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DOPAS
FINAL REPORT

The Full-Scale Demonstration of Plugs and Seals (DOPAS) 2012-2016

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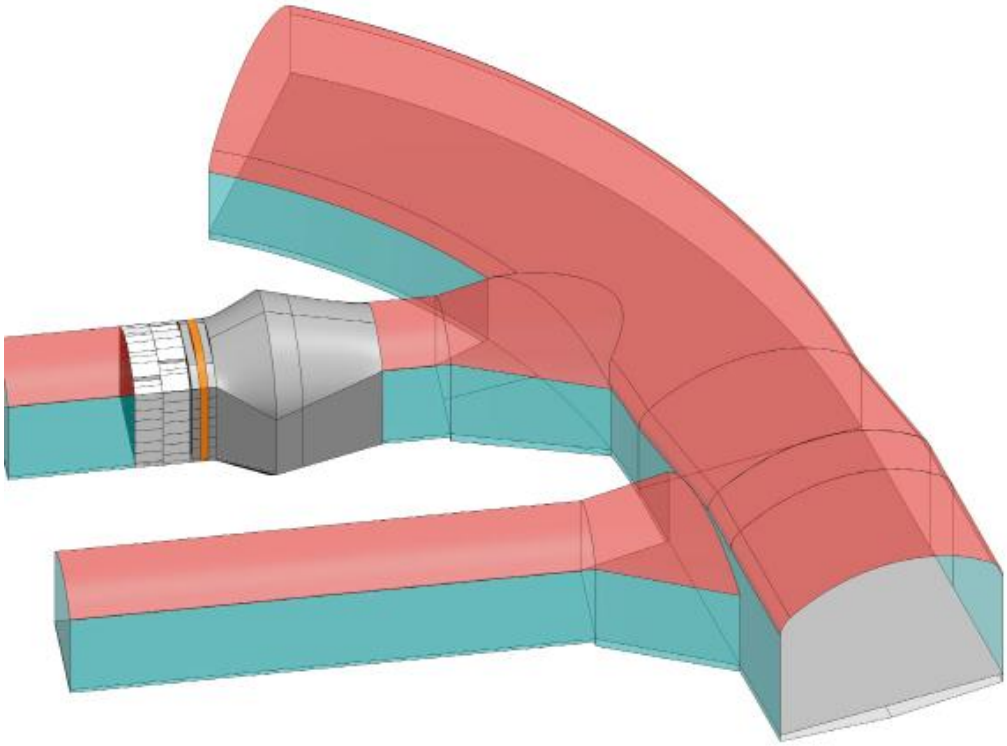

Public Summary of Project Progress

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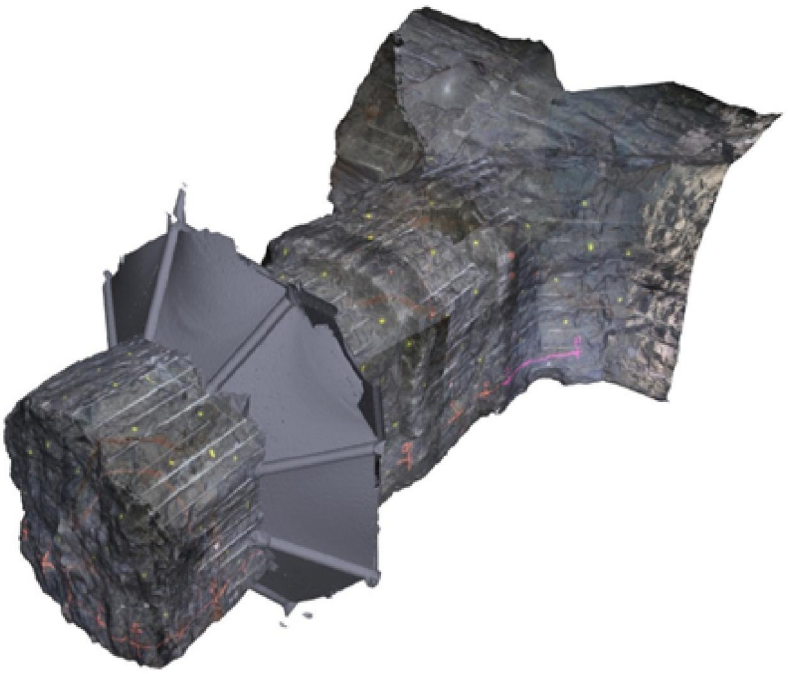
DOPAS



The DOMPLU (one of the DOPAS full scale experiments) plug location in crystalline host rock based on laser scanning in 3D model and the plug location in reality after wire sawing in Äspö Hard Rock Laboratory in Sweden. Photo: SKB

Executive summary

The Full-Scale Demonstration of Plugs and Seals (DOPAS) Project was a European Commission (EC) programme of work jointly funded by the Euratom Seventh Framework Programme and European nuclear waste management organisations (WMOs). The DOPAS Project was undertaken in the period September 2012 – August 2016. Fourteen European WMOs, and research and consultancy institutions, from eight European countries participated in the DOPAS Project. The Project was coordinated by Posiva (Finland). A set of five full-scale experiments, materials research projects, and performance assessment studies of plugs and seals for geological repositories were undertaken in the course of the Project.

The DOPAS Project aimed to improve the industrial feasibility of full-scale plugs and seals, the measurement of their characteristics, the control of their behaviour in repository conditions, and their performance with respect to safety objectives. To achieve these objectives, the DOPAS Project addressed the development of the design basis, reference design's and strategies to demonstrate the compliance of the reference designs to the design basis for plugs and seals in repositories. In the DOPAS Project, the development activities were divided between work on the design basis, technology, and material development, on full-scale implementation; and on performance assessment of the materials and components. The Project was structured into seven Work Packages (WPs). WP1 included project management and coordination and was led by Posiva, Finland. WP2, WP3, WP4 and WP5 addressed, respectively, the design basis, construction, compliance testing, and performance assessment modelling of full-scale experiments and materials research projects. WP2, WP3, WP4 and WP5 were led by SKB (Sweden), Andra (France), RWM (United Kingdom), and GRS (Germany), respectively. WP6 and WP7 addressed cross-cutting activities common to the whole Project through review and integration of results, and their dissemination to other interested organisations in Europe and beyond. WP6 and WP7 were led by Posiva. The main outcome for defining the design basis and requirements for plugs and seals were the requirements on plugs and seals considered in the DOPAS Project, conceptual and basic designs, and the strategy adopted in programmes for demonstrating compliance with the design basis. The design basis is presented for both the repository reference design, i.e., the design used to underpin the safety case or licence application, and for the full-scale experiment design, i.e., the design of the plug or seal that is being tested in the DOPAS Project. The strategy is presented in Workflow outlining how the design basis and designs of plugs and seals are developed throughout a programme at an increasing level of detail. The main outcome from design and construction feasibility for plugs and seals are the lessons learned from the detailed design, site selection and characterisation, and construction of the experiments. These include the 4 full-scale demonstrators, materials research and its up-scaling, and the learning provided by the practical experience in constructing the experiments. The plugs and seals demonstrated in DOPAS were the Full-scale Seal (FSS) experiment, undertaken by Andra in a surface facility at St Dizier, Experimental Pressure and Sealing Plug (EPSP) experiment undertaken by SÚRAO and the Czech Technical University (CTU) at the Josef underground research centre (URC) and underground laboratory in the Czech Republic, the Dome Plug (DOMPLU) experiment undertaken by SKB and Posiva at the Äspö Hard Rock Laboratory (Äspö HRL) in Sweden, and the Posiva Plug (POPLU) experiment undertaken by Posiva, SKB, VTT and BTECH at the ONKALO Underground Rock Characterisation Facility (URCF) in Finland. Additionally in situ tests related to seals in vertical shafts complemented by materials research projects were conducted for ELSA shaft seal project. Appraisal of plug and seal systems' function considers what can be concluded from the experiments conducted in the DOPAS Project with respect to the technical feasibility of installing the reference designs, the performance of the reference designs with respect to the safety functions listed in the design basis, and identifies and summarises achievements from starting the conceptual design and leading to the full scale demonstrator. It also counteracts to collect the feedback from the implemented structures back to the design basis, while development is usually an iterative process and it is important to consider the aspects on the way for industrialisation and implementing the structures in repository. In the DOPAS Project, performance assessment was taken to cover the performance of plugs and seals following the installation of the plug/seal materials in the experiment/repository. This included, therefore, the saturation of the materials following installation, their long-term thermal, hydraulic, mechanical and chemical (THMC) behaviour, and their representation in safety assessments.

Integrating analysis including cross-review of each other's work included the use of an Expert Elicitation (EE) process to integrate critical analyses of the achievements and results from the implementation and monitoring of the DOPAS Project plugs and seals. The work also included external experts' review of drafts of the main WP2 - WP5 summary reports (DOPAS Deliverables D2.4, D3.30, D4.4 and D5.10).The work was initiated by incorporating a revision of Posiva's safety case elicitation process for this type of technical work by carrying out a pilot elicitation prior the summary deliverable drafts' elicitation. Additionally three staff exchanges were organised for competence exchange between the experiments and the participating organisations' staff. Concluding the integration the DOPAS Project final public technical summary report (Deliverable D6.4) was published in the end of DOPAS Project.

The DOPAS Project also contributes to the implementation of geological disposal across Europe. The eight WMOs in the consortium benefitted from the continuous exchange of experience and expertise. The Project advanced the state-of-the-art by including a broad scope of work, and by integrating activities between different programmes and between different disciplines. This state-of-the-art has been captured in guidelines for future exploitation of the Project findings. The Project results are mainly focused on waste management programmes that are close to licensing, but they also demonstrate the technical feasibility of repository designs and thus also support less advanced programmes.

The results were widely disseminated in 94 dissemination activities and by organising a DOPAS training workshop in Prague, and Josef Gallery, Czech Republic in September 2015 http://www.posiva.fi/en/dopas/wp_7/dopas_training_workshop_2015 and DOPAS 2016 plugging and sealing seminar in Turku, Finland in May 2016 http://www.posiva.fi/en/dopas/dopas_2016_seminar.

DOPAS related material Deliverables, Dissemination activities, videos are available for download via DOPAS website http://www.posiva.fi/en/dopas

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Left page: DOPAS General Assembly with Work Package leaders and Experiment leaders in November 2015

A summary description of project context and objectives

For all types of host rocks, geological disposal concepts include engineered barrier systems (EBS) made from specific technical structures, e.g. plugs and seals, consisting of engineered and natural materials that are designed to provide a range of isolation and containment functions. The plugs and seals may counteract to keep the already installed materials in place or they might provide tightness or separate two different type of groundwater areas from each other. Within IGD-TP (Implementing geological disposal - Technical platform) was raised a common need to study plugs and seals. For organisations achieving the licensing and implementation phase the driver was to support the development of reference design or alternative plug/seal designs for which detailed design needs to be available within the next few years. For organisations which have the licensing in future the primary driver for involvement in the DOPAS Project is to support long-term research and development (R&D) on the feasibility of geological disposal.[2]

The DOPAS Project aimed to improve the industrial feasibility of full-scale plugs and seals, the measurement of their characteristics, the control of their behaviour in repository conditions, and their performance with respect to safety objectives. The Project was structured into seven Work Packages (WPs). WP1 included project management and coordination and was led by Posiva, Finland. WP2, WP3, WP4 and WP5 addressed, respectively, the design basis, construction, compliance testing, and performance assessment modelling of full-scale experiments and materials research projects. WP2, WP3, WP4 and WP5 were led by SKB (Sweden), Andra (France), RWM (United Kingdom), and GRS (Germany), respectively. WP6 and WP7 addressed cross-cutting activities common to the whole Project through review and integration of results, and their dissemination to other interested organisations in Europe and beyond. WP6 and WP7 were led by Posiva. DOPAS project have been studying the following issues and gives the answers and the updated state of the art in European level for plugs and seals tested within DOPAS project.

- Design basis processes: How are requirements on plugs and seals structured, and how can compliance with requirements be demonstrated? Can the learning from development of design bases for plugs and seals be applied to other repository elements?
- Conceptual designs of plugs and seals: What conceptual designs exist for plugs and seals and what are their roles within the overall safety concept?
- Plug and seal materials, and detailed design: The DOPAS Project addressed further development of plugs and seals materials, and the detailed design of the full-scale demonstration experiments.
- Siting and excavation of plug/seal locations: How are the locations of plugs and seals selected? Further development of methods for the excavation of plug and seal locations. What operational safety issues are posed by the excavation of plug and seal locations and how can one overcome these?
- Installation of plugs and seals: Further developments in the technology for emplacing plug and seal materials. What are the operational safety and logistical issues posed by the installation of plugs and seals?
- Monitoring of plugs and seals: Does suitable technology for monitoring the performance of plugs and seals exist. What are the issues with monitoring of plugs and seals?
- Performance of plugs and seals: How do plugs and seals perform with respect to detailed requirements on their performance?
- Compliance of plug and seal designs with their functions: To what extent can the current designs of plugs and seals be considered to meet their overall and safety functions?
- Project management during plug and seal construction and full-scale testing: What learning has the DOPAS Project provided with respect to the management of plug and seal implementation, conducting of full-scale tests and repository operations?
- Dissemination about and integration of learning on plugs and seals: Have the dissemination activities in the DOPAS Project been successful, and can the approaches adopted in the DOPAS Project be applied elsewhere?
- Technical readiness level of plugs and seals and remaining issues: What further development including testing of plugs and seals is required before designs are ready for implementation in operating repositories?

WP1 of the DOPAS Project included project management and coordination and was led by Posiva. The coordination of all activities and catalysing interaction between WP -teams to the benefit of scrutinizing of results and quality control of project deliverables are included in this WP. In this work package also other contractual matters are dealt with. The main objectives were to:

- manage and coordinate the DOPAS project and provide project management coordination support to consortium activities and to oversee the DOPAS work progress in the different work packages;

• steer and support the work package leaders and in the work package planning.
• organise in cooperation with the IGD-TP Secretariat the project website and extranet and publish the public project results with open access on the public website.
• act as an information and communication centre about the public activities of the DOPAS including a project website for open access and a restricted extranet. The coordinator organisation's other dissemination activities are included in the WP7.
• collect and compile project management information of the DOPAS project to ensure compliance with the requirements set in the ECGA and the Consortium Agreement (CA) and organise for the distribution of EC financial contribution and for collecting audit certificates; and
• provide means of quality assurance and control of project results.

WP2 addressed the design basis for plugs and seals. WP2 was led by SKB (Sweden). The WP2 summary report is Deliverable D2.4 of the DOPAS Project (DOPAS, 2016a). This report describes the outcomes from WP2, including the requirements on plugs and seals considered in the DOPAS Project, conceptual and basic designs, and the strategy adopted in programmes for demonstrating compliance with the design basis. The design basis is presented for both the repository reference design, i.e., the design used to underpin the safety case or licence application, and for the full-scale experiment design, i.e., the design of the plug or seal that is being tested in the DOPAS Project. The main objectives were to:
• compile the design basis for the ongoing and planned five demonstration experiment in DOPAS.
• develop reference designs for the same experiments.
• establish strategies for demonstrating the compliance of the reference designs to the design basis
• and finally integrate the work into the summary report.

WP3 addressed the detailed design and construction of the full-scale tests in DOPAS. WP3 was led by Andra (France). The WP3 summary report is Deliverable D3.30 of the DOPAS Project (DOPAS, 2016b). The report describes the outcomes from WP3, and summarises the work undertaken and the lessons learned from the detailed design, site selection and characterisation, and construction of the experiments. These include the full-scale demonstrators, materials research and its up-scaling, and the learning provided by the practical experience in constructing the experiments. The main objectives were to:
• (further) develop a comprehensive design basis for the in-situ demonstration experiments planned in the Czech Republic, Finland and France;
• to carry out large/full-scale tests (EPSP, FSS) in underground rock laboratories or mock-up drifts, and URCF ONKALO (POPLU), proving that the stated reference design, which is used as subsystem justification in the license applications for the final repositories fulfils the requirements and can be implemented on an industrial scale;
• to monitor full-scale demonstration (DOMPLU) at Äspö HRL; and
• to address seal plug materials with respect to long-term behaviour, providing experimental data needed for numerical simulations in order to demonstrate material suitability.

WP4 addressed the performance appraisal of the full-scale experiments in DOPAS. WP4 was led by RWM (United Kingdom). The WP4 summary report is Deliverable D4.4 of the DOPAS Project (DOPAS, 2016c). The report describes the outcomes from WP4, and summarises what was learnt in the DOPAS Project with respect to the repository reference designs for plugs and seals, drawing heavily on the summary reports for the five experiments and materials research projects (Noiret et al., 2016; Svoboda et al., 2016; Grahm et al., 2015; Holt and Koho, 2016; Jantschik and Moog, 2016; Czaikowski and Wieczorek, 2016; and Zhang, 2016). The report also considers alternatives to the reference designs. It considers what can be concluded from the experiments conducted in the DOPAS Project with respect to the technical feasibility of installing the reference designs, the performance of the reference designs with respect to the safety functions listed in the design basis, and identifies and summarises achievements of WP2, WP3 and WP4. WP4 summary report (DOPAS, 2016c) also considers the feedback from the work to the design basis which may include modifications to the design basis.
The objective of this Work Package is to assess and evaluate:
• the construction methodologies and technologies for plugs and seals (WP3);
• the results of the subsequent monitoring phase and the outcome of the dismantling activities to evaluate the predictions against the actual measured performance;
• and summarise the achievements made in design and the industrial scale implementation construction, in the light of the specified required performance of plugs and seals as defined in Work Package 2.

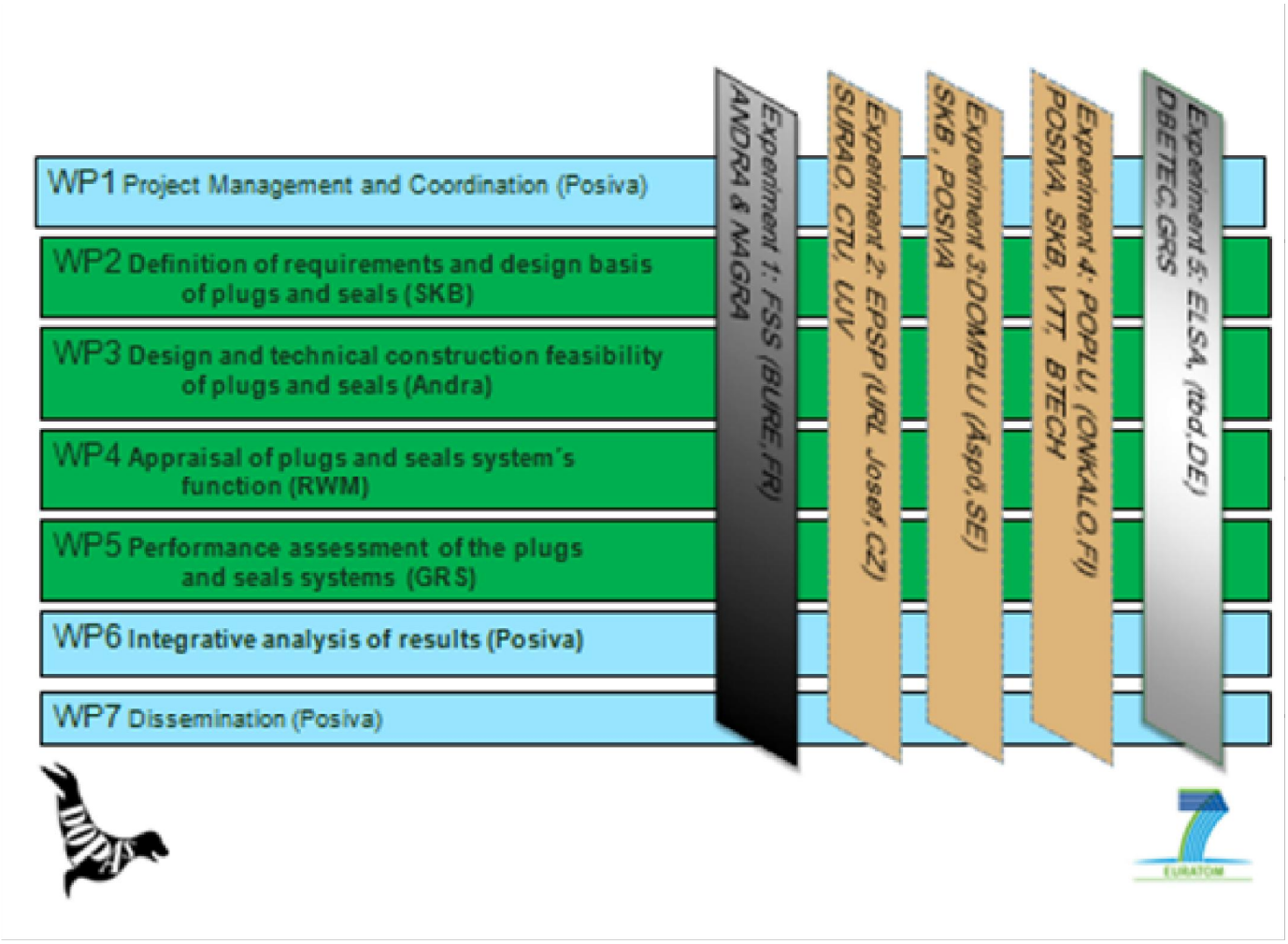


Illustration of the DOPAS Project work breakdown structure, as implemented in the seven work packages and the cross-cutting experiments and materials research projects.

WP5 addressed the performance assessment (PA) of plugs and seals. WP5 was led by GRS (Germany). The WP5 summary report is Deliverable D5.10 of the DOPAS Project (DOPAS, 2016d). In the DOPAS Project, performance assessment was taken to cover the performance of plugs and seals following the installation of the plug/seal materials in the experiment/repository. This included, therefore, the saturation of the materials following installation, their long-term thermal, hydraulic, mechanical and chemical (THMC) behaviour, and their representation in safety assessments. Much of the work done in WP5 was used to support the design of the experiments in WP3.
More specifically the objectives can be defined as follows:

- process modelling of the experiments performed in WP3 to gain process understanding
- identify the main processes that are relevant and thus to be considered for predicting the short and long-term behaviour of the plug and sealing systems;
- identify remaining uncertainties and their influence on performance assessment,
- development and justification of conceptual models of plugs and seals for the different disposal concepts and geological environments;
- simulation of processes and their evolution within individual sealing components;
- further develop and apply the PA methodology and (conservative) PA models for analysing the system behaviour.

WP6 was led by Posiva and included the use of an Expert

Elicitation (EE) process to integrate critical analyses of the achievements and results from the implementation and monitoring of the DOPAS Project plugs and seals. The work also included external experts' review of drafts of the main WP2 - WP5 summary reports (D2.4, D3.30, D4.4 and D5.10). WP6 incorporated a revision of Posiva's safety case elicitation process for this type of technical work by carrying out a pilot elicitation prior the summary deliverable drafts' elicitation. Three staff exchanges were organised under WP6 for competence exchange between the experiments and the participating organisations' staff. The production and compilation of the DOPAS Project final public technical summary report (D6.4) is a part of this work package, too.

The objectives were to:

- to review the project results by using EE method and ensure that the quality of the results are assured
- to provide possibility for expert staff exchange and enhance the integration between experiments
- to compile the lessons learned and experiences useful for implementing plugs and seals in various disposal concepts and high-lighting the future open questions related to plugs and seals, and
- to produce the final public DOPAS RTD report.

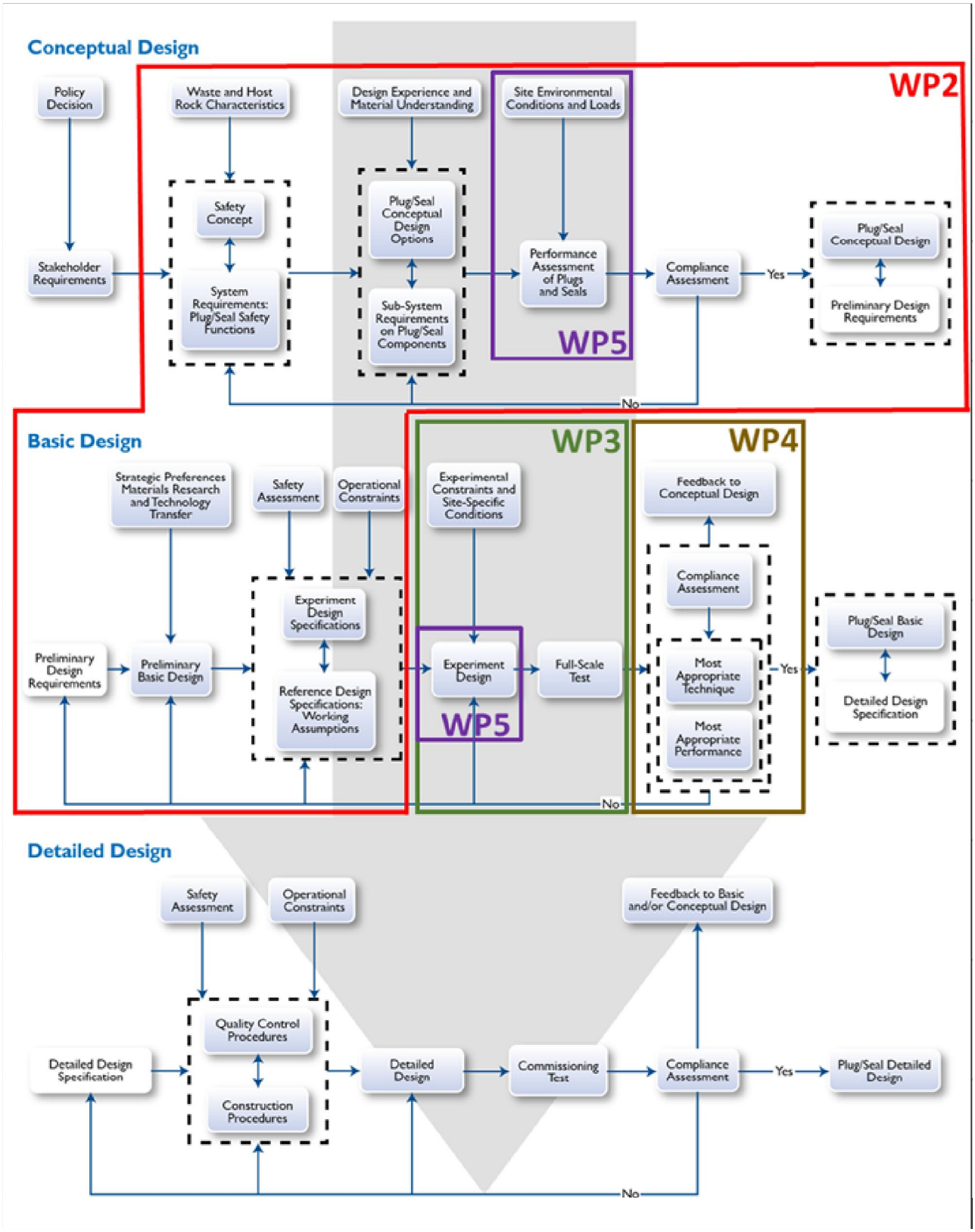
WP7 addressed dissemination activities of the Project results to other interested organisations in Europe and beyond. WP7 included an international seminar, DOPAS 2016, and a training workshop, the DOPAS Training Workshop 2015, both of which were used to facilitate dissemination of the Project results. WP7 was also led by Posiva.

More specifically the objectives in this work package were to:

- Produce a comprehensive dissemination plan, implement it and carry out an active follow-up of the activities undertaken.
- To set up a training planning group and to organise one plugs and seals training workshop that is open also for participants outside the consortium. The learning outcomes of the training will be 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.
- To organise topical international seminar focussing on plugs and seals and the lessons learned around the full scale demonstrations from 2012 to 2015. A programme planning group in cooperation with the IGD-TP will be set up as a task force for planning the programme content.
- On the four experiment sites either at the entry of the underground facilities or adjacent to the experiments underground (depending on safety requirements set by each underground facility) posters describing the experiment are set up for information purposes to visitors and experts at the sites.
- To publish and present the DOPAS project's public results by producing scientific/technical papers and conference presentations. For this purpose also regular newsletters of the project's progress are published in pdf-format at 9 months intervals.

A description of the main Science and Technology results/ foregrounds

The DOPAS project was established around the full scale demonstrators, but still the driving force were the integration of the results and this was sufficient way to divide the work into the technical work packages. WP2 defined the requirements and design basis of the plugs and seals to be demonstrated and developed a workflow based on the experiences from full scale demonstrators and organisations achieving the licensing phase. WP3 addressed the experiences from the developing the design, and the related materials, siting and implementing the experiment designs and their monitoring systems. It draws the lessons from the implementation of these full-scale experiments. The work in WP4 covers evaluation and assessment of each experiment performance and the ability of plug and seal designs to meet their foreseen functions specified in the experimental design bases. WP5 of the DOPAS Project was focused on the implications of plug and seal performance on safety over the assessment period, including the development of justifications for model simplifications applied in long-term safety assessment simulations. The main objective was to improve the state-of-the-art in process modelling and its abstraction in integrated performance assessment. The figure describing how the design process is compiled and how the areas are integrated in DOPAS is shown in next page. The development work and considerations for individual experiments related to this work flow are presented in DOPAS Deliverable D2.4 report. The short summary of each Experiment and related work are described below and thereafter the main lessons learned are presented. The more detailed techical issues and lessons learned for each experiment are presented in DOPAS Deliverables D4.3, D4.5, D4.7 and D4.8.


Conceptual Design
WP2
Policy Decision
Waste and Host Rock Characteristics
Design Experience and Material Understanding
Site Environmental Conditions and Loads
Safety Concept
Plug/Seal Conceptual Design Options
Stakeholder Requirements
System Requirements: Plug/Seal Safety Functions
Sub-System Requirements on Plug/Seal Components
Performance Assessment of Plugs and Seals
WP5
Compliance Assessment
Yes
Plug/Seal Conceptual Design
Preliminary Design Requirements
No
Basic Design
WP3
WP4
Strategic Preferences Materials Research and Technology Transfer
Safety Assessment
Operational Constraints
Experimental Constraints and Site-Specific Conditions
Feedback to Conceptual Design
Compliance Assessment
Experiment Design Specifications
Preliminary Design Requirements
Preliminary Basic Design
Reference Design Specifications: Working Assumptions
Experiment Design
Full-Scale Test
WP5
Most Appropriate Technique
Most Appropriate Performance
Yes
Plug/Seal Basic Design
Detailed Design Specification
No
Detailed Design
Safety Assessment
Operational Constraints
Feedback to Basic and/or Conceptual Design
Quality Control Procedures
Detailed Design Specification
Detailed Design
Commissioning Test
Compliance Assessment
Yes
Plug/Seal Detailed Design
Construction Procedures
No

DOPAS Experiment 1 FSS (Full-scale seal)

Work on the FSS experiment within the DOPAS Project included the design, construction and monitoring and dismantling of the experiment.

For FSS, design work was undertaken in the period August 2012-April 2014, the upstream containment wall was cast in July 2013, the clay core was emplaced in August 2014 and the downstream shotcrete plug was emplaced in September 2014. Investigations of FSS were undertaken in the period October 2014 to July 2015, and the dismantling and rehabilitation of the experimental surface facility was completed in December 2015.

Unlike the other DOPAS full-scale experiments, the FSS experiment was not hydraulically pressurised. Instead the FSS experiment was dismantled during the duration of the DOPAS Project. The dismantling of the FSS experiment included the collection of observations about the success of the construction and materials and additional information related to the properties of the installed components.

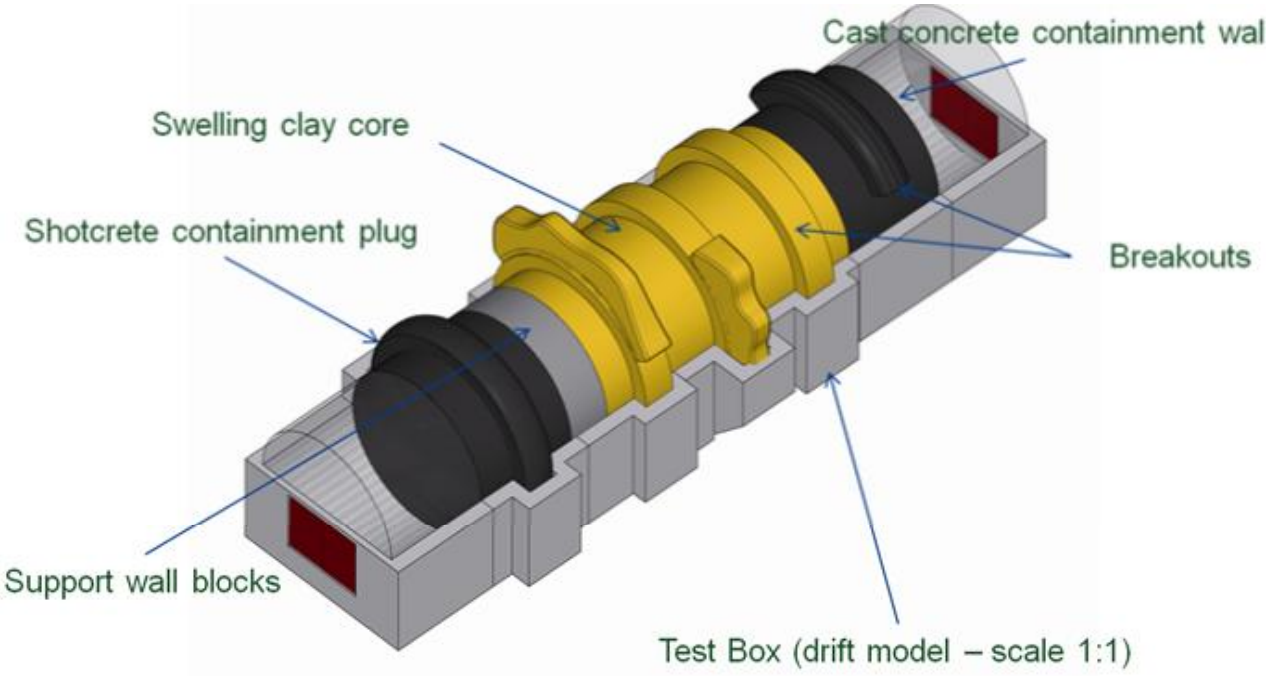


Figure: Andra

FSS Component	Dimensions	Materials
Test box	Internal diameter: 7.6 m. Internal length: 35.5 m Concrete lining thickness: 0.7 m.	Ordinary Portland Concrete
Upstream entrance hall	Length of 5 m to allow for installation of equipment (e.g. core drilling machines).	N/A
Upstream low-pH SCC wall	Length of 5 m, with a recess on its upper part that is 1.5 m long and 0.3 m deep beyond the concrete lining. Volume of ~250 m^3	Low-pH SCC
Swelling clay core	Length of 13.5 m and has three recesses, each recess is 1.5 m long. The recesses are 3 m apart.	WH2 bentonite from Wyoming
Downstream support wall	Length of 2 m.	Half-cubic-meter low-pH concrete blocks made with the same SCC as that used for the first containment wall
Downstream low-pH shotcrete wall	Length of 5 m, with a recess on its upper part that is 1.5 m long and 0.3 m deep beyond the concrete lining.	Low-pH shotcrete
Downstream entrance hall	Length of 5 m to allow for installation of equipment (e.g. core drilling machines).	N/A

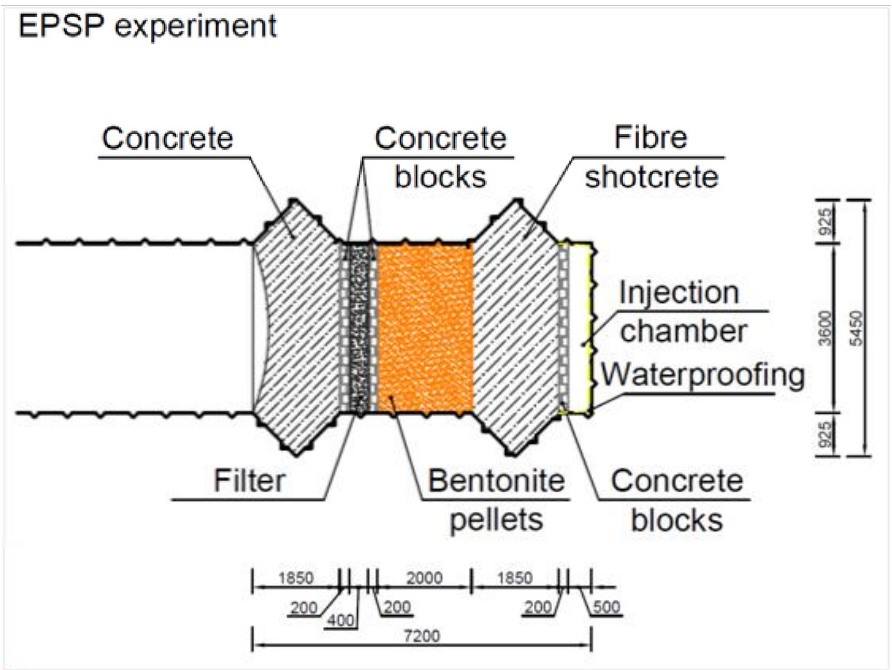
Photo: Andra

DOPAS Experiment 2 EPSP (Experimental pressure sealing plug)

Work on the EPSP experiment within the DOPAS Project included the design, construction and initial monitoring of the experiment.

The location of the EPSP plug was selected in the period September 2012 - December 2012, and ground works were undertaken in the period January 2013 - August 2014. The EPSP's inner plug was sprayed in November 2014, the bentonite core was emplaced in June 2015 and the outer plug was sprayed in June 2015.

Experimental testing and pressurisation of EPSP started during the construction process. The inner plug was pressurised to check the water tightness of the concrete and to determine if grouting was needed through injection of water and air into the injection chamber up to 0.5 MPa. A series of short water injection tests followed by long-term tests at various pressure levels (starting at 0.1 MPa going gradually to up to 1 MPa) were undertaken once the outer plug had cured. The testing sequence was then interrupted and the bentonite sealing section was saturated by injection of water into both the filter and the pressurisation chamber to allow swelling pressure to develop. A short pressure test was then undertaken involving injection of bentonite slurry into the pressurisation chamber at pressures up to 3 MPa (2.5 MPa being the original target value). The pressurisation chamber was then cleaned up, and water pressurisation of the experiment through the pressurisation chamber was resumed. Further pressurisation and monitoring of the EPSP experiment, and evaluation of the results, will be undertaken after the completion of the DOPAS Project.



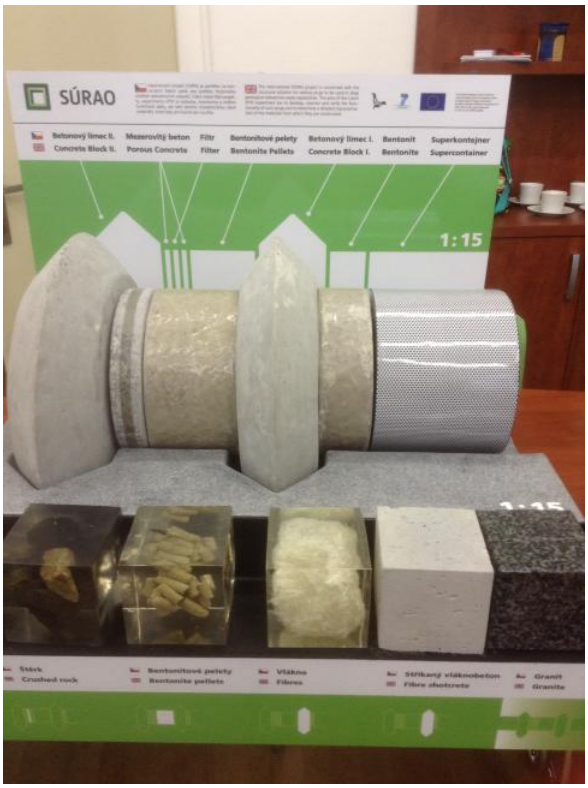


Figure: CTU

EPSP Component	Dimensions	Materials
Tunnel	Cross-section of ~ 15 m^2 (experiment length ~ 7.2 m).	In crystalline rock (granitoid with quartz veins)
Pressure chamber	Length of 0.1 m and diameter of 3.6 m.	The walls and floor were prepared using shotcrete and resin. The surface of the remodelled chamber was treated with a 3 mm thin resin waterproofing finish.
Concrete separation walls	Length of 0.2 m and diameter of 3.6 m.	Concrete blocks
Inner shotcrete plug	Length of 1.85 m and diameter of 3.6 m (slots are 0.925 m into the rock).	Glass-fibre-reinforced low-pH shotcrete
Bentonite pellets	Length of 2 m and diameter of 3.6 m.	B75 Czech Bentonite (>95% vibration-compacted bentonite pellets, remainder is sprayed bentonite)
Filter	Length of 0.4 m and diameter of 3.6 m.	Inert gravel
Outer shotcrete plug	Length of 1.85 m and diameter of 3.6 m (slots are 0.925 m into the rock).	Glass-fibre-reinforced low-pH shotcrete

Photo: SURAO

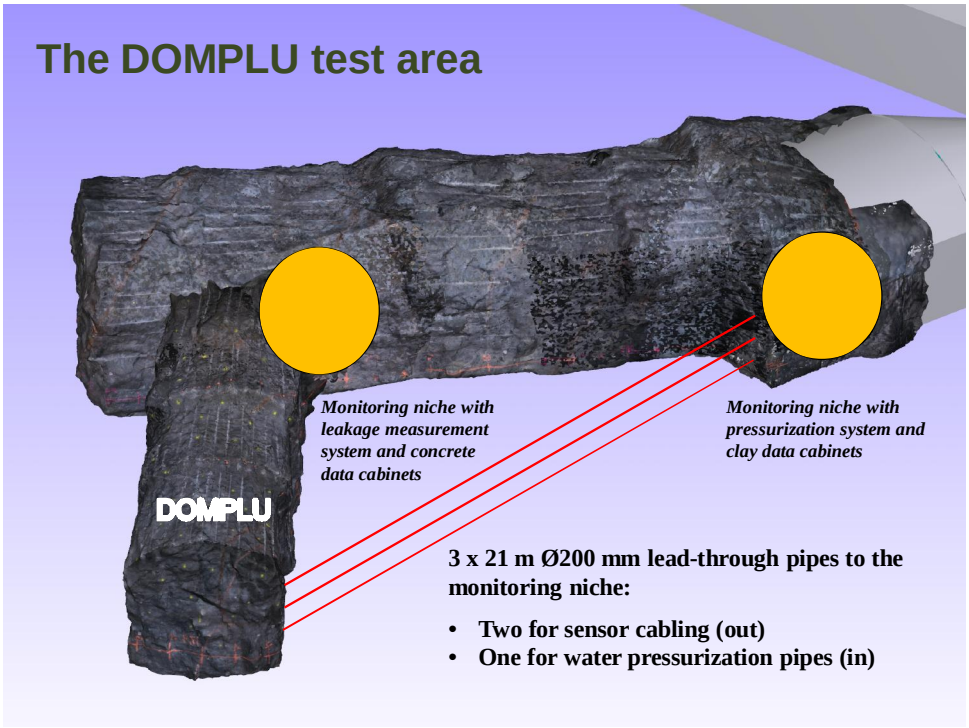
DOPAS Experiment 3 DOMPLU

Work on the DOMPLU experiment within the DOPAS Project included the management, final installation and monitoring of the DOMPLU experiment up to 30 September 2014, and evaluation and technical reporting. The main part of the design and construction of the DOMPLU experiment was not part of the DOPAS Project.

Excavation work for the DOMPLU experiment was undertaken between February and October 2012. The DOMPLU experiment's concrete dome was cast in March 2013 and the contact grouting was undertaken in June 2013. Monitoring was undertaken from March 2013.

Pressurisation of the system was started in December 2013 by injection of water into the filter and backfill, followed by saturation and development of swelling pressure in the watertight seal and backfill transition zone. The water pressure was artificially increased in steps inside the plug until it reached 4 MPa in February 2014. The water pressure was kept at this level for the remainder of the testing reported here. Further monitoring of the DOMPLU experiment, and evaluation of the results, will be undertaken after the completion of the DOPAS Project.

DOMPLU Component	Dimensions	Materials
Tunnel	Length of 13.5 m (experiment length of 6.5 m). Cross section of ~ 18 m^2	In crystalline rock (granite)
Concrete back wall	Length of 0.5 m	Unreinforced low-pH SCC B200 mix
Backfill end zone	Length of 1 m made of blocks of dimensions: 300x150x75 mm	Bentonite blocks (also included 15 cm pellets between the backfill blocks and the LECA® beam)
LECA® delimeter	Length of 0.3 m	LECA® beams
Filter	Length of 0.3 m	Gravel with grain sizes of 2 4 mm
Geotextile delimeter		Geotextile delimiter was also installed to separate the gravel from the bentonite seal.
Watertight seal	Length of 0.5 m	MX-80 bentonite blocks, compacted by uniaxial compression to a size of 500 mm x 571 mm x 300 mm.
Concrete delimiter	Length of 0.3 m	Low-pH concrete beams
Concrete dome	Length of 1.79 m at the centre (length of slot excavation is 3.2 m).	Unreinforced low-pH SCC B200 mix



DOMPLU Experiment location at Äspö is located at the similar depth in cruystalline host rock where the disposal faclitity are planned to be constructed. The different phases from prduction of plug location, and installing all structures and monitoring system have taken place in underground conditions. Figure and photos: SKB

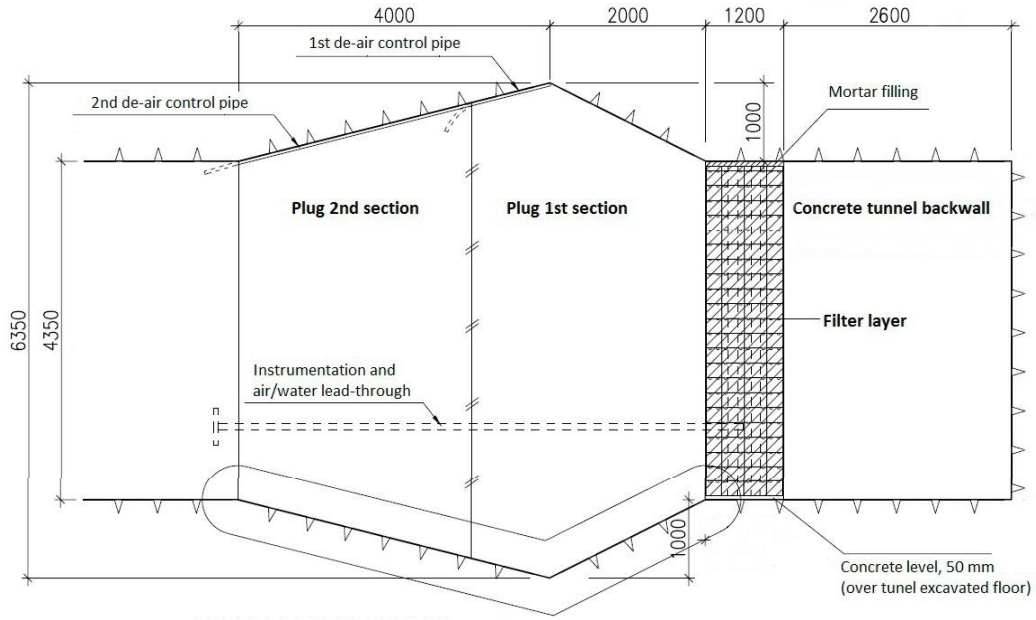
DOPAS Experiment 4 POPLU

Work on the POPLU experiment within the DOPAS Project included the concrete recipe design and performance evaluation, bentonite tape and filter system planning, slot excavation planning and implementations, monitoring and pressurisation systems' design and implementation, modelling of water tightness and mechanical integrity, pressurisation of the experiment plug and its performance assessment. Outside the scope of the DOPAS Project (self-funded by Posiva) were some aspects of the plug design, the tunnel excavation and construction activities themselves.

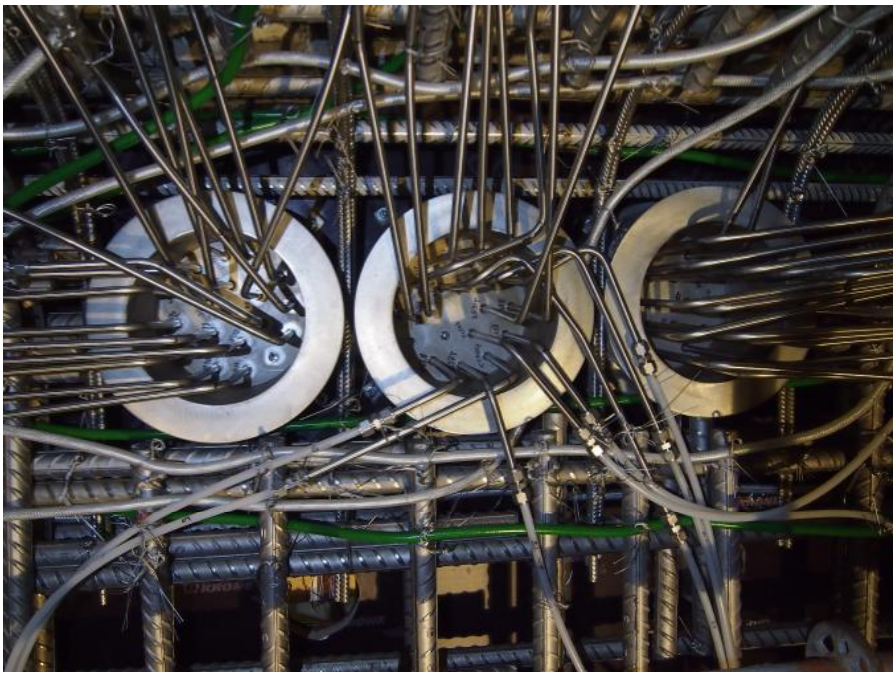
The design of the POPLU experiment was undertaken between November 2012 and September 2013. Excavation of the demonstration tunnels (one for the plug experiment and one for its monitoring data collection) and then the slot were undertaken in the period September 2013-February 2015. The first section of the POPLU concrete wedge was cast in July 2015 and the second section was cast in September 2015. Grouting of the plug-rock interface was undertaken in December 2015. Pressurisation of the plug commenced in mid-January 2016.

Once the filter section was filled with water, pressurisation of the plug could commence. In the early stage of pressurisation, the water pressure in the filter was increased to 1.4 MPa over a one month period, and a shorter duration higher pressure test to 4.1 MPa over a 3 day period that resulted in excessive leakage. It was decided to re-grout the plug interface with an improved grout mix and methodology. It is expected that the pressurisation and performance evaluation will be undertaken again with pressures up to 4.2 MPa after the re-grouting is completed. Further monitoring of the POPLU experiment and the evaluation of the results will be undertaken after the completion of the DOPAS Project.

POPLU Component	Dimensions	Materials
Tunnel	Length of 25 m (experiment length of 11 m). Cross section of ~ 14.5 m^2	In crystalline rock (mainly veined mica gneiss)
Concrete back wall	Length of 2.6 m	Unreinforced low-pH self compacting concrete (SCC)
Filter	Length of 1.2 m	Lightweight concrete blocks, manufactured using LECA® with a maximum grain size of 10 mm
Wedge sections	Length of 6 m in total consisting of two sections (4 m and 2 m of length)	Stainless steel reinforced low-pH self compacting concrete (SCC)
Bentonite tapes	3 x Circumference (60 kg of tape)	Granular bentonite



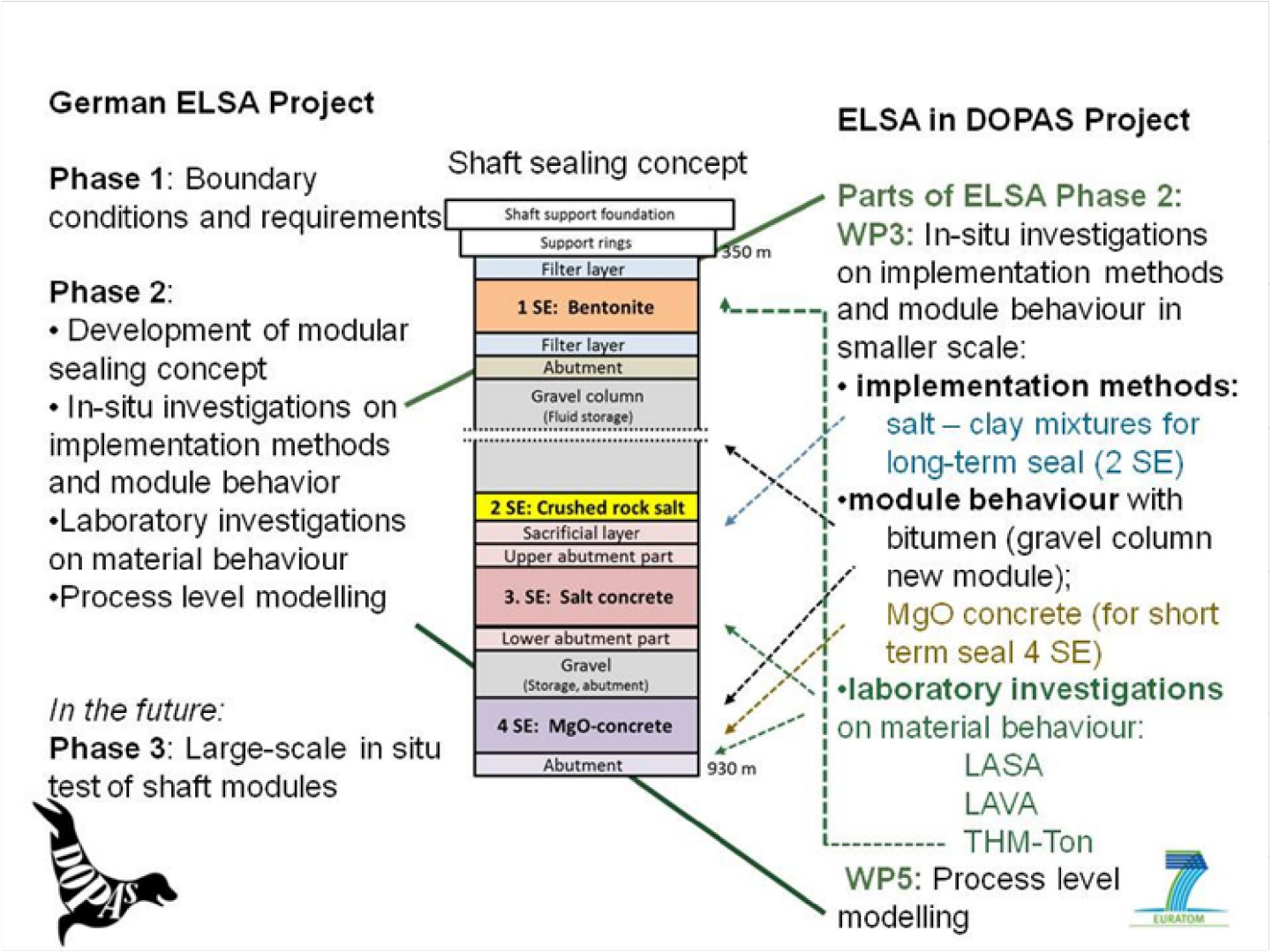
POPLU installed and monitoring phase ongoing. Photo: Marjatta Palmu, Posiva Oy



POPLU instrumentation ready for operation. Photo: VTT

DOPAS Experiment 5 ELSA and related material research

No full-scale test as part of the German ELSA project has been carried out within the DOPAS Project. The aims of the experiments were to develop generic design concepts for shaft seals's sealing elements in both salt and clay host rocks that comply with the requirements for a repository for high-level waste (Jobmann, 2013; Kudla et al., 2013; Herold & Müller-Hoeppe, 2013) and to carry out the necessary preparatory work in the shaft seal design project. Large-scale demonstration tests of individual shaft sealing elements will be undertaken after the DOPAS Project. The German experiments within the DOPAS Project consist of ELSA Project phase two work method development and of the related material studies (LASA, LAVA and THM-Ton). The relation between ELSA Project and LAVA, LASA and THM-Ton are presented in the Figure below.



Overall conclusions and lessons learned

Full-scale testing of future repository components has a significant role of developing the future procedures for repository design, licensing, commissioning and operation. Plugs and seals are part of an integrated EBS and provide safety with the surrounding host rock and other components of the engineered and natural barrier system.

Plugs and seals in certain repository concepts are part of the deposition tunnel backfill and their expected service life is intended assist the backfill to reach saturation and to stay within the design target after the plug has served its function. In other concepts, the seals have direct safety functions and their service life needs to cover longer periods, i.e. until host rock creep has re-established in situ hydraulic conductivity or for the whole assessment period for long-term safety. Due to these reasons the safety functions for plugs and seal vary and therefore many different designs for them are needed depending on the host rock conditions, on the role of the plug and seal in questions, on their dimensions and the planned lifetime of the plug or seal and their components (especially the materials).

Within the DOPAS Project, various plug and seal designs for different repository concepts have been tested at full-scale taking into account the above mentioned variations in their functions and their future repository environment. Since the participating WMOs and Member States are in different phases of development with regard to their disposal concepts, the full-scale experiments and supporting materials research projects carried out have been implemented to meet the maturity of the participating waste management programmes. For the programmes closer to licensing, the work carried out has contributed to advances in the basic design of the plugs and seals. For the programmes planning to start their repository in decades from now, the DOPAS Project has advanced their conceptual designs and provided input to the formulation of preliminary design requirements for their plugs and seal. The DOPAS Design Basis Development Workflow developed in WP2 (DOPAS, 2016a) integrated in an unprecedented way the experiences of the consortium into an iterative and step-wise approach that produces a requirements-compliant design. The workflow has much value as a generic guideline for any design work in the various development stages and it can be used as a yardstick for assessing the future development steps.

The experiments, and the design and implementation solutions discussed and reasoned collaboratively within the consortium and in the work package meetings have provided a forum for mutual learning irrespective of the state of the repository development. This interaction has provided complementary exchanges and it has given each partner and experiment comprehensive knowledge on the different areas of plug and seal development needs from different viewpoints. Any full scale experiment has limitations both due to its test function with additional components that are not required in the real repository and also due to the changing conditions due to the natural host rock environment and conditions (including the differences in the local thermal, mechanical, hydraulic and chemical properties). Therefore, in repeating the experiences or the experiments from the DOPAS Project, these limitations need to be addressed and an adaptation to the case in question is required. Still the learning and knowledge accumulated and widely disseminated also outside the consortium during the four-year-long project can be used for further development of other EBS components as well as for plugs and seals. This collected knowledge of the DOPAS Project can be used for development of mechanical and hydraulic plugs in crystalline, in clay and in salt host rock environments. The DOPAS Project experiments have provided to date experimental options for a wide variety of composite plug and seal sizes in variable groundwater and loading conditions: the dimensions of plugs and seals varying from 100 m3 to 1200 m3; the host rock groundwater chemistry varying from fresh surface water into the saline groundwater and hydrostatic pressure varying from 0 MPa up to 4.2 MPa.

There are still needs to be considered for industrialisation aspects, when making tens of plugs. The lessons learned within DOPAS needs to be applied for reference design and the proper documentation of DOPAS work has been really helpful in this sense.

The potential impact and the main dissemination activities and exploitation of results

Since beginning of the DOPAS project it was obvious that the distribution of different aspects of DOPAS project is one of the key issues to increase the knowledge about plugs and seals within different stakeholders. Within DOPAS project worked actively over 160 persons from Consortium and additionally similar amount of persons as subcontractors and their experience in plugs and seals and communicating the things further is already major achievement. Through review and integration of results, and their dissemination did increase the knowledge even more as have been explained in Chapters below.

DOPAS Staff Exchange programme

The first staff exchange took place to St-Dizier, in France to the FSS experiment and the Bure URL during the first period (June 10-13, 2014). The visit hosted by Andra received three professionals: two from Posiva and one from GSL. The staff exchange visit was reported in deliverable D6.2 during the second project period.

The second staff exchange took place to the EPSP experiment in the Josef underground laboratory in the Czech Republic. This exchange was hosted jointly by CTU and SÚRAO and took place during 12-14 November 2014 and it was attended by two staff members, one from Posiva, Finland and another from Andra, France.

The third and last planned staff exchange took place to the POPLU experiment at Posiva's ONKALO URCF in Eurajoki, Finland. The staff exchange was carried out from 30 June until 2 July 2015 and four staff members participated in it, one from CTU in Czech Republic, two from GSL in Great Britain and one from SKB, Sweden.

Expert Elicitation for DOPAS main reports

The original proposal plan for expert elicitation (EE) was to carry out one single elicitation to all of the Work packages. In hindsight due to the experiment progress and other developments, the GA decision to split the elicitations of each work package into separate processes has proved to be more practical to implement. At the same time it has increased the scope of task 6.3 demanding the organisation of more meetings with the experts than originally foreseen. A decision was made to engage on single expert to participate in all of the different elicitations to ensure consistency and a wider view throughout the process. Regarding the end result of the EE, we anticipated that a more concise consensus view on such issues that need to be taken into account as input in the final public deliverables of the DOPAS work packages WP2, WP3, WP4, and WP5 will be received as the individual experts have a more focused task at hand. This happened. The experts also gave their views and feedback on the EE process for its further development and this input is included into the D6.1 (in Task 6.1).

Dissemination and exploitation of DOPAS Project

The work started by defining the dissemination strategy, target groups and methods for reaching the groups. Dissemination of the DOPAS Project results was planned to be in alignment with the Vision 2025 (IGD-TP, 2009) and it meets the IGD-TP SRA requirements (IGD-TP, 2011 Chapter 4.1.4).

There were four different group of stakeholders (general public, WMOs, TSO's and regulators, and higher education people not working in area) identified and the dissemination activities were planned so that all of the groups were reached by different type of dissemination activities.

The dissemination and exploitation plan DOPAS Deliverable D7.1 (Hansen and Palmu, 2013) was published in the beginning of the DOPAS Project aiming to describe the dissemination strategy, philosophy and methods including the target groups. The planned dissemination activities were discussed and agreed by the DOPAS Project General Assembly yearly and the dissemination activities were conducted according to the plan, which was updated yearly and compiled to represent both the national needs for Beneficiaries and to reach the DOPAS target groups sufficient way. Altogether 94 dissemination activities divided to the different categories were published during the DOPAS Project. The main part of the dissemination activities have been published through DOPAS web site and the scientific and oral presentations in many different conferences and seminar, reaching the target groups. Other dissemination activities are related to the publicity of DOPAS Project and its content and therefore DOPAS Experiments have been topics or presented in different public materials produced by organisations implementing the experiments (like company journals, web interviews, annual reports, calendars, video films, miniature model, posters for visitors).

Staff exchange FSS Experiment (above Photo: Andra) and POPLU Experiment (below Photo: Posiva)

DOPAS Training Workshop 2015

The dissemination of the DOPAS experiences included an activity to set up a training workshop for participants outside the project consortium. 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 June 2013, when the location and the time for the training was were agreed.

The learning outcomes for the training workshop were described applying the ECVET approach dividing them into Knowledge, Skills and Competence that the participants were expected to acquire from the Training Workshop. A recommendation for recognising academic credits equalling 4 ECTS for graduate or post-graduate level studies was issued by CTU's and Posiva's representative for the participants who had completed the full DOPAS Training Workshop.

The detailed content planning for the training workshop started in May 2015. The planning consortium consisted of Posiva, SKB, Andra, CTU, SURAO, RWM and GRS 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. The week in September 2015 that was scheduled for the training provided unhindered access for the trainees to the Josef URC and underground laboratory. The other training locations were at the faculty of Civil Engineering at the CTU in Prague and at the ÚJV Řež, a.s. in the Czech Republic. 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.

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 the time that is applicable to the plugs and seals and for their needed isolation and containment function. These vary significantly among the various plugs and seals depending on the repository safety concept and on the host rock environment. Second, the training order was planned in such a way that each of the learning outcomes 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. One of the feedbacks from the participants confirmed the usefulness of this approach in creating increased interest in the participant to gain more knowledge about the national programme and in being able to assist in the programme by using the learning outcomes.

The training workshop was advertised on different venues and using contact lists of the planning group in the waste management community and universities and 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 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, at the same time they were working at various organizations. All of the participants had a scientific or technical background, with most of them with a background in geotechnical engineering or geology.

The training materials consisted of about 40 different presentations, of five major exercises and of other supporting materials, presentations of the tutor organizations and of the documentary movie "Into eternity" by director M. Madsen shown at the courtesy of the movie's producer Magic Hour Films.

The participants' activities and interaction were observed during the whole week as part of the assessment of their learning. The trainees worked very well together as a group 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 the peer assessment of the other group's outcomes compared with the group's own results and complemented with the tutor/s' feedback.

In the beginning of the workshop the participants set their own expectations and goals for the training and concluded that most of their objectives were achieved at the end. In addition to this group assessment, the participants also gave their individual evaluation of the workshop on an evaluation form. The outcomes of the evaluation varied on a scale from 1 (low) to 5 (high), with the average scores varying from 4.3 to 4.8 on nine different evaluated items. Replies were received from all 12 participants. The tutors present made a similar evaluation as a group during the last training day and came to the same conclusion as the participants.

The workshop was successfully implemented according to plans 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.

The training workshop plan and the training process content are produced as a deliverable of the project (DOPAS Deliverable D7.2, Palmu & al. 2016). The material produced is open access unless otherwise mentioned in the materials for non-commercial use of any interested stakeholders. All materials are available at http://www.posiva.fi/en/dopas under WP7.

Training workshop participants in underground conditions.

Jiri Svoboda shows how to prepare the instrumentation and that supports to understand what the main challenges for monitoring systems are.

Photo: Marjatta Palmu, Posiva

DOPAS 2016 seminar

The DOPAS 2016 seminar planning was initiated in February 2015, and the Conference topics were decided by the DOPAS 2016 seminar planning group. The seminar planning group did represent the different type of organisations participating in DOPAS project with representatives from IGD-TP and European Commission.

The first call for abstracts was published and the DOPAS 2016 website established around a year before the seminar. The advertisement of DOPAS 2016 seminar was initiated via IGD-TP web site and DOPAS website during the summer 2015 and was continued on the internet. Additional seminar advertisement took place in the end of the 2015 and the scope was experts working with plugs and seals and related stakeholders worldwide. The advertisement did continue at the time of publishing the DOPAS 2016 programme.

The deadline for submitting the abstracts were extended from the end of November until the 18th December and altogether 47 abstracts or proposal for presentations/poster was received. Based on the received abstracts the seminar sessions were modified to inform about DOPAS outcome starting from very general level and going into the detailed aspects on different areas for designing and implementing the plugs and seals. The information from individual experiments was integrated into the presentations which summaries the achievements and experiences.

The extended abstracts were submitted to the seminar in the end of March 2016 and the received abstracts are published as part of the DOPAS 2016 seminar proceedings as DOPAS Deliverable D7.3 (DOPAS 2016f)

The DOPAS 2016 Seminar took place in Turku, Finland 25th and 26th May, with a site visit to Olkiluoto on 27th May. Over 110 participants representing WMO's, TSO's, regulators, university persons, consultants and material specialists related to design, development, production or sales from around 50 organisations and 16 countries worldwide attended the Seminar. The DOPAS 2016 programme was divided into six sessions:

- Session 1 provided an introduction to the role of full scale demonstrations and their role in the development of disposal concepts.

- Session 2 integrated the outcomes from the DOPAS project including development of the design basis for plugs and seals, lessons learnt from construction of plug and seal demonstrators and performance assessment of plugs and seals.

- Session 3 presented plugs and seals experiences from past or work done for other purposes like borehole sealing, and underground hazardous waste disposal facilities. The reason for this session was to examine the topic of plugs and seals in broader context and also gain an understanding of how plugs and seals are treated in safety cases.

- Session 4 was concentrated more detailed on the plug and seal designs, materials used in plugs and implementation of demonstrators. The presentations provided the audience with case examples of how plug location is selected, how to design concrete, bentonite and other materials to be used in plugs, and how to install plugs and seals using different DOPAS related or other experiment information.

- Session 5 highlighted the role of plugs in safety and performance assessments, even the long term safety related issues were handled in almost all DOPAS 2016 presentations. Monitoring of plugs and seals and case studies related to the DOPAS Project was given in this session.

- Session 6 examined topics related to training, information dissemination and regulatory supervision of plugs and seals. In addition, questions related to the lessons learned were collected via Panel discussion, and where DOPAS Experiment leaders were quizzed via questions that the attendees had submitted via the message wall earlier in the seminar.

During the Olkiluoto site visit the visitors did receive an introduction to the selecting a suitable plug location in crystalline host rock and how POPLU plug was designed, constructed and monitored. The visitors did visit in the VLJ-repository with similar host rock as for Finnish spent nuclear fuel repository. The seminar was found very informative not only in relation to the plugs and seals but as well to the other engineered barrier demonstrations and getting information how the desk studies will be transferred into the full scale experiments in future repository.

The DOPAS 2016 seminar public participated actively for the Q/A opportunities in the sessions.

Different plug material samples and miniatyr EPSP were interesting during the poster session and coffee breaks giving the opportunity to touch and discuss the materials properties.

Photo: Posiva

Publication of DOPAS foreground

DOPAS Deliverables mainly contains the project outcome related to the DOPAS foreground as stated in DOPAS Project plan (DOPAS Deliverable D1.2). DOPAS Project published almost 100 reports or other Deliverables, and most of them were scientific in their nature. During the course of DOPAS Project some Deliverables were combined to compile information related to each other and in some areas the results were divided into the separate Deliverables with different schedule or other appropriate reason to publish it in parts. The deliverable categories are divided into the reports, others and demonstrators. Reports are the scientific and other written documents, which describe the outcome of the work packages. Most of them are public and are published at DOPAS public website, but few which present interim information or project internal materials are restricted only for consortium members, but even those deliverables have been summarised in Work package and Experiment summary reports (DOPAS, 2016a; DOPAS, 2016b; DOPAS, 2016c; DOPAS, 2016d, Noiret et al., 2016; Svoboda et al., 2016; Grahm et al., 2015; Holt and Koho, 2016; Jantschik and Moog, 2016; Czaikowski and Wieczorek, 2016; and Zhang, 2016). Some deliverables (e.g., plans, posters, meeting materials and test results) are materials and are classified as "others". To the demonstrator's category belong the DOPAS full-scale experiments. Two short video films were produced of the experiments, and these have been published on the DOPAS website or on YouTube, aiming to show the work phases in descriptive and informative manner.

Key outcomes from DOPAS Dissemination and Exploitation

The main outcome was to create and publish planned deliverables and organisation of DOPAS training workshop in September 2015 and DOPAS 2016 seminar in May 2016, and actively disseminate the progress and achievements of DOPAS Project work and Experiments for different target groups. The dissemination activities were planned and implemented according to the plan and the extent was greater than anticipated. Altogether, there were around 100 dissemination activities and the DOPAS Project was highly visible among IGD-TP frames and in different seminars and conferences going beyond waste management area (e.g. concrete research and monitoring research). The DOPAS Project is referred in materials published by Ministries responsible for licensing the waste management programmes in some of the participating countries.

The DOPAS Project has successfully shared the knowledge gained during the course of the project through the following activities:

- The emplacement locations for DOPAS Experiments (St Dizier, Josef Gallery, Äspö HRL, ONKALO and VLJ repository ONKALO Exhibition) have been open to visitors including project partners, experts, authorities and the general public. The amount of visitors in those places yearly exceeds 16 000 persons with different background, except the St Dizier where the plug was dismantled already during 2015.
- The DOPAS public web page have been visited by over 4 000 persons
- DOPAS internal work package meetings and task meetings
- Networking and direct contacts between experts and engineers and subcontractors ~160 persons working for DOPAS Project.
- Dialogue between the Experts in Expert Elicitation (15 men and 2 women) and DOPAS domain experts (WP leaders)
- The DOPAS project have been presented in internal events in participating organisations for hundreds of Participants
- The DOPAS project intranet at Projectplace have hosted ~70 persons.
- Public DOPAS training workshop for 12 participants
- Public DOPAS 2016 seminar for 110 participants
- DOPAS organisations internal staff exchange programme for three full scale experiments FSS, EPSP & POPLU (with 10 participants).
- Published over 60 articles relating to the work performed within the DOPAS project.
- Produced 3 movies or video clips relating to the work performed within the DOPAS project available at http://www.posiva.fi/en/dopas/dopas_2016_seminar

The materials and proceedings from the dissemination activities including the proceedings from the seminar and the training workshop training materials are all publicly available for the interested stakeholders.

* http://www.posiva.fi/en/dopas
* DOPAS@posiva.fi

DOPAS Deliverables

Deliverable Title	Lead Partner	Reference
D1.1 General Assembly meetings and minutes	POSIVA	NA
D1.1 General Assembly meeting minutes 3 (D1.1.2)	POSIVA	NA
D1.1 General Assembly meeting minutes 3 (D1.1.3)	POSIVA	NA
D1.1 General Assembly meeting minutes 4 (D1.1.4)	POSIVA	NA
D1.1 General Assembly meeting minutes 5 (D1.1.5)	POSIVA	The meeting was replaced with MTM meeting
D1.2 Project Plan including risk management plan	POSIVA	DOPAS (2013) DOPAS Project plan. DOPAS Project Deliverable D1.2
D1.3 DOPAS website (public) and Extranet (for IGD-TP)	POSIVA	NA
D2.1 Design Basis and Criteria Report	SKB	White, M.J., Doudou, S., and Neall, F.B. (2014). DOPAS Work Package 2, Deliverable D2.1: Design Bases and Criteria, Version 1.1, February 2014.
D2.1 Design Basis and Criteria (Task meeting)	SKB	NA
D2.2 Reference Designs Report	SKB	White, M.J. and Doudou, S. (2014). Design of Reference Concepts and DOPAS Experiments. DOPAS Work package 2, Deliverable D2.2
D2.3 Strategies of demonstrating conformity of reference design to design basis	SKB	White, M.J. and Doudou, S. (2015). Strategies for Demonstrating Compliance of the Reference Designs with the Design Basis. DOPAS Work package 2, Deliverable D2.3
D2.4 WP2 Final Report	SKB	DOPAS (2016). DOPAS Work Package 2, Deliverable D2.4. WP2 Final Report: Design Basis for DOPAS Plugs and Seals.
D3.1 FSS Experiment	ANDRA	Bosgiraud, J.-M. and Foin, R.(2016). FSS construction summary report. DOPAS Work Package 3, Deliverable D3.1 Andra:
D3.2 FSS tunnel model design report	ANDRA	Bosgiraud, J.-M. and Foin, R. (2013). DOPAS Work Package 3, Deliverable D3.2. FSS tunnel model design report, Version A.
D3.3 Report on clayish material definition for FSS	ANDRA	See D3.7
D3.4 Report on low-pH concrete formulas for FSS	ANDRA	See D3.8
D3.5 Lab test report on the performance of the clayish material for FSS	ANDRA	See D3.7
D3.6 Lab report on the performance of low-pH concrete for FSS	ANDRA	See D3.8
D3.7 Test report on FSS metric core emplacement	ANDRA	Bosgiraud, J.-M. and Foin, R. (2016). D3.7 Test report on FSS metric core emplacement with clayish materials definition for FSS and Laboratory work on the performance of clayish materials for FSS. DOPAS Work Package 3. Deliverable D3.7. Andra
D3.8 Test report on FSS cast in-box concrete	ANDRA	Bosgiraud, J.-M. and Foin, R. (2013). D3.8 Test report on FSS cast in box concrete with low pH concrete formulas for FSS and Laboratory work on the performance of low pH concrete for FSS. DOPAS Work Package 3. Deliverable D3.8. Andra
D3.9 Test report on FSS test panel for shotcrete	ANDRA	See D3.1

Deliverable Title	Lead Partner	Reference
D3.10 Drift model FSS construction report	ANDRA	Bosgiraud, J.-M. and Foin, R. (2013). Drift model FSS construction report. D3.10 DOPAS Work Package 3. Deliverable D3.10. Andra
D3.11 Report on FSS cast concrete plug construction	ANDRA	Bosgiraud, J-M., Foin, R., Bethmont, S. (2014) FSS cast concrete plug construction. DOPAS WP3 Deliverable D3.11. Andra
D3.12 Report on construction of FSS swelling clay core	ANDRA	See D3.1
D3.13 Report on shotcrete plug construction	ANDRA	See D3.1
D3.14 EPSP experiment	SURAO	Svoboda, J., Nadherna, D. (2015) EPSP Experiment. DOPAS Work Package 3. Deliverable D3.1. CTU
D3.15 Detail design of EPSP plug	SURAO	Svoboda, J.; Vašíček, R.; Smutek, J. and Šťástka, J. (2015a). DOPAS WP3 Detail design of EPSP plug. DOPAS Project Deliverable D3.15, Version 1, 28 February 2015
D3.16 Testing plan for EPSP laboratory experiment	SURAO	Vašíček, R.; Levorová, M.; Hausmannová, L.; Šťástka, J.; Večerník, P.; Trpkošová, D. and Gondolli, J. (2013). DOPAS WP3Testing plan for EPSP laboratory experimentDOPAS Project Deliverable D3.16
D3.17 Interim results of EPSP laboratory testing	SURAO	Vašíček, R.; Levorová, M.; Hausmannová, L.; Šťástka, J.; Večerník, P.; Trpkošová, D. and Gondolli, J. (2014). DOPAS WP3 Interim results of EPSP laboratory testing. DOPAS Project Deliverable D3.17, Version 1, 31 January 2014
D3.18 Testing plan for EPSP instrumentation and monitoring	SURAO	Svoboda, J., Vasicek, R., Smutek, J., Stastka, J. (2014). DOPAS Deliverable D3.18: Testing plan for EPSP instrumentation and monitoring, Version 1.0, June 2014.
D3.19 EPSP Functionalities demonstration	CTU	Svoboda, J., Nadherna, D. (2015) EPSP Functionalities demonstration. DOPAS Work Package 3. Deliverable D3.19. CTU
D3.20 EPSP Plug test installation report	SURAO	Svoboda et al. (2016), EPSP plug test installation report, Deliverable D3.20, EU FP7 project DOPAS no. 323273, Czech Technical University in Prague, Prague
D3.21 Final laboratory test report of EPSP	SURAO	Vašíček, R., Hausmannová, L., Šťástka, J., Svoboda, J., Nádherná, D., Pacovská, D., Hu-bálovská, J., Večerník, P., Trpkošová, D., Gondolli, J., Dvořáková, D., Hanusová, I., Bělíčková, L. (2016). Finalresults of EPSP laboratory testing. DOPAS Work package 3, Deliverable D3.21, CTU in Prague, 67 p.
D3.22 DOMPLU experiment	SKB	Grahm, P. (2015). DOMPLU Experiment. DOPAS Work Package 3. Deliverable D3.22
D3.23 POPLU experiment	POSIVA	Holt, E., Koho, P. (2016). POPLU Experiment. DOPAS Work Package 3. Deliverable D3.23
D3.24 Detailed design of POPLU deposition tunnel end plug	POSIVA	Holt, E. and Dunder, J. (2014). DOPAS Work Package 3 Deliverable D3.24. Detailed Design of POPLU Deposition Tunnel End Plug.
D3.25 Test plan for the full-scale test including the instrumentation plan for POPLU plug	POSIVA	Hakola, I., Halonen, M., Bohner, E. (2013). Test plan for the full-scale test including the instrumentation plan for POPLU plug. DOPAS Work Package 3. Deliverable D3.25. VTT
D3.26 URCF RSC work memorandum (POPLU)	POSIVA	Kosunen, P. (2014). URCF RSC Work Memorandum (POPLU). DOPAS Work Package 3 Deliverable D3.26.
D3.27 POPLU concrete test memorandum	POSIVA	Holt, E. (2014). DOPAS Work Package 3, Deliverable D3.27. POPLU concrete test memorandum Concrete mix design and performance study, Version 1.
D3.28 Status report on ELSA laboratory tests	GRS	Meyer, T. and Herbert, H-J., (2014) DOPAS Work Package 3, Deliverable D3.28. Status report on ELSA/LAVA related laboratory tests (D3.28) and on process modelling activities (D5.5). GRS.

Deliverable Title	Lead Partner	Reference
D3.29 Final Technical Report ELSA related testing	GRS	Jantschik, K. and Moog, H. (2016). DOPAS Work Package 3, Deliverable D3.29. Final technical report on ELSA related testing on chemical-hydraulical behaviour – LAVA.
D3.30 WP3 Final summary report	ANDRA	DOPAS (2016). DOPAS Work Package 3, Deliverable D3.30. WP3 Final Summary Report: Summary of, and Lessons Learned from, Design and Construction of the DOPAS Experiments.
D3.31 Final Technical Report on ELSA related testing of mechanical - hydraulic behaviour of the shaft seal (LASA)	GRS	Czaikowski, O. and Wieczorek, K. (2016). DOPAS Work Package 3, Deliverable D3.31. Final technical report on ELSA related testing on mechanical-hydraulical behaviour - LASA, 29 February 2016.
D3.32 Final technical report on sealing behaviour of clay rock (THM-TON)	GRS	Zhang, C-L. (2016). DOPAS Work Package 3, Deliverable D3.32. Final report on the sealing behaviour of fractured claystone and seal materials (THM-Ton).
DOPAS material database	VTT	NA
D4.1 Report on qualification of commissioning methods	ANDRA	Noiret, A., Bosgiraud J-M. and Foin R. (2016b).. DOPAS Work Package 4, Deliverable D4.1. FSS Experiment – Report on Qualification of Commissioning Methods, Version A, 12 August 2016
D4.2 Report on bentonite saturation test	ANDRA	Conil, N., Talandier, J., Noiret, A., Armand, G. and Bosgiraud, J-M. (2015). DOPAS Work Package 4, Deliverable D4.2. Report on Bentonite Saturation Test (REM), Version B.
D4.3 DOMPLU experiment summary report	SKB	Grahm, P.; Malm, R.; Eriksson, D. (2015). DOPAS Work Package 4, Deliverable D4.3: DOMPLU Summary Report, Version 1, December 2015 (content identical to SKB publication SKB TR-14-23).
D4.4 WP4 Integrated Report	RWM	DOPAS (2016). DOPAS Work Package 4 Deliverable D4.4. WP4 Integrated Report. Summary of Progress on Design, Construction and Monitoring of Plugs and Seals.
D4.5 POPLU experiment summary report	POSIVA	Holt, E. and Koho. P. (2016). DOPAS Work Package 4, Deliverable D4.5. POPLU Experiment Summary Report.
D4.6 Monitoring data from EPSP plug test summary report	SURAO	Svoboda, J., Hausmannová, L., Vašíček, R., Smutek, J., Stastka, J., Nádherná, D., and Pacovská, D. (2016). Monitoring Data Taken from the EPSP Plug Test Summary Report. DOPAS Work Package 4, Deliverable D4.6.
D4.7 EPSP experiment summary report	CTU	Svoboda, J., Hausmannová, L., Vašíček, R., Smutek, J., Stastka, J., Nádherná, D., Pacovská, D., Dvorakova, M., Hanusová, I., Belickova, L., Havlová, V., Večerník, P. and Trpkošová, D. (2016). DOPAS Work Package 4, Deliverable D4.7. EPSP Experiment Summary Report.
D4.8 FSS experiment summary report	ANDRA	Noiret, A., Bethmont, S., Bosgiraud J-M. and Foin R. (2016). DOPAS Work Package 4, Deliverable D4.8. FSS Experiment Summary Report, Version A.
D4.9 Application of the DOPAS lessons learnt in less-advanced programmes	RWM	White, M.J., Doudou, S., Neall, F.B., Richardson, P. (2016). Application of the DOPAS lessons learnt in less-advanced programmes. DOPAS Work Package 4, Deliverable D4.9
D5.1 Modelling plan for EPSP PA	SURAO	Dvořáková, D., Hanusová, I., Trpkošová, D., Vokál., A. (2013) Models and modelling summary report for EPSP. DOPAS Work package 5. Deliverable D5.1.
D5.2 Report on Andra's PA methodology for scaling systems	ANDRA	Wendling, J., Calsyn, L., Bosgiraud, J-M. (2015). DOPAS Work Package 5, Deliverable D5.2. Report on Andra's PA Methodology for scaling systems, Version B.

Deliverable Title	Lead Partner	Reference
D5.3 Report on Andra's understanding of processes involved in time and space	ANDRA	Wendling J., Pepin G.., Bosgiraud J.M. (2015). Report on Andra's Understanding of Processes involved in Time and Space. DOPAS Work package 5, Deliverable D5.3
D5.4 Report on approach concerning uncertainties	ANDRA	Wendling J., Pepin G.., Bosgiraud J.M. (2015b), Report on Andra's PA approach concerning uncertainties. DOPAS Work package 5, Deliverable D5.4
D5.5 Status report on process modelling activities	GRS	Zhang, C-L. (2014). DOPAS Work Package 5, Status report on ELSA/THM-TON related laboratory tests (D3.28) and on process modelling activities (D5.5)
D5.6 Status report on conceptual and integrated modelling activities	GRS	Rübel, A., Buhmann, D. and Kindlein, J. (2014). Status report on conceptual and integrated modelling activities. DOPAS Work package 5, Deliverable 5.6.
D5.7 Models and modelling summary report for EPSP	SURAO	Dvořáková, D., Lukin, D., Trpkošová, D. (2016) Models and modelling summary report for EPSP. DOPAS Work package 5. Deliverable D5.7.
D5.8 Final report on process, conceptual and integrated modelling activities	GRS	Rübel, A.; Buhmann, D.; Kindlein, J.; Lauke, T. (2016). Performance Assessment of Sealing Systems - Conceptual and integrated modelling of plugs and seals. GRS-415, Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Braunschweig. DOPAS Work package 5, Deliverable D5.8
D5.9 Integration of results of demonstrators in total repository system's PA by special performance indicators.	NRG	T.J. Schröder, E. Rosca-Bocancea, J. Hart (2016). Integration of demonstrator activities in performance assessment: analysis of processes and indicators. DOPAS Work package 5, Deliverable D5.9.
D5.10 WP5 Final integrated report	GRS	DOPAS (2016). DOPAS Work Package 5, Deliverable D5.10. WP5 Final Integrated Report. DOPAS Project Deliverable D5.10.
D5.11 Status report on ELSA/LASA related laboratory tests and on process modelling activities	GRS	Czaikowski O. (2014). DOPAS Work Package 5, Deliverable D5.11. Status report on ELSA/LASA related laboratory tests (D3.28) and on process modelling activities (D5.5). GRS.
D5.12 Assessment of water tightness and mechanical integrity of POPLU plug.	POSIVA	Rautioaho, E., Börgesson, L., Åkesson, M., Kristensson O., Valli, J., Hakala, M., Pintado, X. and Koskinen, K. (2016). DOPAS Work Package 5 Deliverable D5.12. Assessment of Watertightness and Mechanical Integrity of POPLU Plug
D6.1 Plan for the integrating analysis by experts and selection of experts	POSIVA	Palmu, M. (2016). Plan for integrating analysis by experts and selection of experts (Expert Elicitation). DOPAS Work Package 6, Deliverable D6.1, Posiva Oy.
D6.1.1. Pilot EE consensus memorandum for D3.25 POPLU test plan (D6.1.1.)	POSIVA	Posiva 2013. DOPAS WP6 Task 6.1 Consensus Memorandum of Pilot EE for POPLU Test Plan. DOPAS Work Package 6 Deliverable D6.1.1 Eurajoki, Finland. Posiva Oy
D6.2 Expert staff visit travel reports	POSIVA	Doudou,S., Rantamäki, P. (2014) FSS staff exchange. DOPAS WP6. Deliverable D6.2.
D6.2.2 EPSP staff exchange	POSIVA	Uusi-Uola, T., Dabouz, Y. (2015) EPSP staff exchange. DOPAS WP6. Deliverable D6.2.2
D6.2.3 POPLU staff exchange	POSIVA	Smith, J., Crawford, M., Grahm, P., Roll, M. (2015) POPLU staff exchange. DOPAS WP6. Deliverable D6.2.3
D6.3 WP2 Expert Elicitation	POSIVA	Palmu, M. (2015). Consensus memorandum for D2.4Expert Elicitation. DOPAS Work Package 6, Deliverable D6.3. Posiva Oy
D6.3.1 WP3 Expert elicitation	POSIVA	Palmu, M. (2016). Consensus memorandum for D3.30 Expert Elicitation. DOPAS Work Package 6, Deliverable D6.3.1. Posiva Oy
D6.3.2 WP4 Expert Elicitation	POSIVA	Palmu, M. (2016). Consensus memorandum for D4.4 Expert Elicitation. DOPAS Work Package 6, Deliverable D6.3.2. Posiva Oy

Deliverable Title	Lead Partner	Reference
D6.3.3 WP5 Expert Elicitation	POSIVA	Palmu, M. (2016). Consensus memorandum for D5.10 Expert Elicitation. DOPAS Work Package 6, Deliverable D6.3.3. Posiva Oy
D6.4 DOPAS Final Project Summary Report	POSIVA	DOPAS (2016). DOPAS project final summary report DOPAS WP6. Deliverable D6.4
D7.1 Dissemination Plan (incl. exploitation)	POSIVA	Hansen, J. and Palmu, M. (2013) DOPAS Work Package 7. Deliverable D7.1 Dissemination Plan (incl. Exploitation). Posiva Oy.
D7.2 Plug and Seal Training Workshop planning and implementation report	POSIVA	Palmu, M. and Vašíček, R. (2016). Plug and seal training workshop planning and implementation report. DOPAS Training Workshop 2015. DOPAS Work Package 7. Deliverable D7.2. Posiva Oy and CTU.
D7.3 Organisation and publication of proceeding an international seminar in 2016	POSIVA	DOPAS (2016) DOPAS 2016 proceedings Deliverable D7.3
D7.4 Publishing in total six newsletters in pdf-format at 9 months interval on the IGD-TP/DOPAS website	POSIVA	NA
D7.4 DOPAS Newsletter 2 on the IGD-TP/DOPAS website (D7.4.2)	POSIVA	NA
D7.4 DOPAS Newsletter 3 on the IGD-TP/DOPAS website (D7.4.3)	POSIVA	NA
D7.4 DOPAS Newsletter 4 on the IGD-TP/DOPAS website (D7.4.4)	POSIVA	NA
D7.4 DOPAS Newsletter 5 on the IGD-TP/DOPAS website (D7.4.5)	POSIVA	NA
D7.4 DOPAS Newsletter 6 on the IGD-TP/DOPAS website (D7.4.6)	POSIVA	NA
D7.5 Project description for the EC FP7 project compendium	POSIVA	NA
D7.6 Two journalist edited 2-page summary documents of project's scientific and technical achievement	POSIVA	NA
D7.7 Experiment poster of DOMPLU with EC acknowledgements at the underground site in Äspö (Sweden)	SKB	NA
D7.8 Experiment poster of POPLU with EC acknowledgements at the ONKALO site (Finland)	POSIVA	NA
D7.9 Experiment poster of FSS at the underground site with EC acknowledgements in BURE (France)	ANDRA	NA

Deliverable Title	Lead Partner	Reference
D7.10 Experiment poster of EPSP at the underground site with EC acknowledgements in URC Josef Gallery (Czech Republic)	CTU	NA
D7.11. DOPAS dissemination activities other (0-18 M) (D7.11.4)	POSIVA	NA
D7.11. DOPAS dissemination activities press releases (0-18 M) (D7.11.1)	POSIVA	NA
D7.11. DOPAS dissemination activities articles in popular press (0-18 M) (D7.11.2)	POSIVA	NA
D7.11. DOPAS dissemination activities papers, presentations and posters (0-18 M) (D7.11.3)	POSIVA	NA
D7.12. DOPAS dissemination activities other (19-36 M) (D7.12.4)	POSIVA	NA
D7.12. DOPAS dissemination activities press releases (19-36 M) (D7.12.1)	POSIVA	NA
D7.12. DOPAS dissemination activities articles in popular press (19-36 M) (D7.12.2)	POSIVA	NA
D7.12. DOPAS dissemination activities papers, presentations and posters (19-36 M) (D7.12.3)	POSIVA	NA
D7.13. DOPAS dissemination activities other (37-48 M) (D7.13.4)	POSIVA	NA
D7.13. DOPAS dissemination activities press releases (37-48 M) (D7.13.1)	POSIVA	NA
D7.13. DOPAS dissemination activities articles in popular press (37-48 M) (D7.13.2)	POSIVA	NA
D7.13. DOPAS dissemination activities papers, presentations and posters (37-48 M) (D7.13.3)	POSIVA	NA

NA - Scientific reference not available

DOPAS Partners

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 gGmbH	Germany
Nagra	Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (National Cooperative for the Disposal of Radioactive Waste)	Switzerland
RWM	Radioactive Waste Management Limited	United Kingdom
SÚRAO	Správa Úložišť Radioaktivních Odpadu (Radioactive Waste Repository 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	United Kingdom
BTECH	B+ Tech Oy	Finland
VTT	Teknologian Tutkimuskeskus VTT Oy (VTT Technical Research Centre of Finland Ltd)	Finland
UJV	Ustav Jaderneho Vyzkumu (Nuclear Research Institute)	Czech Republic

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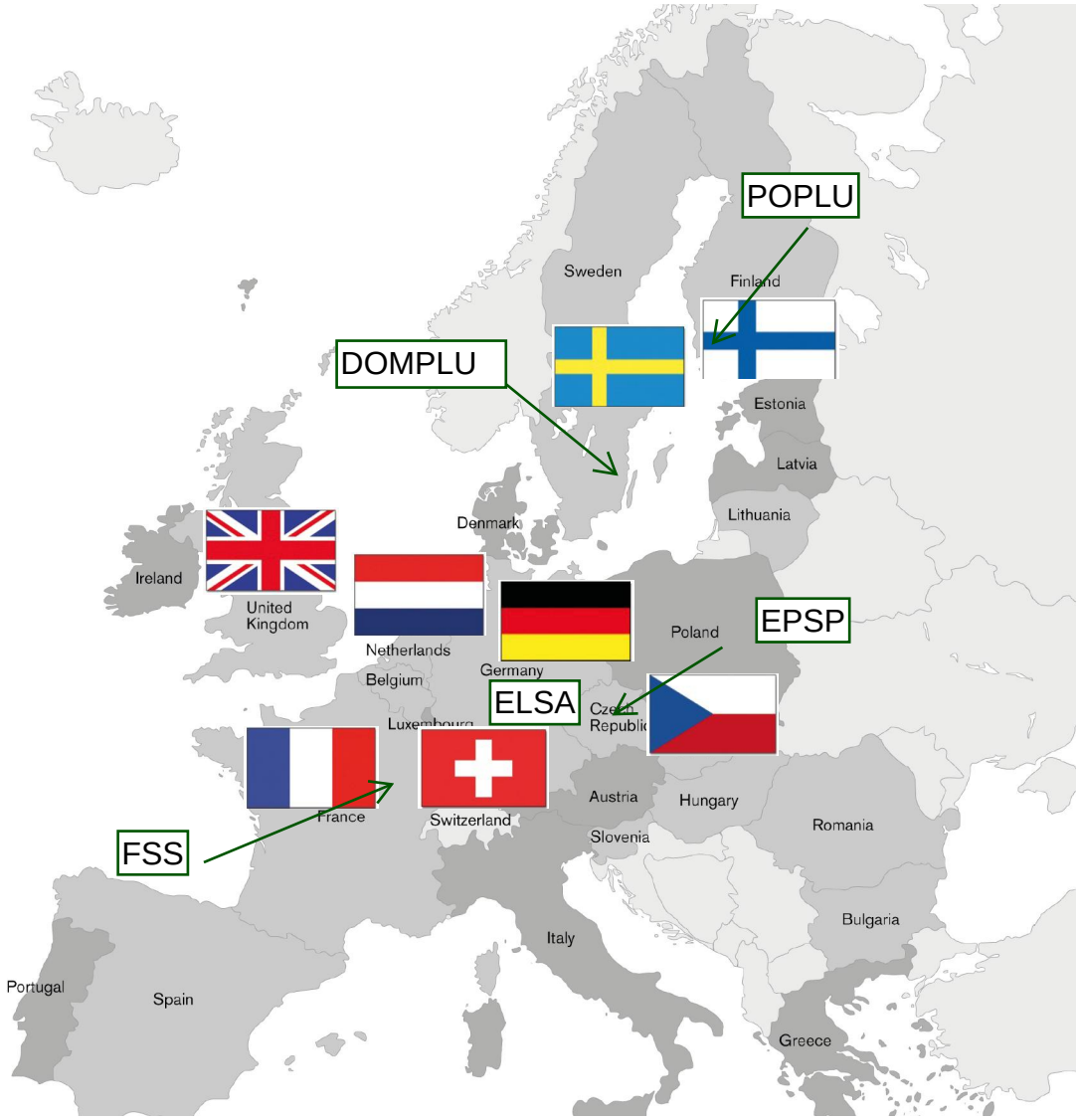
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