Contract Number: 622177

Deliverable n°6.4

Report on the Modern2020 Training School

Work Package 6

Project Acronym	Modern2020
Project Title	Development and Demonstration of Monitoring Strategies and Technologies for Geological Disposal
Start date of project	01/06/2015
Duration	48 Months
Lead Beneficiary	*Andra*
Contributor(s)	*SKB*
Contractual Delivery Date	30/05/2019
Actual Delivery Date	30/07/2019
Reporting period 3:	01/06/2018 – 30/05/2019
Version	final

Project co-funded by the European Commission under the Euratom Research and Training Programme on Nuclear Energy within the Horizon 2020 Framework Programme

Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the partners of the Modern2020 project	
CO	Confidential, only for partners of the Modern2020 project and EC	

History chart			
Type of revision	Document name	Partner	Date

Reviewed by:

This report has been reviewed according to the Modern2020 Quality Plan and the Deliverables Review Procedure therein by Assen Simeonov

Approved by:

This report has been approved by:

- Johan Bertrand, the Modern2020 Project Co-ordinator (on behalf of the Modern2020 Project Executive Board), *19/08/2019*

Abstract

The Modern2020 Training School was targeted to offer an overview of monitoring aspects in the field of geological disposal (in crystalline and clay host rocks) and methodology to conduct a monitoring strategy.

The training school aims to provide participants a set of competences based on the work inside the Modern2020. Through lectures, practical works and field demonstration activities, the participants improved their understanding of:

- Nuclear fuel cycle and radioactive waste types
- Relevant processes for the geological disposal during operational phases and early post-closure phase
- Role of monitoring for geological disposal during operational phases and early post-closure phase
- Methodology to select monitoring parameters
- Monitoring sensors and technologies
- Monitoring system design, installation and operation
- Contribution of monitoring data to decison making
- Expectations from different stakeholders

Figure 1: Modern2020 training school participants (2019) after a practical exercise session

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Glossary

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

CLAB : SKB interim storage for spent fuel.

DGR: Deep geological repository

GBM: Granular Bentonite Material

SP: Sodium Polyacrilate

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

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

NKM Nuclear Knowledge Management

NOVA: Center for University Studies, Research and Development and Municipality of Oskarshamn

WMO (Radioactive) Waste Management Organisation

1. Introduction

1.1 Background

The Development and Demonstration of Monitoring Strategies and Technologies for Geological Disposal (Modern2020) Project is a European Commission (EC) project jointly funded by the Euratom research and training programme 2014-2018 and European nuclear waste management organisations (WMOs). The Project was carried out between June 1 2015 and May 31 2019, and 29 WMOs and research and consultancy organisations from 12 countries have participated to it.

The overall aim of the Modern2020 Project is to provide the means for developing and implementing an effective and efficient repository operational monitoring programme, taking into account requirements of specific national programmes.

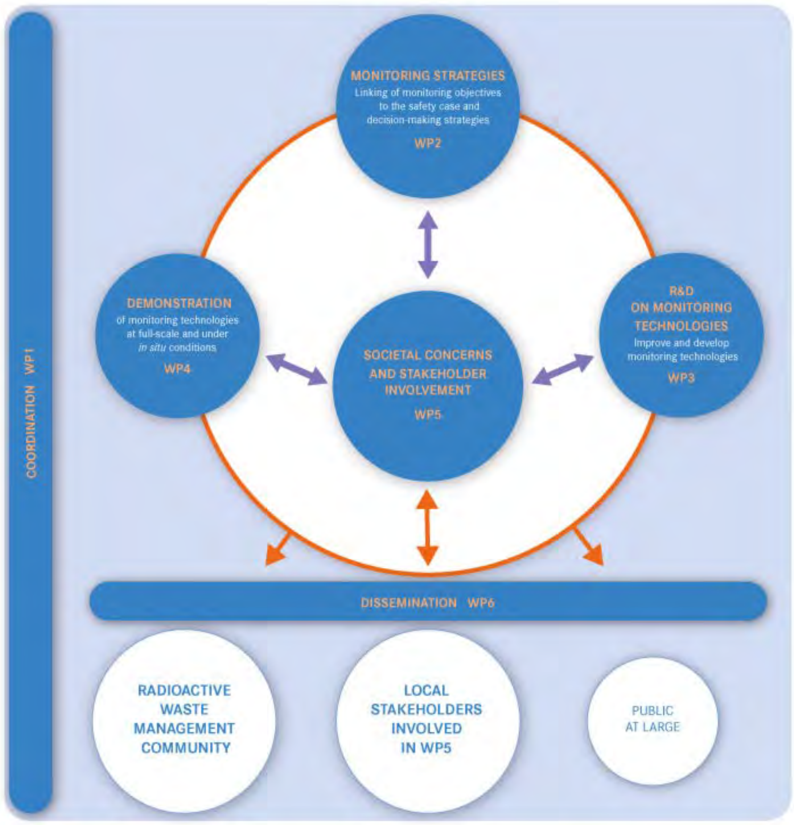

Figure 2: Modern2020 PERT Chart

The Project is divided into six Work Packages (WPs), see the PERT chart in Figure 2:

- WP1: Coordination and project management.
- WP2: Monitoring programme design basis, monitoring strategies and decision-making. This WP aims to define the requirements on monitoring systems in terms of the parameters to be monitored in repository monitoring programmes with explicit links to the safety case and the wider scientific programme (see below).
- WP3: Research and development of relevant monitoring technologies, including wireless data transmission systems, new sensors, and geophysical methods. This WP will also assess the

readiness levels of relevant technologies, and establish a common methodology for qualifying the elements of the monitoring system intended for repository use.

- WP4: Demonstration of monitoring implementation in repository-like conditions. The intended demonstrators, each addressing a range of monitoring-related objectives, are the Full-scale *in situ* System Test in Finland, the Highly-active (HA) Industrial Pilot Experiment in France, the Long-term Rock Buffer Monitoring (LTRBM) Experiment in France, and the Full-scale Emplacement (FE) Experiment in Switzerland. An assessment and synthesis of a number of other tests and demonstrators will also be undertaken, and this will include consideration of the reliability of monitoring results.
- WP5: Effectively engaging local citizen stakeholders in research and development (R&D) and research, development and demonstration (RD&D) on monitoring for geological disposal.
- WP6: Communication and dissemination, to include an international conference, a training school, and the Modern2020 Synthesis Report.

The training school plan and the training process content were planned to be produced as a deliverable of the project (i.e. this deliverable report D6.4) and published on the website www.modern2020.eu

1.2 Objectives of this Report

Nuclear knowledge management (NKM) is defined as an integrated and systematic approach for identifying, acquiring, transforming, developing, disseminating, using, and preserving the nuclear knowledge that is critical to an individual or organisation in achieving specified objectives.

The objective of the task 6.4 was to organise a prototype training school for early-career scientists/engineers (advanced PhD candidates, postdoctoral scientists and engineers affiliated to European research institutions) in the field of monitoring in relation with the geological disposal.

The objective was also to look how the content/results of the Modern2020 project in relation to the structure of the Modern2020 project (Figure 2) could be transferred to early-career scientists/engineers in the field of monitoring for geological disposal.

This report addresses the following objectives of task 6.4:

- to build a set of lessons based on the Modern2020 project content
- to share the set of “monitoring” lessons through training of students and young engineers from EU Member states
- to develop the knowledge, abilities, attitudes and professional qualities for monitoring activities in relation to geological disposal.

Remarks: Because only Modern2020 consortium members contributed to the training material, there were no specific limitations to publishing training material in the respect of the grant agreement.

1.3 Rationale

The training was built in a way to develop a monitoring programme following methods and methodologies based on the MoDeRn-fp7 and Modern2020 results. The training is specifically geared to consider key drivers (physical and societal boundary condition) and to address challenges in implementation (ex: innovative technologies such as wireless and fiber optic sensing in addition to more routine monitoring technologies).

The school was designed to transfer and keep the knowledge on this particular topic where no particular teaching exist.

A safety case is a formal compilation of evidence, analyses and arguments that quantify and substantiate a claim that the repository will be safe. An initial safety case can be established early in the course of a repository project. Such a preliminary safety case then evolves into a more comprehensive safety case as a result of work carried out, incorporating experience gained and information obtained throughout the stepwise evolution of the project including any pre-closure monitoring phase.

The ultimate goal of “monitoring” is to provide information about the performance of geological disposal facility in order to facilitate decision-making and increase the confidence in the post-closure safety. In doing so, monitoring comprises a very wide range of activities which, through different technologies, collect knowledge about the performance of each compound of the different barrier over their life-cycle.

It is also known that experience can be very valuable and it has been often utilized, as a basis for identifying efficient strategies for their performance management. A structured approach to developing, implementing and operating a monitoring program has to be well established by each organisation.

The Modern2020 Project has enhanced our ability to implement, both strategically and technically, repository monitoring during the operational phase to build further confidence in the post-closure safety case and to develop a common understanding of how monitoring during the operational phase in support of building further confidence in the post-closure safety case would be beneficial.

1.4 Report structure

The remainder of this report is set out as follows:

Chapter 2 is dedicated to the preparation phase of the training;

Chapter 3 is the description of the Learning unit as it was implemented during the training school;

Chapter 4 describes the practical exercices;

Chapter 5 details some aspectsof the different visits realized during the training;

Chapter 6 gives some considerations about the implementation of the school;

Chapter 7 contains an analysis and short evaluation of the modern2020 training school;

Chapter 8 concludes the report.

The Appendix give details information on the training school and training materials.

2. Preparation phase of the monitoring training school

2.1 Planning

The prototype training school designed was planned to be implemented in May 2019 (19-25 May 2019) after the project had been running around four years. This enabled a training design that was based on the project structure and it could exploit the lessons learned during the four years of project.

The school targeted to offer an overview of monitoring aspects in the field of geological disposal (in crystalline and clay host rocks) and a methodology to conduct a monitoring strategy

The training school program was composed of short lessons on specific topics relating to different monitoring aspects. The programme started by giving a common basis on the nuclear fuel cycle and monitoring, and then went more deeply into the field of monitoring strategy, monitoring technologies and the use of monitoring data.

The training school was designed to provide learning activities in both theoretical knowledge and practical skills and using teamwork like in the surface facility of the Aspö laboratory.

The prototype training school offered courses that may help people (students) to have a complete overview of the monitoring issue in geological disposal.

The detailed content planning for the training started in April 2017 by establishing an Organising Committee of the training school. Committee members are listed in Table 1.

Table 1: Members of the Training School Organising Committee

Name	Institution
Johan Bertrand	Andra, France
Mauro Cappelli	ENEA, Italy
Juan-Carlos Mayor	ENRESA, Spain
Jan Verstricht	EIG EURIDICE, Belgium
Assen Simeonov	SKB, Sweden
Pieter Cools	University of Antwerp, Belgium
Anne Bergmans	University of Antwerp, Belgium

Three meetings were held face-to-face to elaborate the structure of the school and one by teleconference. The details of these meetings are given hereunder:

- Meeting 1 : Organising Committee dedicated to the monitoring school met at University Club of Universiteit Antwerpen (UA), Prinsstraat 13b, Antwepern, Belgium on 26 April 2017 to start the preparation and organisation of the training (content, contact with experts, logistical aspects). The meeting was also dedicated to evaluate the best and practical place to perform the school.

- Meeting 2: A Modern2020 Project workshop was held at BRGM - Maison de la géologie, Paris, France on 14 December 2017 (in connection to executive board meeting). This meeting is the second meeting of the organization of the monitoring school dedicated to the scientific and technical program. Discussion on the trainer was also done.

- Meeting 3: A Modern2020 Project workshop was held at Aspö, Oskarshamn, Sweden on 29 August 2018. The meeting was dedicated to the elaboration of the school (detailed programme) and the visit of the facility, including practical aspects (logistics).

2.2 Selection of the site.

Three URL has been pre-selected to become the training place:

1. Aspö Hard Rock Laboratory (HRL), Sweden
2. Josef laboratory in collaboration to CTU, Czech republic
3. Bure laboratory, France

The organizing committee selected the Aspö HRL taking into account the past experience with the organization of such event, accommodation in the neighborhood, the possibility to visit a nuclear facility (CLAB) and the support offered by the Oskarshamn municipality through NOVA (event organization office).

Figure 3: surface buildings at the Äspö HRL

3. Implementation

3.1 Selection of the participants

In case a selection would be needed when many applicant would show an interest in the school, the committee defined some selection criteria. The table below highlights the specific competencies and background information desired from participants and could be used to screen whether the training activity would be a key element for improving their daily work, and would be beneficial to their institution as a whole through further training and dissemination activities.

In relation to their overall ranking: the lower their score, the more suitable their profile to attend the training session.

Criteria	detail	ranking
1) Institution	Is the applicant engaged by a competent organization in the field of geological disposal?	1- Works for WMO 2- Works for electricity producers or TSO 3- Works for research entities connected to Geological disposal 4- Works for private company connected to Geological disposal 5- Works for entity only loosely related to geological disposal
2) Position	Is the applicant occupying a post in which the training would have a direct impact on the daily work?	1 – Applicant would greatly benefit from participation in the training, and would utilize information gained **regularly.** 2 – Applicant might benefit from training and could use the information **occasionally**. 3 – Applicant would **rarely** use the specific information from the training.
3) Motivation/cover letter	Is the motivation well explained in the cover letter?	1- Applicant demonstrates **perfectly** the direct link with his work/project and the benefit to participate to the training school 2- Applicant demonstrates **partially** the link with his work/project and the benefit to participate to the training school 3- Applicant doesn't demonstrate the link with his work/project and the benefit to participate to the training school
4) Experience	Does the applicant have experience to understand the training content and benefit from training as much as possible?	1- Applicant's experience is highly relevant and applicant would greatly benefit from participation in the training 2- Applicant's experience is highly relevant and applicant would greatly benefit from participation in the training and is junior in the field of monitoring 3- Applicant's experience is highly relevant and applicant would greatly benefit from participation in the training and is senior in the field of monitoring 4- Applicant's experience is moderately relevant and applicant could benefit from participation in the training. 5- Applicant's experience is minimally relevant and applicant is not likely to benefit from participation in the training.
5) Support Letter	Does a support letter join the application?	Yes / No
6) Dissemination	Could the applicant be counted on to further disseminate the training materials through obligatory national trainings, submitting articles for publication in the press and/or distributing training materials to colleagues?	1- Applicant is responsible for training/communications within his/her institution and would be doing attending as part of their job requirements. 2- Applicant does not formally do so, but in the past has taken similar initiatives and so would be likely to do so. 3- Applicant does not have to do so.

3.2 Participants

A total of 26 persons, representing 12 countries, applied for participation to the course. As this number was close to the envisaged number of 20, and after considering the application letters, nobody was refused. As two persons finally had to cancel for personal reasons, 24 participants from 10 countries (presenting a very equitable gender distribution, see Table 5) finally attended the course during the entire week.

Table 2: distribution of the participants in relation to their provenance

Country	number of participants
Czech Republic	5
Finland	5
France	1
Germany	4
Hungary	1
Italy	3
Russia	1
Sweden	1
Ukraine	1
United Kingdom	2
total	24

Table 3: Distribution of participants

	Gender		Total
	male	female	
Participants	12	12	24

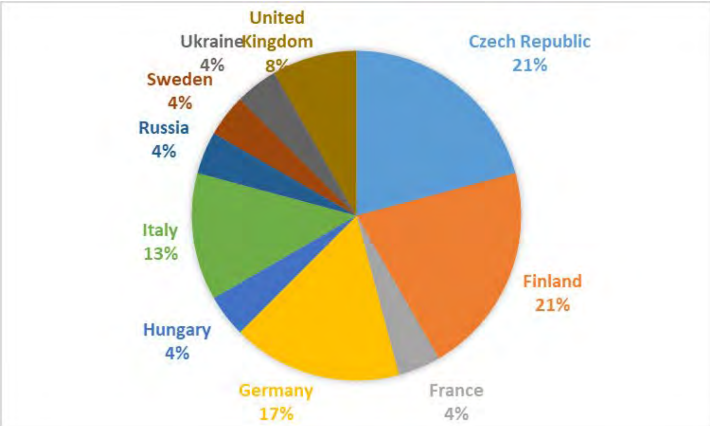

Figure 4: diagram of the participant distribution by country

Figure 5 detials the profiles of the participants.

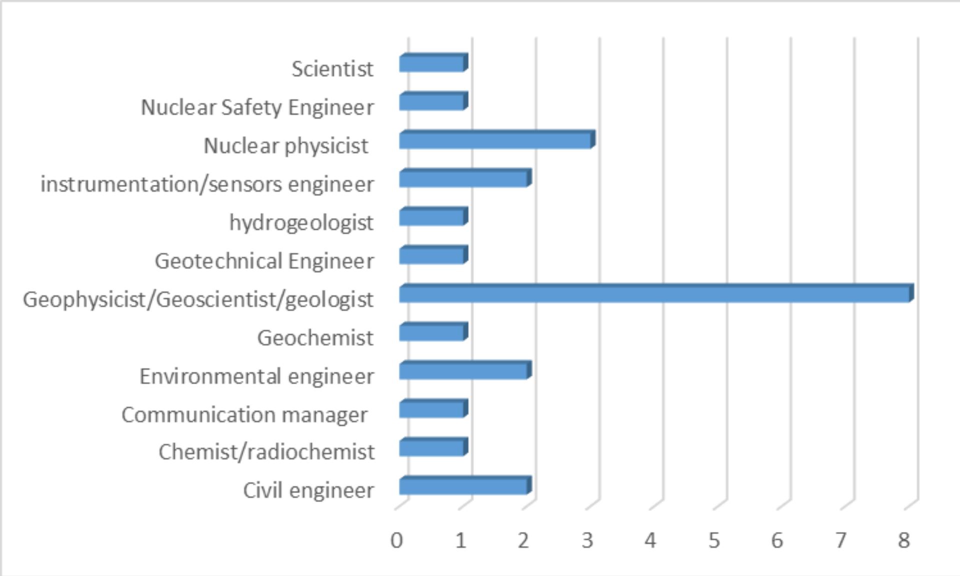

Figure 5 : Different professional profiles of the participants

Figure 6: Lecture during the training course (given by Assen Simeonov from SKB)

4. Learning unit

One of the main objectives was to build a set of courses for students with different backgrounds. “Monitoring for geological dispsoal” is a broad topic covering different fields: physics, materials, sensors, electronics, geophysics, data science and even social science. This means that participants can come with a different background.

The first aim was to give a common background to the participants about the nuclear fuel cycle and geological waste disposal concepts in a way that they can understand the main challenges that can occur in this particular field.

The “learning outcomes” describe what students should be able to demonstrate in terms of knowledge, skills, and values upon completion of a course, a span of several courses, or a program. Clear articulation of learning outcomes serves as the foundation to evaluate the effectiveness of the teaching and learning process.

Different approaches were discussed. The “W” system was decided in order to take into account the main questions an engineer has to solve to design and build a monitoring system.The W system is to consider the main questions about monitoring : What, Why, how, for whom?

Table 4: Learning outcomes

Develop + implement		1-Broadly Explain nuclear cycle and Identify radioactive wastes types
	Where/When	2-Understand of the most important process in the deep geological concept
	What Why	3-Explain the role of monitoring for geological repository
	How	4-Explain the process to select monitoring parameters 5-Identify the different sensors and techniques 6-Explain monitoring design and installation 7-Inspections of demonstration of monitoring system (SKB system/field trip with examples)
Use + evolve	Whom	8-Broadly explain the contribution of monitoring data to decision making process 9-Understanding different expectations from different stakeholders (interest parties)

4.1 Learning unit 1 : Nuclear fuel cycle and geological dispsoal concept

→ LU 1-1: Overview of the nuclear fuel cycle

Objective: This course introduces the key technologies and materials of nuclear fuel cycle ranging mining & milling, processing & enrichment, fuel design & fabrication, storage, and reprocessing, and disposal. This course also covers the policy analysis of nuclear fuel cycle including safety, security, non-proliferation, economics, and environmental impact.

Johan BERTRAND (Andra- DRD-3C) was in charge of this course.

Johan BERTRAND (Male), received the M.S. degree solid and inorganic chemistry from Rennes 1 University, France, in 2005. In 2008, He got a PhD degree in physic and chemistry from the University of Tubingen (Germany) and École des Mines de Saint-Étienne (France). Since 2009, he works for the National Radioactive Waste Management Agency as a Research Engineer working on the overall monitoring strategy and sensors development for the deep geological disposal for highlevel and long-lived radioactive waste. He is responsible for the coordination of the Andra research laboratories group dedicated to sensors and monitoring. He is charge of the development of metrology.

→ LU1-2: Clay concept

Objective: Properties of clay host rocks in general (Opalinus Clay), different concepts in different clay host rocks; description of specific concept (including details of each element of the EBS (waste, container, buffer, backfill, closure, geosphere) including safety functions of each element, research undertaken to develop concept.

Dr. Matt WHITE (Galson sciences Ltd) was in charge of this course

Dr. Matt White has been working as a scientific consultant in geological disposal of radioactive waste for the last 26 years, the last 18 of which have been with Galson Sciences Limited. Matt has expertise in repository monitoring, the post-closure safety case, geology and hydrogeology, repository design, full-scale testing and engineered barrier materials performance, and requirements management. Matt has been deeply involved in disposal facility monitoring projects for 15 years, developing a post-closure monitoring programme for the UK geological disposal facility and contributing to the monitoring programme for the low-level disposal facility at Dounreay in the UK. He instigated the Geneva Workshop, which led to the recent international collaborative efforts in repository monitoring, including the MoDeRn and Modern2020 Projects. He was the lead author of the MoDeRn Project Synthesis.

→ LU1-3: Crystalline concept

Objective: Same structure as the LU1-2 has been following for the presentation of the crystalline concept: Properties of crystalline host rocks in general , details on the KBS-3v (waste, container, buffer, backfill, closure, geosphere) including safety functions of each element.

Assen Simeonov (SKB, Sweden) was in charge of this course.

Assen Simeonov is specialist in geological modelling and investigations. He has been Manager of the unit Rock Characterisation and Rock Engineering, Technology Department at Äspö HRL. He has a degree in geology from University of Lund. After 20 years in mineral exploration and mining, mainly working with modelling, ore evaluation, and exploration strategies and also had a position as exploration manager, he joined SKB 2004, responsible for the geological investigations during the site investigation at Forsmark. He was also member of the site descriptive modelling team working with 3D-geological modelling, and also member of the team for repository design, reviewing the design to meet the requirement for long term safety according to the Site Descriptive Models. After the site investigation for the repository for spent fuel he worked with the preparation of the site investigation program for the expansion of SFR. He was also leading the preparation of a detailed investigation program, including geo-scientific investigations, monitoring and modelling during construction and operation of the repository for spent nuclear fuel, a document which is a reference to the license application for the repository at Forsmark.

4.2 Learning unit 2 : Monitoring : objectives, process and parameters

→ LU2-1: General consideration about monitoring for geological disposal

Objective: General consideration about monitoring for geological disposal: What is monitoring? Wide understanding of monitoring (e.g. including monitoring of socio-economic impact of repository, even though this is not a focus of the training course). Different reasons for monitoring (operational safety, retrievability/reversibility, environmental assessment, security/safeguards, building further confidence in post-closure safety). All of the IAEA and NEA guidance on monitoring noting that some is specific to geological disposal and some all disposal facilities. Different phases of monitoring: baseline and site characterisation, construction, operation, closure and post-closure

Dr. Johan BERTRAND (Andra- DRD-3C) was in charge of this course.

→ LU2-2: Safety Fundamentals aspects and monitoring parameters

Objective: is to establish the fundamental safety objective, safety principles and concepts that provide the bases for the geological concept and its safety related programme. The relation between monitoring and safety will be explain. The screening methodology for the determination of the monitoring parameter will be explain

Dr. Matt WHITE (Galson sciences Ltd) was in charge of this course.

→ LU2-3: Damage zone monitoring:

Objective The purpose of this Master Class on EDZ monitoring is to provide the keys results of the experimental program on EDZ monitoring deployed since 2004 at the Meuse/Haute-Marne Underground Research Laboratory. This experimental program helps to observe, to quantify and to better understand the damaged area around the experimental galleries excavated in the Callovo-Oxfordian claystone. Due to the strength of the Callovo-Oxfordian claystone (UCS~ 21 MPa) and the depth at about -490 m depth, significant excavation induced fractures appears around the opening. Two types of methods are used to characterize the excavation induced fractures network in this experimental program: direct methods and indirect methods. Direct method include macroscopic observation by geological surveys such as structural analysis of front and side wall of the tunnel and structural analysis of drill core made around excavated tunnel; and resin injection technique to visualize the fractures network that has been impregnated. On the other hand, indirect methods are geophysical methods and the analysis of coupled hydro-mechanical parameters such as hydraulic conductivity, permeability, near and far fields rock mass displacement and rock strain rate. For geophysical methods, ultrasonic velocity measurements, seismic tomography, seismic refraction and ultra-sonic tomography were used during the shaft sinking, around a slot, around micro tunnel and around soft or rigid support drift. Both methods, plus specifics experimentation help define the damaged area around experimental tunnels dug following the two main directions of the horizontal stress (σh and σH). According to Tsang et al. (2005), EDZ is a zone in which hydro-mechanical and geo-chemical modifications induce significant changes in flow and transport properties. “Significant changes” highly depends on safety calculation according to a concept of repository. This definition could be interpret in several ways that brings the EDZ itself at the stage of “philosophical concept” more than a practical limit in term of measurement. It is important to noticed that due the interpretation of the EDZ definition, assumption on threshold values can conduct that mechanical damage and significant change on transport properties do not correspond exactly, especially with rock like claystone which are enable to have self-sealing properties. Indeed, within the experimental program on EDZ monitoring, a connected fracture zone located in a near field (closed to the gallery wall), followed by an unconnected fractured zone have been identified around the galleries. Safety calculations for the French concept of nuclear waste repository in the Callovo Oxforidan claystone exhibit that an hydraulic conductivity of K ~ 10-10 m/s could be considered as the limit for significant changes. The analysis of hydro-mechanical parameters, in particular the hydraulic conductivity of healthy vs. damaged rock provided a relationship between high permeability values and the connected fractured area. Both conditions represents our approach to EDZ definition.

Dr Hippolyte Djizanne (Anra-DRD/MFS) was in charge of this course.

Dr Hippolyte Djizanne is a rock mechanics scientist at Meuse/Haute-Marne Underground Research Laboratory in France. Hippolyte holds a Master's degree in Rock mechanics from the Ecole Centrale Paris and a PhD in Rock Mechanics from the École Polytechnique in Palaiseau, France. During his doctoral thesis, Hippolyte worked on the mechanical stability of salt caverns used for strategic underground oil and gas storage facilities. He then joined a Geomechanics team in Bure, France where he work since 4 years designing, implementing, analyzing and interpreting in-situ experiments on the damaged area around the tunnels excavated at -490 m depth

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4.3 Learning unit 3 : Monitoring program design

→ LU3-1: EBS construction and quality control aspect and monitoring

Objective: This course starts with a presentation of the criteria and demands that are put on the engineered barriers and which are dependent on one another and on the bedrock properties. The safety function, criteria and development/manufacturing of the canister are presented. The role of the quality control will be explain as well as the monitoring.

David Luterkort (SKB, Sweden) was in charge of this course.

David Luterkort got his master's degree in mining and geotechnology at Luleå Technical University and University of Idaho in 1996. Since then he has been involved in the technical development of the Engineered barriers of the KBS-3 system. He is currently responsible for buffer, backfill, closure and the overarching monitoring program at SKB.

→ LU3-2: Monitoring technologies

Objective: Overview of technologies used to monitor structures is introduced. Information about various sensors, wireless system, energy consideration, geophysics methods is presented.

José Luis García-Siñeriz M (Head of New Developments in AMBERG Infraestructuras S.A) was in charge of this course

José Luis García-Siñeriz heads the Direction of New Developments of Amberg Infraestructuras S.A. (Spain) and the Competence Centre on Nuclear Waste Management, both belonging to Amberg Group (Switzerland). He got a master's degree in mining engineering (Energy and Fuels speciality) at the School of Mines -Polytechnic University of Madrid- in 1987. Most of his professional life has been related with underground engineering. He participated in several projects in the fields of mining and civil engineering, the environment and energy, and fundamentally in the field of nuclear waste management in projects supported by Euratom and H2020 programmes. He collaborates regularly with the European international laboratories of Grimsel and Mont Terri in Switzerland or Bure and Tournemire in France

→ LU3-3: Example of monitoring system

Objective: Based on current running and past experiments in the European URL, different focus on the monitoring system is described and explained.

Dr. Jan Verstricht (Euridice EIG) was in charge of this course.

Jan Verstricht holds a master in Electrotechnical Engineering (KU Leuven, Belgium). For about 20 years he is involved in the experimental work related to the Belgain radwaste disposal programme. This includes design, implementation and follow-up of instrumented test set-up's in the underground lab HADES, as well as in surface mock-up's. He was responsible for the design and implementation of the PRACLAY Heater Test. He further participated in many European projects including CLIPEX, CROP, ESDRED, and MoDeRn, and also reviews similar set-up's abroad.

4.4 Learning unit 4 : Implementation and governance

→ LU4-1: Data Management

Objective: Comprehensive monitoring programs include numerous sensors using both standard fixed-point "static" sensors and newer technology sensors such as fiber-optic distributed temperature sensing (DTS). Management and overview of the hardware, installation, operation and monitoring becomes challenging in larger experiments. This course offers a comprehensive introduction to problematic in connection to monitoring network and the database management systems to collect and disseminate information. The Course will give you the Andra's example through the SAGD (Data Acquisition and management System) system.

Guillaume HERMAND (Andra-DRD/3C) was in charge of this course.

Guillaume HERMAND (Male), earned a master's degree in Applied Physics from UMPC in 2000.After developing sensors for marine petroleum seismic survey at Western Geco (a Schlumberger company), he organized and led the "on-ground" test campaigns (AIV/AIT) for ultrasensitive accelerometers dedicated to the GOCE space mission. In 2007, he started in Andra at Bure underground research laboratory to work on the geological in-situ sensors network. Three years later, he moved to the monitoring team in Andra's headquarters in order to develop a monitoring system for Cigeo project (underground nuclear waste geological repository). His current studies concern vibrating gauge development, wireless transmission studies, decision-making and data treatment.

→ LU4-2: Contribution to monitoring to decision making

Objective: What decisions need to be made during repository operations? Who is responsible for making decisions? What would be assumed at the start of repository operations? This course is responding to the previous question. Decision-making processes (BPEO and MCDA), attributes, scoring and scoring criteria, weighting, top-down and bottom-up is shown with example.

Dr. Matt WHITE (Galson sciences Ltd) was in charge of this course.

→ LU4-3: Citizen Stakeholders participation

Objective: In this training course, participants will discuss how citizens can be involve in such big R&D project. Participants will also learn the perception about monitoring from public stakeholders. Elements about inclusive governance will be include.

This course is given by *Göran SUNDQVIST*

Prof. Dr. Göran Sundqvist will act as senior researcher. Sundqvist holds a PhD in sociology from the University of Gothenburg (1992) and has been professor in Science and Technology Studies (STS) at the University of Oslo (since 2008) and the University of Gothenburg (since 2014). His research is focusing on the politics of expertise, and public engagement in science and technology policy, including stakeholder involvement and risk governance. Sundqvist has studied nuclear waste management in Sweden since the early 1990s and has made comparisons between European nuclear nations during the last decade. He is the author of the book The Bedrock of Opinion: Science, Technology and Society in the Siting of High-Level Nuclear Waste (Kluwer, 2002) and co-editor of Governing the Air: The Dynamics of Science, Policy and Citizen Interaction (The MIT Press, 2011). Sundqvist recently participated in the MoDeRn project (Monitoring Developments for safe Repository operation and stage closure), a multidisciplinary FP7-EURATOM collaborative project (2009-2012), which addresses possibilities for early stakeholder engagement in defining repository monitoring objectives and strategies. He also participated in the FP7-EURATOM collaborative research project on the interrelation between social and technical challenges for geological disposal as a long-term solution for the safeguarding of radioactive waste (InSOTEC 2011-2014).

5. Practical exercises

The training school included five practical exercises. Johan BERTRAND provided the participants with a general introduction to the five training school exercises. This included the objectives of each exercise and a template for reflecting on the exercise as a part of their reporting

5.1 Practical exercise 1: Optical fiber sensors

Objective: This exercise is to provide to students a hands-on knowledge and the ability to identify fiber types, recognize various connectors used in fiber installation; and install, terminate, splice and properly fault test installed fiber cable. These programs explore the history and future of Fiber Optics and Fiber Optics Capabilities and cost of installation. A Brillouin measurement or/and Raman measurement is performed

Figure 7: Explanation of the exercise by J. Bertrand (Andra).

Figure 8: Student performing a fusion splicing of optical fiber.

Figure 9: Cable handling by students.

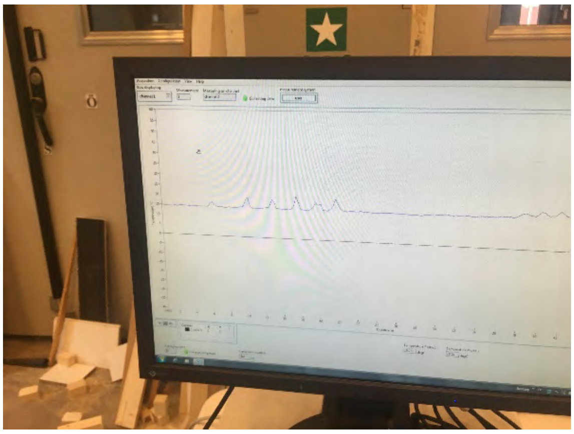


Figure 10: Localization of the student (hot spot) on the screen of the Raman device.

5.2 Practical exercise 2: Concrete deformation measurement using vibrating wire strain gage

Objectives:

- Practical sense of sensor installation;
- Basic data measurement, including setting up of measurement program (e.g. measurement frequency, use of a multiplexer) and interpretation (e.g. application of thermal correction)
- Make installation of vibrating wire strain gauge – connection to data-acquisition system and Perform measurements during casting of concrete
- Perform measurement and simple interpretation of sensor data during hydration of concrete – temperature & shrinkage
- Perform a measurement while loading the hardened concrete piece

Figure 11: Exercise explanation by J. Verstricht (Euridice).

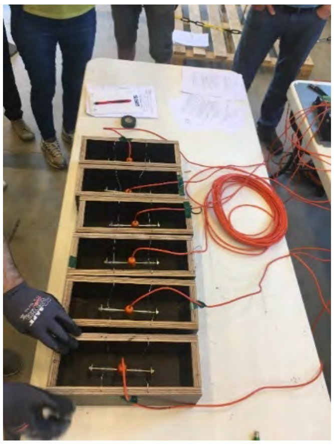


Figure 12: Vibrating wire gage inside wood mould.

Figure 13: Realization of the concrete sample.

Figure 14: Measurement of strain gauge response under mechanical loading.

5.3 Practical exercise 3: Water content measurement using different sensor technologies

Objective: Distinguish the concept and measurement of suction and water content (volumetric and gravimetric)

Proposed exercise: Simulate the behaviour of a bentonite using Sodium polyacrylate (to accelerate the process) and GBM of bentonite too, and to compare it for instance with sand.

One open plastic transparent vessel was used, first with sand, then with SP and finally with GBM. The material was located on top of a perforated support covered with a geotextile to see the water drainage if any. Three different measuring devices were used: RH sensor, psychrometer and FDR sensor.

The practice consisted on pouring water slowly in steps to the material in the vessel and measuring with the three sensors. SP and GBM provided decreasing values of suction and increasing water contents (volumetric), sand provided water content changes only. No free water (drain) was seen in SP and GBM (with time) while yes in the sand.

Figure 15: Exercice explanation by J.L Garcia Sineriz (Amberg).

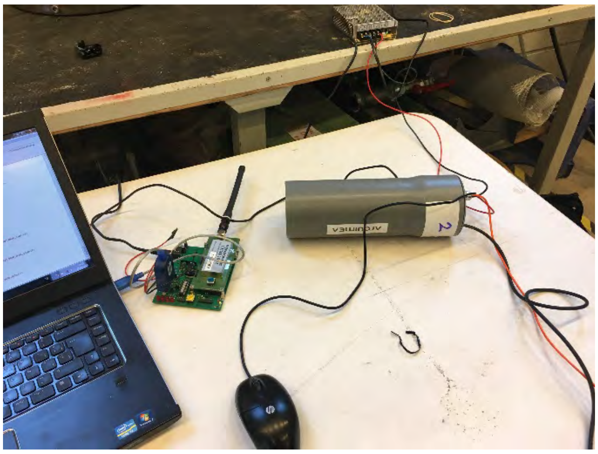


Figure 16: Picture of the wireless module (from Arquimea).

Figure 17: Humidity sensors measuring in different materials (sand and bentonite pellets).

Figure 18: Data collection on humidity sensors.

Theoretical background: Bentonites take water from the surroundings (rock and ambient) that is incorporated in the clay structure (swelling) and later filled the pores. The structure and the porosity (macro and micro) of the bentonite changes with the degree of water saturation. The ability of the bentonite to take water is given by the suction while the water content volumetric and gravimetric is not directly proportional due to the changes in structure and porosity. THM models are based on suction evolution.

5.4 Practical exercise 4: Stakeholders

5.4.1 "Into Eternity" movie: introduction for the stakeholders

Into Eternity is a documentary film directed by Danish director Michael Madsen, released in 2010. It follows the construction of the Onkalo waste repository at the Olkiluoto Nuclear Power Plant on the island of Olkiluoto, Finland. Director Michael Madsen questions Onkalo's intended eternal existence, addressing an audience in the remote future. Into Eternity raises the question of the authorities' responsibility of ensuring compliance with relatively new safety criteria legislation and the principles at the core of nuclear waste management.

Figure 19 : Participant before the film projection (left) and French DVD cover of the movie (right)

The movie gives the opportunity to observe the communication of specialists and experts to a broad public and notes how they interact and exchange information with others. The movie and the discussion after the movie nicely introduced the challenges and different aspects about the interaction with stakeholders and especially public stakeholders.

5.4.2 Different discussion and role game about stakeholder's interaction.

A group exercise has been organised to facilitate discussion about the following topics:

- "Controversial" statements
- The curious and engaged (critical) public stakeholder meets the technical expert
- Discussion about public stakeholder engagement

Figure 20: Pictures on group exercise about stakeholders.

6. Visits during the training

6.1 Clab – Central Interim Storage Facility for Spent Nuclear Fuel

Clab is an interim radioactive waste repository located about 25 kilometers north of Oskarshamn Nuclear Power Plant [1] and is owned by Oskarshamnsverkets Kraftgrupp AB (OKG). The operation started in 1985 for interimstorage of spent nuclear fuel from all Swedish nuclear power plants. The fuel is stored for 30 to 40 years, in preparation for final repository which is planned at Formark.

Table 5: facts about the CLAB (source SKB)

Location	Next to the Oskarshamn nuclear power plant
Start of construction	1980
Start of operation	1985, second cavern finished in 2005
Capacity	8,000 tonnes of spent nuclear fuel
Reception	About 220 tonnes of uranium plus six storage canisters of core components per year
Surface facility	Reception, offices, ventilation, electricity
Underground facility	Two rock caverns with eight storage pools, 40 metres beneath the surface
Personnel	About 80 Full-Time Equivalents

6.2 Aspö Hard rock laboratory

The Äspö Hard Rock Laboratory (HRL) is located at the south east coast of Sweden, on the island of Äspö, 25 kilometers north of Oskarshamn.

One of the fundamental reasons behind SKB's decision to construct an underground laboratory was to create an opportunity for research, development and demonstration in a realistic and undisturbed rock environment at representative repository depth. Most of the research is concerned with processes of importance for the post-closure safety of a future Final Repository for Spent Nuclear Fuel and the capability to model the processes. Demonstration addresses the performance of the engineered barriers, and practical means of constructing a repository and emplacing the canisters with spent fuel. This work also includes the development and testing of methods for use in the characterisation of a suitable repository site.

The underground part of the laboratory consists of a main access tunnel from the Simpevarp peninsula to the southern part of the Äspö-island, where the tunnel continues in a spiral down to a depth of 460 m, see Figure 1-1. The total length of the tunnel is 3 600 m, where the main part of the tunnel has been excavated by conventional drill and blast technique and the last 400 m have been excavated by a tunnel boring machine (TBM) with a diameter of 5 m. The underground tunnel is connected to the ground surface through a hoist shaft and two ventilation shafts

Figure 21: Overview of the Äspö HRL facilities, including the new areas produced in the tunnel expansion (marked in red).

The work with Äspö HRL has been divided into three phases: Pre-Investigation phase, Construction phase and Operational phase.

- During the Pre-Investigation phase, 1986–1990, extensive field studies were made to provide a basis for the decision to locate the laboratory to a suitable site. The natural conditions of the bedrock were described and predictions made of geological, hydrogeological, geotechnical and rock-mechanical conditions to be observed during excavation of the laboratory. This phase also included planning for the construction and operational phases.
- During the Construction phase, 1990–1995, comprehensive investigations and experiments were performed in parallel with construction of the laboratory. The excavation of the main

access tunnel and the construction of the Äspö Research Village at the ground surface were completed.

- The Operational phase began in 1996. A preliminary outline of the programme for this phase was given in SKB's Research, Development and Demonstration (RD&D) Programme 1992. Since then the programme has been revised every third year and the detailed basis for the period 2017–2022 is described in SKB's RD&D-Programme 2016 (SKB 2016).

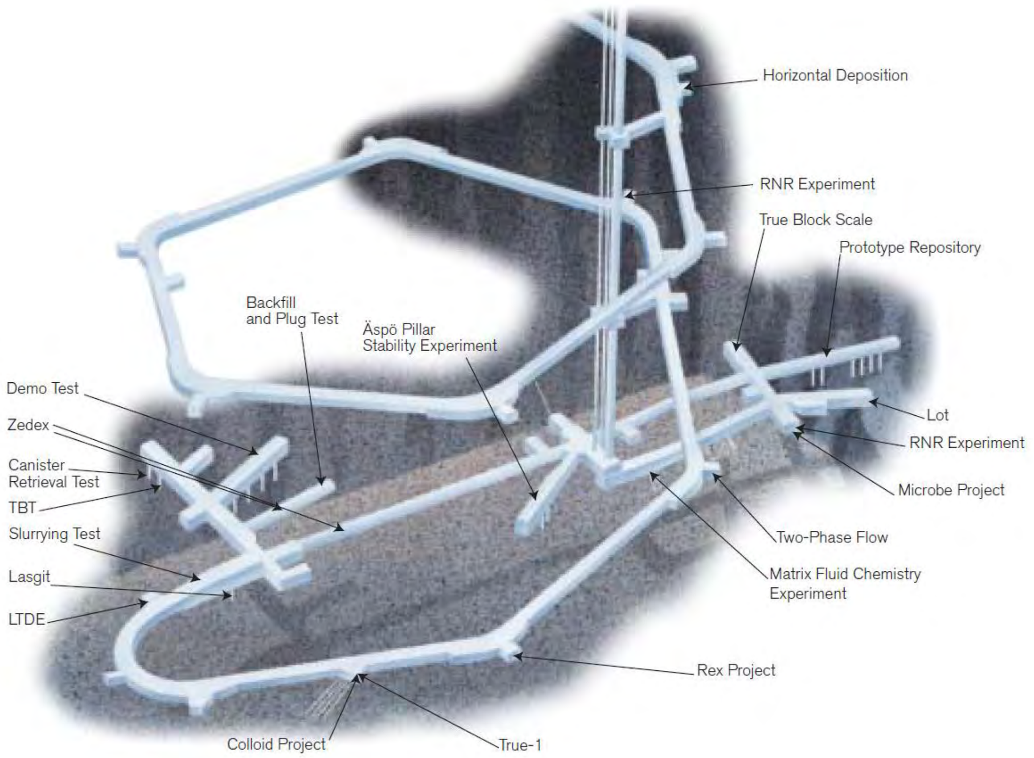


Figure 22: Allocation of experiment sites from −220 m to −460 m level.

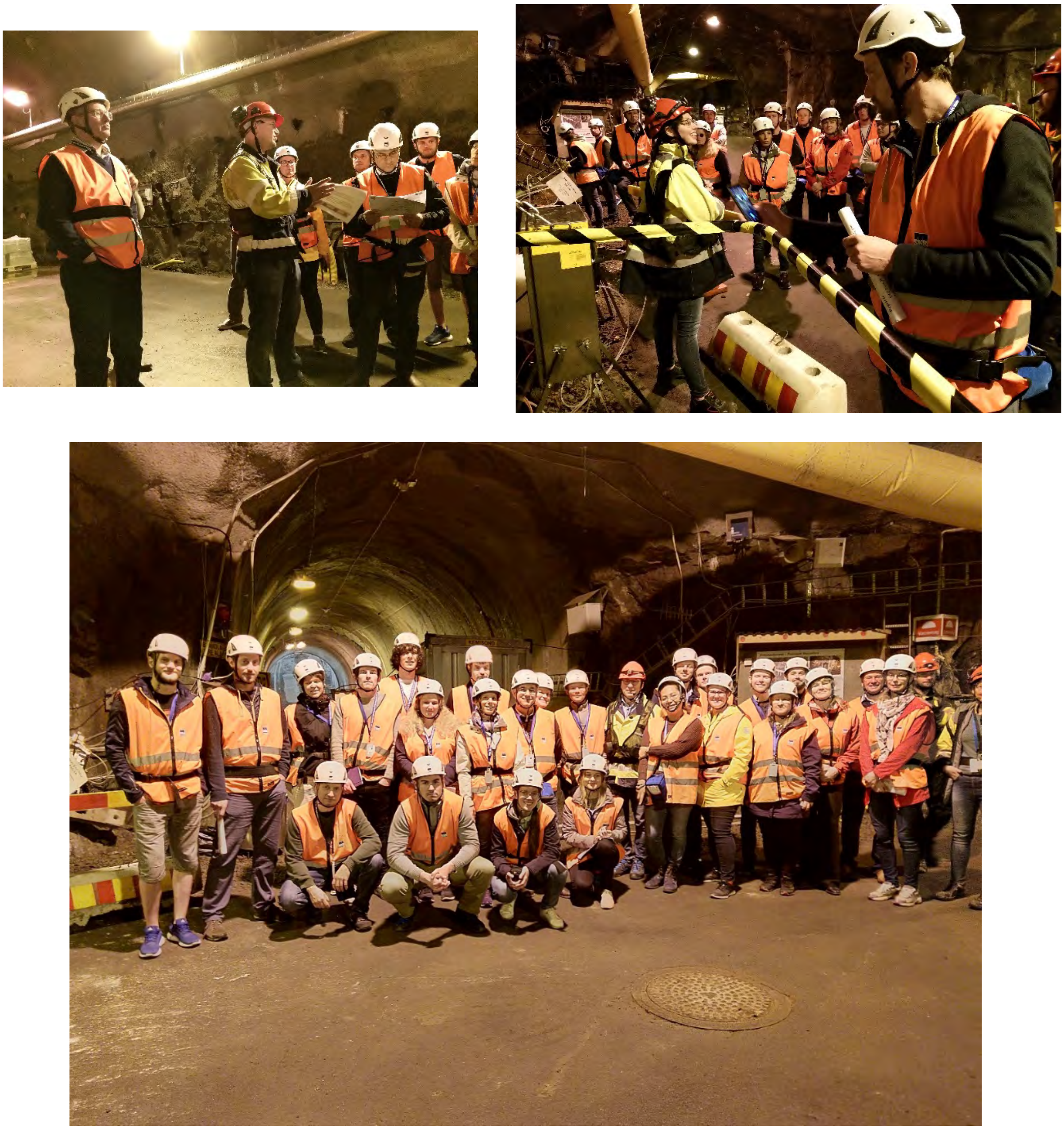


Figure 23: Visit of the monitoring implementations in the Äspö HRL

7. Assessment of the Modern2020 training school

7.1 Set up

At the end of the training, a training evaluation form was distributed to the participants to collect they general opinion. The evaluation form can be seen in the appendix 4. The evaluation form asked the participants to quote on the following topics (the best mark is 4):

- Compliance with your objectives
- Trainer
- Time/Pace
- Training school Program
- Personal satisfaction
- Visit
- Professional interest
- Support/Documents

The participants' activities and interaction were observed during the whole week by the different trainers. Both tools has been used to evaluate the training.

7.2 Evaluation of the Modern2020 training school

Here we present an evaluation overview based on the evaluation forms.

Taking into account the topic of the course, 85% of the participant considered that the **training program** was adequate, 25% considered that the **Time/pace** of the training could be adjusted. Some days were very long with many theoretical courses; the time for practical exercises was, in some way, noted as too limited. The quality of the talks and **trainers** was appreciated at 83%. A lack of supervising staff has been pointed out for the practical course. This aspect is also connected to the means for this training school. The organisation of the course was well perceived in general.

About the **accommodation**, we get three opinions of nearly equally sized groups. 30% do not like to stay in small cottages in the camping area, for 30% it was acceptable , while for 35% it was good. The result was not gender dependent.

The **visit** was perceived as very interesting by 85% of the participants. The visit of the CLAB facility was really appreciated by all participants. For the Aspö laboratory, some of the participants expressed the desire to stay longer, have more technical details and possible (even if they know it is not easy to organise) to have a practical exercise on site.

The **quality of the document**s and support was appreciated on an average of 70%. The participants say that the quality was good but the form was not all the time equal. The main complaint dealt with the necessity to send training material some weeks before the beginning of the training in order to be more prepared.

76% of the participant found **compliance with the objectives** expressed at the beginning of the training school

Regarding the **Personal satisfaction,** the participants qualified it as good (79%); Participants expressed particularly the nice atmosphere, the satisfaction to discuss with different experts on monitoring field and the opportunity to develop contacts (network).

8. Conclusion & Acknowledgement

The training school was successfully implemented and well received by the participants. The training was built according to the structure of the Modern2020 project, and the results obtained during the four years program. The following items can be highlighted:

- After the different research on monitoring (Modern-Fp7, Modern2020), the topic is mature and ready for knowledge transfer;
- Monitoring is a broad topic covering various field with no specific teaching on it. The need for a training dedicated to monitoring for geological disposal has been confirmed; the number of applicants and participants confirmed the interest on such topics.
- The target audience has been reached. The school gave the opportunity to put different generations in the field of monitoring in contact with each other.
- Several adjustment can be realised to make the training more practical with more exercises. Two weeks could be the good way for Monitoring: a first week with theoretical and general presentation and a second week dedicated to practical exercise on table and field.

We hope the training materials will be useful and used in future training.

Special acknowledgements are given to

- All members of the training school committee;
- All trainers;
- To Assen Simenov for his support during the training;
- To the Nova Center for University Studies, Research and Development and Municipality of Oskarshamn, especially Anna Rockström (coordinator);
- The Aspö hard rock laboratory staff for their support during the training.

Appendix 1: Training school agenda

Modern2020 training school 19-26 May 2019 Aspö Sweden

Day 0	Time					
19/05/2019	17h55	shuttle bus		transfert from Kalmar airport to Oskharshamn Gunarsö		
	19h	arrival at oskharshamn				

Day 1	time	duration	location	lesson	organisation and Tutor nar	activity
20/05/2019	9:00-9:20	20min	Aspö	Welcome introduction to training school programme	Johan BERTRAND (Andra)	presentation
	09:20-9:40	20min	"	Some word about the region of Orskshamn	Assen SIMEONOV (SKB)	presentation
	9:40-10:00	20min	"	Introduction to the MOdern2020 project	Johan BERTRAND (Andra)	presentation
	10:00-10:45	45min	"	Participant presentation	all	
	10:45-11:00	15min	"	break		
	11:00-12:00	1h	"	**LU1.1 Overview of the nuclear fuel cylcle**	Johan BERTRAND (Andra)	lecture
	12:00-13:00		"	Lunch		
	13:00-14:30	1h30	"	**LU1.2 Crystalline concept**	Assen SIMEONOV (SKB)	lecture
	14:30-16:00	1h30	"	**LU1.3 Clay concept**	Matt white (GSL)	lecture
	16:00-16h20	20min	"	break		
	16:20-18:00	1h30	"	**LU2. 1 General consideration about monitoring for geological disposal**	Johan BERTRAND (Andra)	lecture
	18:00			**end of the Day 1**		

Day 2	time	duration	location	lesson	organisation and Tutor nar	activity
21/05/2019	09:00:00		oskarshar	Arrival at the Clab entrance. (Security- and passport control.)	Assen Simeonov (SKB)	visit
	09:30:00	30min	oskarshar	Presentation of SKB and Clab.	Assen Simeonov (SKB)	visit
	10:00-11:30	1h30	oskarshar	Guided tour of the facility.	Assen Simeonov (SKB)	visit
	11:30-12h15		oskarshar	Lunch Claberian.		visit
	12:15:00			Transport from Clab to Äspö.	Assen Simeonov (SKB)	visit
	12:30:00		Aspö	Arrival at the Äspö Hard Rock Laboratory. (passport control)	Assen Simeonov (SKB)	visit
	12:45-13:15	30min	Aspö	Presentation of SKB and the Äspö HRL.	Assen Simeonov (SKB)	visit
	13:15-14:30	1h15	Aspö	Guided tour by elevator + questions	Assen Simeonov (SKB)	visit
	15:00:00		Aspö	End of visit.		visit
	15:00-15:30		Aspö	break		
	15:30-17:30	2h	Aspö	**LU2.2 Safety Fundamentals aspects and monitoring parameters**	Matt White (Galson Scienc	lecture
	17:30-18:00	30min		introduction to practical works	Johan BERTRAND (Andra)	presentation

Day 3	time	duration	location	lesson	organisation and Tutor nar	activity
22/05/2019	9:00-10:00	1h	Aspö	**LU4.1 contribution of monitoring data to decision making**	Matt White (Galson Scienc	lecture
	10:00-10:15			break		
	10:15:12:15	2h		**LU3.2: Monitoring technologies**	José-Luis GARCIA-SINERIZ	lecture
	12:15-13:15			lunch		
	13:15-16:15	3h		practical activities	José-Luis GARCIA-SINERIZ (Amberg), Jan VERSTRICHT (euridice), Johan BERTRAND (Andra)	exercices
	16:15-16:30			break		
	16:30-18:00	2h		**LU3.1 EBS construction and monitoring**	David Luterkort (SKb)	lecture
	20:30:00-22:00			movies "into eternity"		

Day 4	time	duration	location	lesson	organisation and Tutor nar	activity
23/05/2019	9:00-10:00	1h	Aspö	LU 4.3: stakeholders participation	Göran Sundqvist (University Goteborg)	lecture
	10:00-10:15	15min	"	break		
	10:15-12:00	1h45	"	A role-playing game for practising discussion with stakeholders	Göran Sundqvist (University Goteborg)	exercice
	12:00-13:00			lunch		
	13:15-16:15	3h	"	practical activities	José-Luis GARCIA-SINERIZ (Amberg), Jan VERSTRICHT (euridice), Johan BERTRAND (Andra)	exercices
	16:15-16:30			break		
	16:30-18:00	2h	"	LU 4.1 Data Management	Guillaume HERMAND	lecture
	18:00			**end of Day 4**		

Day 5	time	duration	location	lesson	organisation and Tutor nar	activity
24/05/2019	9:00-10:30	1h30	Aspö	LU. 2.3: EDZ monitoring	Gilles ARMAND (Andra)	lecture
	10:30-11:00		"	break		
	11:00-12:00	1h30	"	LU3.3 Example of monitoring system	Jan VERSTRICHT (euridice)	lecture
	12:00-13:00			lunch		
	13:15-16:15	3h	"	practical activities	José-Luis GARCIA-SINERIZ (Amberg), Jan VERSTRICHT (euridice), Johan BERTRAND (Andra)	exercice
	16:15-16:30			break		
	16:30-17:30		"	short evaluation	Johan Bertrandn(Andra)	
	17:30		"	**End of the day**		

Day 6	time	duration	location	lesson	organisation and Tutor nar	activity
25/05/2019	9:00_17:00	8h		excursion		

Appendix 2: Trainers and courses

Topics	Trainers
General aspect (Nuclear cycle, wastes, disposal):	Dr. Johan BERTRAND – (Andra-France)
General monitoring Aspect:	Dr. Johan BERTRAND – (Andra-France)
Clay Concept:	Dr Matthew WHITE – (Galson Sciences Limited-United Kingdom)
Crystalline concept :	Assen SIMEONOV – (SKB-Sweden)
Instruction for practical work:	Dr. Johan BERTRAND – (Andra-France)
Parameters and screening process:	Dr Matthew WHITE – (Galson Sciences Limited-United Kingdom)
Monitoring Technology Requirements/constraints, State of art Part 1:	José Luis García-Siñeriz M. – (AMBERG Infraestructuras S.A, SPAIN
Monitoring Technology Requirements/constraints, State of art Part 2:	José Luis García-Siñeriz M. – (AMBERG Infraestructuras S.A, Spain)
EDZ monitoring :	Dr. Hippolyte Djizanne – (Andra, France)
Data management (SAGD example):	Guillaume HERMAND – (Andra, France)
Stakeholders, Public involvement and participation:	Prof. Göran Sundqvist – (University of Gothenburg, Sweden)
EBS construction and quality control aspect and monitoring	Dr. David Luterkort –(SKB-Sweden)
Example of design and installation of monitoring system	Jan Verstricht – (EIG EURIDICE- Belgium)
Contribution of monitoring to decision making	Dr Matthew WHITE – (Galson Sciences Limited-United Kingdom)

Appendix 3: List of participants

Surname	Name	Organisation	country
Ville	Rinta-Hiiro	VTT	Finland
Rocio Paola	Leon Vargas	TU Braunschweig - Institute of Foundation Engineering and Soil Mechanics, Braunschweig	Germany
Jan	Smutek	SURAO	Czech Republic
Katerina	Cernochova	Czech Technical University, Centre of Experimental Geotechnics	Czech Republic
Gerda Marianna	Németh	PURAM	Hungary
Daniele	Marta	Sogin S.p.A;	Italy
Vladimir	Gupalo	NUST "MISIS"	Russia
Kevin	O'Donoghue	RWM	UK
Matilda	Svensson	SKB	Sweden
Chiara	Telloli	ENEA	Italy
Tea	Laurila	AINS group - Civil Engineering	Finland
Iryna	Poliakova	Chornobyl Research and Development Institute	Ukraine
Alberto	Ubaldini	ENEA	Italy
Pavol	Stajanca	Federal Institute for Material Research and Testing (BAM)	Germany
Sophie	Bahl	TU Clausthal	Germany
Hendrik	Bollmann	TU Clausthal	Germany
Christopher	Herbert	Galson Sciences Ltd	United Kingdom
Mira	Markovaara-Koivisto	Geological Survey of Finland	Finland
Heini	Reijonen	Geological Survey Of Finland	Finland
Jakub	Kokinda	Research Centre Rez	Czech Republic
Taija	Huotari	Geological Survey Of Finland	Finland
Julien	Cotton	Andra	France
Filip	Jankovský	ÚJV Řež, a.s.	Czech Republic
Milan	Zuna	ÚJV Řež, a.s.	Czech Republic

Appendix 4: Modern2020 training material

DAY1

DAY and ID#	File content
D1_int1	Introduction to the training school about Monitoring
D1_int2	Modern2020_Overview
D1_LU1_1	Knowledge of radioactive waste and its conditioning through the nuclear cycle
D1_LU1_2	Clay concept
D1_LU1_3	Crystalline concept
D1_LU2_1	General consideration about monitoring for geological disposal

DAY 2

D2_vis1	Presentation from Clab SKB
D2_vis2	Presentation of SKB and Aspö HRL
D2_vis3	Äspö MPT (Multi-Purpose Test)
D2_LU2_2	Monitoring During the Operational Phase to Provide Further Confidence in the Post_Closure Safety Case Strategies and Parameters
D2_P1	Introduction to practical exercises

DAY3

D3_LU4_2	Responding to Monitoring Results
D3_LU3_2	Monitoring technologies
D3_LU3_1	EBS construction and monitoring

DAY4

D4_LU4_3	Stakeholder involvement in technical RD&D projects
D4_LU4_1	Data Management

DAY5

D5_LU2_3	EDZ monitoring
D5_LU3_3	Example of monitoring system

Appendix 5: Modern2020 training evaluation form

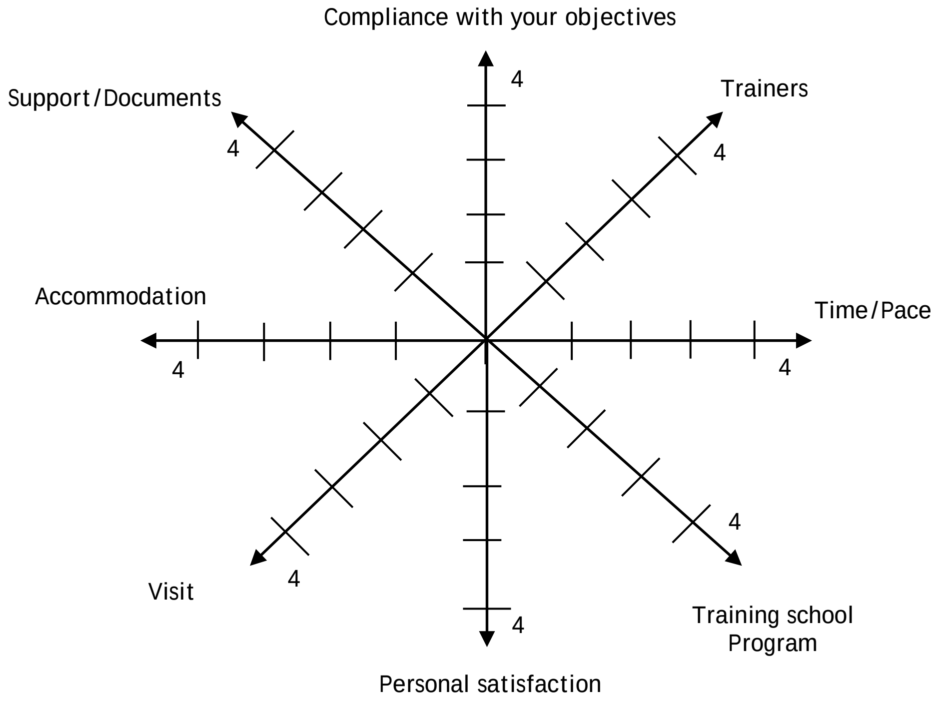
Evaluation Questionnaire

TRAINING SCHOOL ABOUT MONITORING IN GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Name: .... **mail adress :** ....

Training animated by Modern2020 staff **Dates :** ....

Evaluation grid



NB : connect the corresponding numbers to your appreciation (the best rating is 4)

What did you appreciate most during this training? ....

....

....

....

....

What would you change to further improve the training for the next groups? ....

....

....

....

....

Other suggestions / remarks / comments:

....

....

....

....

....

Appendix 6: Modern2020 training school Flyer

Who should attend?

For early-career scientists/engineers (advanced PhD candidates, postdoctoral scientists and engineers affiliated to European research institutions) in the field of monitoring in relation with the geological disposal. The total number of participants is limited to 20.

Priority is given to Junior scientists/engineers enrolled in **Waste Management Organisation.** The detailed selection criteria in case of over-subscription to the school will be posted on the Modern2020 website (**www.modern2020.eu**).

Courses fees and grants

▶ The Modern2020 Monitoring School participation is free of charge to the selected participants including accommodation, local transportation from designated hotels to the training location or laboratory, daily lunches/dinners, and coffees during the school.

▶ The participants are responsible for their own travel to and from Oskarshamn.

Cottage in the First camp Gunnarso

Accommodation

A family-friendly stay in Oskarshamn awaits you at First Camp Gunnarso, 3.4 km from central Oskarshanm, 76 km from Kalmar airport and 40 km from the Äspö HRL. Highlights a sauna, and in-room kitchenettes.

Application

▶ **Application will be open until February, 28th 2019.**

▶ A cover letter should describe your motivation and the relation of the training to your work and studies.

▶ The ***application form*** is available on the Modern2020 website (**www.modern2020.eu**). Information required: full name, date of birth, gender, organisation, address, post code, email, telephone (+ country code), dietary restrictions.

Special requirement for the participants

▶ Each individual needs to be able to move unassisted and carry out hands-on exercises underground.

▶ Each individual needs to have insurance coverage against injuries and illness for the duration of their stay at the workshop. Please check the sufficiency of your insurance coverage prior participation. Proof of sufficient insurance coverage may be requested by the organiser.

▶ To inform the organiser at the time of registration of any dietary restrictions that may apply.

For more information

For more information about the Modern2020 training school and its details visit the **www.modern2020.eu** or contact **johan.bertrand@andra.fr**

MODERN 2020

Development and Demonstration of monitoring strategies and technologies for geological disposal

This project has received funding from Euratom research and training programme 2014-2018 under grant agreement no 662177

TRAINING SCHOOL ABOUT MONITORING IN GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE

Organised by the Modern2020 Project

"Monitoring strategies, technologies and public involvement"

Aspö Hard Rock Laboratory

19 - 26 May 2019

Sweden

A WEEK PROGRAMME IN ASPÖ (SWEDEN)

Registration deadline: 28 February 2019

Increase your knowledge in monitoring technologies and techniques

Provide basic knowledge on monitoring system design, installation and operation

Discuss social aspects of geological disposal monitoring

Contact: Johan BERTRAND
Johan.bertrand@andra.fr

MODERN 2020

Development and Demonstration of monitoring strategies and technologies for geological disposal

Orientation map:
Sweden - Stockholm Äspö HRL

A successful strategy for radioactive waste disposal should address both technical and societal needs, and monitoring has the potential to contribute to both of these aspects. Monitoring during repository operations can be used to build further understanding of the processes occurring in the repository during operational phase (construction, waste emplacement, backfilling and closure) and early post-closure phase.

Monitoring can also contribute to public and stakeholder understanding of processes occurring in the repository, and hence, it can respond to public concerns and be used to build further confidence in geological disposal in addition to that achieved during licensing. Monitoring can therefore play a role in enabling waste management organisations to work towards the safe and accepted implementation of geological disposal.

The Äspö Hard Rock Laboratory is situated in the Misterhult Archipelago close to the Oskarshamn nuclear power plant

The Äspö Laboratory is a unique research facility and there are only a few like it in the rest of the world. Almost 500 metres underground, we conduct experiments in collaboration with Swedish and international experts. This research means that we can study the interaction of bentonite clay and copper canisters with the rock in realistic conditions. Here experiments are made to identify the role of the rock as a barrier. This can, for instance, concern how the rock slows down the movement of radioactive substances or how microbes affect conditions at this depth.

Preliminary programme

All classes, lectures and visits will be held in English

The Modern2020 Training School starts on Sunday evening 19 May 2019 at 7:30 p.m. in Oskarshamn (Sweden) and continues until 2 p.m. on Sunday 26 May 2019. The Training School comprises some practical exercices. The length of the individual days varies due to logistics and activities, in general, with exception of the first and the last day, the training days extend from 8:30 a.m. to 6:30 p.m. with evening social events.

Day 1
- 6:00 p.m.: Transport from Airport (Kalmar)
- Welcome dinner: Tour de table, introduction and organisation of training

Day 2
- Introduction
- General considerations on radioactive waste (nuclear cycle, waste, disposal)
- Deep geological diposal concepts in crystalline and clay host rocks
- General monitoring aspects (Rationale, context, definition, state of the art)

Day 3
- Monitoring of the excavated damaged zone
- Monitoring of engineered barrier systems
- Instruction for practical work / division to group for the week
- **Visit of the Central Interim Storage Facility for Spent Nuclear Fuel**
- **Visit of the Aspö underground research laboratory**

Day 4
- Generic methodology for parameters screening process
- Monitoring technologies – Part I
- Practical works (monitoring technologies)
- Contribution of monitoring to decision making
- Examples of monitoring system

Day 5
- Citizen stakeholders and monitoring + practical exercises
- Monitoring technologies – Part II
- Data management (Examples of Data Acquisition System)
- Practical works (monitoring technologies)
- Monitoring test case exercices

Day 6
- Participants' evaluation
- Feedback from participants

Day 7
- Excursion to Blue Maiden Island (where witches go to roam)

Day 8
- 2:00 p.m.: Transport to Airport (Kalmar)

Blå Jungfrun (the Blue Maiden), view from the Oskarshamn coast

Please note that changes to the order of the content and individual programme details may apply

Learning Outcomes

The Modern2020 Training School is targeted to offer an overview of monitoring aspects in the field of geological disposal (in crystalline and clay host rocks) and methodology to conduct a monitoring strategy. The training school aims to provide participants a set of competences based on the work inside the Modern2020. Through lectures, practical works and field demonstration activities, the participants will improve their understanding of:

1. Nuclear fuel cycle and radioactive waste types
2. Relevant processes for the geological disposal during operational phases and early post-closure phase
3. Role of monitoring for geological disposal during operational phases and early post-closure phase
4. Methodology to select monitoring parameters
5. Monitoring sensors and technologies
6. Monitoring system design, installation and operation
7. Contribution of monitoring data to decison making
8. Expectations from differents stakeholders