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Deliverable D5.1

Modelling plan for Experiment 2 EPSP PA

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ABSTRACT:

This report outlines the modelling plan for an experimental pressure and sealing plug (EPSP). The EPSP experiment is not intended to test a specific plug or seal; rather it has been constructed at a similar scale to a real disposal tunnel plug and will contribute specifically to the development of the reference design for such structures. Modelling will focus primarily on the analysis of the THM properties of the various EPSP components.

RESPONSIBLE:

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Executive Summary

This report outlines the modelling plan for an experimental pressure and sealing plug (EPSP). The EPSP experiment is not intended to test a specific plug or seal; rather it has been constructed at a similar scale to a real disposal tunnel plug and will contribute specifically to the development of the reference design for such structures. The objective of the EPSP experiment is to test the materials and technology to be employed for implementation purposes, not to test the design or performance of reference disposal tunnel plugs. At this early stage in the Czech geological disposal programme, with more than 50 years to go before operation is scheduled to commence, it is considered more important to build knowledge and experience rather than to refine designs for implementation at an, as yet, unidentified site for which, clearly, it is not possible to detail specific mechanical, hydrogeological and chemical characteristics.

The main features, events and processes related to the proposed plug and sealing system have already been identified. Assessment has been divided into short-term assessment which covers the operational period and long-term assessment which takes into account the post-operational period. The main functional component with regard to the short-term period will consist of the concrete walls which will prevent the seepage of water from the disposal drifts. The main component will consist of a compacted, saturated bentonite layer which aim is to seal any preferential paths which might arise and to prevent the migration of radionuclides following the eventual failure of the canisters containing spent fuel assemblies. Modelling will focus primarily on the analysis of the THM properties of the various EPSP components.

List of Acronyms

AECL:	Atomic Energy of Canada Limited.
ASN:	Autorité de Sûreté Nucléaire.
BAT:	Best available technique.
BMU:	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit.
BSK-3:	BrennStabKokille-3.
CIGEO:	Centre Industriel de Stockage Géologique.
DBE:	Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH.
DOMPLU:	Dome Plug.
DOPAS:	Full-scale Demonstration of Plugs and Seals.
EBS:	Engineered barrier system.
EC:	European Commission.
EDZ:	Excavation damaged zone.
ELSA:	Entwicklung von Schachtverschlusskonzepten (development of shaft closure concepts)
EPSP:	Experimental Pressure and Sealing Plug.
ESDRED:	Engineering Studies and Demonstration of Repository Designs.
FEBEX:	Full-scale Engineered Barriers Experiment.
FSS:	Full-scale Seal.
GDF:	Geological disposal facility.
HADES:	High-activity Disposal Experimental Site.
HCB:	Highly-compacted bentonite.
HLW:	High-level waste.
HRL:	Hard rock laboratory.
IAEA:	International Atomic Energy Agency.
ILW:	Intermediate-level waste.
IRSN:	Institut de Recherche sur la Sûreté Nucléaire.
KBS-3:	KärnBränsleSäkerhet-3.
LLW:	Low-level waste.
POPLU:	Posiva Plug.
R&D:	Research and development.
RCF:	Rock characterisation facility.

RESEAL:	A large scale *in situ* demonstration test for repository sealing in an argillaceous host rock.
RMS:	Requirements management system.
SCC:	Self-compacting concrete.
TSX:	Tunnel sealing experiment.
URCF:	Underground rock characterisation facility.
URF:	Underground research facility.
URL:	Underground research laboratory.
VOP:	Vaatimuksia Ohjaava Päätös (Decisions Guiding Requirements).
VSG:	Vorläufige Sicherheitsanalyse Gorleben (Preliminary Safety Analysis for Gorleben).
WMO:	Waste management organisation.
WP:	Work package.

List of DOPAS Project Partners

A list of the partners involved in the DOPAS Project is provided below. Each partner will be referred to in the remainder of this report as indicated:

Posiva	Posiva Oy	Finland
Andra	Agence nationale pour la gestion des déchets radioactifs	France
DBE TEC	DBE TECHNOLOGY GmbH	Germany
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit	Germany
Nagra	Die Nationale Genossenschaft für die LagerungRadioaktiver Abfälle	Switzerland
RWM	Radioactive Waste Management Limited	UK
SÚRAO	Správa Úložišť Radioaktivních Odpadu (RadioactiveWasteRepository Authority–RAWRA)	Czech Republic
SKB	Svensk Kärnbränslehantering AB	Sweden
CTU	Czech Technical University	Czech Republic
NRG	Nuclear Research and Consultancy Group	Netherlands
GSL	Galson Sciences Limited	UK
BTECH	B+ Tech Oy	Finland
VTT	Valtion Teknillinen Tutkimuskeskus (TechnicalResearch Centre of Finland)	Finland
UJV	Ustav Jaderneho Vyzkumu (Nuclear Research Institute)	Czech Republic

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1. Background

The Czech Republic's deep geological repository (DGR) will be designed to ensure safety for a period of thousands of years. The Czech geological disposal programme for spent fuel and HLW is currently in the generic phase with no specific site having yet been selected. It is planned that construction work will commence in 2050 and operation in 2065.

As far as the Czech Republic is concerned solely crystalline rock formations can be considered for the construction of a deep geological repository. The Czech DGR concept states that nuclear waste will be encased in steel-based canisters placed in vertical or horizontal boreholes at a depth of ~ 500m below the surface. The space between the canisters and the host crystalline rock will be filled with compacted bentonite. The waste packages will be emplaced in the disposal tunnels in the form of supercontainers. This concept formed the basis for generic safety assessment studies conducted in 2011. The conceptual design (rather than the manufacturing details) of plug and seal systems was considered with reference to the Swedish and Finnish KBS-3V and KBS-3H concepts. Although KBS-3H is now generally regarded as the reference concept, both the KBS-3H and KBS-3V designs will be further developed simultaneously.

The first assessment concerning the disposal of spent fuel and HLW in the Czech Republic considered a generic reference concept based on KBS-3V (SÚRAO, 1999). The main aim of this performance assessment was to summarise performance assessment requirements based on an analysis of Czech legislation and IAEA recommendations. However, subsequent performance studies focussed on a horizontal variant of that concept known as KBS-3H (SÚRAO, 2011). Plug and sealing systems were not considered in these preliminary safety assessments.

The Euratoms 7th Framework Programme project for demonstrating of plugging and sealing (DOPAS) did compile design basis and reference designs of plugs and seals that can be used for sealing disposal drifts and backfilled tunnels in the disposal facilities.

The design basis of the EPSP plug is based on experience gained of the sealing of an underground gas storage facility located near the town of Příbram in the Czech Republic. The plugs used in the facility were constructed using steel fibre-reinforced sprayed concrete (SFRC). Trial plugs were employed for the underground verification of the construction and testing techniques. The plugs were constructed using wet-process sprayed SFRC with a high fibre content (90kg/m^3) (Hilar and Pruška, 2011).

2. EPSP Design Basis

The proposed design of the EPSP is consistent with the conceptual approach adopted in the 2011 KBS-3H study. The design basis for the disposal tunnel plug in the repository concept is not highly-developed yet and specific requirements with regard to the reference plug have to be specified.

The EPSP experiment represents the first time that SÚRAO has carried out any detailed research work on plugs and seals. Historically, the key objectives of the EPSP experiment derived from WP 2 (Del 2.1). The stated aims of the experiment include the testing of materials and technology (including that technology which might become part of the test) and to extend laboratory experience both in an underground environment and at full scale. EPSP will also provide a significant test-bed in terms of developing the final design of such plugs and the procedure to be adopted with regard to eventual implementation.

The conceptual design of EPSP (Figure 1) includes the following components (Dvořáková et al., 2014 and White et al., 2014):

- Injection Chamber: The pressure chamber is an open area that can be used to exert pressure on the inner concrete plug. The chamber contains an inlet valve and a drain valve that can be used to fill the chamber with air (gas), water or bentonite slurry. The chamber will be constructed so as to be as small as possible which will allow the pressure to be readily controlled. The pressure chamber will be sealed with a specially designed membrane.

  The pressurising medium will be transported to the injection chamber via 23m-long connecting boreholes from the neighbouring service centre niche. The chamber has been enclosed with a porous concrete wall which will serve to support the inner concrete plug (see Fig. 1 no. 2).

- Concrete Walls (Blocks): Concrete walls will be used in order to facilitate the construction of the EPSP experiment. Three concrete walls will be built: one between the pressure chamber and the inner concrete plug, one between the bentonite and the filter, and one between the filter and the outer concrete plug.

- Inner Concrete Plug (Fig. 1 no. 3): The inner concrete plug will form the primary sealing component for the EPSP model and will be constructed of fibre shotcrete. It is anticipated that the plug will require additional contact grouting; however, the extent to which such grouting is required will be determined by measurements taken during the course of the experiment. The fibre concrete will be of relatively low pH; however, the exact mix of components and pH values will be determined during the detailed design stage.

  The inner concrete plug has two basic functions, i.e. static and hydraulic which means primarily that it must provide for the mechanical stability of the entire system even under high pressure conditions and, at the same time, must restrict flow through the plug so that the bentonite sealing is not damaged through the creation of erosion channels during the period in which the bentonite sealing zone is undergoing, but has not yet reached, full saturation.

- Sprayed Bentonite Pellets: The bentonite pellet zone will be made up of B75 bentonite, a natural, high smectite content Ca-Mg bentonite with a notably high iron content in the octahedral layer of the smectite. The purpose of the bentonite is to absorb any water that leaks across the inner concrete plug. Owing to its exceptional swelling properties (and consequent self-healing capacity) and very low permeability, bentonite in particularly suitable for fulfilling this function.

  The bentonite zone will be 2 metres long.

- Filter: The filter will collect any water that is not absorbed by the bentonite layer which will be most likely to occur should the leakage rate across the inner concrete plug be sufficient to allow the piping and subsequent erosion of the bentonite. The filter has been designed in such a way that it might also be used to reverse the direction of pressurisation of the EPSP model.

- Outer Concrete Wall (see Fig. 1 no. 3): The outer concrete plug has been designed to hold the other components of EPSP in place. However, should the direction of pressurisation of EPSP be reversed, the outer concrete plug will be required to perform as well as the inner concrete plug.

  Pressure testing will be carried out on the inner concrete plug prior to the emplacement of the bentonite so as to verify the quality of the plug and to facilitate the decision, following inspection, as to whether grouting will be required around the plug; this initial testing stage will involve the use of water as the pressurisation medium.

The EPSP experiment has been designed to be flexible so as to allow the contractor responsible for implementation to adapt to developments and experience gained as the experiment proceeds. Specific issues to be investigated relate to: achieving the target bentonite density level, the quality of the concrete (lack of voids, homogeneity), strength, shrinkage and the absence of cracking, and how these factors can be demonstrated. Importantly, the experiment must be conducted in a manner that complies with national mining and environmental health and safety regulations.

Material requirements are shown in Table 1.

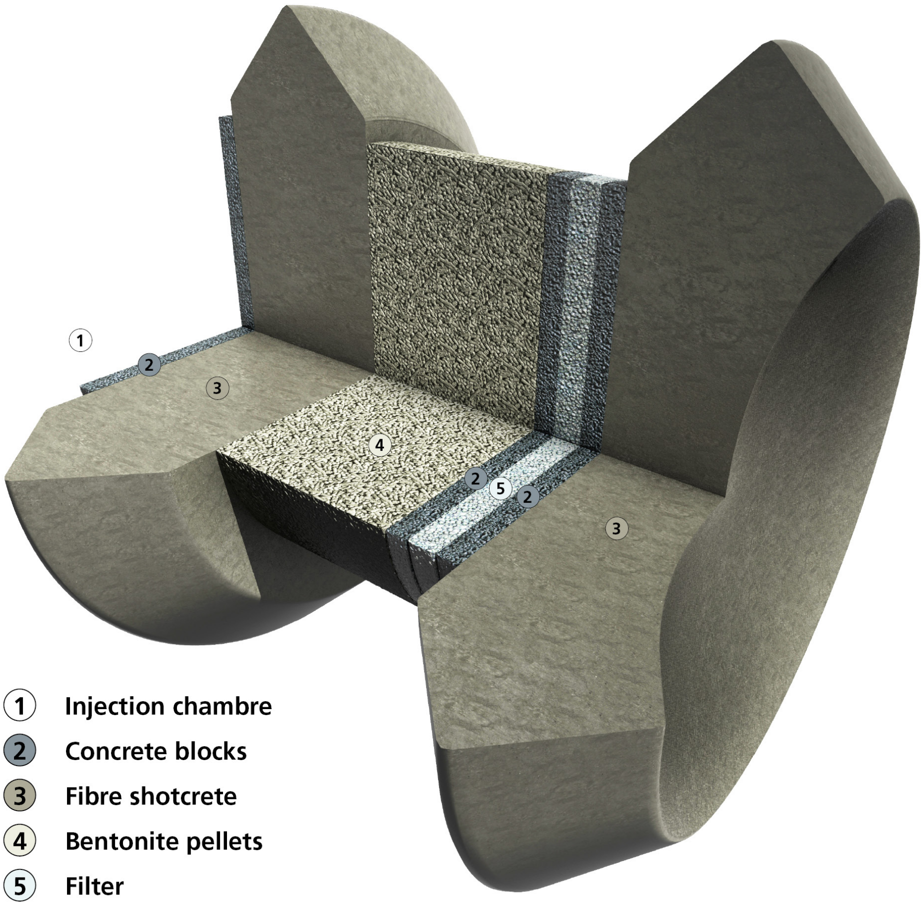

Figure 1: Cross-section through the plug

Table 1 Characteristics of the materials used

Host rock	granodiorite	quartz/carbonate veins (1-14cm thick)	$k=10^{-9}-10^{-10}$m/s	Grouted with polyurethane resin (Webac type)
Bentonite	B75_2013 (Ca-Mg type)	$\rho_d=1.4$g/cm^3	$k=10^{-12}-10^{-13}$m/s	
Concrete	Containing alkaline - resistant glass fibres	$\sigma \geq 30$MPa	$k<10^{-10}$m/s	pH<11.7

3. Modelling plan for EPSP performance assessment

The main objectives of EPSP performance assessment are as follows:

- To gain an understanding of the processes which occur in plug and sealing systems and their impact on the safety functions of the various repository components over different time periods.
- To develop conceptual models and to simulate the processes which occur within the sealing system.
- To evaluate the impact of certain critical processes which are likely to occur within the sealing system during the operational phase

This document provides a summary of the modelling plan for testing the performance of the EPSP experiment both during the operational and post-operation periods. Modelling will be divided into the initial modelling of processes observed in the laboratory and at field scale and the subsequent modelling of processes which are expected to occur during the operational period and during the post-closure period once the repository has been backfilled.

3.1 Overall approach to modelling

3.1.1 Physical model

This project includes two types of physical model - interaction models used to examine changes in the materials due to the interaction of the various chemical reactions between the components, and hydraulic models which are used for studying the saturation of the bentonite material. By means of numerical modelling the physical hydraulic models will be repeated with the aim of identifying those material parameters that did not form output from the laboratory examination conducted as part of WP3 (Vašíček et al., 2013, Table 2) and which will be taken from literature, particularly those parameters which describe the mechanical behaviour of the materials.

The rate of saturation and other processes that might occur within the bentonite following the penetration of water through the concrete wall and the interface between the host rock and concrete will initially be studied using laboratory-scale physical models constructed by ÚJV Řež. The first physical model consists of a cylindrically-shaped stainless steel chamber with dimensions of 0.45m in length and 0.08m in diameter equipped with sensors for the recording of the distribution of water content and pore water pressure within the bentonite material. Bentonite with an estimated bulk density of 1.4g/cm^3 (the same bulk density as assumed in the EPSP experiment) will be pressed into the test chamber and gradually saturated with water under pressure of 2MPa. A sample of the bentonite material will be removed following the conclusion of the experiment and divided into layers with an estimated thickness of 1cm. The water content of each layer will then be determined. It is assumed that the duration of the experiment will be around 1 year.

The numerical model will be calibrated by changing the material parameters in order to achieve the best agreements between the model and the measurement results of the physical models in the WP3 stage. It is expected that the following data will be achieved from the physical models:

1. Development of pore water pressure at the observation points.
2. Evolution of relative water content at the observation points
3. Water content profile along the sample (along the direction of flow) following the conclusion of the experiment, dismantling and division into layers with a thickness of approximately 1cm

Observation points will be selected during the experiment according to the current development of the monitored values so as to obtain data for numerical modelling purposes. The physical model chamber will allow the measurement of pore pressure and relative water content at 5cm intervals (Figure 2 and Figure 3) and 2 sensors each will be available for the measurement of relative humidity and pore pressure.

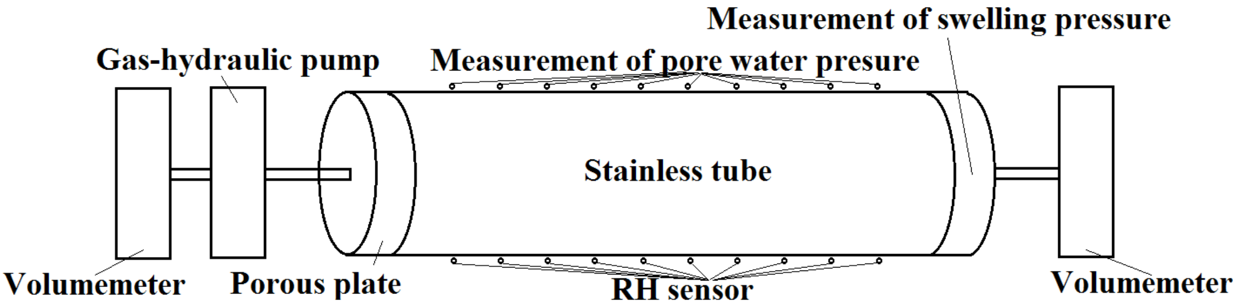

Figure 2 Schematic view of the physical model for the testing of bentonite saturation.

The outputs from the numerical simulations of the physical models will consist of calibrated material parameters and the spatial distribution of water content and pressure conditions inside the bentonite material. The parameters obtained and the variability of the spatial arrangement of the pressure and water content conditions will serve for the definition of a conceptual model of the EPSP experiment.

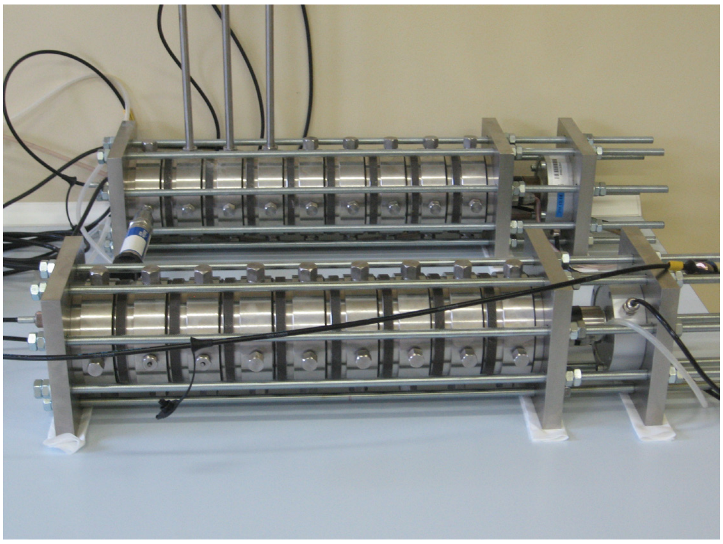

Figure 3 The physical model.

3.1.2 EPSP

The safety functions of plug and sealing systems (SÚRAO, 2011) installed during the operational period prior to repository closure consist of:

- Separating the closed parts of the DGR
- Preventing the flow of water from the disposal drifts
- Preventing the erosion/displacement of the bentonite buffer from the disposal drifts

In order to satisfy these requirements the proposed plug and sealing system must be able to withstand any water or gas pressure exerted from the side of the disposal drifts up to the time that free space in the vicinity of sealed tunnels are backfilled.

The preliminary requirements with concern to the proposed plug and seal system during the operational period are described in DOPAS Deliverable 2.1. These basic design requirements and the initial state of the proposed plug and sealing system will be verified by means of constructing a half-scale experimental pressure and sealing plug (EPSP) in the crystalline rock environment of the Josef gallery (Figure 4 a, b).

The basic engineering barriers during the operational period will consist of concrete walls made up of a special reduced-pH concrete containing glass fibres. The precise properties of this material will be developed and tested in co-operation with the contractor who will participate to the building of the EPSP system.

It is envisaged that the functioning of the plug in the Josef gallery will be significantly affected by the fractured nature of the local host rock (Figure 7); therefore, the host rock has been grouted to a depth of 5m (see Figure 6).

Additional hydro-insulation should prevent the spread of pressurised water to the host rock before entering the concrete wall. The concrete wall will initially be tested using water at a pressure of approximately 1MPa prior to the application of the bentonite layer. Places at which water penetrates through the interface between concrete wall and the host rock will also be grouted.

Figure 4a SP-59 (October 2013)

Figure 5b SP-59 (September 2014)

Figure 6 Grouting in niche SP-59

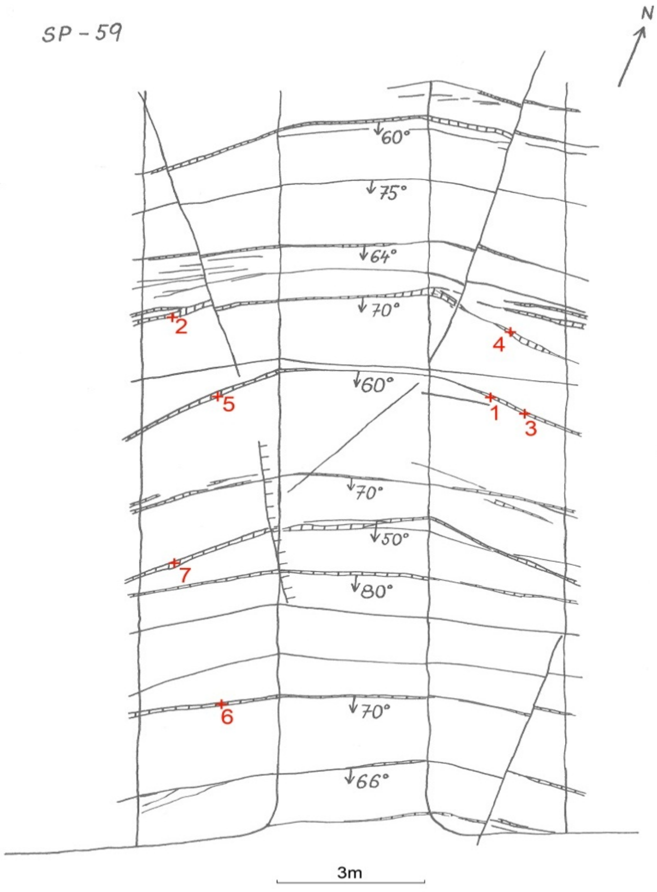

Figure 7 Documentation of niche SP-59

It is expected that water which leaks in through the first concrete wall during the operational period will be absorbed by the bentonite emplaced between the two concrete walls applied by means of the spraying of bentonite pellets which were tested as part of WP3. It is also expected that the bentonite pellets will gradually be saturated with water and will subsequently serve to completely seal all the free spaces. Thus, this bentonite layer will assume the sealing function in the repository post-closure period which will be provided by the concrete wall during the operational period.

Following the end of the construction period, the plug will be saturated firstly with water, then air and eventually with various water-bentonite mixtures; the time of saturation with each medium is scheduled to be 3 months. The plug will be fitted with measuring equipment for the observation of the processes underway in a number of profiles (Figure 8). Saturation will be simulated by means of numerical modelling and the numerical results will be compared with the results from the EPSP experiment. It is envisaged that the numerical model will assist in explaining the processes observed. The geometry of the EPSP experiment and thus the model area will be clarified once the plug construction stage is completed.

The comparison of the measured and modelled results will be based on data extracted from observation points in monitoring phase which belongs to the WP4 (Figure 9 to Figure 13).

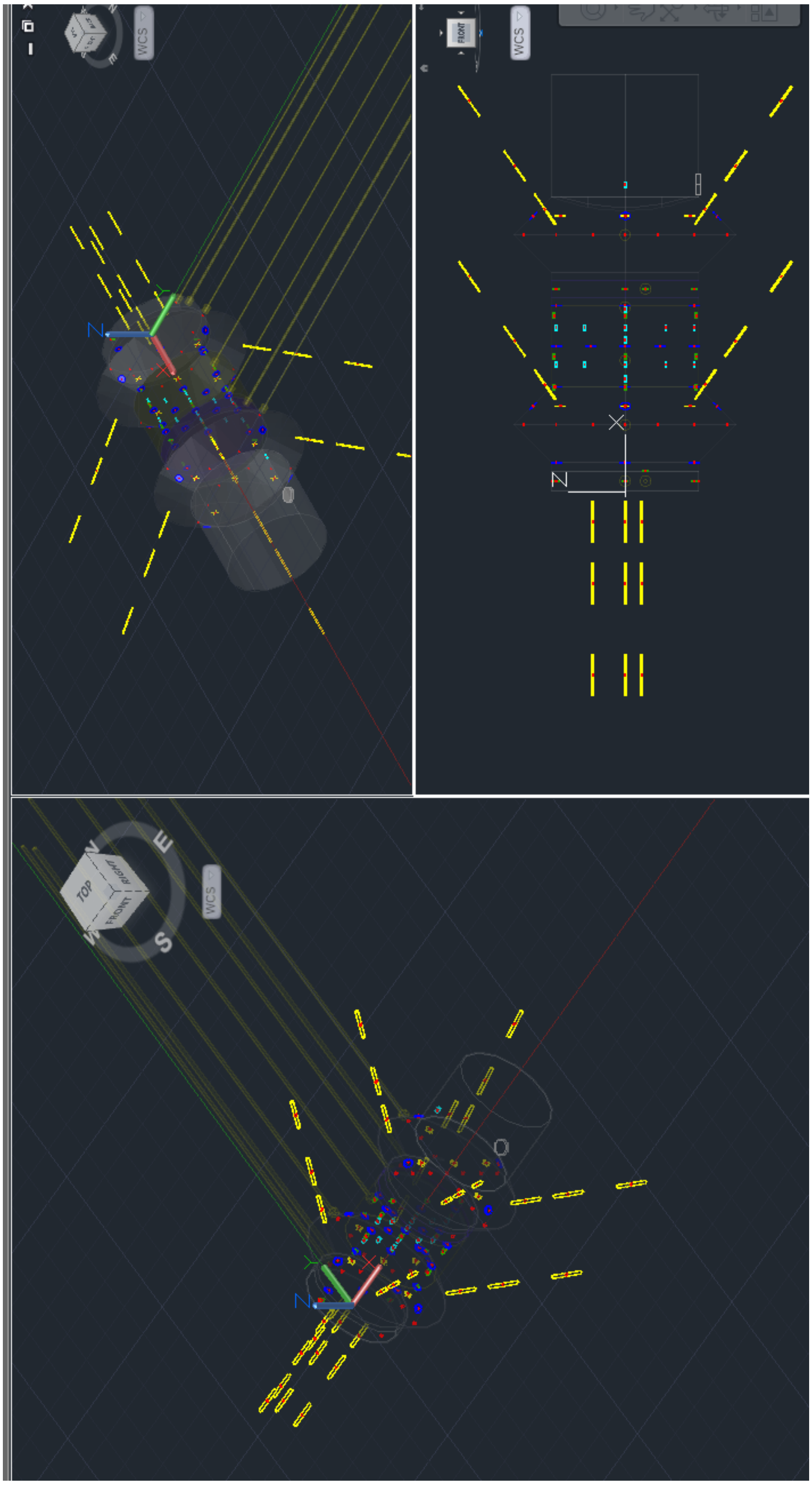

Figure 8 3D model of the instrumentation

(Taken from Del 3.18; Svoboda, 2014)

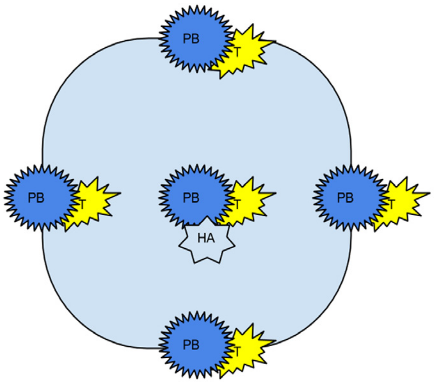

Figure 9 Cross-section D1, D3

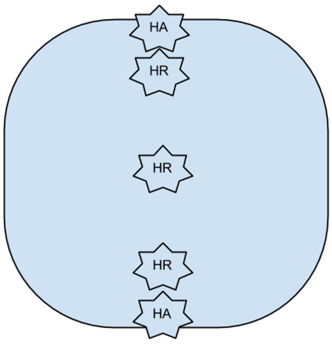

Figure 10 Cross-section D2, D4

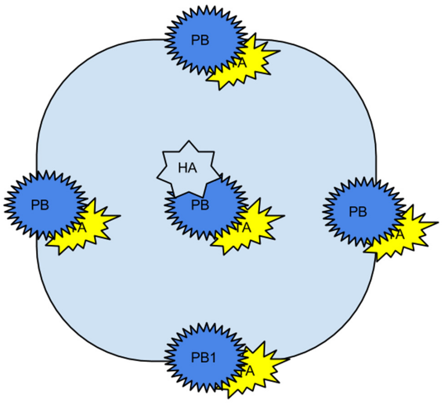

Figure 11 Cross-section D5

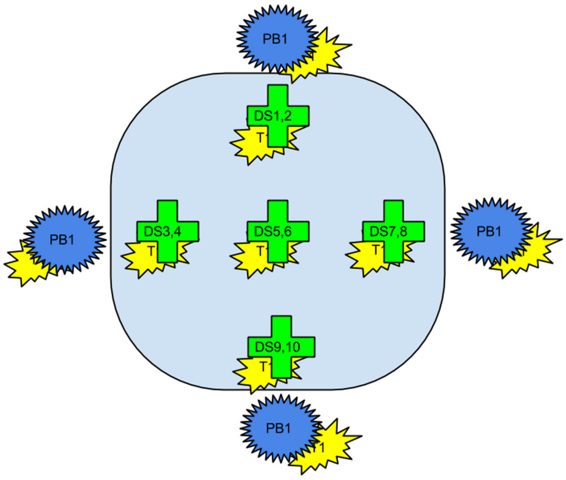

Figure 12 Cross-section E1

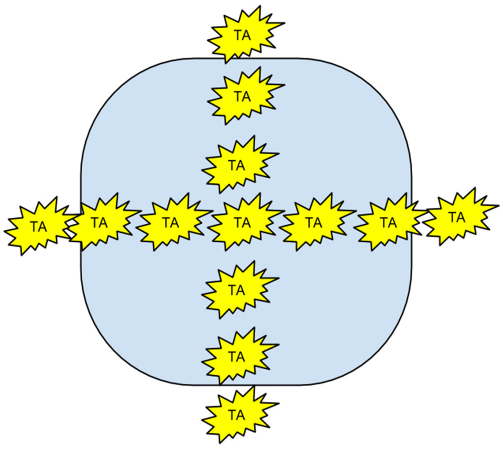

Figure captions for Figs. 8-12

PP pressure (liquid)

PB pressure cell

TA thermometer

DS strain gauge

HA humidity sensor (absolute)

HR humidity sensor (relative)

Figure 13 Cross-section E2

3.1.3 GoldSim

Plugs and seals will have no direct safety function during the post-operational period; however, it is important that they do not subsequently adversely affect the functioning of the primary safety components in the repository (buffer/backfill, canister, host rock) during the post-closure period. The main concern during the post-closure period will consist of the formation of preferential paths in the sealing and plug systems which could lead to the formation of preferential paths in the backfilled tunnels and host rock.

Preferential paths could be formed following the rapid saturation of the bentonite material as a result of the preferential leaching of the material. Bentonite in the unsaturated state does not exhibit significant swelling capacity and therefore does not have the same crack-filling ability as it does in the saturated state. This might be a problem in terms of the migration of radionuclides into the rock environment. Therefore, the influence of various extents of bentonite material disruption on the total effective dose rate will have to be simulated.

Simulation will be based on a stochastic description of degrees of damage to the bentonite material; the results of numerical simulation will consist of a description of the influence of damage to the bentonite on the overall safety of the deep geological repository defined in terms of effective dose rate. A conceptual model in GoldSim transport code will be created for one disposal drive with an assumed preferential path in the bentonite. The other parameters used in the GoldSim model will be the same as those employed in the Czech reference DGR concept at a hypothetical site (SÚRAO, 2011). Sensitivity analysis will be conducted describing the effect of preferential paths in the plug and seal areas for the most mobile radionuclides.

3.2 Software employed

The Code_bright (UPC, 2014) program will be used for the numerical simulation of the physical models and EPSP experiments in terms of changes in hydraulic parameters in response to changes in the mechanical state of the material.

The GoldSim (GoldSim Technology Group, 2010) program will be employed to simulate the same issue during the post-closure period by using a comprehensive model based on the Czech DGR concept developed at ÚJV Řež (Landa, 2013).

3.3 Input parameters

HM (hydro-mechanical) processes will be simulated using the numerical modelling of both physical models and the EPSP experiment. The material parameters determined in WP3 will serve as input parameters for the physical models (Table 2). The remaining parameters required for the simulation of HM processes will be taken from technical literature with regard to the similarity of the materials. The numerical model will be calibrated by changing the input parameters in order to achieve the best agreement between the measured and modelled results. The material parameters resulting from the numerical simulation of the physical models will be used as input material parameters in the numerical simulation of EPSP.

Table 2 Material parameters determined by laboratory tests in WP3 (Vašíček et al., 2014).

Material	Parameter	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Bentonite	Hydraulic conductivity	ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil - Part 11: Determination of permeability by constant and falling head	compacted powder, dry densities 1100-1800kg/m3	12/2013-04/2014
Bentonite	Swelling pressure	Testing without volume change	compacted powder, dry densities 1100-1800kg/m3	12/2013-04/2014
Bentonite	Thermal conductivity, heat capacity	ISOMET 2104 device	powder - compacted, dry densities 1100-1800kg/m3	12/2013-04/2014
Bentonite	Specific density	ČSN CEN ISO/TS 17892-3 - Geotechnical investigation and testing - Laboratory testing of soil - Part 3: Determination of particle density - Pycnometer method	powder	12/2013-04/2014
Bentonite	Gas permeability	internal procedure based on ČSN CEN ISO/TS 17892-11 Geotechnical investigation and testing - Laboratory testing of soil	dry densities 1100-1800kg/m3	12/2013-04/2014
Bentonite	Porosity	internal procedure	dry densities 1100-1800kg/m3	12/2013-04/2014

Material	Parameter	Test procedure/ Standard	Test and material conditions (size of samples, density, water content...)	Testing period
Concrete	Thermal conductivity, heat capacity	ISOMET 2104 device	samples taken during installation, according to Standard	09/2013-03/2014
Concrete	Hydraulic conductivity	based on ČSN CEN ISO /TS 17892	cylindrical sample	07/2013-03/2014
Concrete	Gas permeability	internal procedure	cylindrical sample	07/2013-03/2014
Concrete	Porosity	mercury porosimetry / water immersion method	external analysis / cubes, discs	07/2013-03/2014
Rock samples	Density	e.g. ČSN CEN ISO/TS 17892-2	drilled cores	5/2013-7/2013
Rock samples	Permeability	Changes in rock permeability due to grouting,	drilled cores	07/2013-03/2014
Rock samples	Porosity	mercury porosimetry / water immersion method	external analysis / cubes, discs of plug material	07/2013-03/2014
Rock massif	Hydraulic conductivity	Hydraulic pressure test	field test, 5 boreholes (5m)	5/2013-7/2013

3.4 Expected results

The output of the numerical simulation of the physical model will consist of calibrated material parameters and a description of the spatial distribution of water content and pressure conditions inside the bentonite material. The parameters obtained and the variability of the spatial arrangement of the pressure and water content conditions will serve to define a conceptual model of the EPSP experiment.

The output of the numerical simulation of the EPSP experiments will consist of the ideal spatial distribution of water content and pressure conditions within each component of the plug and the mechanical behaviour of the plug.

The results of the numerical simulation of problems likely to occur during the post-closure period will consist of a description of the dependence between the disruption of the bentonite material and the effective dose rate.

3.5 Time schedule

The numerical simulation of the physical models and the EPSP experiment depends on the delivery of outputs from WP3 and WP4. According to the laboratory work plan (D3.16, Vašíček et al., 2013) the results of the physical models will be available in June 2015. The availability of the results of the EPSP experiment will depend on the progress of plug construction.

The simulation of the disruption of the bentonite layers as part of a comprehensive evaluation model of the deep geological repository is not dependent on the input data. This simulation will be performed with respect to the submission deadline of output DOPAS Deliverable D5.7 (December 2015).

4. Conclusions

Numerical models of water distribution within the plug and the mechanical behaviour of the EPSP experiment will be constructed based on the physical models, material parameters and real data obtained during the operation of the EPSP experiment.

5. Literature

Code_bright tutorial manual. Universitat Polytecnica de Catalunya, Barcelona, 2014

https://www.etcg.upc.edu/recerca/webs/code_bright/code_bright (19.8.2014).

Dvořáková, M., Hanusová, I., Svoboda, J., Vencl, M.: EPSP Experiment – Construction of a plug for a deep geological radioactive waste repository as part of the European DOPAS Project, Tunel 23, 2/2014.

GoldSim Contamninat Transport Module, User's Guide, Version 6.0, GoldSim Technology Group, Washington, USA, December 2010.

Hilar, M. and Pruška, J. (2011). Fiber Concrete – Construction Material of Underground Structures. fib Symposium Prague, 2011.

Landa, J., Trpkošová, D., Vetešník, A.: Tvorba celkového robustního modelu hodnocení bezpečnosti úložiště a aplikace modelu. Zpráva ÚJV 14276, ÚJV Řež, a. s., 2013.

SÚRAO: Update of the Reference Project of a Deep Geological Repository in a Hypothetical Locality. Accompanying Report. Report EGP 5014-F-120055, 2011.

Svoboda J.: testing plan for EPSP instrumentation and monitoring. DOPAS Deliverable D3.18, CTU Prague, 2014.

Vašíček, R., Svoboda, J., Trpkošová, D., Večerník, P., Dvořáková, M.: Testing plan for the EPSP laboratory experiment. DOPAS Deliverable D3.16, CTU Prague, 2013.

White, M., Doudou, S., Neall, F.: Design Bases and Criteria. DOPAS Deliverable D2.1, Galson Sciences Limited, 2014.