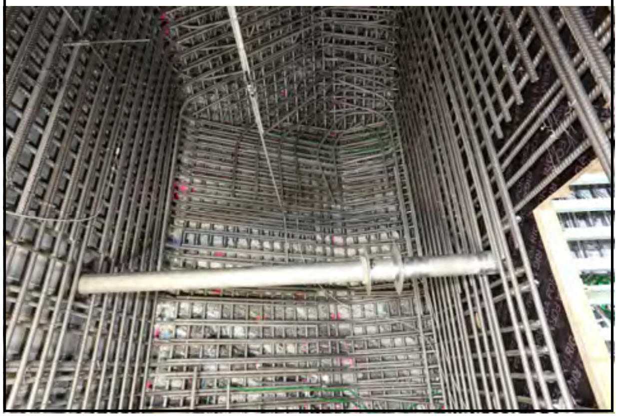

POPLU Construction

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POPLU Instrumentation Installation

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Forthcoming Activities

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- Reinforcement and instrumentation of 2nd plug part
- Casting of the 2nd plug part on September 16th 2015
- Contact grouting method test in October 2015
- Contact grouting of POPLU concrete plug component in December 2015
- Pressurisation of the experiment in January 2016
- Test programme for POPLU in long term under development
- Decommissioning / removal of POPLU experiment TBD – some future date in 2020's?

Sources of Photos and Pictures

29

- Unless otherwise stated the photos and pictures in this presentation are by Posiva.
- Pictures on slide 11 are by B+Tech.
- Pictures on slides 15 and 17 are by VTT.

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Training Workshop 2015

D4 4.1.4
Feasibility of a seal in a clay rich host environment

Régis FOIN, Andra
17 th October 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

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Contents

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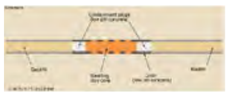
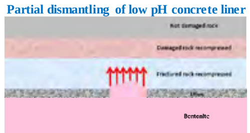
Cigéo seals concepts

Nominal concept*

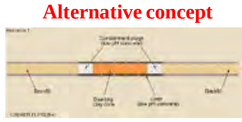


Partial dismantling of low pH concrete liner

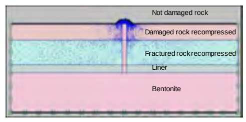


Bentonite swelling pressure required 4 to 7 MPa

Alternative concept



Hydraulic cut-offs in the host rock



Bentonite swelling pressure required 2 to 3 MPa

*) current reference

Seal emplacement preparation operations
Nominal concept

Dismantling context
- Dismantling is realized in nuclear zone à Nuclear security and safety required in all the different procedures of dismantling
- Minimum of dust is imposed to prevent HEPA filter clogging
- Stability of liner is required to take care of the stability of the drift
- Safety of workers during dismantling is to be ensured

Dismantling methods

No specific method defined at time but 2 methods envisaged to dismantle the liner :
- Wire sawing the liner and later concrete breaking with hydraulic hammer
- Shearing (mining) machine with rotating drums

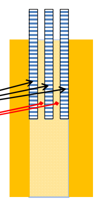
The main problem is to find a solution, which generates minimum dust and a solution to capture dust at emission source to evacuate it.

Seal emplacement preparation operations
Alternative concept

Dismantling context
- Dismantling is realized in nuclear zone à Nuclear security and safety required in all the different procedures of dismantling
- Minimum of dust is imposed to prevent HEPA filter from clogging
- Safety of workers during dismantling is to be ensured

Dismantling methods

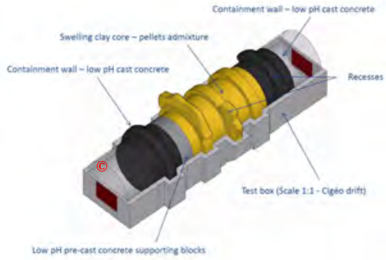
For hydraulic cut-offs (30 cm large & 2.5 m deep): TSS1 experiment.
The method used consisted in:
- Making 3 lines by saw (7 cm large) in the host rock
- Breaking the host rock between the lines of saw
- Evacuating the pieces of rock & the dust at the bottom of the cut-off
- To put wire mesh to protect people below the cut-off



Seals emplacements preparation

Alternative concept

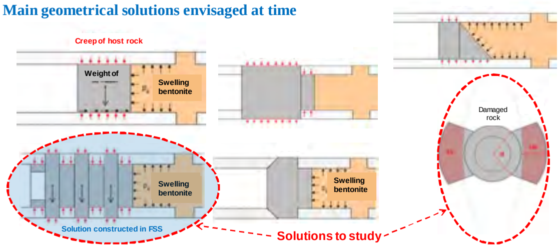
DOPAS - FSS experiment : Nominal



The experience described in the presentation: the nominal sealing solution

Containment walls realization

Main geometrical solutions envisaged at time



The 2 concepts of seals need containment walls but in the alternative solution (hydraulic cut-offs) they are dimensioned to resist at a lower pressure à so they should be shorter (not dimensioned yet).

Containment walls realization

Length of the monolith:

- Depends on the diameter of the drift
- Depends on the conception (anchored into the host rock or into the liner of the drift) that means depending on where the pressure is transmitted to (rock or liner)
- Depends on the level of pressure transmitted by the bentonite
- Depends on the quality of low pH concrete or shotcrete envisaged

Note: The backfill of the drift behind the containment wall is not considered to participate at any withholding of the containment wall

At time the length envisaged for the containment wall of a seal, lodged inside a 7.6 m ID (9 m OD) drift and anchored in the drift liner, for C50/60 concrete is:

- around 14 m long
- with 3 notches (penetrating the drift liner), 2 m wide

Using a low pH shotcrete C25/30 it should be about 19 m long with 5 notches

The containment walls construction for FSS experiment was with the real diameter and thickness of drift liner but with a shorter monolith length (only 5 m long)

Containment walls realization

Low pH SCC and shotcrete conceptions :

- Requirements of the FSS Project

Plug #1 (upstream)		Plug #2 (downstream)	
Self-Compacting Concrete	Injection grout	Precast concrete	Shotcrete
pH of the poral solution (28d) ≤ 11.0 (ideally between 10.5 and 11.0)			
Slump flow ≥ 65 cm	-	-	-
Period of use ≥ 2 h	-	-	Period of use ≥ 2 h
Max temp < 50°C	-	-	Max temp < 50°C
f_c(28d) ≥ 30 MPa f_c(90d) ≥ 40 MPa	-	-	f_c(28d) ≥ 25 MPa f_c(90d) ≥ 35 MPa
Shrinkage (90d) ≤ 350 µm/m	-	-	Shrinkage (90d) ≤ 350 µm/m
Pumpable	Pumpable	-	Sprayable

Containment walls realization

Low pH SCC and shotcrete conceptions:

- Three SCC mixes were selected for metric-scale tests

Compound (kg/m³)	B50 CEM I 52.5 Le Teil	B50 CEM III/A 42.5 Héming	B50 CEM III/A 52.5 Rombas
Gravel 5/12 (dry)	807.7	737.8	682.1
Sand 0/4 (dry)	762.1	656.6	698.7
Cement	108.0	132.0	130.0
Silica fume	108.0	132.0	130.0
Limestone filler	335.5	396.9	408.4
Admixtures	SP 3.0% - RA 0.2%	SP 2.2% - RA 0.1%	SP 2.2% - RA 0.1%
Water	179.5	205.7	204.1

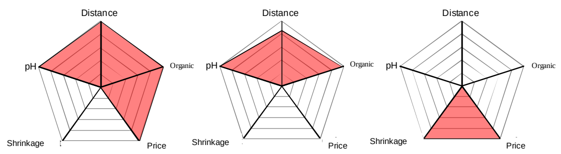
B50 CEM I: 50% OPC + 50% SF - **B50 CEM III/A**: 50% CEM III/A + 50% SF
SP: superplasticizer – **RA**: retarding admixture

Containment walls realization

Low pH SCC and shotcrete conceptions:

- The best SCC was selected by multi-criteria analysis made after the metric tests

B50 CEM III/A 52.5 Rombas | B50 CEM III/A 42.5 Héming | B50 CEM I 52.5 Le Teil



Average mark: 4/5 | Average mark: 2.8/5 | Average mark: 2/5

⇒ Selection of the mix B50 CEM III/A 52.5 Rombas

Containment walls realization

Low pH SCC and shotcrete conceptions:

- Three shotcretes were selected for metric tests

Compound (kg/m³)	B50 CEM III /A Rombas	B50 CEM I Le Teil	B40 CEM III /A Rombas
Gravel 4/8 (dry)	408	408	398
Sand 0/4 (dry)	1347	1347	1347
Cement	190	190	252
Silica fume	190	190	128
Admixtures	SP 3.68 - RA 0.7	SP 3.43 - RA 0.7	SP 3.71 - RA 0.7
Water	220	200	190

SP: superplasticizer – RA: retarding admixture

Containment walls realization

Low pH SCC and shotcrete conceptions :

- The best shotcrete was selected by multi-criteria analysis made after the metric tests

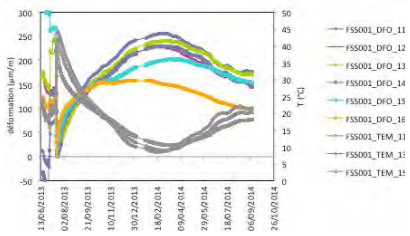
B50 CEM III/A Rombas projeté (100 % fumée de silice) | B50 CEM I Le Teil projeté (100% fumée silice) | B40 CEM III/A Rombas projeté (100 % fumée de silice)

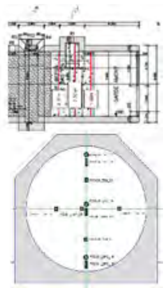
=>Selection of B50 CEM I 52.5 Le Teil

Containment walls realization

Containment walls SCC instrumentation :

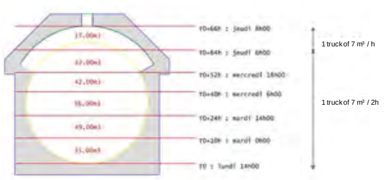
- Before casting, sensors were emplaced inside the formwork to monitor concrete temperature and shrinkage





Containment walls realization

Low PH SCC containment wall schedule :



Forecast schedule

Containment walls realization

Low pH SCC containment wall construction :

Slump control 2 hours after fabrication (as to be between 55 cm to 75 cm) | **After 8 hours** | **After 60 hours**

Film

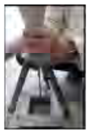
FSS_Construction_mock-upandSCC_containment_wall.mp4

Contact Andra or see DOPAS Seminar 2016 materials
(not included into the DOPAS TWS materials)

Containment walls realization

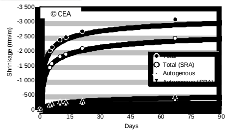
SCC containment wall injection with bonding grout:

- Formulation:
  - Same binder as the selected SCC → pH
  - Compressive strength ≈ 30 MPa
  - Flowing time (Marsh funnel) ≤ 25 s
  - Period of use = 30 min
- Methodology:
  - First run using BétonLab Pro (strength)
  - Empirical adjustment (flow)



Flow time: 13 s (t_0)
13 s (t_0+30')
Strength (28d): 27 MPa

Compounds	Amount (kg/m³)
CEM III/A 52.5 Rombas	311.7
Silica fume	311.7
Filler	0.0
Fine sand (0/315 µm)	781.7
Water	438.0
Superplasticizer	1.9%
Shrinkage reducing admixture	2.0%

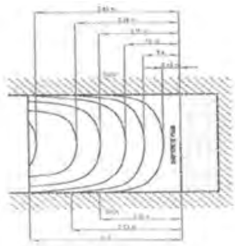


=> quantity finally injected almost zero

Containment walls realization

Low pH shotcrete containment wall construction:

Verification of slump flow after 2 hours



- **Projection in form of onion peel to have a better adhesion between the different layers and a better contact with the mock-up drift inner wall**
- **Delay of 4 hours between 2 layers of 7 m³**

Containment walls realization

Low pH Shotcrete containment wall construction:

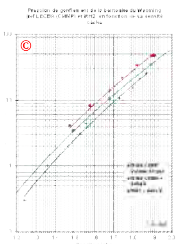
Shotcrete emplacement

End of construction

Swelling clay core realization

Facts

- The swelling pressure after hydration around 7 MPa corresponds to a 1.62 Mg/m³ dry density of pure WH2 (Wyoming bentonite) swelling clay
- Few data available for pellets admixture density above 1.5 Mg/m³ in literature (RESEAL, ESDRED, EB, …)
- Pure bentonite admixture
- Choice of pellets production machine design



Solution envisaged in FSS to reach 7 MPa:

- **Pellets of 32 mm in diameter**
- **Powder made by crushed pellets**

Swelling clay core realization

Fabrication of swelling clay materials :

Pellets Characteristics

- Pellets are 32 mm in height and in diameter,
- Their mass is 43 g/piece,
- Water content is 4.5%,
- Dry density is 2.05 to 2.08 g/cm³.

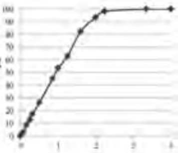
Swelling clay core realization

Fabrication of swelling clay materials:

Manufacturing of the powder to fill the voids between the pellets

- To improve the final density in place, crushed pellets selected for their high bulk density compared to a powder dried down to 2% of water content (1.20 to 1.25 g/cm3 vs. 1.05 to 1.11g/cm3)

- Flails crusher used to crush the pellets industrially, in Limay plant
- Production rate is 1 T/h
- Grain size distribution : 0-2mm



Swelling clay core realization

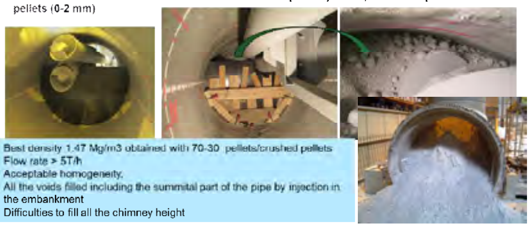
Conception of swelling clay mixture:

- In parallel to laboratory studies, a mock-up was developed for testing selected formulations and the backfilling device , based on two augers for transportation of pellets and powder. Augers can be acted separately to adjust flow and material ratio .
- A 1.5m OD concrete pipe equipped with a perpendicular pipe simulates the drift and its breakouts.

Swelling clay core realization

Conception of swelling clay materials:

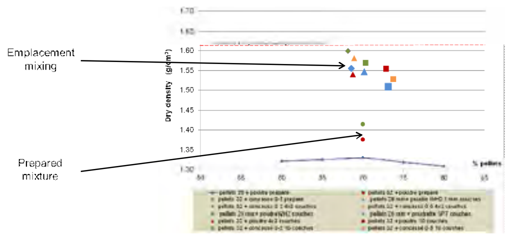
- For the first run, the augers were placed along a vertical axis, in order for the powder flow to drop unto the pellets ,
- Tests were focussed on 3 mixtures : 70-30 and 75–25 pellets/powder, and 70–30 pellets/crushed pellets (0-2 mm)



Best density 1.47 Mg/m3 obtained with 70-30 pellets/crushed pellets
Flow rate > 5T/h
Acceptable homogeneity.
All the voids filled including the summital part of the pipe by injection in the embankment
Difficulties to fill all the chimney height

Swelling clay core realization

Conception of swelling clay materials:



It was decided not to prepare in advance the mixture to obtain a good homogeneity but rather to mix the components during emplacement operations.

Swelling clay core realization

Final conception of swelling clay materials:

- The bentonite (sodic montmorillonite WH2 with a high content of smectite) was supplied from Wyoming
- After several tests, the choice made to reach a swelling pressure of 7 MPa was to mix:
  - Ø 32 mm pellets (70%)
  - Ø Powder made with crushed pellets (30%)
- The pellets provide the maximum of dry density and the powder made with crushed pellets has a best density than ordinary powder of bentonite in order to fill the voids between the pellets
- Construction of the majority of the core (lower part: about 2/3) with the augers one above the other to reproduce the metric tests during which the best results were obtained
- Construction of the end of the core (upper part: about 1/3) with the augers side by side to obtain the filling of the top recesses (best backfilling pressure)

Swelling clay core realization

Method to fill the core:

- **All bentonite materials delivered on FSS site prior to operations start-up**
  - **847 tons of 32 mm pellets (770 octabins)**
  - **368.5 tons of crushed pellets powder (335 big-bags)**
- **The emplacement equipment installed on the site is composed of :**
  - **A filling machine**
  - **A forklift truck (MANISCOPIC MT 1435)**
  - **An unloading station equipped with 2 hoppers**

Swelling clay core realization

Method to fill the core:

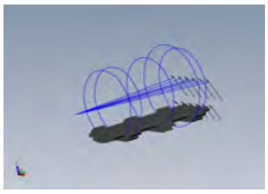
The filling machine

- **Moves X, Y, Z**
  - X : turret
  - Y : rail mounted 0.84 to 1.68 m/min
  - Z : crane lift of boom with manual hoist
- **32 tons**
- **Control panel**
- **Cameras & Monitor**

Swelling clay core realization

Method to fill the core:

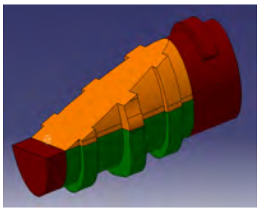
- **General method for lower part**
  - The emplacement principle consists in creating linear mounds of ~ 17 cm in height (Y move) with the powder auger above the pellets auger
  - After finishing a mound (linear heap), the rotation angle of the machine is changed (X move) to create a new mound beside the previous one …
  - For the upper layers, the mounds will be intercalated (by adjusting the rotation angle) in order to fill the grooves thus created



Swelling clay core realization

Method to fill the core:

- **General method for lower part**
  - Filling the lower part of the recesses
  - Filling the horizontal part of the core delimited by the upstream containment wall and the first part of the supporting wall
  - Filling the inclined part (angle of 34° between the top of the upstream containment wall and the top of the first part of the supporting wall)



Swelling clay core realization

Method to fill the core:

- **General method for higher part**
  - The screws are side by side and inside the heap previously formed.
  - The brakes are released on request according to the predefined values of the auger engine intensities.
  - In the same time, the last rows of the support wall are built using the telescopic carriage and its lifting bracket.
  - At the end it will be necessary to adapt the central upper block to facilitate the end of the core filling operation.

Swelling clay core realization

Method to fill the core:

- **Details on the construction of the higher part**

The construction of the higher part is done after a change of position of the conveyor screws

- Filling the higher part (first phase): constitution of the massive slope upstream, including the recess upstream
- Installation of the concrete blocks row 4 to rise the supporting wall
- Filling the higher part (second phase): including the median recess
- Installation of the last concrete blocks
- Filling the high part (third phase) including the last recess and the final key wedge

Swelling clay core realization

Data on filling operations:

- **Human resources**
  - Activity 24 hours a day, 5 days a week
  - 3 shifts, including in each team:
    - 1 person responsible in charge of the operational procedure and of the reporting
    - 1 pilot of the filling machine
    - 1 driver of the telescopic carriage (forklift)
    - 1 operator in charge of unloading the octabins and the big-bags

Swelling clay core realization

Data on filling operations :

- **Duration of the operations**

Phase	Estimated duration (hours)	Estimated duration (days)	Comments
No-load test. Calibration of the filling machine	20	2	
Filling of the recesses	12	0.5	2 hours of gap related to the shifting of the teams
Filling horizontal part	188	8	
Filling of the inclined part	133	5.5	
Change position screw	12	0.5	3D Scan, Pt volume, films, photo
Filling of the high part (1)	26	1.1	Slope, phase 1
Installation of the concrete blocks	16	0.7	Row 4
Filling of the high part (2)	26	1.1	Slope, phase 2
Installation of the concrete blocks	16	0.7	Row 5
Keying-up	48	2	Including concrete blocks
Total	500	23	

Film:

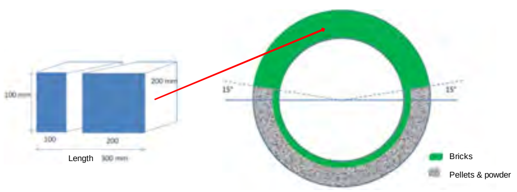
FSS_Clay_and_shotcrete_containment_wall.mp4

Ask Andra or see DOPAS Seminar 2016 materials (not included into the DOPAS TWS materials)

Alternative solution with hydraulic cut-offs

Filling the hydraulic cut-offs:

- The hydraulic cut-off is filled in 2 steps :
  - The upper part is first filled with bricks constituted by 2 half-bricks assembled by wedging
  - The lower part (angle of 15° with horizontal axe) is then filled with a mixture of pellets and powder introduced by flexibles screws and contained by 2 rows of bricks



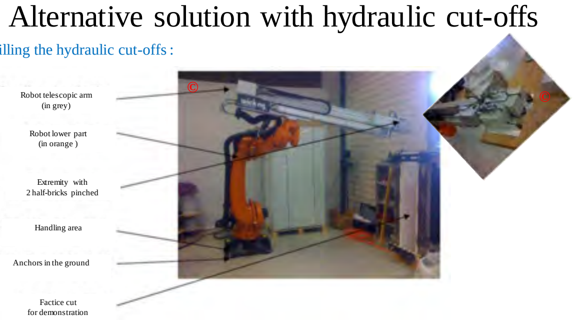
Alternative solution with hydraulic cut-offs

Fabrication of the components:

- BRICKS (BLOCKS) : Mix of WH2 – Sand TH1000 (ratio 80% - 20% in dry mass)
  - Water content W = 10 to 10.5 %
  - Compaction Pressure = 80 MPa
  - Dry density 1.94 to 1.95 g/cm3
- PELLETS : Pure WH2
  - diameter 7 mm
- POWDER : Pure WH2

Alternative solution with hydraulic cut-offs

Filling the hydraulic cut-offs :

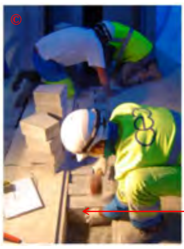


Alternative solution with hydraulic cut-offs

Filling the hydraulic cuts :

Alternative solution with hydraulic cut-offs

Filling the hydraulic cut-offs:



Filling the lower part

Installation of bricks to limit the filling of the lower part with pellets and powder

End of filling

CIGEO/15-0523

Andra – Régis Foin

Safety in operations

- **To construct a seal, whatever the method of your choice, it's necessary to pay attention in the different operations:**
  - **Excavating the host rock, dismantling the drift liner or realizing the cut-offs**
    - falling of stones / concrete blocks
    - dust
  - **Construction of the containment walls**
    - Silica fume
    - Contact with cement
  - **Filling the bentonite core**
    - Dust

It's necessary to produce safety procedures for operations to take care of your staff !!!

CIGEO/15-0523

Andra – Régis Foin

References

- Formulation des bétons autoplaçants de FSS — Andra 2013
- Bétons bas pH autoplaçants : bilan des essais à l'échelle industrielle — Andra 2013
- Bétons bas pH projetés : bilan des études de laboratoire — Andra 2013
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- FSS-1 : conception des matériaux à base d'argile gonflante — Andra 2012
- FSS-1 : réalisation des plots d'essais bentonite — Andra 2013
- Rapport final remplissage du massif amont en béton projeté pH — Andra 2013
- Rapport final fabrication du massif aval en béton projeté bas pH — Andra 2014
- FSS-1 : réalisation du noyau de bentonite : rapport final — Andra 2014
- Rapport d'activité réalisation de la saignée TSS1 — Andra 2012
- Dossier de demande de réception SET — Andra 2014

D4 4.1.4 Feasibility of a seal in a clay rich host environment

Thank you for your attention!

Any questions

CIGEO/15-0523

Andra – Régis Foin

DOPAS Training Workshop 2015
Participants and Tutors

Photo: Lucie Hausmannová

END OF DAY 4

DOPAS TRAINING WORKSHOP 2015

Sealing Nuclear Waste Repositories in Salt
The ELSA Experiment

André Rübel (GRS)

D5 4.3.2
18 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

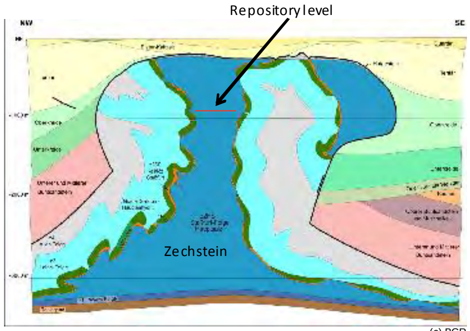
German safety concept for a repository in salt

Background

- Since 1970's salt dome Gorleben is investigated as potential site for heat-generating waste
- Start of construction of underground mine in 1986
- Site specific research project on long-term safety 2010 – 2013
  - Preliminary Gorleben Safety Analysis (VSG)
  - ® Sealing concept for salt used in DOPAS is based on VSG work

- 2011: Phase out from nuclear energy in Germany until 2022
- Strategy of the site selection and licensing procedure for a nuclear waste repository for high-level waste in Germany is under discussion
- New start of site selection with "white map"
- Three geologies will be considered in the future
  - Salt, Clay, Crystalline

Geological situation at Gorleben site



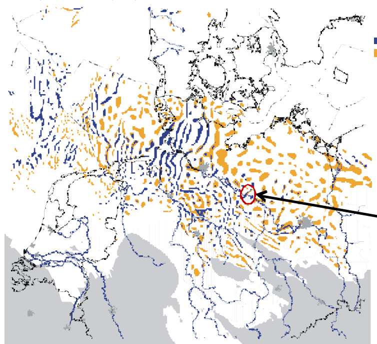
(c) BGR

View into the Gorleben underground mine

(c) BfS

Salt structures in Germany

Perm (296-251 million years)

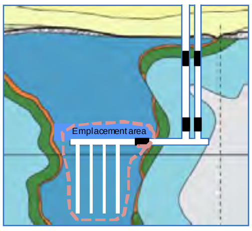


BGR

Safety concept (general)

German Safety Requirements (2010)

- Radioactive waste must be concentrated and contained in the Isolating Rock Zone (ewG)
- No intervention or maintenance work is required during the post-closure phase
- The isolating rock zone is part of the repository system which, in conjunction with the technical seals ensures containment of the waste.
- Release of radioactivity only negligibly increases the risks associated with natural radiation exposure
- Allowance for simplified radiological statement at ewG boundary

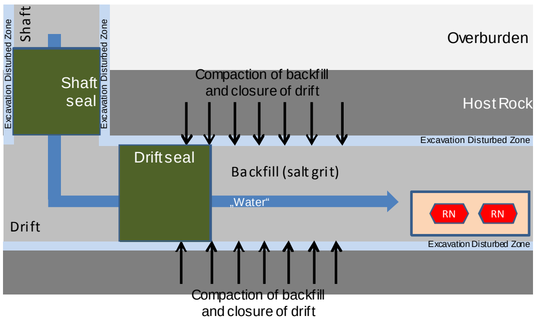


Safety concept salt

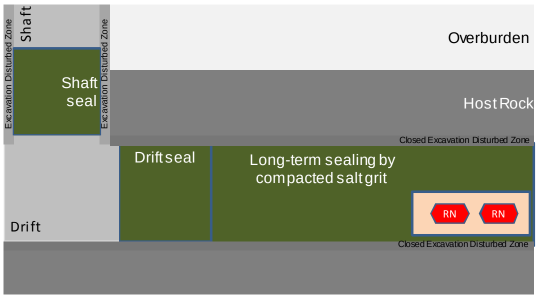
Preliminary Gorleben Safety Analysis (VSG)

- Isolation should be achieved by minimizing contact of the waste with water
- For probable evolutions of repository it is strived for that no or at the most very small amounts of external water gets in contact with the waste
- Salt host rock is dry and impermeable for water, inflow only through drift system
  - → Sealing of shaft and access drifts is of high importance for the safety concept
    - Short term: Constructed shaft and drift seals
    - Long term: Compacted salt grit backfill in access drifts
      - Salt grit is compacted by convergence of the salt host rock
      - Pre-compaction is used to speed up compaction process
      - Addition of 0.6% of water is discussed to speed up compaction process
      - Compaction under these circumstances within a few 1 000 of years to a permeability to less than 1E-19 m²

Safety concept salt

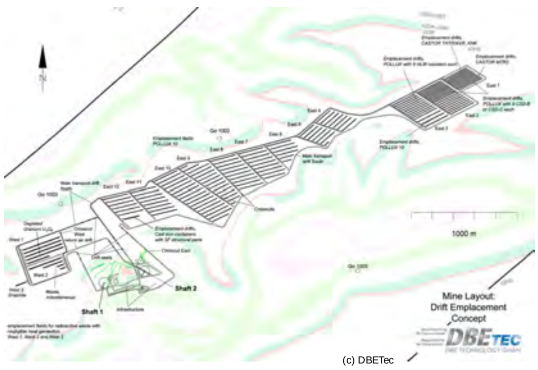


Safety concept salt

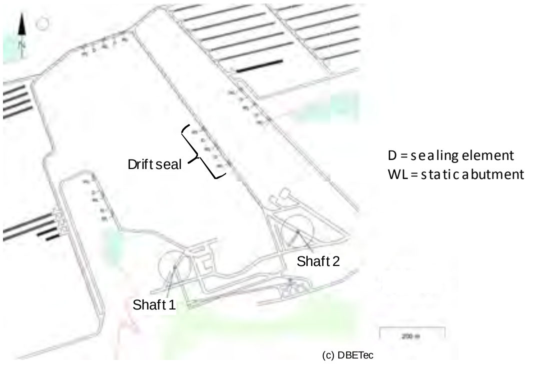


Repository concept for a high-level waste repository at Gorleben

Repository layout (drift emplacement concept)



Infrastructure area and drift sealing system



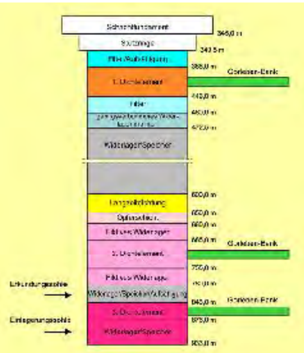
Boundary conditions

Envisaged life time of shaft sealing is 50 000 years

Materials
- Bentonite
- Crushed salt (long-term sealing)
- Salt concrete (cement and crushed salt)
- Sorel concrete (MgO as adhesive cement and crushed salt as aggregate)

Main Impacts
- Mechanical
  - Forces and tensions like weight, rock pressure, fluid pressure...
  - Distortions like swelling/shrinkage, creep/relaxation...
- Chemical
  - Dissolution and alteration from solutions and gases
- Temperature induced effects

Shaft sealing system



Shaft foundation
Support rings
Drainage layer (sand/gravel)
1. Sealing element (bentonite)
Drainage layer (basalt gravel)
Abutment (salt concrete)
Abutment/reservoir (basalt gravel)
Long term sealing (compacted salt grit)
Sacrificial layer (salt concrete)
Abutment (salt concrete)
2. Sealing element (salt concrete)
Abutment (salt concrete)
Abutment/reservoir (basalt gravel + bischofite)
3. Sealing element (sorel concrete)
Abutment (sorel concrete)

Work on sealing material in DOPAS and related projects

ELSA - Experiment

Phase 1 (completed)
- Boundary conditions and requirements for shaft seal

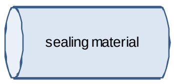
Phase 2 (running)
- Experimental investigations and process modelling
  - Optimization of the preliminary shaft sealing concept
  - Material selection and characterization (Lab tests)
  - Further development and (in-situ) test of
    - compaction procedures of salt grit or salt grit/bentonite mixtures
    - injection procedure (EDZ)
    - specific bitumen elements
    - accelerated and uniform bentonite plug saturation

Phase 3 (future)
- Large scale in-situ demonstration test of individual functional shaft sealing components

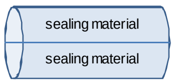
Geochemical laboratory experiments and modelling (GRS)

Static and flow corrosion experiments on salt concrete and sorel concrete with different porosities and different solutions

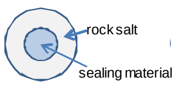
Matrix corrosion



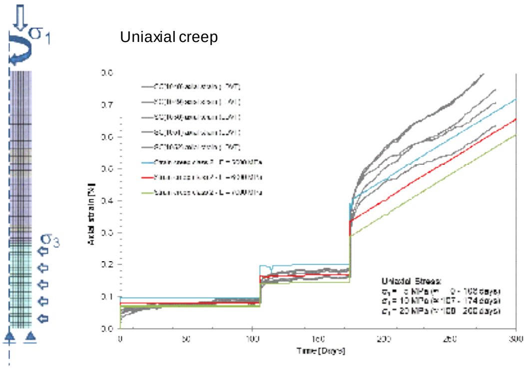
Corrosion on cracks



Corrosion at interfaces



Geotechnical laboratory experiments and modelling (GRS)



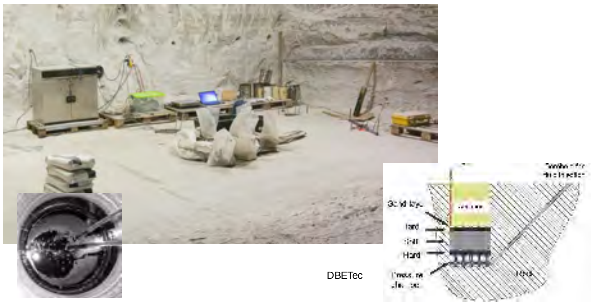
Mid-Scale in situ testing on material behaviour (DBETec)

- In-situ test using sorel concrete
  - Large borehole including monitoring equipment has been filled
  - Wait for stable conditions (hardening)
  - Permeability measurements

DBETec

Mid-Scale in situ testing on material behaviour (DBETec)

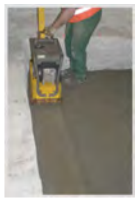
- In-situ test using bitumen and asphalt
  - Permeability ≤ 3E-21 to 6E-20 m² for bitumen and ≤ 3E-20 m² for asphalt



DBETec

In-situ testing on emplacement and compaction procedures (DBETec)

Total porosity: 13.3%
Permeability (brine): 6.6E-16 m² (start)
1,8E-19 m² (end, 22h)



DBETec

Future steps in ELSA experiment

Large scale in-situ demonstration test of individual functional shaft sealing components

- Already done prior to DOPAS:
  - Large scale in-situ experiment on gravel column as shaft filling material
  - Large scale in-situ experiment on bentonite shaft sealing element
  - Large scale in-situ experiment on salt concrete drift sealing

- Locations for future experiments to be found for experiments on shaft sealing elements from
  - Salt concrete
  - Sorel concrete
  - Crushed salt (Long-term sealing element)

- References for further reading:
  - Reports of the Preliminary Gorleben Safety Analysis (VSG) (mainly in German): http://www.grs.de/endlagersicherheit/gorleben/ergebnisse
  - Jobmann, M. (2013). Requirements for shaft seals for HLW repositories in Germany, Technical Report, translated extraction from (Kudla et al. 2013), DBE TECHNOLOGY, Peine. http://www.posiva.fi/files/3562/Requirements_shaft-sealing_Germany.pdf
  - Herold, P. & Müller-Hoeppe, N. (2013). Safety demonstration and verification concept - Principle and application examples - Technical Report, translated extraction from (Kudla et al. 2013), DBE TECHNOLOGY GmbH, Peine. http://www.posiva.fi/files/3563/Safety_demonstration_for_shaft_sealing_elements_Germany.pdf

Acknowledgement

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and contracts
02E11122, 02E11132, 02E10377, 02E11142, 02E11193 A and B
from the German Federal Ministry of Economic Affairs and Energy (BMWi).

DOPAS Training Workshop 2015

The Application of DOPAS Lessons Learnt to Less Advanced Waste Management Programmes

Dean Gentles
Radioactive Waste Management Ltd
Date: 18.9.2015

D5 4.3.1

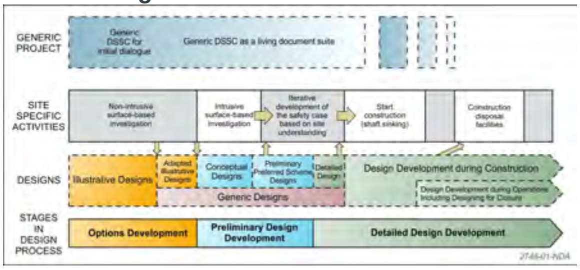
The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Radioactive Waste Management Ltd (RWM)

- Radioactive Waste Management Limited (RWM) is a wholly owned subsidiary of Nuclear Decommissioning Authority (NDA).
- RWMs mission is to deliver a geological disposal facility and provide radioactive waste management solutions.
- In the near term this includes:
  - Engagement with national and local governments and communities to identify a geological disposal site; and
  - In conjunction with waste producers, identify and deliver solutions to optimise the management of higher activity waste.
- 2014 White Paper 'Implementing Geological Disposal' – An 'enabling' document

Radioactive Waste Management

Engineering Design Development Stages – Generic Stage

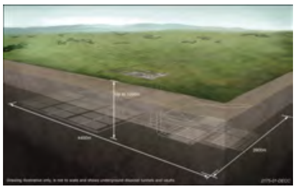


Radioactive Waste Management

Geological Disposal

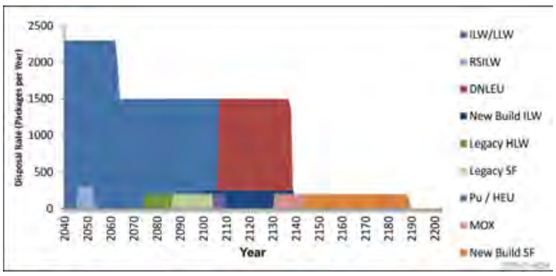
- ISOLATES radioactivity from surface
- CONTAINS until hazard has decayed
- Provides passively safe system

Needs:
- Suitable geological environment and
- a willing community



Radioactive Waste Management

GDF* Waste Emplacement Timings – 160 Year Operational Period



Radioactive Waste Management

* Geological disposal facility

Geological environments

© SKB Äspö Hard Rock Laboratory – Sweden

© ANDRA underground test and research site – Bure, France

© DoE - Waste Isolation Pilot Plant

Radioactive Waste Management

Sources of illustrative geological disposal concepts for host geological environments and classes of waste

Host rock	Illustrative Geological Disposal Concept Examples[a]	
	LHGW	HHGW
Higher strength rocks[a]	UK LHGW Concept (RWM, UK)	KBS-3V Concept (SKB, Sweden)
Lower strength sedimentary rock[b]	Opalinus Clay Concept (Nagra, Switzerland)	Opalinus Clay Concept (Nagra, Switzerland)
Evaporites[c]	WIPP Bedded Salt Concept (US-DOE, USA)	Gorleben Salt Dome Concept (DBE-Technology, Germany)

Radioactive Waste Management

Geological disposal – 2014 White Paper overview

© DECC

- National Geological Screening (RWM)
- Preparing to work with communities (DECC)
- Developing land-use planning processes (DECC)

Radioactive Waste Management

Initial Action: National Geological Screening (RWM)

- **The objective of the National Geological Screening exercise is to provide authoritative information that can be used in discussions with communities and may help RWM focus its engagement activities**
- **Screening will:**
  - focus on long-term environmental safety of a GDF
  - draw on the requirements in the existing Disposal System Safety Case
  - consider existing geological information only
- **Screening will not:**
  - definitively rule all areas as either 'suitable' or 'unsuitable'
  - target individual sites
  - select sites
  - replace statutory processes

Radioactive Waste Management

RWMs role in DOPAS

- The integrated report will present a synthesis of the learning gained from the installation and commissioning of the full-scale tests (DOMPLU, POPLU, EPSP and FSS).

© Posiva

Radioactive Waste Management

Current RWM Strategy for Plugging and Sealing

- **Higher Strength Rock**

Low-permeability seals consisting of highly compacted bentonite retained by a concrete structure would be constructed to isolate vault modules, disposal areas, shafts and the drift.

- **Lower Strength Sedimentary Rock**

Highly compacted bentonite and a concrete bulkhead. Seals would retain backfill materials within the disposal vaults and tunnels and also minimise the potential for radionuclide migration in the long term.

- **Evaporite Rock**

Rigid concrete wall with contact grouting around the concrete component, as required. 15 – 30m apart within the disposal tunnel.

Radioactive Waste Management

Disposal System Technical Specification

- RWM currently captures requirements in the disposal system technical specification (DSTS). The following requirements are related to disposal areas:

- Where appropriate, backfilling equipment shall be segregated from the waste disposal areas of the facility and the number of operational interfaces between disposal areas and backfill equipment shall be minimised.

- After backfilling of the disposal areas, each disposal module shall be sealed through installation of a Sealing Plug, which shall be designed to:
  - provide mechanical support to the backfill material in a disposal module and be strong enough to withstand the combined pressure from the groundwater and any swelling of the backfill and buffer materials;
  - limit water flow from a disposal module to the access ways;
  - consider requirements on gas migration from a disposal module into the access ways.

Radioactive Waste Management

Safety Functions and Requirements (1)

- The safety functions of plugs and seals differ between programmes, depending on the geological environment, disposal concept and approach to safety case development.

- However, typical safety functions include:
  - – Confinement of tunnel backfill
  - – Prevention of groundwater flow through waste disposal areas
  - – Prevention of access to the repository after closure.

- Short term vs. long term safety functions.

- As mentioned, in the UK we have three generic illustrative designs for three potential host environments; higher strength rock, lower strength sedimentary rock and evaporite rock.

Safety Functions and Requirements (2)

Higher Strength Rock:
- Aim to achieve a hydraulic conductivity comparable to that of the rock mass, ensuring a good contact is established between the plug/seal and the host rock.

Lower Strength Sedimentary Rock:
- Need to ensure that low hydraulic conductivities are achieved to match those of the clay. Removal of host rock lining may become necessary in this regard.

Evaporite Rock:
- All seals must be introduced in such a way that brine migration through the artificial openings to the waste packages is avoided until the backfill is sufficiently compacted (creep).

Conceptual Design(s) – Plugs/Seals

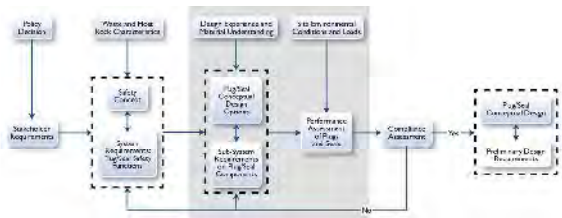
- Currently a level of detail which we do not have in our current illustrative designs.

- Designs for plugs and seals are significantly more complex than currently accounted for in RWMs generic illustrative designs, where specific sub-system components required to deliver the safety functions (e.g. filters and delimiters).

- Plugs and seals tailored to deliver different safety functions for a specific type of host rock. (However, at RWM the term is used at a high level across all geologies).

- The design of plugs and seals is dependent on the boundary conditions, therefore it is difficult to design without out site specific information.

Conceptual Design – Process Flow



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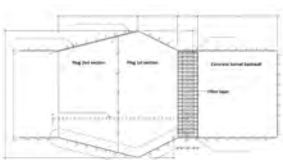
Basis for Conceptual Designs Summary



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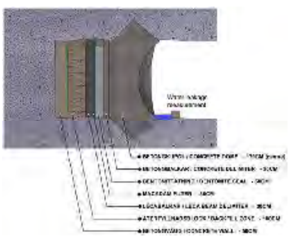

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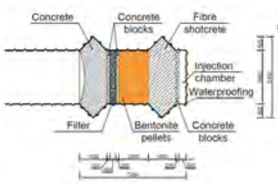
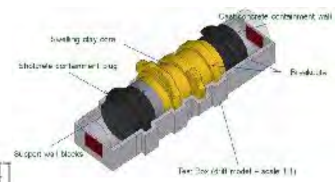
Basis for Conceptual Designs

© CTU - EPSP





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High Level Design Assumptions

- Tunnel Cross Sections to be kept to a minimum
- Low Permeability plugs/seals
- Reinforced Concrete Plugs
- Seal composition – Bentonite
- Location of plugs and seals – 1 plug every 100m
- 40m long plug placed in main disposal facility accesses
- Operating plugs and permanent plugs

High Level Design Assumptions

Operating Plugs

	Dimensions (m)	Cross Section (m^2)	Thickness (m)	Volume of Concrete (m^3)	Mass of Reinforcement (kg)
Operating Plug	5.5 wide x 5.5 high	25	5	40,000	
Retaining Wall	5.5 wide x 5.5 high		0.3	2400	
Retaining wall reinforcement			1000kg		320,000

Permanent Plugs

	Dimensions (m)	Cross Section (m^2)	Thickness (m)	Volume of Concrete (m^3)	Mass of Reinforcement (kg)
Permanent Plugs	5.5 wide x 5.5 high	25	10	4,000	
Retaining Wall	5.5 wide x 5.5 high	25	0.3	120	
Retaining Wall Reinforcement				1000	16,000

Technology

- Engineered Barrier Materials
- Excavation techniques – Wire Sawing (occupational safety)
- Concrete Recipes – low pH - Impact on near-field performance
- Impact of operational and post closure safety on design of plugs and seals
- Monitoring of plugs and seals
- Achieving the required density

Conclusion

- RWM is currently in a generic stage of work, therefore designs are at a high level.
- Participation in DOPAS has allowed RWM to develop and enhance its knowledge of plugging and sealing.
- Work is currently ongoing with our supply chain to apply the lessons learnt from DOPAS to the UK Programme.
- This work will result in updates to RWM GDF design report and to the Disposal System Technical Specification.
- Further work on the application of lessons learnt from the DOPAS project will be presented during the DOPAS Seminar 2016.

Thank you – Any Questions?

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

References

1. Radioactive Waste Management Limited, Corporate Strategy 2015 – 2018.

2. Department for Energy and Climate Change, White Paper: Implementing Geological Disposal, 2014.

3. NDA RWMD, Geological Disposal – Generic disposal facility designs, NDA/RWMD/048, December 2010.

4. NDA RWMD, Geological Disposal: Disposal System Technical Specification, NDA/RWMD/044, November 2010.

Salt concrete samples (ELSA) DAY 5

PANEL DAY 5

DOPAS Training Workshop 2015
Planning Group Members and Main Tutors

Photos: Marjatta Palmu and Radek Vašíček

DOPAS Training Workshop 2015
Planning Group Members and Main Tutors
Legend for Photos

CTU: Radek Vasicek	Posiva: Marjatta Palmu	SKB: Pär Grahm	Andra: Jacques Wendling
CTU: Jiri Svoboda	Posiva: Petri Koho	GRS: Andre Rübel	Andra: Régis Foin
SURAO: Lucie Belickova	SURAO: Marketa Dvorakova	RWM: Dean Gentles	UJV: Petr Vecernik
UJV: Katerina Videnska; Dagmar Trpkosova	CTU: Michal Roll	CTU: Mia	CTU: Lucie Hausmannova

Material Reference: D3.6
Content Reference: 3.2.3

Exercise 3: Stress test of concrete

Simplified stress test on cement paste samples - evaluation of compressive strength.

- Methodology introduction and description.
- Characterisation of samples - samples origin, samples dimensions.
- Guided tests on laboratory device.
- Evaluation of results.

Samples: Cement paste specimens

Testing device: FORM+TEST Digi Maxx C-20 PROTEUS

Evaluation:

$$\text{compressive strength} = \frac{\text{force}}{\text{sample area}}$$

sample no.	sample dimensions	sample area	force	compressive strength

Material Reference: D3.8
Content Reference: 3.2.5

Exercise 4: Interaction of concrete with bentonite

Evaluation of pH in cement/concrete and bentonite - role of pH in cement-bentonite interactions.

- Methodology introduction and description.
- Preparation and characterisation of the samples - weights, volumes.
- Interaction of solid and liquid phases.
- Calibration of electrodes.
- Guided and students pH measurement. Evaluation of results.

Materials: hardened cement paste, low-pH concrete, bentonite, and distilled water

pH measurements: glass pH electrode, pH buffers: 7, 9, 11, 13

Reference: SKB, 2012: Development of an accurate pH measurement methodology for the pore fluids of low pH cementitious materials. SKB report R-12-02.

sample no.	solid phase weight	water volume	interaction time	pH

1 FEEDBACK SUMMARY FROM TRAINING WORKSHOP PARTICIPANTS

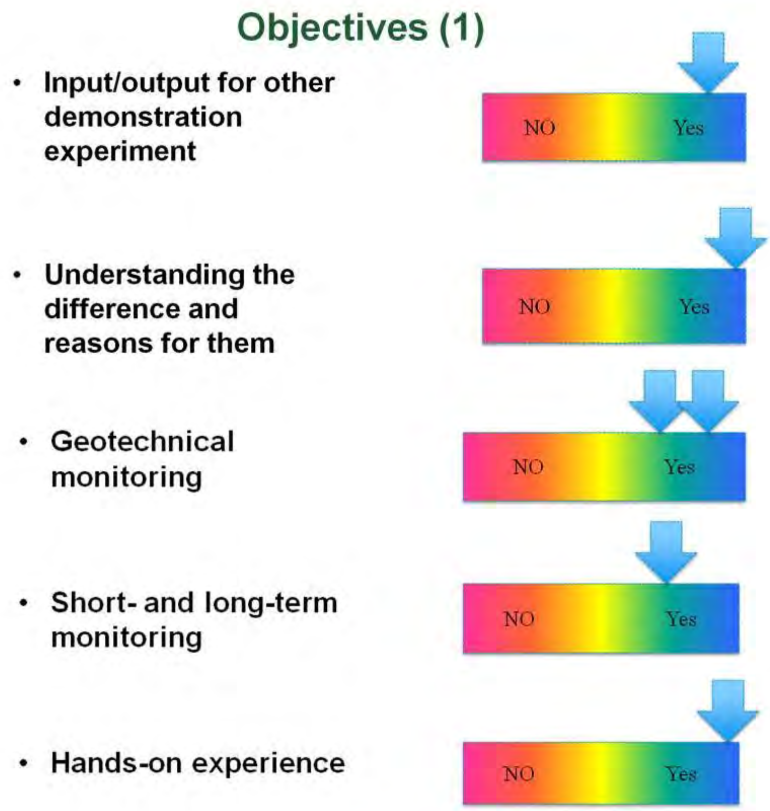
This appendix describes the collection and content of the feedback from the DOPAS Training Workshop from the participants' point of view.

1.1 Achievement of DOPAS Training Workshop Objectives and Fulfilment of Expectations

The participants set the following objectives, expectations for the training workshop, and expected benefits from it during the first training day. The achievement of each of these is included in the following. The icebreaker exercise with the outcomes is attached to the end of this appendix.

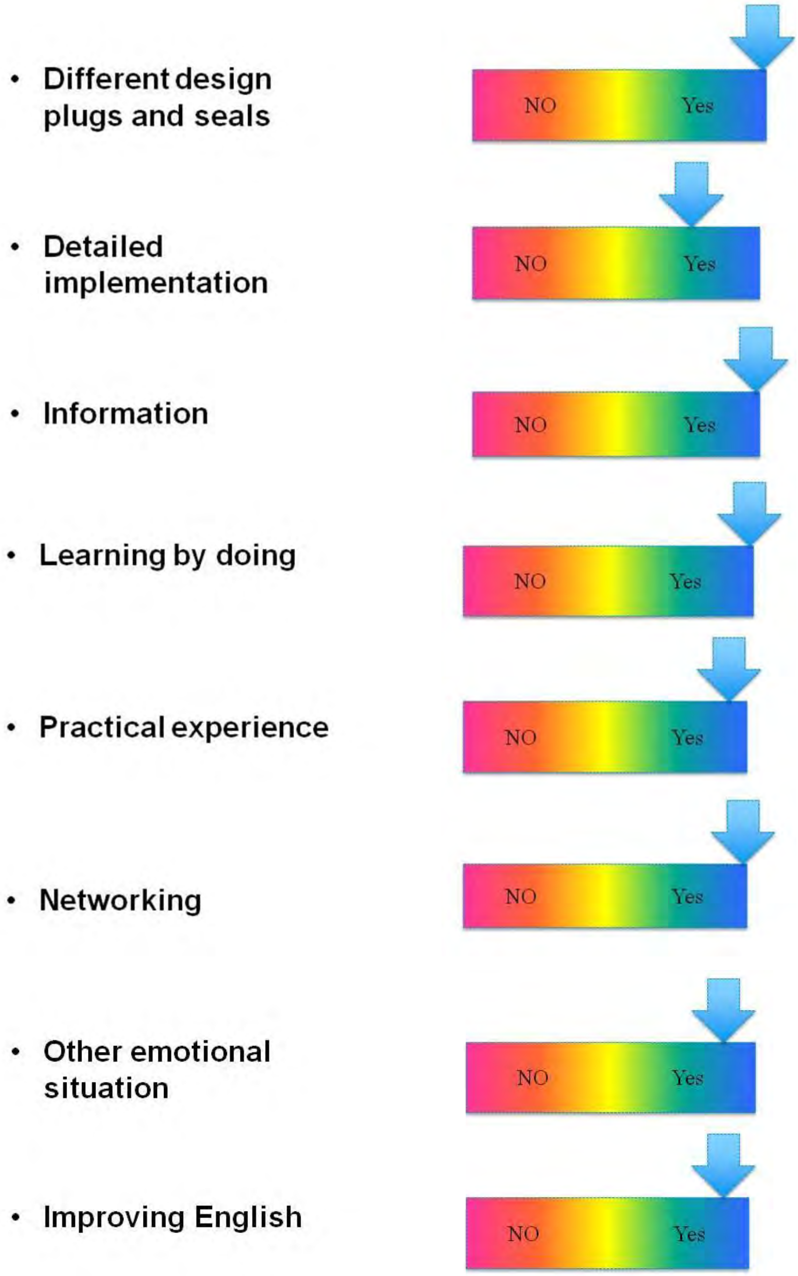
Objectives

- Input/output for other demonstration experiment
- Understanding the difference and reasons for them
- Geotechnical monitoring
- Short- and long-term monitoring
- Hands-on experience



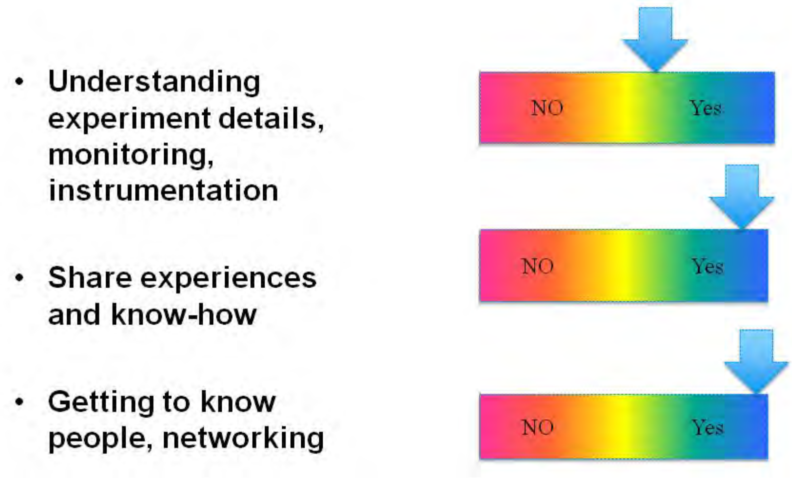
Expectations

- Different design plugs and seals
- Detailed implementation
- Information
- Learning by doing
- Practical experience
- Networking
- Other emotional situation
- Improving English



Benefits

- Understanding experiment details, monitoring, instrumentation
- Share experiences and know-how
- Getting to know people, networking.



During the last training day, the participants assessed how well they had reached the objectives and how well their expectations were met. For this assessment made by the group collectively a "slide ruler" was used, the better the objectives/expectations were met, the greener the result on the ruler. In few cases, the results were not in agreement by the group and therefore two arrows are given to indicate the feedback result.

10 participants stated that the training workshop had met their expectations, two of the participants stated that they did not have prior expectations for the training.

1.2 Spontaneous feedback

The participants were asked to give 3-5 adjectives that in their view described the workshop. Main adjectives included well organised /planned, very interesting, practical, informative, good learning experience/ environment, friendly, meeting great people.

In addition, they were asked to complement four sentences. Examples of the replies complementing the sentences are:

Now I know about ...

- the differences between the development status of plugs and seals in the different countries, in Europe
- how much work goes into planning and doing a full-scale demonstration test… with results that can be implemented in further development

- full-scale test requirements and designs in different host rocks
- practical implementation factors for full-scale tests
- project scoping, WBS and risk management
- working underground

I did not feel I understood the following content ...

- related to the iterative safety assessment process (I am new to safety assessment methodology)
- handling large amount of data and the best means for it
- enough Czech ;-). All the technical concepts were explained very well. I need more practice in electronics

I would have liked to have ...

- more time for reflection after the exercises and to discuss with group
- the words ”Excellent job” from the tutor, but I recognise that our
- output for one exercise was not optimal enough. That’s why we got just ”a good job”
- some numerical simulations practices or technical design, too.
- chance to take part in another such workshop
- this course in Finland
- more information about the Josef URC’s other ongoing research, but I know it was not the topic of the programme, so I will check them :-)

After this training workshop I would like to learn more about...

- the practical side to be an engineer (monitoring, construction, etc.)
- modelling of full-scale tests and how can one use them in safety assessment models and learn to use some of the codes mentioned
- placing and installation of different sensors
- concrete composition
- other big in-situ experiments and what can be learned from them for repository
- know more about my own country’s concept and future plans

Other feedback

- It was a great honour to be here. Thanks.
- It was perfect for getting an overview on the topic.

1.3 Replies to formal feedback questionnaire

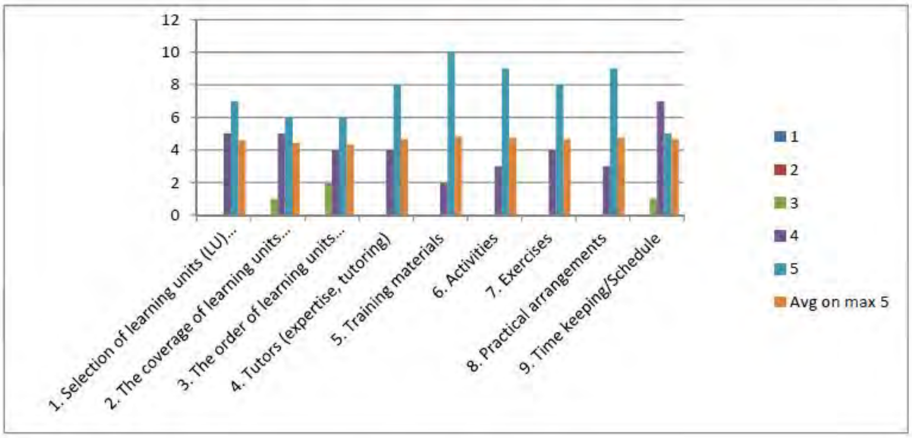
All participants replied as requested to a feedback questionnaire that is available on the DOPAS website together with the training materials. The participants included their name to their feedback, too. The general scoring for the DOPAS Training Workshop varied between 4.3-4.8 out of a maximum of 5 (score 1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = very good).

The participants were asked to score the following areas:

Assessment areas	Average score given by participants (n =12)
1. Selection of learning units and topics	4.6/5
2. The coverage of learning units and topic presentations	4.4/5
3. The order of learning units and topic presentations	4.3/5
4. Tutors (expertise, tutoring)	4.7/5
5. Training materials	4.8/5
6. Activities	4.8/5
7. Exercises	4.7/5
8. Practical arrangements	4.8/5
9. Time keeping/Schedule	4.7/5

Distribution of the feedback scores was as follows:

Scale (very poor/poor-average-good/very good)	1	2	3	4	5	Avg on max 5
1. Selection of learning units (LU) and topics	0	0	0	5	7	4,6
2. The coverage of learning units and topic presentations	0	0	1	5	6	4,4
3. The order of learning units and topic presentations	0	0	2	4	6	4,3
4. Tutors (expertise, tutoring)	0	0	0	4	8	4,7
5. Training materials	0	0	0	2	10	4,8
6. Activities	0	0	0	3	9	4,8
7. Exercises	0	0	0	4	8	4,7
8. Practical arrangements	0	0	0	3	9	4,8
9. Time keeping/Schedule	0	0	1	7	5	4,7



1.4 Other replies to the questionnaire

The main content of the questionnaire consisted of 8 questions in addition to the overall scoring of the training workshop. The participants were also given the option to provide tutor specific feedback, but only a couple of participants wished to give it.

1. What do you believe are the greatest challenges related to repository plugs and seals?
2. Did the training workshop meet your expectations?
3. What type of knowledge or skills did you learn during the training workshop? Which learning's do you consider most important to you?
4. How do you plan to use the knowledge and/or skills in your work in the future?
5. Did the training workshop fulfil the objectives you set for it? Please explain.
6. What kind of benefits can you foresee resulting from your participation to this training workshop?
7. What kind of disadvantages do you foresee as a result of this training workshop?
8. Would you recommend participation to this training workshop to others? Why?

Part of the questions on the questionnaire were also designed to enable the assessment of the participants' learning by asking them what they now found to be the most challenging tasks related to the plugs and seals, about what the participants learned in terms of knowledge, skills and competence; what they considered most important learning for them and also how they plan to use what they now learned. As a main disadvantage several participants felt that their English language skills were limited, but they also mentioned that they had improved their language skill during the week.

The questionnaire results were in alignment with the last day's assessment. All participants were ready to recommend the training workshop for other people. The participants were also sent a copy of their feedback summary without the names of the persons replying.

More details about the feedback and its collection is in the following.

2 FEEDBACK COLLECTION DETAILS

DOPAS Training Workshop 2015

Ice-breaker and Feedback D1 & D5

Marjatta Palmu
14-18 September 2015

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

D1 5.3 Course expectations, objectives and about the concept of "Time" DAY 1

Instructions

2

Step 1. Work first with a pair

- You have picked a piece of paper including some letters. **Please find a pair so that your letter combination forms an understandable word.**
- After this**, introduce yourself** so that your pair is able to introduce you to the rest of the participants. **Share** with each others **your expectations and objectives** for this training workshop and how you believe the training workshop will **benefit** you.
- Mark these down on sheet/s of white A4 paper. When you are **done, find another pair** (preferably people you do not know earlier).

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Step 2. Working in a group

- **Introduce** yourselves **again** shortly to the other pair, **share** the results of **your previous discussion** about your expectations, objectives and expected benefits related to the training workshop.
- **Take white A4** papers and write down **one item per one A4 paper** all the different expectations, objectives and benefits you have identified in your group. **Post** these papers **on the wall** of the classroom adjacent to other similar replies.
- **After this spend some time discussion with your group how do you understand time:**
  - **what does it mean to you, what is a short time, what is a long time? how do you visualise time?**
  - **after this draw a group picture or a cartoon about time on A4 or flipchart paper and clue it on the wall.**
- When you are finished, please look at the work of the other two groups and prepare to introduce your group members and your results to the audience**.**

4

Find a pair and a group

CL__	__AY
S__T	_AL_
B__E	_RIN_
G__SS	_NEI
G__NIT	RA___E
MI__	_CA

Key:
CLAY
SALT
BRINE
GNEISS
GRANITE
MICA

5

Identified objectives and expectations

- **Input/output for other demonstration experiment**
- **Understanding the difference and reasons for them**
- **Geotechnical monitoring**
- **Short- and long-term monitoring**
- **Hands-on experience**

Expectations:

- **Different design plugs and seals**
- **Detailed implementation**
- **Information**
- **Learning by doing**
- **Practical experience**
- **Networking**
- **Other emotional situation**
- **Improving English**

6

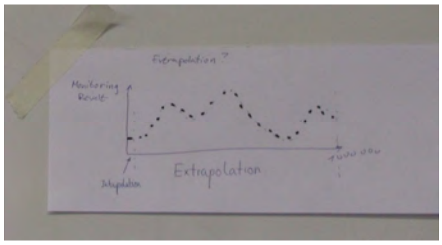
Identified benefits

- Understanding experiment details, monitoring, instrumentation
- Share experiences and know-how
- Getting to know people, networking

7

About time – what kind of thoughts

- ideas, pictures



8

About time 14.9.2015

Short time:
  DOPAS 4 years + exeriment
How long is "long time"
  Finland: 100 000 yrs
  France; GD 1 000 000 yrs
Is this enough?

- - - - - - - - - - - -

Laboratory scales ~5 years
Repository timescales 10^6 years
UNCERTAINTIES
Perceptions of time

DEEP TIME ← HUMAN TIME

9

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D5 Feedback discussion

DAY 5

11

Your sentiments at this moment?

- Write down several adjectives (3-5) that you believe describe the DOPAS Training Workshop 2015

- Open questions for evaluation
  - Now I know about ...
  - I did not feel I understood the following content ....
  - I would have liked to have ...
  - After this training workshop I would like to learn more about...

12

Your sentiments at this moment?

- Write down several adjectives (3-5) that you believe describe the DOPAS Training Workshop 2015:

- D – demonstrative
- O – optimistic
- P – positive
- A – accurate
- S – serious

Your sentiments at this moment?

- Open questions for evaluation
  - Now I know about ...
  - I did not feel I understood the following content ....
  - I would have liked to have ...
  - After this training workshop I would like to learn more about...

Evaluation against identified objectives

- Your results from DAY 1 listed

Photos © Marjatta Palmu

Identified objectives and expectations

- Input/output for other demonstration experiment
- Understanding the difference and reasons for them
- Geotechnical monitoring
- Short- and long-term monitoring
- Hands-on experience

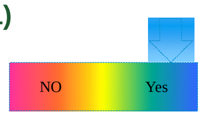
Expectations:

- Different design plugs and seals
- Detailed implementation
- Information
- Learning by doing
- Practical experience
- Networking
- Other emotional situation
- Improving English


Photos © Marjatta Palmu


Objectives (1)

- Input/output for other demonstration experiment



- Understanding the difference and reasons for them

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20

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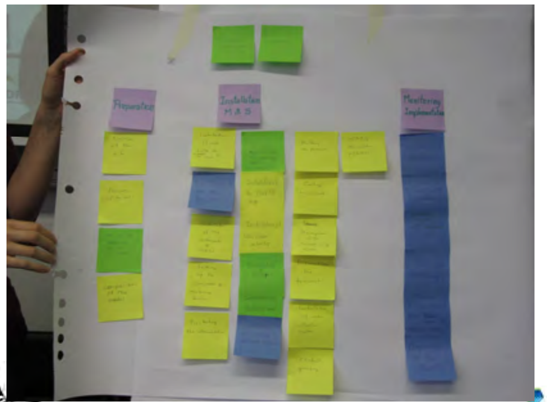

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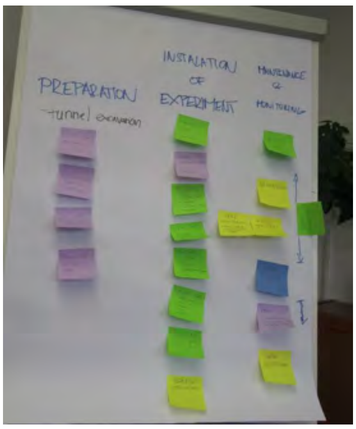

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Objectives (2)

- Geotechnical monitoring — NO / Yes
- Short- and long-term monitoring — NO / Yes
- Hands-on experience — NO / Yes

25

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26

Expectations (1)

- Different design plugs and seals — NO / Yes
- Detailed implementation — NO / Yes
- Information — NO / Yes

27

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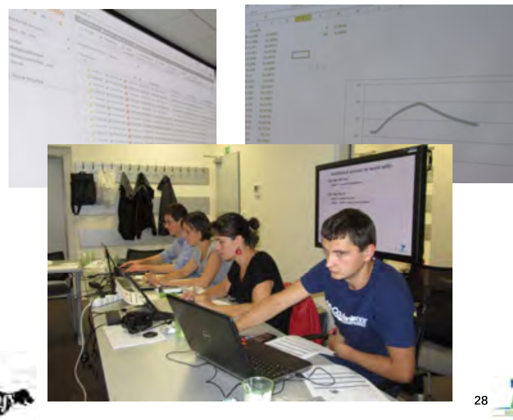

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Expectations (2)

- Learning by doing — NO / Yes
- Practical experience — NO / Yes
- Networking — NO / Yes

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Expectations (3)

- **Other emotional situation** — NO / Yes
- **Improving English** — NO / Yes

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Benefits

- **Understanding experiment details, monitoring, instrumentation** — NO / Yes
- **Share experiences and know-how** — NO / Yes
- **Getting to know people, networking** — NO / Yes

DOPAS

- **D – demonstrative**
- **O – optimistic**
- **P – positive**
- **A – accurate**
- **S - serious**

Photo: CTU/Lucie Hausmannova

The research leading to these results has received funding from the European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

Wanted/Improvement

- **More time for reflection/discussion with the group (n = 3)**

Tutor view:

- The exercises generally take more time than anticipated. To speed up exercises on approach is to describe the detailed steps of the hands-on exercises in advance to enable overall orientation to the exercise and also group task division.
- The original plan was that some time of the exercises could be used for the reporting (especially on Day 4), but this was not possible.
- Some prior preparation of e.g. samples could also be made and let the participants do only one or two samples themselves e.g. very much time was spend just on weighing the solid material for the solution samples for pH measurements.
- One solution proposed is also to split the exercise on two days. First to do the work and next morning first thing do the reporting.

DOPAS

The DOPAS project and the tutors thank you for your great participation.

DOPAS Training Workshop 2015 - Feedback questionnaire Summary 2015
Total of 12/12 replies received

Self-assessment of attainment of desired results

1. What do you believe are the greatest challenges related to repository plugs and seals?

Replies fall into three main categories - implementation, quality assurance and post-closure safety (long-term safety)
The greatest challenges related to repository plugs and seal are the project's quality assessment and to find the suitable materials to build them.
I think the greatest challenge is to set back the primary transmissivity properties of the rock with the plugs. In other cases it will not seal as long as needed (whether the rock will leak or the plug itself).
Plug location – without water bearing fractures and bypass fractures Plug excavation – health and safety during excavation; use of nonstandard methods such as wire sawing Plug building – proper properties of concrete solid Bentonite saturation - to saturate whole body without creating preferential water flow pathways
In my opinion the greatest challenge related to repository plugs and seals is to ensure the same level of quality of every plug or seal. For example the materials can be influenced easily by logistical problems or human faults while constructing. Another challenge is to find the best site in the repository/ emplacement tunnel for construction of the plug or seal.
Practical implementation and QA of designs, overcoming issues such as achieving required water pressures, bentonite densities, contact grouting, constructing large concrete plugs (logistical issues related to concrete production, transport and emplacement). Demonstration of applicability of laboratory, metric and full-scale tests to repository seals to regulators and the public. Decisions about monitoring of plugs and seals in the final repository. Long timescales between now and the final emplacement of drift and shaft seals in repositories (knowledge management). Noted that deposition tunnel end plugs in the KBS-3 concepts are emplaced during operations, so the technology will be needed much sooner for these components. Communication challenges associated with multi-disciplinary projects. For example, design, technical implementation and safety assessment teams need to understand each other's constraints and work together to ensure that requirements are not set too high at the start of the project (this results in revision of objectives part-way through and potential for sub-optimal selection of materials and construction methods).
In my opinion, the greatest challenge related to disposal plugs and seals are to demonstrate long-term safety and establishment long-time monitoring.
The greatest challenge for repository plugs and seals will be time. Only time will check correctness of construction of plugs and seals.
I think that one of the biggest challenges is the verification and validation process of the plugs and seals - to show public and stakeholders that the concept can meet all of the different types of requirements, everything from technical to long-term safety, in a structured and mannered way
The greatest challenges would be the long-term durability that the safety functions last for the required time (and beyond). With potentially changing groundwater chemistry, salinity, loads on plugs (glaciations /surface erosion), and material degradation it is difficult to give valid evidence that the sealing purpose remains for the required time. So there are actually two problems: • first is validation, finding enough proof that the safety functions are filled for the required time, and

• second is the actual problem that WILL the safety functions remain as they will be explained and promised to remain. The first we can affect, but the second one will occur in long-term and we will get no idea, of how right our proofed evidences have been in this era.
Even after the training I think the long-term safety is the greatest challenge. We have and will have more demonstration plugs and seals, but the monitoring of them can’t take as long as in the real life it will be. So it is possible, that the demonstration one works well, but who knows what kind of unexpected problems will be during the installation of the final ones?! I know, everything is planned, therefore is the risk management. But for the long term… I have big trust in engineers and I hope that we, nowadays, and as well the new generations will think seriously and will be able to “do the best”. So for me the greatest challenges are the followings: safety, good quality, control, people’s trust.
To manage the long time-scale is a big challenge. To implement several plugs and seals worldwide in an appropriate quality that remain efficient even on that unmanageably long time-scale the expert team have to master a lot of fields like: material sciences, chemistry, construction technology, quality insurance, design theory, numerical modelling, geology, rock mechanics, management. We constantly have to improve all of these fields, because one tiny mistake can lead to the failure of one plug or seal in long-term or in short-term as well.

2. Did the training workshop meet your expectations?

Tutors's view on 18.9.2015: expectations were met

Replies summary: N = 10 for yes, met expectations, two did not have any expectations. One partly yes reply.
The training workshop exceeded my expectations in terms of the breadth of topics covered and the quality of the presentations and discussion exercises. The group work and practical exercises met my expectations, other attendees were engaged and contributed to discussions and were experienced in a range of different areas, which provided useful perspective for me. We completed interesting hands-on activities in the underground facility at Josef and in the UJV Řež research centre and developed some practical skills.
Yes, the training met my expectations. My knowledge about full scale demonstration experiments of plugs and seals and their implications has been enhanced. I could networking with people from other countries and learn more about their national programs.
Yes, it has met my expectations because it included not only theoretical background knowledge regarding plugs and seals but also basics of engineering and natural sciences. The exercises illustrated the great range of abilities that an engineer needs to work on his/ her project properly.
The workshop did meet my expectations and more. Yes, the training workshop met my expectations.
Yes, I have a lot of new information and I think we can use them on a good way, to help our country’s development and hope our company will be involved in the project. :-)
Yes, because I received a lot of information from real experts of the field, I met many interesting people, and also learned much about the individual demonstrations.
Yes, partly. I expected more detailed description of monitoring.
I did not know what to expect from this training. I met with this project at the time of application.

3. What type of knowledge or skills did you learn during the training workshop? Which learning's do you consider most important to you?

18.9. Tutors' expected the following: how demanding it is to plan, implement and address requirements, working together.

Replies summary: the overall view related to demonstrations and safety assessment as an iterative process and the different steps in it, project and risk management techniques and about requirements and designs link and comparison between the different type of repository settings/host rock requirements. And the importance of interacting and communicating with the people working in these activities.
I would say that I got an overall perspective of the different procedures related to both safety assessment and full-scale demonstration tests and how the interaction occurs between them in the iterative process of repository development.
Firstly to think about the project in general (with view from above) than focused on details. Resource-Quality-Time Scope triangle.
I obtained knowledge, among others, the range projected plugs and seals in deep geological disposal, management project and skills of recognizing potential risks in implemented projects. I think most important learning's for me is about requirements and siting process.
Knowledge of full-scale test requirements and designs in different host rocks, including differences between the reference and experimental designs and the reasons for those differences. Understanding of the scale of the experiments (both deposition holes and deposition tunnel end plug experiments were observed at Josef) and by extrapolation of the scale of plugs and seals in a repository. Understanding of the practical implementation challenges and factors that need to be taken into account when working in an industrial or nuclear-licensed environment, and above or underground. Practical skills in constructing and installing sensors and conducting and interpreting measurements from data systems. A better understanding of potential sources of uncertainties and risks in monitoring of experiments, and mitigation measures that can be taken to address some of these risks.
The Brainstorming method with the Post-it's at the beginning was really useful. I am convinced that my new knowledge about the "Design basis development Workflow for P&S", the "Five Risk Management processes" and the "Work Breakdown Structure (WBS)" is going to be very useful for my professional future.
My priority was to take as much learning from risk assessment as possible, to learn more details about monitoring, instrumentation and data handling, and finally to meet people (networking). All these goals were reached. The course was very good and it was easy to define the goals and think during the course how they are met, because the course was well described from the start on with initial programs etc. The training workshop was very well organized.
I have learnt about the construction of plugs, about the research phases, about risk management and scope management. The last two were very important and I plan to learn more about them as they are really important to have a well going and well planned programme.
The most important point is the knowledge about the influence of communication between all participants of a project. Additionally the practical exercises illustrated that my focus should not only be rock mechanics. Before the practical exercise I was afraid of work concerning electro-technics, but while constructing the sensors my interests for electro-technics rose. In the future I want to improve my skills and apply them to the development of new monitoring systems. The measuring of the pH-value of the low-pH-concrete illustrates an important experience for me as

well. Finally I have taken into consideration to visit more lectures focusing on project management because the workshop outlined the significance of a well-structured organization in a project.
I cannot say exactly about one, that that one was the most important. I think these topics of the presentations are connected, so they have higher value all together, for the whole training. Because most of them stands alone, but when we see the connection, that is the big result of them. I was happy to hear about the projects, and listen not only to the good, excellent parts, but as well the problems, too. As – if I remember well – Marjatta said on one day, that was the place to / can discuss about those things, too.
The most interesting thing I learned was that how different the sealing concept of a nuclear waste repository in salt was. I really liked learning about the iterative work flow of the development and management models, and also liked the well-structured RD&D plan for seals of Andra. The Hungarian plans should be that structured as well. The most important thing which I had already known, but I learned again was that the international cooperation is essential about such major projects like nuclear waste repositories. And I also learned to solder :-)
I didn´t know anything about repository plugs and seals. I learned a lot of new information about the projects DOMPLU and POPLU.
Exercises and experiences from other countries.

4. How do you plan to use the knowledge and/or skills in your work in the future?

Replies summary: Share it with colleagues, use in my country's repository programme, develop requirements, apply in safety assessment, apply in project and risk management, apply in planning and construction of demonstration.
I plan use the knowledge and skills during the assessment process of siting and construction of surface and geological disposal in my country.
In the technical development of engineered barriers and also in a full-scale demonstration test of one of the engineered barriers for the repository extension
I understand the iterative process of developing requirements and designs better and this insight will be immediately useful as I am about to start managing a project for a waste management organisation on developing requirements for a large waste package. I will use the knowledge of concepts and designs for plugs and seals in any future projects on repository development that I am involved in. Likewise, the understanding of monitoring of plugs and seals in experiments and potential issues with implementing this in a future repository complements my existing background in above-ground monitoring, can be applied to future monitoring projects. I will use the scoping and risk assessment skills developed in Exercises 1 and 5 when I next develop a project proposal, to better understand the basis for our cost and schedule estimates.
I am much involved these days in three different fields: risk assessment, closure design and foreign materials. All have a relation to safety case and long term safety. For closure design I discovered a new experiment lead I need to discuss with the WMO, and much details of other countries ideas for plug execution, data about monitoring and instrumentation and probably other things I cannot even put into words at this moment. For risk related work the final exercise was a good one, and I can definitely use this experience for my work (especially the discussions of this exercise, not the actual results we got).
I would like to learn more about scoping and use it. I also would like to have conversation about the future plans in my country's repository programme related to plugs and seals and try to utilize the ideas of other research projects.
As I mentioned it in question 3, I plan to improve my skills in electro-technics.

Furthermore I will accustom me to begin a project by having a general overview and a methodology. In former times I have always begun a project too specifically so my time schedule collapsed immediately.
I think I will use the work breakdown structure (WBS) and the risk prioritizing more consciously. Partially I already used both of them somehow, but I used them less precisely as well. I hope I will be able to use the design principles and the other recommendations for the design of a demonstration plug in a future repository.
My company is a subcontractor for the national waste management organisation and we are working at the construction of their repository programme. In this year the demonstration chamber (for plug) was shaped, and there is no accepted plan, so there is time and possibility to work on it.
I'll know how to better evaluate and assess safety.
I am going to have presentation about DOPAS for my colleagues.
I will implement knowledge in my doctoral thesis and in my research project.
I am not sure I use new knowledge in my future work. Time will show me.

5. Did the training workshop fulfil the objectives you set for it? Please explain.

Tutors' 18.9.2015 view: yes, balance between theory and practice
Marjatta recommends, **please follow up the projects: Modern (http://www.modern-fp7.eu/)** and **Modern2020 (http://www.modern2020.eu/).**

Replies summary (red indicates areas that were felt missing): **Learning about other countries programmes, and of different types of experiments. Desire to have more details on the instrumentation and monitoring.**
Yes, I wanted to get better knowledge of other countries plugs construction approach
Yes. Learn about the other countries' experiences about radioactive waste management and how they handle with this problem it is/will be very useful for me.
Yes, it did. In our repository the plugs and seals demonstration project is in an initial phase. My intent was to get an overview of other projects and see how other research projects are built up and get to know some ideas and experiences. The next step would be to be more detailed oriented.
Yes, it has fulfilled my objectives because I received an overview of many projects regarding to the construction of plugs and seals. Furthermore I was able to get in contact with other people working on the special topic of the radioactive waste management.
Yes, my main objectives were to understand the differences between the experiment designs and the reasons for those differences and to get hands-on experience in an underground facility. I felt that both of these were completely fulfilled. During the workshop, I also identified several areas for further development, particularly modelling of full-scale tests and laboratory experiments and how these results are used in safety assessment models, which was touched upon but not in too much detail.
Yes, I learned more than I expected
Overall I would say that the objectives were fulfilled, but some related to more detailed knowledge. The good thing is that I know who I can contact if I have any questions.
I wrote this in answer to question three. One thing I perhaps would have wanted to discuss more or have a some sort of exercise of, is how to design where sensors are put in the large scale experiments. How to determine the adequate amount of sensors and exactly where to put them in plug? This I still don't know, and I don't know if there is a one right answer or does this scheme change with every experiment. There must some "universal rules" to that too, and I haven't found them yet. We did discuss that there needs to be redundancy and quantity, but not in detail about what is considered enough and where the sensors are actually put.
Generally I can say: yes. I found the presentations and the exercises really interesting and they formed

my approach to the right direction. However as I already mentioned you on the paper sheet I also would have liked some numerical modelling or technical design exercises too. I have to admit that there wasn't enough time to fit further examples in the tight schedule. So all in all, definitely I can say: Yes.
Yes, I have learned a lot, on what we need to concentrate. The only one, I think was the instrumentation, as we all said on the last day, that there were not so much exact information about the projects' instrumentation.
I did not know what to expect and I was pleasantly surprised.
I can´t explain. I didn´t set any objectives.

6. What kind of benefits can you foresee resulting from your participation to this training workshop?

Replies summary: Network and contacts for asking information and cooperating and for new opportunities, new knowledge.
To get in touch with foreign countries experts.
I gained links into each of the programmes represented by the staff and other students in the training workshop, which included Czech Republic, Hungary, Poland, Finland, Sweden and Germany as well as with the DOPAS project partners. I learnt some Czech and enjoyed working with people from different European countries and with different cultural approached to the same issues, which will be useful for any future involvement in EC projects.
A network, see also answers to the above questions.
I got to know other people from this special field of engineering geology and I think we can share information.
By participating in the workshop I became the contact person regarding to plugs and seals in the my own organisation. Now people contact me to respond their questions concerning international projects, project designs, construction materials, etc..
I can ask for advice from the lot of experts and colleagues, who I met on the workshop. And maybe we will also work together someday.
Better job opportunities in the future. More skills to enhance my job. My professional Network has increased.
Benefits: Improving my English skills, meeting new people, working in group of people with different knowledge and skills.
As the main benefit I can replace the experience gained in the subject radioactive waste disposal. It seems to me that in the further professional work might help along to interact with other participants.
Benefits are clearly in my work, I learned new things and I can use this knowledge in my projects. Meeting the people was an excellent benefit too! It is good to know more professionals from different areas working with these same matters, this can lead to co-operation and makes it easier to contact people from their organizations, not just to contact the people I have met.
I think after the training I have a more realistic "picture" about what is going on in the other countries. We can read sometimes some new papers about the constructions, developments, etc., but just in short, and not so detailed version. I think we got to know very kind people, it was a real good group all together, so hope in the future once more of us, we can work together, get some cooperation between our countries, companies.
New knowledge, I can take advantage of its focus on security.

7. What kind of disadvantages do you foresee as a result of this training workshop?

Replies summary: Fatigue, potentially misunderstanding something in the content as one is not using mother tongue. In general no major disadvantages, only few replies mainly stating that no disadvantages.

Overall assessment of training workshop

8. Would you recommend participation to this training workshop to others? 12 replies with yes. Why?

Replies summary: for contacts, for improving your language skills, getting an overview and new knowledge, being enjoyable
To practise English; to get overview.
It was very interesting and instructive training workshop.
It provided an excellent overview of: the proposed disposal concepts in five repository development programmes; the way the safety functions are implemented through the plugs and seals and demonstrated through experimental programmes; the wider context of managing these experiments; and implementation challenges experienced as a result of materials and construction techniques selected for the different designs.
This training offered new knowledge about R&D of advance national programs and new skills to work in such important projects. The exchange and networking with other colleagues from the same field was another positive aspect too.
I would recommend because of receiving new contacts and knowledge.
I would definitely recommend this training workshop to others. It is a great learning experience and gives the opportunity to get to know others working on the same issues and challenges.
I would definitely recommend this workshop to anyone, whose work is related to monitoring, closure, long term safety etc. This is very specific course and not a general course for anyone. I would think that the participant need basic knowledge of what disposal of spent fuel/radioactive waste is, and is familiar with the jargon used. For certain category professionals this is extremely beneficial. This is because for desk workers it gives a glimpse to field work, ties them together: the design and implementation, and discusses the aftermath: what to do with the results. Personally I enjoyed every second of this training workshop!
I would recommend, because it was very well organized and gave a complex overview on the plugs demonstrations. If somebody has already knowledge about the topic, he/she can share information as everybody was direct and open to communicate.
ABSOLUTELY! It is familiar, you get in contact with other people, you get many useful impressions.
Of course, I would and I will recommend, for all those good reasons what I have mentioned.
I've learned new things, new information, expand my information on this subject.
I would recommend the workshop to others too, because it was really informative and enlightening. I met amazing people, and learned from real experts about the plugs and seals and the related challenges.

9. **General evaluation of training workshop** - give a rating after each line
Rating scale: 1-5 (very poor – poor - average – good - very good)

Rating	1	2	3	4	5	Avg
No of replies			*n=*	*n=*	*n=*	*N=12*
1. Selection of learning units (LU) and topics				5	7	4.6
2. The coverage of learning units and topic presentations			1	5	6	4.4
3. The order of learning units and topic presentations			2	6	4	4.3
4. Tutors (expertise, tutoring)				4	8	4.7
5. Training materials				2	10	4.8
6. Activities				3	9	4.8
7. Exercises				4	8	4.7
8. Practical arrangements				3	9	4.8
9. Time keeping/Schedule			1	7	4 (:-))	4.7

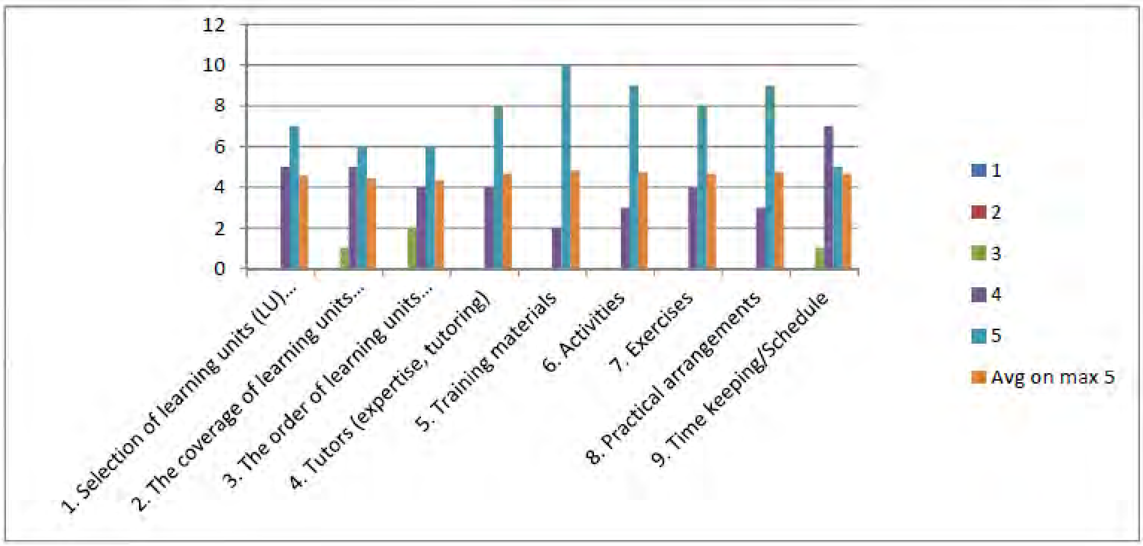
Tutors's expectation on 18.9.2015 - rating between 4-5
Unmet expectation: More on sensor details for the content expected.

One of the assessments was systematically one category lower than all others ratings (the yardstick difference is partly culturally dependent e.g. in the UK and in the US tendency to give systematically higher ratings than e.g. in Finland, this shown in the normative tests of marketing studies).

2.10.2015

Overall rating of the DOPAS Training Workshop 2015

Scale (very poor/poor-average-good/very good)	1	2	3	4	5	Avg on max 5
1. Selection of learning units (LU) and topics	0	0	0	5	7	**4,6**
2. The coverage of learning units and topic presentations	0	0	1	5	6	**4,4**
3. The order of learning units and topic presentations	0	0	2	4	6	**4,3**
4. Tutors (expertise, tutoring)	0	0	0	4	8	**4,7**
5. Training materials	0	0	0	2	10	**4,8**
6. Activities	0	0	0	3	9	**4,8**
7. Exercises	0	0	0	4	8	**4,7**
8. Practical arrangements	0	0	0	3	9	**4,8**
9. Time keeping/Schedule	0	0	1	7	5	**4,7**



General comments

What did you like? Which training days did you like best?

18.9.2015 Tutors' view would state that Days 2 and 4 in Josef, all exercises

Replies: All days were liked, but DAY 2 was a special favorite.
I liked it all, especially technical details of DOMPLU and POPLU. (DAYS 2, 3)
All training workshop was conducted in an interesting way. I like best training days in Josef. (DAYS 2 and 4)
I liked the two days we spent at UTC Josef (DAYS 2 and 4). I enjoyed the talks about implementation of the full-scale experiments and monitoring/sensor selection and then the complementary exercise on preparing and installing thermometers in the MPO TIP Řež heater experiment underground. I enjoyed the information about the current status of Czech waste management programme from the talks at SURAO and discussions with Czech participants. (DAY3) The talks on the DOPAS experiments were really well-structured and, when taken together provided many insights into disposal concept development and design processes. I also enjoyed the social activities we did as a group, where we got to know each other better (networking!). I would love to spend more time in Prague, it was a beautiful city and the surrounding countryside was equally attractive.
Day 2: Temperature monitoring exercise in Josef. Day 3: Excursion to SURAO and the experiments. Day 4: Data Interpretation of the measurements of our sensors.
I liked the second and the third training day best. I liked working in group and practical exercises. (DAYS 2 and 3)
I liked the variety of activities and that the days were very well planned with lectures and exercises that were linked to each other. I liked the training days in Josef the best (DAYS 2 & 4)
I liked the overall program and that it was carried through quite as planned. Favourite day is hard to pick, but perhaps it was Tuesday DAY 2 (because we got to actually make sensors! we never get to do those kind of things.) I liked every exercise. Some of the lecture topics were quite familiar to me, but even from the familiar topics I found new aspects and details.
I really liked the exercises (DAYS 1-4) as they helped to understand more the training topics and we got some practical experiences even though the time was less as in reality. Each day was good as on each day there were exercises. I also really liked the first “ice breaking” exercise (DAY 1). It helped a lot to be more open. The last day was also really good when every project-participant shared his/her thoughts about the project and the lessons learned from the experiments so far.
I liked all exercises that have been made and their presentation in front of all participants (all days). My favourite day was DAY 2 because the construction of the sensor and the visit of Josef gallery were very exciting.
All was great, but different, so for me it is not possible to take the rating about them. But maybe the “culture at the Cathedral” was the most grandiose! (DAY 4) The time keeping – as I wrote over – was fantastic, never late, always on time, everybody kept the time. I haven't seen before so well organised training, conference, which would not have problems with time keeping!
All the exercises, DAY 2
Well it's hard to choose but I would say that I liked the best the third and the fifth day (DAY 3, DAY 5) because of the Andra scientific program and the ELSA experiment presentations.

Improvement suggestions?

Tutors' view on 18.9.2015 - a bit easier programme in terms of time would have been better. Suggestion to do exercise one day afternoon, reporting first thing next morning.

Replies summary: time for reflection and for producing the report together with the group
To keep time (DAY2) and be gentle with criticism on contractors remembering the influence of scope.
There were several questions over what was needed in terms of the presentations and reporting, and a short recap part-way through the week (once some of the exercises have been completed and we have a better feel for what we are doing) may have been helpful – i.e. identifying on Wednesday night that teams need to arrange time outside the course schedule to discuss and develop the presentations. Include some time in the schedule, perhaps an hour on Friday morning, for the group to prepare for the final presentations together and discuss their conclusions. We did not organise ourselves to arrive earlier that morning, so I felt the final presentations were not as considered and logically-presented as they should have been. Finish times in the evening were late and people were staying in different places, so it was not possible to discuss over breakfast, for example. The groups worked much better in the practical exercises on Wednesday than they did on Tuesday, partly because we knew each other better and partly because the groups were smaller (3 rather than 6). If it was possible to split the groups further (perhaps by having 3 people prepare the analogue and digital sensors in parallel), I think we would have had less time pressures and been able to participate in more of the process steps. A lot of the discussions in the lab on Tuesday also took place in Czech, which made it rather difficult to follow at times.
We needed more time for the experiments and time to discuss about the experiments for the presentation on Friday too. Unfortunately, even though I wanted to discuss about it, my colleagues did not show any interest to talk about our reports.
I would like to hear more about laboratory and in-situ results.
I would have wanted more time for reflection together with the group in some exercises.
The schedule was very tight and we were all a bit tired sometimes. It was good in that way, that I would not have wanted to miss anything of the course, and was happy that all was included that was there. The Wednesday morning was a bit harsh, because Krystal people did not have time to have breakfast (well we had ten minutes to have it)... Small detail, but it would have been nice to have had time for it.
A little bit more time to reflect on the lectures (perhaps with a small discussion)
Now nothing, I really liked the training!
Enhanced cooperation between organizations
Maybe some additional numerical modelling with a specific seal would be useful as an optional exercise for those who are interested. I mean to investigate what are the possibilities and the consequences of using the fully coupling and the decoupling of the processes and so on. Or some basic (or not basic) laboratory exercises with bentonite swelling pressure measurement would be also interesting.

Any other ideas, comments?

Tutors 18.9.2015 - main aims of the training: SA, risk, technical points, well covered.

Replies summary: good package including location.
Generally speaking, I am very glad that I could participate in DOPAS Training Workshop 14-18 September 2015. In my opinion selection of learning units and topics was very good and teaching was on a high level.
Second training held in ONKALO would be nice.
General feedback to the tutors: very good teaching materials, exercises and presentations. In some cases the instructions for the exercises could have been clearer. Pictures, illustrations and movies are appreciated. Last but not least, thank you for a great week in Prague.
One point I brought up earlier: it would have been nice to learn about how the sensors are sited in the plugs, are there general rules for that, recommendations for quantities etc. I find it sad somehow, if this really was just a one course that will never be held again… Sincere thanks to everyone involved in organizing this course and participating in implementation!
It was a really intensive, well organized week. I really liked it as we were there to learn and experience as much as possible. I think we met many ideas and thoughts which will be very useful in our future work, but we need some time to process all of them.
Thank you very much for the possibility, I loved it and I enjoyed! We just were talking on road to home, that was no topic or presentation, on what we would not like to listen to, or we were bored, etc. So congratulation for you all!
The location of the workshop was a very good choice.

Final comment:
Only few evaluation results were given to the tutor specific feedback question, thus the results are not shared in this summary.

THANK YOU FOR YOUR EXTENSIVE FEEDBACK! :-)

Tutor guide DOPAS Training Workshop 2015
General instruction list for the training material preparation, presentation and logistics checklist

1 DOPAS TRAINING WORKSHOP - GENERAL ABOUT THE WORKSHOP

1.1 General learning objectives

1.1.1 Disseminate and share the experiences from the full-scale plugging and sealing experiments from the DOPAS project

1.1.2 To address the areas related to requirements for plugs and seals, developing a design basis for an experiment, modelling and assessing the performance of a plug or a seal, developing materials, methods and constructing such a full-scale experiment and assessing the outcomes from such experiments

1.2 General learning outcomes

- To understand (K) the process/es of designing a full-scale experiment from a set of requirements related to the performance of a plug or a seal as a repository component in geological disposal.
- To be able to contrast (S) the differences of such processes resulting from the different boundary conditions e.g. from the host rock environments (clay, crystalline rock, and salt), the experimental settings (above ground, underground experimental facilities vs. real repository conditions) and other site and disposal concept specific features.
- To comprehend (K) the linking of different experiment project's related subprojects and tasks and their inputs and outputs as a part of the experiment implementation.
- To acquire (S) hands-on experiences in experimenting with materials' testing and monitoring techniques needed in an experiment, and
- To know how (C) the individual experiments and their outputs contribute to the overall demonstration planning and demonstration programmes for safety of the waste management programmes at the different stages of repository development.

1.3 Suitable descriptions for the learning outcomes and for assessment of participants during the DOPAS training workshop - do they demonstrate the following behaviours:

1.3.1 For Knowledge:

Remember or Understand e.g.

shown by ability to name, define, list, reproduce, tell
discovering relevant information from a set of knowledge
to discuss and explain basics of a topic to others

Analyse

compare, contrast, outline, examine, differentiate, categorise, survey, determine, classify, report

1.3.2 For Skills:

Apply, Create:

questions, draw, illustrate, paint, compose, model, imagine
construct, simulate action, rearrange, produce, design, suggest,

1.3.3 For Competence:

Evaluate

ability to conclude, rank, support, prioritize, justify, select, defend, discuss, compare, verify, give an opinion, summarize

1.4 The learning outcome related content of training corresponds to EQF levels 4-6[1]

EQF-level	KNOWLEDGE	SKILLS	COMPETENCE
EQF = 4	> factual and theoretical knowledge in broad contexts within a field of work or study	> a range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	> exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change > supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities
EQF = 5	> comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	> a comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	> exercise management and supervision in contexts of work or study activities where there is unpredictable change > review and develop performance of self and others
EQF = 6	> advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	> advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialised field of work or study	> manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work or study contexts > take responsibility for managing professional development of individuals and groups

Green: aiming at this level for the participants
Yellow: not likely to address this level, some may reach it, depending on prior KS.
The exercise work may also result for some in the group to reach C at level 6.

[1] Source: https://ec.europa.eu/ploteus/en/content/descriptors-page Descriptors defining EQF-levels, last downloaded August 2016

2 GENERAL MATERIAL PREPARATION AND PRESENTATION GUIDELINES FOR TUTORS

2.1 Slide templates and use Powerpoint text size with a min. of 18 pts text (only on exception 16 pts)

2.1.1 If smaller font size is needed provide such documents also in A4 text size pdf:s in addition to the ppt

2.1.2 You are free to use your organisation's template, too, but make sure the DOPAS and the Euratom FP7 logo are visible **on all pages**

2.1.3 Number all the pages of your slides. Date is optional on the other pages, as long as it is on the front page. If you use the date, check that it is the same as on the front page.

2.1.4 On your title page and on your last page use the EU support statement with the DOPAS grant agreement no

Front page of each presentation shall include the following:

DOPAS TRAINING WORKSHOP 2015
Name of your presentation
Name of the presenter
Date of presenting the presentation
The statement:
The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.
with the relevant DOPAS and FP7 Euratom logos (see the training material folder for the template model).

2.1.5 Give few slides about the organisation you are coming from in the beginning of your first presentation (max. 4 slides) for the audience, if this has not been done already (CTU and SURAO do not need this)

2.2 Referencing

2.2.1 Make sure that all figures include a reference to the source/copyright owner and that you have the right to publish this material as open access.

In case the material is allowed for publication, but not open access, please state the conditions for using the material in your presentation

2.2.2 Give complete reference list to published documents that you use as a basis of your presentation at the end of your training material

2.2.3 Make a list of all abbreviations and their source (e.g. if the original set of words is in French, write both the French and the English version or explanation). This can be a slide at the end of the presentation, too. For abbreviations at the end of this document, you can refer during your presentation to the list in the training materials.

2.2.4 Training material will be open access, remember that only material allowed for open access can be used (see point 2.2.1, too).

2.2.5 Provide a book/report references or other learning resources e.g. websites for further recommended reading on the topic at the end of your material/s

2.2.6 You are also welcome to produce more detailed lecture notes for the participants, if you wish (but this is not mandatory) or upload an existing report for the participants as a part of the training materials (remember copyright issues).

2.3 **Cover in all experiment presentations in addition to experiment design and implementation the following topics:**

2.3.1 Objectives of the experiment (including the meaning for safety and the life time of the component) - top level requirements in terms of safety, the safety functions that the plugs and seals are intended to fulfil in your repository concept. If your experiment is not addressing safety functions but technical feasibility, be explicit about this.

2.3.2 Development and testing of materials for the experiment, the function of different materials/components in the experiments

2.3.3 Modelling and predictions made for the experiment, monitored parameters (see also 2.3.4)

2.3.4 Instrumentation and monitoring (selection, types, installation) for assessing the performance of the experiment

2.3.5 Specific technical or safety related boundary conditions for the experiment (e.g. environmental and site specific conditions, see WP2 deliverable D2.4).

3 FOR EACH LEARNING UNIT

3.1 Produce detailed learning outcomes broken down into (these will be compiled together by Marjatta)

3.1.1 Knowledge (K) - Understanding of e.g. theory, concept, process, method, test scheme

3.1.2 Skills (S) - How to do - e.g. a project plan, a risk assessment, a plan for performance assessment, for monitoring a test, ...

3.1.3 Competence (C) - How to be - e.g. when operating in a repository setting; working in groups; working underground

3.2 How to assess the achievement of each of the learning outcomes

3.2.1 Knowledge (K) - How can a participant demonstrate the understanding of e.g. theory, concept, process, method, test scheme?

3.2.2 Skills (S) - How comprehensively does the participant carry out - e.g. a project plan, a risk assessment, a plan for performance assessment, for installing instrumentation, handling monitoring data ...

3.2.3 Competence (C) - How detailed does the participant follow the instructions, how interactively and intensively does the participant follow the training and work in the exercise groups, how well time is managed in the groups?

3.3 How well does the learning unit follow the full learning cycle?

3.3.1 Check that the learning unit includes all of the elements required for a full learning cycle

3.3.2 Propose activities to complement the missing parts of the learning cycle

3.3.3 Other content related considerations

3.4 We recommend you to take with you:

- Your personal computer or tablet with sufficient software (MS Office or equivalent) for your presentation materials' and their last minute updates.
- Your presentation material on a memory stick.
- Please take with you also some teaching aids e.g. small host rock samples, video clips and similar presentation aids you consider of interest for the participants.

4 PRESENTATION AND TASKS OF THE CHAIR

4.1 Provide your Powerpoint presentations to the Projectplace latest on September 3, 2015

They will be transferred into pdf and uploaded for the participants on the database on Monday September 7, 2015.

Please do a test transfer and check that all your figures are visible on the pdf-format. If not please adjust them or notify about this when posting your ppt's as we need to reprocess such presentations.

4.2 Sticking to the timetable

The chair will notify you 5 minutes, 1 minute before your time is due. And signal red, when your time is out

4.3 The chair of the morning to make sure the daily participant list is circulated among the participants.

4.4 The chair to assist the presenter and audience by asking questions or providing related examples from one's own experiences and in Josef checks that everyone is on board the bus when returning to Prague.

5 DOPAS Training Workshop 2015 participants

The DOPAS Training workshop is fully booked with 12 participants presenting universities (3), agencies and WMOs (3) and consulting companies (6). The composition of the participants is 7 females and 5 males. At least two consultants/researchers have a doctoral degree, one doctoral student and one Master's student are included. The other participants are professionals with most likely at least a Master's degree. The participants come from organisations in Germany (2), Czech Republic (3), Finland (1), Sweden (1); Poland (1), Great Britain (1) and Hungary (3).

6 Logistics checklist

BLOCK BOOKINGS FOR HOTELS

RESERVATION DEADLINE OF BLOCK BOOKING

RESERVATION REFERENCE AND HOTEL DETAILS INCLUDING LOCATIONS AND CLOSEST PUBLIC TRANSPORTATION

INFORMATION TO COURSE ORGANISERS OF YOUR HOTEL FOR PICK-UPS AND YOUR CONTACT PHONE NUMBER

LIST OF WHAT YOU NEED TO TAKE WITH YOU

LIST OF WHAT IS PROVIDED BY THE ORGANISERS (including wifi-access)

TRANSPORT FROM/TO AIRPORT

PERSONAL INFORMATION NEEDED FOR ACCESS TO NUCLEAR FACILITIES

Citizenship
Person ID or Passport number (of the document you have with you on entry)
Date of birth
Surname
First names
Place/state of birth
Employer

FIRST DAY MEETING POINT AND TUTOR CONTACT INFORMATION

GENERAL INFORMATION /INFORMATION SOURCES ABOUT THE TRAINING LOCATION

INFORMATION ABOUT THE OTHER TRAINING LOCATIONS AND ABOUT TRANSPORT TO THEM (TIMES, PLACES)

REMINDER OF ID OR PASSPORT FOR THE ACCESS TO NUCLEAR FACILITIES

7 List of most common abbreviations

These lists are distributed to the participants with the learning materials and you can use these in your presentations

Common abbreviations in geological disposal

DGR	Deep geological repository
DOPAS	Full Scale Demonstration of Plugs and Seals (FP7 project running from 2012 to 2016)
EBS	Engineered Barrier System
Euratom	The European Atomic Energy Community
FEP	Features, Events and Processes
FP7	The Seventh Framework Programme (2007-2013) of Euratom

GD	Geological disposal
HLW	High-level Waste (Reprocessed high level radioactive waste)
ILW	Intermediate Level Waste
KBS-3	Kärnbränslesäkerhet - 3, disposal concept developed by SKB (Sweden)
LLW	Low-level Waste
NWM	Nuclear Waste Management
NPP	Nuclear Power Plant
R&D	Research and Development
RD&D	Research, Development and Demonstration
RWM	Radioactive Waste Management
SF (or SNF)	Spent nuclear fuel (also called used fuel (US))
URL	Underground Research Laboratory
WMO	Waste Management Organisation

Underground Facilities referred to

BURE: Underground Research Laboratory located in France in callovo-oxfordian clay (argellite) formation

Josef URC and Underground laboratory: Underground Research Centre located at the Josef exploratory gallery in Czech Republic located in crystalline rock.

Äspö HRL: Äspö Hard Rock Laboratory, a underground research facility located in Oskarshamn, Sweden in granite.

ONKALO (URCF): An Underground Rock Characterisation Facility, located in Olkiluoto, Finland at the site of the future disposal facility for spent nuclear fuel. Located in mica gneiss and pegmatite host rock environment.

Gorleben: Salt dome in Northern Germany that has been investigated for its suitability for disposal of high-level nuclear waste for 40 years from surface and from underground by an exploration mine.

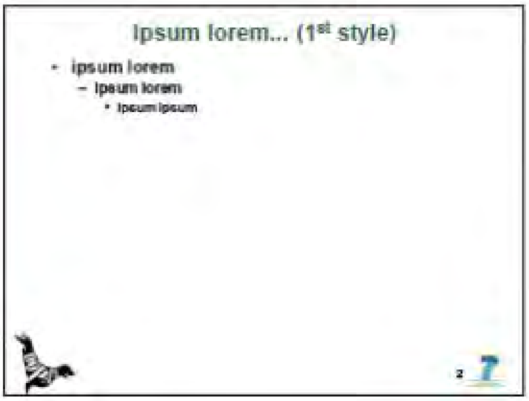
DOPAS Full-scale experiments

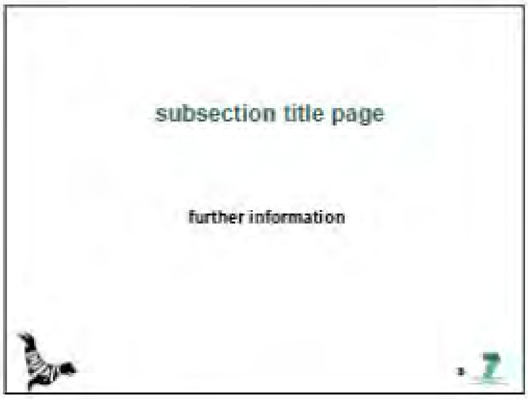
1. FSS — Full-scale Seal constructed in a test hall in St. Dizier in France
2. EPSP — Experimental Pressure and Sealing Plug, plug experiment in the Josef Underground Laboratory in Czech Republic
3. DOMPLU — Dome-shaped plug experiment in Äspö HRL in Sweden.
4. POPLU — Posiva Plug, a wedge-shaped plug experiment in ONKALO, Finland (on the future disposal site)
5. ELSA — Entwicklung von Schachtverschlusskonzepten (Development of shaft closure concepts) in Germany

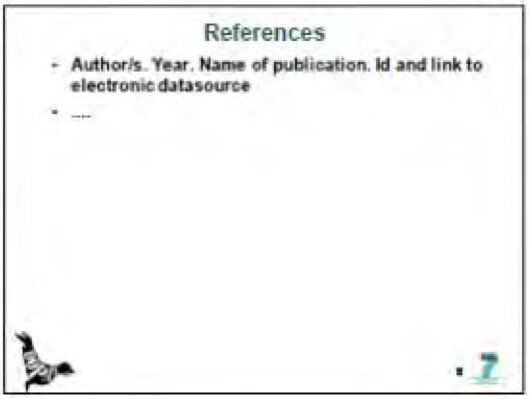
Organisations tutoring in the DOPAS training workshop and some engaged project members

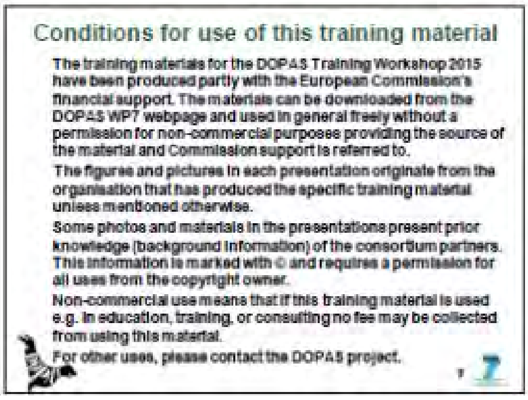
ANDRA	French nuclear waste management company (www.andra.fr)
CTU	Czech Technical University in Prague, Centre of Experimental Geotechnics, (http://www. cvut.cz/)
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) GmbH (www.grs.de)
NAGRA	Swiss nuclear waste management company (www.nagra.ch)
NDA	Nuclear Decommissioning Agency, United Kingdom (http://www.nda.gov.uk/)
Posiva Oy (POSIVA)	A Finnish waste management company in charge of disposal of spent fuel of its owners (www.posiva.fi/en)
RWM	Radioactive Waste Management Limited, a subsidiary of NDA, UK (http://www.nda.gov.uk/rwm/)
SKB	Swedish nuclear waste management company (www.skb.se)
SURAO	Radioactive waste repository authority, Czech Republic (www.surao.cz)
UJV	ÚJV Řež a.s. (http://www.ujv.cz/en/)

Presentation template









EQF Levels 4-6 KNOWLEDGE	Description	General Description
	Overview of Posiva's/Czech/Andra's programmes for radioactive waste disposal POSIVA disposal concept and plans for its implementation at ONKALO. To discuss the spent fuel management activities in the Czech Republic and the future radioactive waste repository programme of Czech Republic	Nuclear waste management R&D programmes overview
	Knowledge of DOPAS project objectives, strategies and interim outcomes	DOPAS Project overview
	Requirements, functions and design basis Hierarchy of requirements applied to a safety classed structure. Requirements on the plug in the POSIVA reference design and the differences to the POPLU experiment Barrier functions and operational aspects Comprehensive knowledge about ONKALO specific requirements for work	Requirements, functions and design basis of plugs and seals
	Sealing openings underground in fractured rock – design and specification of requirements and implementation.	Underground sealing/closure structures and technical solutions for them (design and construction)
	Plug design and technological solutions The POPLU plug design and its development	Mechanical stability of host rock
	Design clay barriers	Clay and concrete barriers
	RSC and other things take account in selection for high radioactive waste repository location. Plug site selection based on RSC (Rock Suitability Classification)	Site location selection methods for the structure/s
	Underground hydrochemistry in seaside areas.	Underground hydrochemistry
	Knowledge about clay material and properties - (bentonite pellets and granules, tapes) Clay barrier technology (mineralogy, geochemistry, physical conditions inside plug)	Clay material knowledge (incl. swelling pressures
	Knowledge about concrete material and properties - SSC, shotcretes, grouts Concrete recipe and mock-up tests	Concrete material knowledge (incl. thermal and mechanical processes)

EQF Levels 4-6 KNOWLEDGE	Description	General Description
	Plug material handling and material handling devices/logistics - CLAY/BENTONITE Handling and work environment of bentonite materials Handling of concrete transport Filling of plug structure with bentonite/ with shotclaying Plug material handling and material handling devices / logistics - CONCRETE Information about materials (shotcrete, bentonite) that were used by shotcreting in the experiment	Material technologies and logistics for clay and concrete materials
	Monitoring and performance confirmation – design of monitoring equipment and test plans. Monitoring strategy and plans Knowledge and high-level understanding of techniques for monitoring plugs and implementation procedures, as used in the POPLU experiment Advanced knowledge of POPLU design and monitoring plans Testing and monitoring of the POPLU experiment Instrumentation of the POPLU experiment and the broader issue of performance confirmation and testing of disposal repository components Sensors set up. Sensors, types and location in plug	Monitoring and performance confirmation
	Knowledge about the work environment and related concerns More information about working in hard working conditions and small tunnels Experience and observations of methods/restrictions for working underground Information about contracting and related difficulties involved in this project	Constraints and boundary conditions including working environment and work safety

EQF Level 4-5 SKILLS	Description	General Description
	Critically evaluate experiment design and/or implementation Observation of different experimentations that are being carried out in-situ underground Evaluation of practicability and implementation of desk-based designs using full-scale tests Observe structure and instrumentation of plug	Critical evaluation of design and implementation
	Specialised skill in planning and organisation of a full-scale experiment Risk management for the POPLU experiment. Critical awareness of the risk management for work underground at ONKALO Work methods in tunnel conditions including reinforcement and concrete works. Reinforcement of the plug.	Specialised planning and organisation for full-scale experiments
	Advanced skill in understanding the technical solutions used for POPLU Obtained a better understanding of the difficulties that can be met in underground conditions. More precisely, difficulties related to concrete transfer logistics (routing and space availability) were discussed and solutions to counter these difficulties have been observed. Obtained a greater understanding of the concrete and bentonite materials used in the EPSP implementation and the development of its specification. A large number of laboratory experiments were carried out to test different bentonite mixture compositions. Concrete formulations and specifications have been produced by the Contractor and have been tested by the EPSP project teams.	Understanding about the used technical solutions (including used materials and handling techniques)
	Specification and management of requirements, how they are arranged in a safety classed structure, and the link between requirements and experimental testing. Relate design basis / requirements to implementation of experiment	Specifying and managing requirement hierarchies and their link to design
	Use of grouting and injection tube installation.	Grouting works/installation
	Concrete recipe and work method development including concrete mock-ups (method tests).	Concrete recipe development and method testing
	Attachment of monitoring (strain, temperature, and humidity) sensors. Sensors, work with received data using specialized programme, digital outcomes	Installation of sensors and monitoring devices

EQF Level 4-5 COMPETENCE	Description	General Description
	Experience of evaluating work carried out by another organisation and providing review feedback on future improvements	Peer discussions
	To discuss the various aspects of the Czech Nuclear Research programme carried out in laboratory setting To discuss the spent fuel management activities in the Czech Republic and the future radioactive waste repository programme of Czech Republic	Peer review
	Use practical observations and experiences to increase own knowledge and understanding; usefully absorb information and apply it in other contexts Evaluation of ongoing installation work conducted for POPLU Review of the coordination of on-site contractors for POPLU	Observations and benchmarking
	Work with other visitors to evaluate observations of the POPLU experiment and provide constructive feedback to Posiva	Peer collaboration and joint development
	Working safely underground	Work safety practices, boundary conditions and constraints

DOPAS
Training Workshop 2015
14 - 18 September 2015

Practicalities on Course Fees and Accommodation

The DOPAS Training Workshop participation is free of charge to the selected participants including local transportation (Monday-Friday) from designated hotels to the training locations, daily lunches, and coffees during the workshop.

The participants are responsible for their own travel to and from and for accommodation expenses in the Czech Republic. Block booking for accommodation is made in Prague and information about it will be sent to the registered participants after the registration is received.

For conditional accommodation support of full-time university students, please make sure that you mention in your application that you are a full-time university student and give the name of your university and professor. This support is discretionary and will not be guaranteed to any participant.

The total number of participants is limited to 12 students. Priority is given to participants coming from other than the DOPAS project consortium organisations. The detailed selection criteria in case of oversubscription to the workshop will be posted on the DOPAS website at http://www.posiva.fi/en/dopas

Special Requirements for the Participants

The training workshop participants need to fulfil the following requirements:

- Each individual needs to be able to move unassisted and carry out hands-on exercises underground.
- Each individual needs to have insurance coverage against injuries and illness for the duration of their stay at the workshop. Please check the sufficiency of your insurance coverage prior participation. Proof of sufficient insurance coverage may be requested by the organisers.
- To inform the organisers at the time of registration of any dietary restrictions that may apply.

For More Information

For more information about the DOPAS training workshop and its details visit www.posiva.fi/en/dopas or contact Mrs Marjatta Palmu at Posiva Oy marjatta.palmu(at)posiva.fi.

The research leading to these results has received funding from the European Union's European Atomic Energy Community's (Euratom) Seventh Framework Programme FP7/2007-2013, under Grant Agreement No. 323273 for the DOPAS project.

REMEMBER ALSO

DOPAS 2016 Seminar
International Topical Seminar On Plugging And Sealing
25 - 27 May 2016, Turku, Finland

www.posiva.fi/en/dopas

DOPAS
Training Workshop 2015

14 - 18 September 2015
Czech Republic, Prague and Josef URC

5-Day Training Workshop
on the Role of Full-scale Experiments on Plugs and Seals
in Demonstrating Safety and Performance
of Geological Disposal

Registration Deadline 10 August 2015

More info:
www.posiva.fi/en/dopas

DOPAS

Learning Outcomes

The 5-Day DOPAS Training Workshop is targeted to full-scale experiments on plugs and seals in geological disposal of radioactive wastes. The workshop learning activities are designed to enable the workshop participants to acquire a set of learning outcomes based on the experiences of the DOPAS project and demonstration programmes of nuclear waste management organisations.

The expected learning outcomes for the participants are:

- To understand the process/es of designing a full-scale experiment from a set of requirements related to the performance of the safety function/s of a plug or a seal as a repository component in geological disposal.
- To be able to contrast the differences of such processes resulting from the different boundary conditions e.g. from the host rock environments (clay, crystalline rock, and salt), the experimental settings (above ground, underground experimental facilities vs. real repository conditions) and other site and disposal concept specific features.
- To comprehend the linking of different experiment project's related subprojects and tasks and their inputs and outputs as a part of the experiment implementation.
- To acquire hands-on experiences in experimenting with materials' testing and monitoring techniques needed in an experiment, and
- To know how the individual experiments and their outputs contribute to the overall demonstration and demonstration programmes for safety of the waste management programmes at the different stages of repository development.

This training workshop is a part of the Euratom FP7 DOPAS project. It is designed and implemented in collaboration by Posiva Oy, Czech Technical University (CTU), Andra, SKB, SURAO, RWM, Nagra, GRS, and UJV (REZ). The learning units of this training workshop are also based on the experiences gained from the DOPAS project experiments FSS in France, EPSP in the Czech Republic, DOMPLU in Sweden, POPLU in Finland, and ELSA planning in Germany.

Registration to the DOPAS Training Workshop

The last registration/application date to the DOPAS training workshop is **August 10, 2015**. Please send your applications including the information below by August 10, 2015 to the following e-mail address: dopas@posiva.fi
The registration form is also available on the DOPAS website: www.posiva.fi/en/dopas .

Registration information required:

Full name:____
Organisation: ______________________________________
Street address:______________________________________
Postal code/Town/Country: ________________________________
E-mail: ____
Telephone (incl. country code): ______________________________
Other information:_____________________________________
Your role: professional or student
As a professional or student, describe the relation of the training workshop to your work or studies:
____
____
Dietary restrictions:____________________________________
Free field for comments:________________________________
____
____

Schedule, Related Learning Units and Locations

The DOPAS Training Workshop starts on Monday 14 September 2015 at 9 hrs a.m. at the Czech Technical University (CTU) in Prague and continues until 4 p.m. on Friday 18 September 2015. The workshop comprises also practical exercises at the Regional Underground Research Centre Josef (Josef URC) of CTU, 60km south of Prague. The length of the individual days varies due to the logistics and other activities. In general, with the exception of the first and last day, the training days extend from around 7:45 am to around 9 p.m. in the evening.

DAY 1

14.9.2015 at CTU in Prague

- Orientation to the DOPAS Training Workshop.
- Learning Unit 1: From requirements to the design basis of plugs and seals including the understanding of requirements management systems and their applications to plugs and seals and developing a basis and scoping an experiment from a project management perspective.

DAY 2

15.9.2015 at Josef URC

- Orientation to the Josef URC and Josef Underground Laboratory
- Learning Unit 2: Preparation of a full-scale plug or sealing experiment in different environmental settings including the development of a coherent demonstrator programme for plugs and seals and the role of instrumentation and monitoring in such an experiment with a hands-on exercise in Josef Underground Laboratory (also in Learning Unit 3).

DAY 3

16.9.2015 at UJV Research Centre in REZ close to Prague and at SURAO in Prague

- Learning Unit 2 continues with what is expected to follow in a demonstrator programme resulting from the implementation of such experiments.
- Learning Unit 3: Designing a sealing component for an experiment or demonstrator and the role of safety assessment and performance assessment of closure as a design input. This unit is about how to move from the initial design in an iterative manner to the final experiment design and construction, and how to assess the outcomes. It also addresses the behaviour of plug component materials and provides practical materials' related testing exercises in a laboratory setting.
- Introducing SURAO's programme on siting and deep geological repository, and information activities to the general public.

DAY 4

17.9.2015 at Josef URC

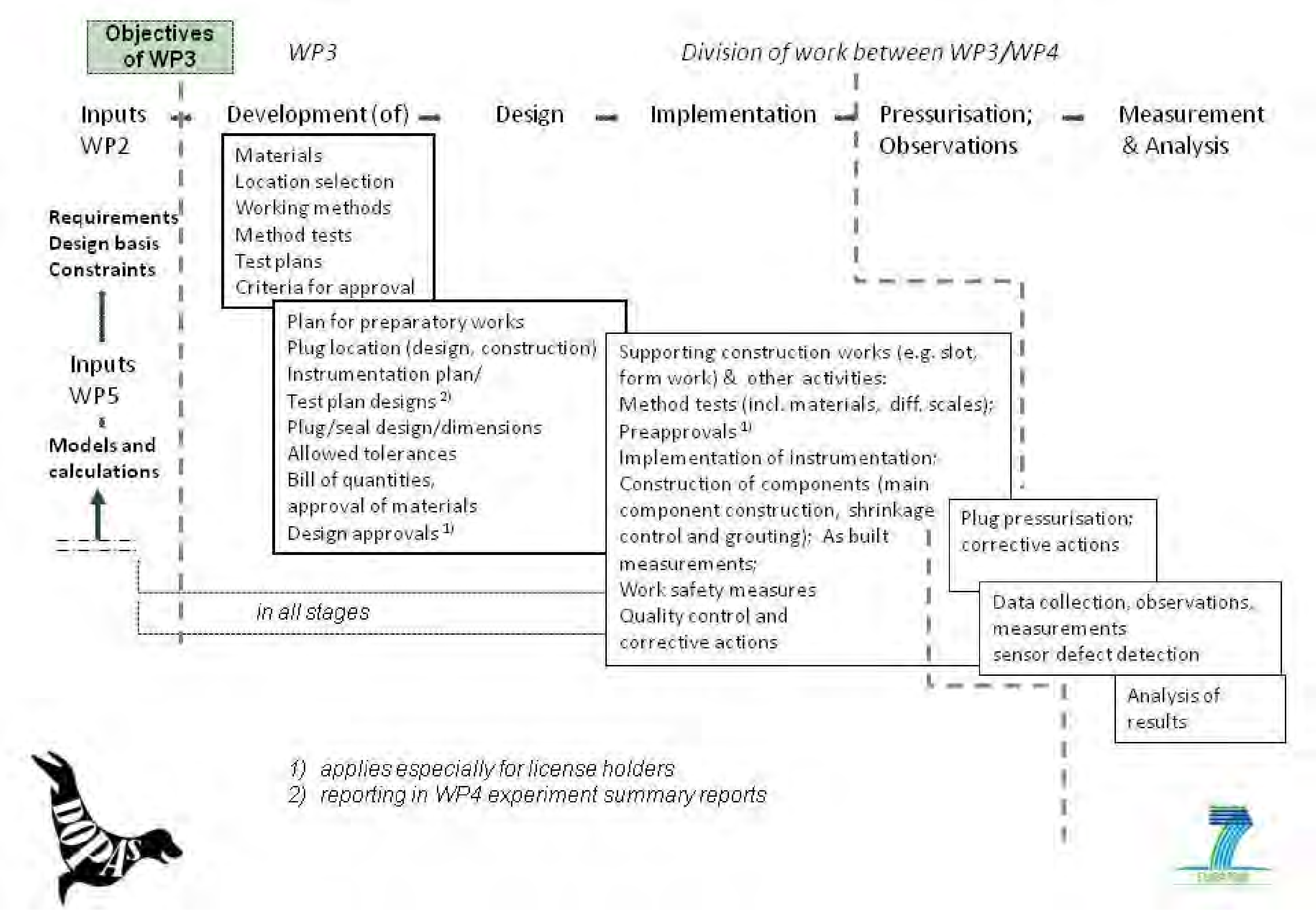
- Learning Unit 3 continues with an introduction to safety assessment and the role of safety case taking into consideration the differences in the time perspectives. The afternoon of DAY 4 includes the handling and interpretation process of data acquired from the Josef Underground Laboratory hands-on monitoring exercise.
- Learning Unit 4: Construction feasibility of a plugging experiment includes the practical and technical concerns related to the construction work and work methods in setting up an in-situ or full-scale experiment. Experiment and work related risks are identified and discussed as a part of this learning unit. This learning unit continues on DAY 5.

DAY 5

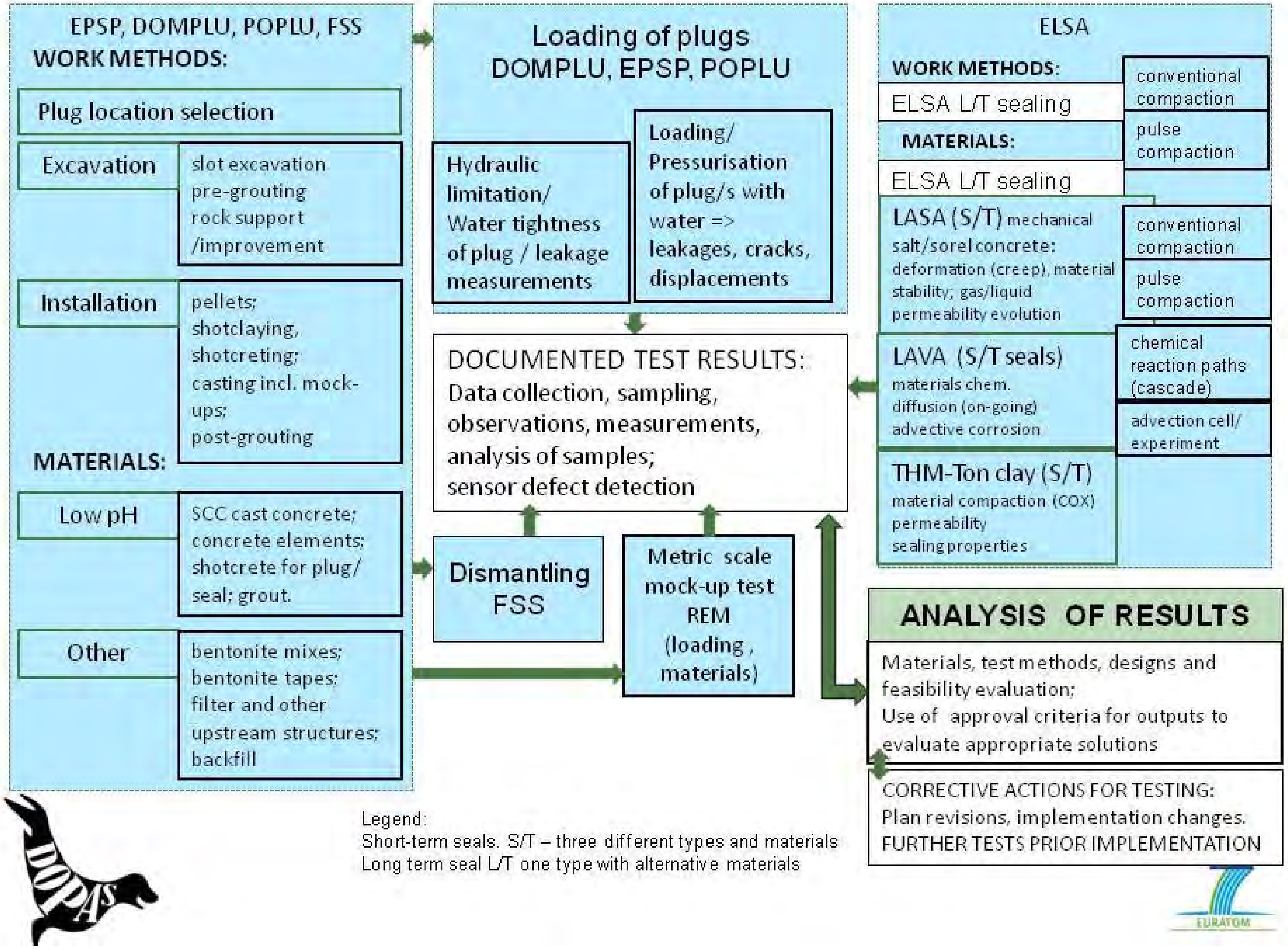
18.9.2015 at CTU, Prague

- Learning Unit 4 continues with the summary perspectives on lessons learned from the experiments until today, and how to apply and use the DOPAS experiences in a waste management programme not yet in the demonstration stage or without a site. Further a case summary is provided in how these activities are implemented in the preparation of a full-scale experiment to be implemented following the four existing DOPAS experiments.
- Student groups provide their preliminary or final exercises reports and preliminary assessment and feedback from the training workshop is collected. Closing of the workshop.

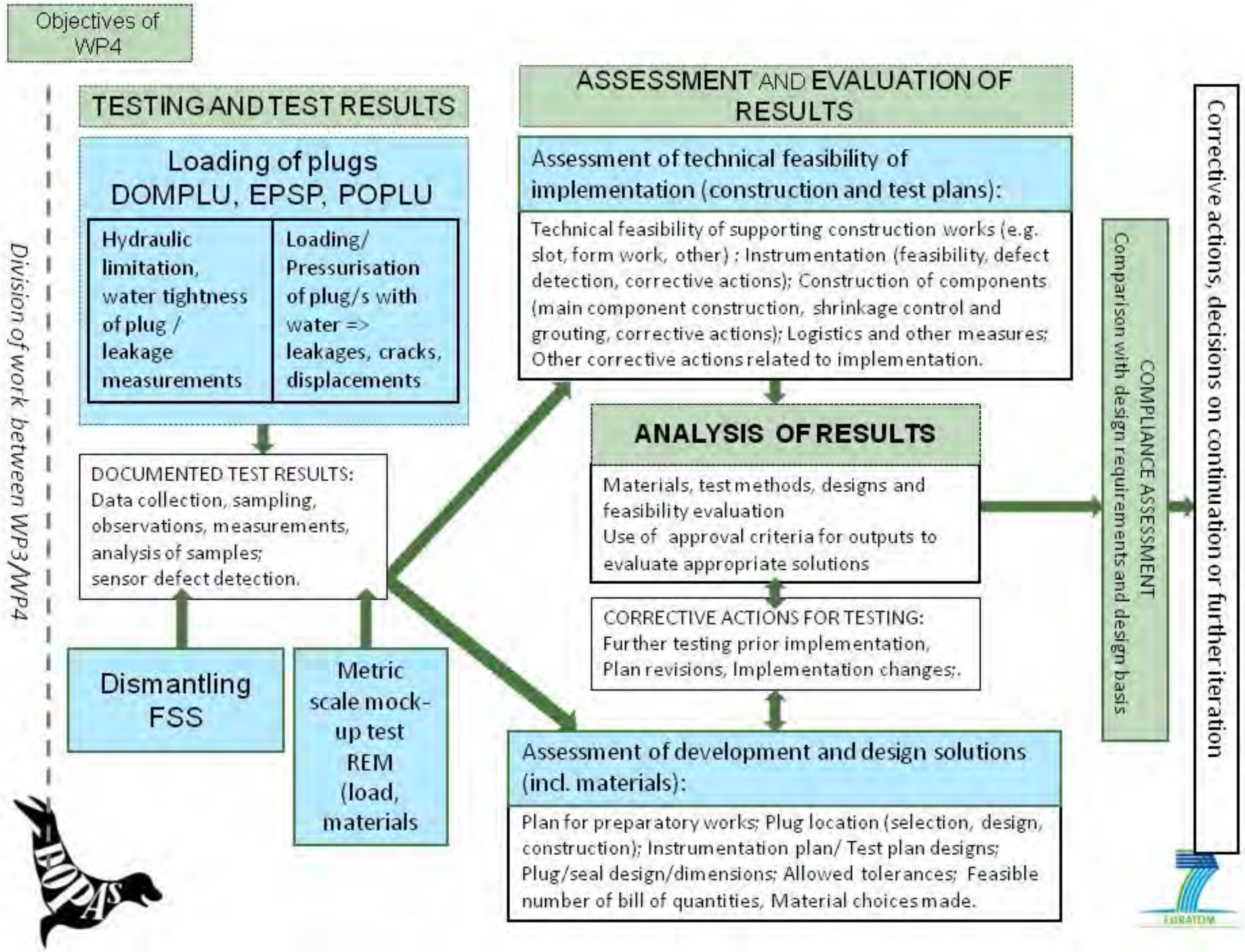
Please note that changes to the order of the content and individual programme details may apply.



DOPAS Project: Simplified structure of lessons learned from work done in WP3



DOPAS Project: Summary of testing and mock-ups in WP3 and WP4 including experiment site selection



DOPAS Project: Summary the structure of work in WP4 prior integration of outcomes and conclusions