Documented needs for future infrastructural improvements in specific ULs

Baltic Sea Underground Innovation Network (BSUIN)

Interreg Baltic Sea Region
EUROPEAN REGIONAL DEVELOPMENT FUND
EUROPEAN UNION
BSUIN

Interreg Baltic Sea Region
EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

Grant Agreement No. Project Acronym Project Full Title	No. R2.073 BSUIN Baltic Sea Underground Innovation Network
Version	Revised version
Dissemination level	Public
Deliverable Name	Documented needs for future infrastructural improvements in specific ULs
WP activity lead	P. Petrov (KGHM Cuprum R&D)
WP / Task Related	WP 4 / A. 4.3.
Author/s	P.Petrov (KaRC RaS) T. Bubunova (KaRC RaS) V. Shekov (KaRC RaS), K. Fuławka (KGHM Cuprum R&D),
Contributors	M. Laaksoharju (SKB), M. Ohlsson (SKB), J. Joutsenvaara (University of Oulu / Callio Lab), T. Müller (Reiche Zeche), I. Savelyeva (Khlopin).
Keywords	Underground pilot sites, intelligent and adaptive lighting, underground environment
Abstract	Underground laboratories provide a unique environment for various industries. They are the perfect place for developing new technologies for mining, geophysical surveys, radiation detection, and many other studies and measurements. Unfortunately, working in underground excavations is associated with exposure to many hazards not necessarily encountered in surface laboratories. Therefore, continuous development of monitoring systems, support technology, etc., is necessary to provide and ensure conditions that will fulfil all H&S requirements. Within this document, some pre-investment plans proposals will be presented—possibilities of intelligent, adaptive lighting for the underground workers.

Contents

1. Content of present document

1.1 Document justification

The present document is a part of the project BSUIN work package four (4) outputs related to Health and Safety in laboratories. This activity aims to develop pre-investment plans for each UL participating in the activity based on the surveys prepared by the Karelian Research Centre of the Russian Academy of Sciences. Proposals of further developments were specified separately for Callio Lab, Äspö HRL, Reiche Zeche, Ruskeala and Conceptual prototype of Underground Laboratory prepared by KGHM Cuprum R&D, depending on the scope of their activity.

The content of this document contains suggestions concerning possible investments and improvement for each laboratory in terms of possible. At the same time, the content of the present document does not oblige UL managers to implement offered solutions in any way.

1.2 Content description

The underground environment is a very specific and, from the science and research point of view, very valuable place. However, at the same time, the working conditions in underground space are extremely harsh. Lack of fresh air, internet and GSM connection make such facilities like Underground Laboratories. A short description of possible improvements and potential pre-investment plans was prepared within the scope of A. 4.3. of the BSUIN project. Therefore, the solutions presented here will describe which technical solutions may be utilised to improve safety. Also, some proposals in terms of adaptation of facility to novel activities will be presented.

2. The BSUIN project

The BSUIN project aims to make the underground laboratories (UL) in the Baltic Sea Region more accessible for innovation, business development and science by improving the information about the underground facilities, the operation, user experiences, the underground working environment and safety. Based on the improved characteristic information, business models and service portfolios are updated to help the underground laboratories the established network to understand the full potential of the facilities. Baltic Sea Underground Innovation Network (BSUIN) is a collaboration project between 13 partners from eight Baltic Sea Region (BSR) countries.

PARTNER LABORATORIES:

- Callio Lab, Pyhäsalmi (Finland),
- Äspö Hard Rock Laboratory, Oskarshamn (Sweden),
- TU-Freiberg's Research and Education Mine "Reiche Zeche" (Germany),
- Conceptual Lab development coordinated by KGHM Cuprum R&D centre (Poland),
- Ruskeala, Karelia (Russia),
- Underground Laboratory of Khlopin Institute in St Petersburg (Russia).

Figure 1 Map of the Baltic Sea region with the underground laboratories involved in the project.

ASSOCIATED ORGANISATION LABORATORIES:

- Experimental mine Barbara (Poland),
- Hagerbach Test Gallery (Switzerland).

Besides project partners, 17 associated partners contribute to achieving project goals. In the project participate five existing underground laboratories around BSR. Moreover, one UL prototype will be developed within BSUIN activities. During the project, the ULs will be characterised both from an infrastructural and operational perspective. As a result, the UL within the network will be more attractive

and known to potential customers. The ULs are looking for customers to develop innovative activities and to increase the usage of laboratories.

The project's main outcome is a sustainable network organisation, which will collect, describe and distribute the information projecting, building and maintaining this kind of facility.

The project is funded by Interreg Baltic Sea funding cooperation. Its duration is 36 months with a total budget of 3.4 M€.

3. Facility improvement

3.1 General classification of UL in BSUIN project

Speaking of underground spaces, we mean natural and manufactured spaces in the bowels of the earth. They are suitable for reuse after exhausting their basic functions. These can be specially created objects and premises for placing structures for various purposes in them. Six underground laboratories take part in the project. All operate year-round and are located at different depths: from deep mines (Cuprum, Äspo, Callio Lab, Reich Zeche) to mine-open pit combination (Ruskeala). Table 1 shows their classification according to the "origin" of the underground space.

Table 1. Classification of Underground Laboratories by "origin."

Underground space class	ULs
1. Underground structures - mine workings or their complexes, equipped in accordance with the functional purpose of the underground facility. Underground geo-urban studies.	Äspö Hard Rock Laboratory, Oskarshamn, Sweden Khlopin Radium Institute Underground Laboratory, Russia
2. Technogenic, man-made cavities are mines of a given shape and size.	Callio Lab, Pyhäsalmi mine, Finland Reiche Zeche, TU Freiberg Research and Education mine, Germany Lab development by KGHM Cuprum R&D centre, Poland Ruskeala Mining Park, Russia
3. Natural voids - cavities in the rock mass formed as a result of various geological processes. Caves can be tectonic, karst, glacial, volcanic. Protected areas.	-

Two facilities were built and equipped specifically for specialised research. Khlopin Radium Institute UL is strictly specialised in its activity. The Äspö Hard Rock Laboratory was created for R&D activities mainly related to the final disposal of spent nuclear fuel. Its activities today are related to R&D (geological disposal of spent nuclear fuel; external customers doing various experiments in the facilities), education (related to geological disposal of spent nuclear fuel, geosciences and rock engineering), communication to build trust and public acceptance in nuclear fuel-related issues, guided tours for schools and the public. The operation phase of the underground laboratory started in 1995.
Four of the six Underground laboratories operate or are planned in existing (Callio Lab at Pyhäsalmi mine, Conceptual underground laboratory at KGHM Cuprum mine)or closed (Ruskeala mining park, Reiche Zeche) mines.

3.2 Fields for facility improvement

The basis for the development of pre-investment plans was to report about possible facility improvements. Furthermore, concerning the scope of the possible improvements, the proposal of further development contained.

- mapping of the future needs for facility improvements of the ULs (both in the underground and surface facilities);
- development of the solutions for better accessibility of the ULs, including measures for disabled visitors;
- elaboration of the ideas for investment plans (pre-investment measures) regarding the profiles of the specific UL and corresponding legal regulations.

As was already mentioned, there are five existing facilities in the BSUIN project (Äspö HRL, Callio Lab, Khlopin, Reiche Zeche and Ruskeala). There is also one concept of an underground laboratory in deep mine condition (Cuprum). However, the scope of activity of each laboratory is quite different. Thus we have analysed objects related to tourism (Ruskeala, Reiche Zeche), Laboratories aimed at research activities (Khlopin, Reiche Zeche, Äspö HRL, Callio Lab, Cuprum) and facilities with core activities strictly related to mining technology development (Äspö HRL, Cuprum).

There is also great variety in the depth of each facility location, which affects the seismicity and geomechanical hazard. For example, two laboratories are located directly below the ground surface (Ruskeala, Khlopin), Two facilities are situated at mid-depth of several hundred meters (Reiche Zeche, Äspö HRL). Finally, two objects are located in the deep underground mines, where the maximum depth below the ground surface reached the value of 1,430 m in the case of Callio Lab and 1,280 m in the case of CUPRUM UL Prototype.

3.2.1 Possible improvements in terms of safety and monitoring

Underground Laboratories of the BSUIN project are characterised by well-established management of the underground space in terms of its monitoring and maintenance in good condition. In most cases, control and measurements are carried out regularly. The monitored parameters are as follows:

- stress-strain state of the rock mass,
- the stability of the roof strata,
- ventilation control;
- seismicity.

In all analysed facilities, rock stability is maintained using rock bolts, meshes and shotcrete for underground maintenance. The bolting pattern depends on rock strength parameters and the purpose of each working. In general, chambers dedicated for the staff for pauses, dining, and meetings are characterised by additional support compared to standard mine workings.

According to the conducted survey, it turns out that Underground Laboratories located in Scandinavian Countries are most developed what is related to the highly advanced mining industry. As a result, it was concluded that ULs Äspö Hard Rock Laboratory and Callio Lab have practically no infrastructural needs. These facilities are currently the most advanced and safe for a wide range of users.

When analysing the situation in Khlopin radium institute, it was decided that most of the technologies utilised in the mining industry are unsuitable due to the shallow location and small size. The small scale of this facility determines the ease of facility risk management, even with no use of sophisticated technologies.

In turn, some additional effort may be required in the case of Reiche Zeche Mine, Underground Lab development by KGHM Cuprum R&D centre and Ruskeala Mining Park. All these facilities are located inactive or abandoned mines. The large scale of the mined-out area and complexity of rock mass disintegration and workings geometry makes these ULs slightly more prone to geomechanical hazard occurrence. Also, some ventilation issues may be expected in these cases.

Based on the analysed questionnaires and after discussion with managing authorities, some proposals for improving the infrastructure of individual laboratories were identified. The data are summarised in Table 2.

Of course, suggestions depend on the features and detailed characteristics of each facility. For example, due to the fact that Ruskeala has a shallow depth and short length of the underground adit, as well as a small number of people in groups, there is no need to change the "System controlling the number of people currently underground". However, for the Cuprum and Reiche Zeche facilities, an improvement is proposed in this position.

In the case of the Ruskeala underground laboratory, the creation of new tourist routes is under development. Expansion of the U.L. area will require additional work-related safety issues. It is proposed to conduct the following tasks.

- partial rock reinforcement of workings,
- building a stand-alone electronic system for integrated underground monitoring, year-round monitoring of microclimate, hydrological and geomechanical parameters,
- arrangement of fibre-optic Internet facilities,
- design of a radiation monitoring system,
- preparation of specialised premises for research and development with the appropriate equipment,
- Installation of a large wall-mounted electrified map of the underground route.

There are also plans for setting up an integrated monitoring and warning system based on fibre-optic Internet technologies in Ruskeala Mining Park. Therefore it will be necessary to formulate indicators for placement of out-of-mining facilities in different rock stability categories (for example, in Russia according to SNiP-II 94-80).

3.2.2 Possible improvements in terms of UL user´s possibilities

Connectivity is a key issue in any modern working environment, and underground laboratories are not different from any of those. Communications between the shift and site manager is a must for safety. Interconnectivity between the underground laboratories and surface facilities make the working practices convenient. Possibilities for internet in underground environments are not always high, but the tendency is going towards fast and secure connectivity, including fibre-optics and 4G and 5G communications. Remote capabilities enable offsite monitoring and control of the activities and including larger consortiums to participate in underground activities. See table 3 for the possible improvements.

Concerning organisational matters, it was decided that some key activities may be implemented in all six facilities. Low costs and high efficiency make the organisational solution very valuable in risk and safety management; therefore, proposed solutions are as follow:

- increasing the availability and visibility of first aid equipment and rescuers (if applicable),
- installation of new information stands, posters and signs, to remind workers and visitors about possible threats, escape routes and methods of accidents reporting,
- the organisation of an accessible environment for various categories of visitors,
- increased access to the data network,
- additional tools with constant data transmission and hazard indicator (flashing led, buzzer etc.),
- training of guides speaking foreign languages (especially in tourism-related facilities).

Underground facilities are constantly maintained and developed to meet the requirements of the new users. The possibilities at the underground facilities depend on the permitting, the available infrastructure and on-site practices. To understand the extent of current practices, please see appendix A. Improvement plans for the facilities are presented in table 3.

3.2.3 Possible improvement in terms of visitors and touristic groups.

Tourism is one form the use of underground facilities. Ruskeala mining park, together with the Reiche Zeche mine, are the leading facilities of the BSUIN underground laboratories in terms of benefitting from tourism. Underground independent tours, interactive poster walls, lecture and showrooms are all on the improvement lists. See table 4 for the improvement plans in terms of visitors and touristic groups. The description of the current status can be seen in appendix A.

Table 2. Suggestions for improvement on general safety issues, regardless of the area of use.

Problem	ULs					
	CUPRUM	REICHE ZECHE	RUSKEALA	CALLIO LAB	ÄSPÖ	KHLOPIN
Rock-stress monitoring	Instrumented rock bolts with permanent data transfer and danger indicator	Implementation of ground control monitoring systems (Instrumented Rockbolts/ inclinometers etc.)	Setting up of an integrated monitoring and warning system based on instrumented rock bolts and fibre-optic Internet technologies are being discussed	Improving the micro-seismic monitoring network	-	N.A.
Type of emergency signalling	Personal emergency indicator (information about evacuation)	Implementation of ground control monitoring systems	-	-	-	N.A.
Safety chambers	-	-	-	-	-	N.A.
The system controlling the number of people currently underground	Individual positioning system	. RFID Tags on helmets IN ADDITION to (not replacing) counting to monitor the exact location of visitors	-	Individual positioning system	-	N.A.
Access to first aid and safety equipment		In the case of new research facilities, the availability of first aid kits will be increased.	-	-	-	N.A.

Table 3. Possible improvements for UL user´s possibilities

Problem	ULs					
	CUPRUM	REICHE ZECHE	RUSKEALA	CALLIO LAB	ÄSPÖ	KHLOPIN
Access to water	System installation for drinkable water.	In the case of new research facilities, the access to service water will be increased	-	-	-	N.A.
Availability of restroom	Installation of additional toilet cabins	-		Installed to new facilities if needed	-	N.A.
Need for radioactivity monitoring	Measurement system assembling if needed	-	Plans include continued monitoring of indicators at the Great Column hall	Per need	-	N.A.
Use of harmful and hazardous substances for research	-	-	-	-	-	N.A.
Possibility for independent visits and working	-	-	-	-	-	N.A.
Availability of premises for group studies, lectures	Preparing rooms for this purpose with proper equipment	-	Such classes will be possible in the premises of the Musem of the Mountain park	Underground office and lecture rooms	-	N.A.
Communication system with a dispatcher	Expanding the range of mobile transmitters to cover the whole area of Conceptual Lab	Increase the data access network,	Setting up of an integrated monitoring and warning system based on fibre-optic Internet technologies is being discussed	-	-	N.A.
Supervisor available for external users	Training more guides who speak foreign languages	-		In future, yes	-	N.A.
Access to internet	Increase range of mobile transmitters	Continuously increasing the data access network	-	Connection to Scientific computing services	An open user network for underground needed. A complimentary open access network to be installed underground	N.A.

Table 4. Possible improvements for visitors and touristic groups

Problem	ULs					
	CUPRUM	REICHE ZECHE	RUSKEALA	CALLIO LAB	ÄSPÖ	KHLOPIN
Need and presence in the team speaking foreign languages	-	Yes, plans of the touristic association are independent of the mine or TUBAF	-	Yes	-	N.A.
Availability of restroom	Installation of additional toilet cabins	-	-	With new facilities new social facilities to be installed		N.A.
Availability of a room for presentations	-	-	The building of the Museum of the Mountain Park is being completed at the entrance to the underground route	With new facilities new social facilities to be installed	-	N.A.
Possibility of excursions for people with disabilities.	-	-	-	-	-	N.A.
Possibility of independent visits, passing tour route	-	-	-	-	-	N.A.

3.3 Possible Improvements in terms of accessibility, business and research

When analysing the possible improvement in terms of accessibility, business and research in underground laboratories, significant differences between each facility may be observed. Therefore a short description of a possible solution for each Laboratory is presented below.

3.3.1 Callio Lab and Reiche Zeche

From the business point of view, the Callio Lab and Reiche Zeche mine seem to be most developed concerning the range of their activities. Both facilities are opened for educational, scientific and research projects. The scope of conducted research changes from basic mining technology development through food production ending at astrophysical measurement. Such attitude provides diversification of incomes and is strongly desired when talking about reuse of underground facility.

3.3.2 UNDERGROUND LOW BACKGROUND LABORATORY OF KHLOPIN RADIUM INSTITUTE

When comparing to Callio Lab and Reiche Zeche mine, the opposite situation may be observed in Khlopin laboratory, where such diversification of projects is impossible due to a very specific scope of activities conducted in this object. Therefore eventual proposals concerning accessibility and business development, in this case, were omitted.

3.3.3 Conceptual Underground Laboratory Development by KGHM Cuprum

In the case of the Conceptual Laboratory developed by KGHM Cuprum, much effort will be required. As it was mentioned in one of W.P. 4 reports, “Design of Underground Laboratory Prototype complying requirements and best practices in deep copper mine conditions” (Fuławka et al., 2020b), two types of facilities are taken into consideration. The first type called a laboratory on a small scale, will be in the form of one underground chamber intended typically for physical and astrophysical research. The creation of such a facility will be related to the necessity of excavation of a large underground chamber, with the creation of at least two main drifts for ventilation and escape routes. Still, the development of such an Underground Laboratory has great scientific potential due to favourable conditions in terms of natural radiation background in the rock mass surrounding the facility.

On the other hand, there is also the idea of setting up a so-called large-scale laboratory for research and education. According to the project, this kind of facility will require a very broad scope of activities, such as excavating workings, creating safety chambers, preparing safety and ventilation routes, developing machine chambers and data collection chambers, etc. Nevertheless, set up if such a facility will be the first commercial underground laboratory of such a scale in Europe.

3.3.4 Ruskeala

The situation at the Ruskeala laboratory is still developing. This object is in constant development. Expansion of the territory and the length of tourist routes are underway. Because of this, a cooperation agreement was signed between the Ruskeala Mining Park and KarRC RAS during the Strategic Planning Leaders Forum (St. Petersburg, Oct. 28-29, 2019). Re-training tour guides were carried out in connection

with a profound revamp of the route logistics of the Mining Park. Nearly complete is constructing a museum in the Mining Park, whose premises can be used for classes, lectures and other events. One of the investment steps is participation in various photography and travel exhibitions, with the BSUIN project mentioned.

Many activities related to developing a new speleo route, "Underground Ruskeala", provide investment cooperation and various forms of partnership, including KarRC RAS. This effort will encompass the following activities:

- research of non-flooded mine workings (in parts closed for tourists), to arrange and put into operation a new part of the speleo route;
- research of the underwater part of the speleo route, creation of the amusement and education park "Underwater Ruskeala";
- designing additional premium tourist products based on the "Underground Ruskeala" speleo route: cave photography tours, scientific excursions;
- creating a Speleology and Mining Culture and Information Centre – a stand-alone building with an exclusive, periodically renewed exhibition.

Moreover, some actions concerning Corporate Social Responsibility actions related to Ruskeala Mining park will be realised in the nearest future. Among them following should be mentioned:

- Creating the photo exhibition and website "Underground worlds: paths, mysteries, discoveries". Key mission: to visualise the good experiences of using underground spaces in Russia and around the world. Main author and coordinator: participant of BSUIN project Anton Yushko. The project intends to involve other contributors of information and visual material. The project is designed as a long-term and self-advancing one. It is a follow-up of the photo project "Ruskeala: secrets of the depth" (partially funded by the "Mining Road" project). It will turn into a guidebook within three to five years to underground tour destinations in Russia and other countries. The project's information partners are the Russian Geographical Society, the Russian Union of Speleologists, data retrieval system "Caves" https://speleoatlas.ru/, the team of the authors of the "Atlas of Russian Caves".
- Album-book "Ruskeala marble quarries" by I.V. Borisov and A.A. Yushko (A4 format, ca. 200 pages, 500-1000 copies). Description of the history of the deposit and its surroundings, the situation today, and a futuristic forecast of the Ruskeala Mining Park development in the coming 5-10 years in the context of advancing cooperation with KarRC RAS and teams of international research projects. The bulk of the manuscript is ready, illustrations are being selected, and the final chapter recapitulating on the challenging year 2020 is being written. Polygraphically, the book can be made similar to the volume of articles published by the "Mining Road" project (366 pages, paper cover, 300 copies). The imprint states that the edition was printed using KarRC RAS facilities. There is some commercial potential in the book about the Mining Park (an earlier first similar edition of 1000 copies have not been sold out over the two years but returned the investment and is constantly used as a gift for partners). The Mining Park is willing to contribute to financing the new edition.
- Setting up a permanent working group for inventory and research of abandoned underground mining heritage sites (Yushko, Borisov) with the participation of speleologists from the RGO St.

Petersburg Division. In the first months and years of its operation, the group could carry out in-depth studies in Ruskeala (Sortavalsky District), survey tectonic cavities on Razboinich'ya mountain near Lake Ristijarvi (Ecopark Ristijarvi being created using Borisov's material), Rogoselga mine (Kolatselga, Pryazhinsky District), adit in Hiidenvuori mountain (Pitkarantsky District), the dry underground reservoir in Kuhavuori mountain (Sortavala), Cave Pirunikirkko (Lahdenpohsky District), "Gora Filina" bunker (Lahdenpohja). Substantial background data have already been amassed on these sites. According to early unofficial reviews, they can (and some already have) become learning tourism and ecotourism destinations in the nearest future. There is a demand for comprehensive monitoring of the sites, and investors, economic actors and local authorities require expert advice on using underground spaces.

3.3.5 Äspö Hard Rock Laboratory

Äspö HRL is the facility that has been continuously updated during its almost 30 years of operation to meet the highest international standard for safety and accessibility for research and technical development (for details, see the SKB questionnaire in the appendix). The plan is to gradually decrease the use of the facility for spent nuclear fuel research and expand the use for other research such as geo-energy, infrastructure such as tunnelling, and mining/minerals.

The following aspects for facility improvements have been met:

- The future need for the facility includes finding a new owner who can widen the use for external users. A program for this is conducted.
- Development of solutions for better accessibility includes a better geoscientific description of the Äspö HRL site (Laaksoharju et al., 2020)
- A long term plan and the business case has been presented so a new owner can take over the facility

It must be highlighted that the facility improvement plan for Äspö HRL is to gradually decrease the use of the facility for spent nuclear fuel research and expand the use for other research and technical development areas.

4. Summary

When analysing the collected data, one may conclude that the safety and availability of U.L. depend on the characteristics and state of the geological environment at the current moment and its predicted future state. Also, the area of use of U.L. plays an important role. Therefore, it is also necessary to take into account the conditions under which the U.L. has been created.

Preferably, the future uses of the mine should be addressed in parallel with the design and construction Underground Laboratory, for example, within the area of waste rock. Such an approach will be base on the development of new technologies suitable to specific mine condition, and in future, may be used for other purposes like science or education.

Underground Laboratories of the BSUIN project are good examples of the reuse of mining workings and their further development.

Based on surveys and on-site verification, the draft technical ideas for improving the safety and accessibility of the facilities taking part in the BSUIN project were prepared. In addition, an analysis of possible pre-investment measures and possible direction of further development were described.

Finally, it was concluded that Underground Laboratories in the Baltic Sea Region, in their current shape, are well adapted for research and scientific purposes. What more, there is also great potential in terms of education and tourism as well. Therefore such direction of post mine workings development should e was taken into consideration and may be categorised as a new type of old mine reclamation, with great value to local society.

5. References

BSUIN WP2.3 Report: “Äspö Hard Rock Laboratory - Site Properties, Data and Models” By: Marcus Laaksoharju (Editor), M. Ohlsson, J. Petersson, M. Morosini, L. Alakangas and P. Hultgren, SKB (2020),

BSUIN WP4 Report: “Health & Safety in Underground Environment” By: K. Fuławka, W. Pytel, M. Szumny, P. Mertuszka, J. Joutsenvaara, V. Shekov and T. Bubunova, Wrocław, KGHM CUPRUM R&D, (2020)

BSUIN WP4 Report: “Design of Underground Laboratory Prototype complying requirements and best practices in deep copper mine conditions” By: K. Fuławka, W. Pytel, M. Szumny, P. Mertuszka, S. Hanzel and M. Madziarz, Wrocław, KGHM CUPRUM R&D, (2020)

APPENDIX A

Current status and possible improvement

Based on survey

CUPRUM		
	Description	Proposition of improvement
Is there a warning system about the possibility of instability of life support systems	Roof separation gauge	Instrumented rock bolts with permanent data transfer and danger indicator (flashing light, buzzer)
Type of emergency signalling	Sirens, red flashing light, warnings messages transmitted by telephones and mobile transmitters	Personal emergency indicator (information about evacuation)
Is there a safety chamber	Safety chambers and additional stations with self rescuers	-
Is there a roof monitoring system	Roof separation gauge	Instrumented rock bolts with permanent data transfer and danger indicator (flashing light, buzzer)
Is there a good escape road plan, accessibility for visitors	Emergency plan contains information of all escape routes, plan is checked regular by mining authorities	-
How many possible escape roads are there (basic additional)	Many escapes roads available to the different shafts	-
The availability and equipping of emergency evacuation routes from the sub. space. Are there any signs for escape road	Escapes roads are marked by reflective markers, that show escape routes to the different shafts. In some of evaluation routes safety chambers or additional stations of self rescuers are available	-
Is there communication system with a dispatcher? What type?	Telephones and mobile transmitters	Increase range of mobile transmitters
System for counting and controlling the number of people which are underground	Information blackboard, information provided to the dispatcher	Personal location system
Availability of first aid, access to first aid kit and other	Lots of first aid kits are available underground, storage places	-

emergency response facilities	are determined and marked, medical point with nurses is available on surface	
Electrification of underground space. Access to electricity	Underground space is electrified	-
Are there any air condition monitoring system	-	-
The need and presence in the team of people who speak foreign languages. At least one person with good English language skills available	-	-
Is there a lot of water and mud on the floors of UL workings, at least on the paths?	Floor condition depends on mining area.	Potential UL should be located in dry place with good floor condition.
Need for a radioactivity monitoring system	There is no need for permanent radioactivity measurement system, periodically measurement is done	Measurement system assembling if needed.
Use of fixing the walls of the developed underground space. Control of the support systems	Support system is monitored and controlled	Assembling additional support system with instrumented rock bolts.
Place for sit/rest during trip	Rest chambers are available	-
Adequate lighting	-	-
Access to room where presentation/slideshow can be made	There is no special room for this purpose	Preparing room for this purpose with proper equipment.
Availability / necessity of a rest room, WC	Limited access to WC	Installation of additional toilet cabins
Access to water underground	Drinking water available in bottle only, industrial water available (not drinkable)	System installation of drinkable water
The presence or the need to use layouts, posters with additional information on the path of the tour route	-	-

The need to use additional protective equipment umbrella, boots, raincoat, etc.)	Protective equipment available. There is a need to use proper PPE.	-
Possibility of excursions for people with disabilities (which category)	There is no access with disabilities. Normal mining activities, too dangerous for people with disabilities.	-
Organization of an accessible environment for various categories of visitors	Limited access to the visitors, special permitting needed	-
Staff members who have experience with people with disabilities	NA, see above	-
The possibility of independent visits, passing the tour route. What equipment for this is provided	Limited access to the visitors, special permitting needed	-
The presence or the need a place where you can change clothes	Baths available	-
The need to use workwear	PPE required and available for visitors	-
The need to use personal protective equipment (for example, gloves, boots, apron, respirator)	See above	-
Access to computer	-	-
Access to internet	-	-
Access to underground communication system	-	
Supervisor available for external researchers	-	Training more guides who speaks foreign languages
Explosives are used to research?	-	-

Are harmful and hazardous substances used for research?	-	-
Availability of premises for group studies, lectures	Limited access, permission needed	-
Equipping specialized premises for practical, laboratory classes	Not available	-
The possibility of independent visits and working	Limited access, permission needed	-
The possibility of receiving (selection, purchase, gift) of various samples and other results of the work performed (for example, a crystal grown from a salt solution or a piece of rock)	Possible, special formal request is needed	Simplification of procedures.

ASPOO SKB		
	Description	Proposition of improvement
Is there a warning system about the possibility of instability of life support systems	There is a fire monitoring system and on-line cameras at key positions in the facility.	-
Type of emergency signalling	There are warning flashing lights, sound and recorded voice messages through speakers.	-
Is there a safety chamber	There are mobile rescue chambers at prioritized locations and one large rock cavern designed as an rescue chamber taking 60 persons.	-
Is there a roof monitoring system	The roof stability is checked regularly and reinforced when needed. No needs for further improvements.	-
Is there a good escape road plan, accessibility for visitors	Signs with escape routes approved by local emergency service. The staff personnel and visitors can escape to rescue chambers or to the nearest elevator stop level (-220m, -340 m and -450 m).	-
How many possible escape roads are there (basic additional)	One access tunnel and one elevator shaft. At least one escape way need to be available to have ongoing activities underground.	-
The availability and equipping of emergency evacuation routes from the sub. space. Are there any signs for escape road	Escape signs exist and the staff has repeated mandatory training. Signs with escape routes and training are approved by local emergency service.	-
Is there communication system with a dispatcher? What type?	A local DECT mobile communication system exists and is used by everyone working underground and in the office area above ground.	-
System for counting and controlling the number of people which are underground	The number of persons including visitors are monitored on-line by the implemented RFID based system.	-
Availability of first aid, access	Available at many key position	-

to first aid kit and other emergency response facilities	underground and in the research village.	
Electrification of underground space. Access to electricity	The whole tunnel system is electrified and there are several distribution boxes along the tunnel and the main working areas.	-
Are there any air condition monitoring system	Not needed. The ventilation of the underground space is regulated from the control room. There is no need to monitor the quality (condition) of the air. Temperature is measured. If the ventilation is stopped the radon gas levels will increase. Hence, it is important to ventilate the underground laboratory.	-
The need and presence in the team of people who speak foreign languages. At least one person with good English language skills available	The on-site staff can communicate in English.	-
Is there a lot of water and mud on the floors of UL workings, at least on the paths?	The roads and floors underground are in very good standard (asphalted) and the incoming ground-water is drained continuously. There could be water puddles if the drainage system fails due to lack of maintenance.	-
Need for a radioactivity monitoring system	The radon gases are regularly measured and some members in the staff is wearing dosimeters to have an extra control of the situation underground.	-
Use of fixing the walls of the developed underground space. Control of the support systems	Stability of walls and ceilings are checked regularly and rock reinforcements are used where needed.	-
Place for sit/rest during trip	Short distances between the facilities. By the elevator you can easily reach restrooms above ground.	-
Adequate lighting	Intelligent lighting is installed in the tunnel.	-

Access to room where presentation/slideshow can be made	Conference rooms are available in the research village above ground.	-
Availability / necessity of a rest room, WC	Also available at the 420 m level.	-
Access to water underground	At several positions. There is one main valve at the 420 m level.	-
The presence or the need to use layouts, posters with additional information on the path of the tour route	There are "posters" close to our experiment locations.	-
The need to use additional protective equipment umbrella, boots, raincoat, etc.)	Boots and raincoats are available for the visitors, but they are seldom needed.	-
Possibility of excursions for people with disabilities (which category)	Depends of the category of disability. Every one need to have the ability to walk in normal speed to the nearest rescue chamber/area in case of alarm (fire, smoke…).	-
Organization of an accessible environment for various categories of visitors	Not planned.	-
Staff members who have experience with people with disabilities	Maybe, but not as a result by planning for guiding visitors with disabilities.	-
The possibility of independent visits, passing the tour route. What equipment for this is provided	It is not possible/permitted to visit the underground space without a guide from the on-site staff.	-
The presence or the need a place where you can change clothes	There is a dressing room for changing clothes.	-
The need to use workwear	If needed, not included in the laboratory services.	-
The need to use personal protective equipment (for example, gloves, boots, apron,	Every one need to wear helmet with chinstrap, clothing with reflexes, working shoes/boots	-

respirator)	and an escape hood.	
Access to computer	Only for the SKB staff and in-hose consultants. An improvement is needed.	-
Access to internet	Only for the SKB staff and in-hose consultants. An improvement is needed.	Requires an open network underground. A complementary open access network will be installed underground.
Access to underground communication system	Possible to borrow DECT phone for underground work.	-
Supervisor available for external researchers	Supervisors/Coordinators and technicians are available.	-
Explosives are used to research?	Only when new tunnels and caverns are needed for new experiments.	-
Are harmful and hazardous substances used for research?	Minor amounts of radioactive tracers are used in some experiments, but very seldom. Chemicals have to be approved by SKB before use.	-
Availability of premises for group studies, lectures	Some of the conference rooms in the research village can be furnished for lectures and conferences.	-
Equipping specialized premises for practical, laboratory classes	Could be arranged in cooperation with customer.	-
The possibility of independent visits and working	All visits and working activities need to be planned and performed together with an on-site coordinator or guide from our staff.	-
The possibility of receiving (selection, purchase, gift) of various samples and other results of the work performed (for example, a crystal grown from a salt solution or a piece of rock)	New samples (groundwater, minerals, piece of rock) or results from previous analysis of samples can be ordered. Results from research activities are owned by the researcher.	-

CALLIO LAB		
	Description	Proposition of improvement
Is there a warning system about the possibility of instability of life support systems	-	-
Type of emergency signalling	-	-
Is there a safety chamber	In almost every level of the mine. Also big safety station at the main level with safety gear, O2, rescue gear etc.	-
Is there a roof monitoring system	-	-
Is there a good escape road plan, accessibility for visitors	Emergency plan contains information of all escape routes, plan is checked regularly by mining authorities. Also for every Project it is a MUST to prepare an emergency and security plan.	-
How many possible escape roads are there (basic additional)	One VT access tunnel and one elevator shaft	-
The availability and equipping of emergency evacuation routes from the sub. space. Are there any signs for escape road	Escapes roads in VT tunnel are marked by reflective white markers, that show escape routes to the safety chambers or additional stations.	-
Is there communication system with a dispatcher? What type?	Mandatory radiophones for all. Additionally a 3G access at the main level of the mine. Wi-Fi access at the main level, 660 level, 400 level and 990 level.	-
System for counting and controlling the number of people which are underground	RFID keys for all employees and visitors, information screen for all people underground	-
Availability of first aid, access to first aid kit and other emergency response facilities	Lots of first aid kits underground, two ambulances at the main level available to serve in case of emergency	-
Electrification of underground space. Access to electricity	Underground space is electrified	-

Are there any air condition monitoring system	At the main level and at the refinery control room	-
The need and presence in the team of people who speak foreign languages. At least one person with good English language skills available	English is used, but all emergency information is in Finnish	-
Is there a lot of water and mud on the floors of UL workings, at least on the paths?	Main roads and caverns are dry at the bottom of the mine	-
Need for a radioactivity monitoring system	There is no need for permanent radioactivity measurement system, periodically measurement is done	-
Use of fixing the walls of the developed underground space. Control of the support systems	Support system is monitored and controlled by seismic sensors	-
Place for sit/rest during trip	Social facilities at the main level, restaurant and toilets and Sauna	-
Adequate lighting	-	-
Access to room where presentation/slideshow can be made	Yes	-
Availability / necessity of a rest room, WC	Social facilities at the main level, Retka restaurant and toilets and Sauna	-
Access to water underground	Social facilities at the main level, Retka restaurant and toilets and Sauna	-
The presence or the need to use layouts, posters with additional information on the path of the tour route	Posters of the tour routes should be done. Mine is in operational mode at the moment and posters not needed	-
The need to use additional protective equipment umbrella, boots, raincoat, etc.)	According to PMO safety procedures: boots, helmet, flashlight etc. Protective equipment.	-
Possibility of excursions for people with disabilities (which category)	Too dangerous and not according to the PMO safety standards. Same for kids under age 18.	-

Organization of an accessible environment for various categories of visitors	Limited access but can be planned per case	-
Staff members who have experience with people with disabilities	-	-
The possibility of independent visits, passing the tour route. What equipment for this is provided	-	-
The presence or the need a place where you can change clothes	Dressing rooms, several	-
The need to use workwear	PPE required	-
The need to use personal protective equipment (for example, gloves, boots, apron, respirator)	PPE required	-
Access to computer	No public PC's	-
Access to internet	Callio Wi-Fi free	-
Access to underground communication system	According to the PMO standards	-
Supervisor available for external researchers	Support services from Callio as needed	-
Explosives are used to research?	Not at the moment	-
Are harmful and hazardous substances used for research?	-	-
Availability of premises for group studies, lectures	Meeting rooms and Retka facility	-
Equipping specialized premises for practical, laboratory classes	Can be arranged in cooperation with customer and PMO	-
The possibility of independent	Limited access, a security personnel needed to host	-

visits and working	visitors	
The possibility of receiving (selection, purchase, gift) of various samples and other results of the work performed (for example, a crystal grown from a salt solution or a piece of rock)	-	-

RUSKEALA		
	Description	Proposition of improvement
Is there a warning system about the possibility of instability of life support systems	partially. There is a fire monitoring system	The creation of an integrated monitoring and warning system based on fibber-optic Internet technologies is being discussed
Type of emergency signalling	sound and recorded voice messages through speakers.	-
Is there a safety chamber	Conventionally, such premises can be considered a mine office and a tunnel between the adits and a large columned marble hall	-
Is there a roof monitoring system	Partially	-
Is there a good escape road plan, accessibility for visitors	-	-
How many possible escape roads are there (basic additional)	Three escape routes (main entrance, marina exit to the water area of the Grand Marble Canyon, ascent to the surface from the Great Column Hall using rope rescue equipment)	-
The availability and equipping of emergency evacuation routes from the sub. space. Are there any signs for escape road	partially. There are no evacuation signs on the route, as the guide and the accompanying technician who own all the necessary information are responsible for the evacuation	-
Is there communication system with a dispatcher? What type?	partially. Communication with the dispatcher on mobile and radio communications from the nodal points of the route.	The creation of an integrated monitoring and warning system based on fibber-optic Internet technologies is being discussed
System for counting and controlling the number of people which are underground	The calculation is carried out by the administrator on duty at the entrance to the route and the accompanying technician, providing the group boarding the ferry in the summer mode of using the route	-
Availability of first aid, access to first aid kit and other emergency response facilities	The first-aid kit is stored by the duty administrator at the mine office	-

Electrification of underground space. Access to electricity	The underground space is electrified. 350 low-current monochromatic and colour waterproof LED lamps controlled from a single centre are installed on the caving route	-
Are there any air condition monitoring system	-	The creation of an integrated monitoring and warning system based on fibber-optic Internet technologies is being discussed
The need and presence in the team of people who speak foreign languages. At least one person with good English language skills available	partially. English and Finnish speaking guides are called upon prior request.	-
Is there a lot of water and mud on the floors of UL workings, at least on the paths?	partially. There is practically no dirt on the route. In flood periods, waterlogging zones appear on concrete walkways that do not require special shoes	-
Need for a radioactivity monitoring system	Preliminary studies showed the absence of increased background radiation along the entire speleo route. Observations of the volumetric activity of radon also yielded results significantly below normal.	In the section between the intersection of the adits and the Great Column Hall, a comparatively higher indicator was recorded (179 Bq / cubic meter at a rate of 250 Bq / cubic meter). The plans include continued monitoring of indicators in this zone.
Use of fixing the walls of the developed underground space. Control of the support systems	Additional static systems for supporting walls and roofs are created between the intersection of adits and the Great Column Hall, they are constantly under visual observation	-
Place for sit/rest during trip	The specifics of the underground route do not provide seating	-
Adequate lighting	-	-
Access to room where presentation/slideshow can be made	Partially. Upon prior request, one of the three cafes of the park will be transformed into the presentation area (usually,	The building of the Museum of the Mountain Park is being completed at the entrance to the underground route, in

	the Summer cafe)	addition,
Availability / necessity of a rest room, WC	there is	-
Access to water underground	to drinking - no	-
The presence or the need to use layouts, posters with additional information on the path of the tour route	-	The development of a large wall-mounted electrified scheme of the underground route is in development plans; project assistance is appropriate for this task
The need to use additional protective equipment umbrella, boots, raincoat, etc.)	Using hard hat, comforter, life vest	-
Possibility of excursions for people with disabilities (which category)	The staff has experience working with wheelchair users, hearing impaired	-
Organization of an accessible environment for various categories of visitors	The staff has experience with older people	-
Staff members who have experience with people with disabilities	A preliminary application is desirable, but all on-duty personnel have basic working skills	-
The possibility of independent visits, passing the tour route. What equipment for this is provided	The caving routing allows only group visits. An exception is made only for film crews on a commercial basis and for researchers with tasks agreed upon with the administration. In all cases, the group is accompanied by an accompanying technician responsible for safety.	-
The presence or the need a place where you can change clothes	Partially	-
The need to use workwear	sometimes	-
The need to use personal protective equipment (for example, gloves, boots, apron, respirator)	-	-
Access to computer	Delivered if necessary	-

Access to internet	At the entrances to the route mobile Internet is available	-
Access to underground communication system	Mobile and radio communications are available at the main sections of the route.	-
Supervisor available for external researchers	Upon preliminary request, one of the guides provides such support to researchers, he can take readings from installed instruments	-
Explosives are used to research?	-	-
Are harmful and hazardous substances used for research?	-	-
Availability of premises for group studies, lectures	-	Such classes will be possible in the premises of the Museum of the Mountain Park, finishing
Equipping specialized premises for practical, laboratory classes	-	While there is no special equipment, project assistance is appropriate
The possibility of independent visits and working	partially. By request and approval	-
The possibility of receiving (selection, purchase, gift) of various samples and other results of the work performed (for example, a crystal grown from a salt solution or a piece of rock)	By request and approval	-

Mine Reiche Zeche		
	Describtion	Proposition of improvement
Is there a warning system about the possibility of instability of life support systems	CO2 Gas detection Systems	Implementation of a Mine Control Station
Type of emergency signalling	Computer Alert	Implementation of a Mine Control Station
Is there a safety chamber	-	-
Is there a roof monitoring system	regular manual checking of roofs, Geophone and seismic stations	-
Is there a good escape road plan, accessibility for visitors	maps on all crossings to point to nearest shaft, escape route, first aid kit and emergency phone	-
How many possible escape roads are there (basic additional)	emergency exit possible via Reiche Zeche shaft and Alte Elisabeth, on nearly every point 2 possible escape routes exist	Plans for a new (additional) access are worked on
The availability and equipping of emergency evacuation routes from the sub. space. Are there any signs for escape road	Unclear question. Signs are available, escape via shaft hoist and stair cases in case of shut down	-
Is there communication system with a dispatcher? What type?	phones at several marked locations	continuously increasing the data access network
System for counting and controlling the number of people which are underground	Tags for guides and miners for manual control, lists at the hoisting machine with claimed guided routes and number of participants	plans for RFID Tags at helmets IN ADDITION to counting (not replacing it) for monitor exact position of visitors in time
Availability of first aid, access to first aid kit and other emergency response facilities	together with signs and installed phones at marked locations	In case of new Research facilities, the availability of first aid kits will be increased
Electrification of underground space. Access to electricity	in areas of research well equipped, not available at all locations in the mine	In case of new Research facilities electrification will be increased
Are there any air condition monitoring system	control of functionality of main fan / CO2 gas detection	-
The need and presence in the team of people who speak foreign languages. At least one	Guides available for English tours. All members of the TU scientific staff speak English. All independent research teams,	Y, plans of the touristic association independent of the mine or TUBAF

person with good English language skills available	groups and tours require at least one person capable of communicating in German language	
Is there a lot of water and mud on the floors of UL workings, at least on the paths?	on several paths and routes, ULs have concrete floors	-
Need for a radioactivity monitoring system	Radon is measured regularly on major routes - obtained data well below reporting level	-
Use of fixing the walls of the developed underground space. Control of the support systems	roof support mostly via rock bolts, in ULs also shotcrete	Y, roof and wall stability in the whole mine checked regularly, and improved wherever necessary
Place for sit/rest during trip	on first level at several locations	not by the mine
Adequate lighting	cap lights are used for every person, electric light at the shaft and major points of interest and Uls, as well as special illumination	-
Access to room where presentation/slideshow can be made	seminar rooms on first level	-
Availability / necessity of a rest room, WC	on surface as well underground on first level, only at one point	-
Access to water underground	access to service water available at all important points on the first level	In case of new Research facilities, the access to service water will be increased
The presence or the need to use layouts, posters with additional information on the path of the tour route	-	new information boards along the main route currently installed , plans for renewal of additional signs and posters
The need to use additional protective equipment umbrella, boots, raincoat, etc.)	hardhats are issued by the mine, especially for longer tours it is necessary to use equipment handed out due to dirt, mud, wetness	-
Possibility of excursions for people with disabilities (which category)	depending on the disabilities possible, but due to safety regulations it is necessary that all persons can reach the second shaft on their own, due to road conditions wheelchairs are not allowed	-

Organization of an accessible environment for various categories of visitors	short tours especially for children and seniors	Restructuring of the exhibition as part of the state exhibition
Staff members who have experience with people with disabilities	-	-
The possibility of independent visits, passing the tour route. What equipment for this is provided	All underground tours require a guide	-
The presence or the need a place where you can change clothes	given at the surface, not underground	-
The need to use workwear	due to mine climate and safety regulations	-
The need to use personal protective equipment (for example, gloves, boots, apron, respirator)	due to mine climate and safety regulations	-
Access to computer	on surface tablets are provided in the touristic area, no researcher computer provided by the mine	Depending on the tests, the operators of the test stands are responsible to provide their own computers
Access to internet	WLAN / LAN / Eduroam on surface as well as at certain points on the first level reserved for research, as this is the main level for research	continuously increasing the data access network
Access to underground communication system	Phones, as well as W-Lan and LAN at certain points on the first level	continuously increasing the data access network
Supervisor available for external researchers	-	-
Explosives are used to research?	-	-
Are harmful and hazardous substances used for research?	not currently used regularly, but the possibility exists / can be created as long as it fulfils the requirements by the German mining law	-

Availability of premises for group studies, lectures	-	-
Equipping specialized premises for practical, laboratory classes	-	-
The possibility of independent visits and working	All tours require a guide, either TUBAF, the mine, or provided by the tourist association, long term research teams will get trained to provide their own guide	-
The possibility of receiving (selection, purchase, gift) of various samples and other results of the work performed (for example, a crystal grown from a salt solution or a piece of rock)	ore samples can and have been handed out, but not on regular bases	-