Documented needs for future infrastructural improvements in specific ULs

Baltic Sea Underground Innovation Network (BSUIN)

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Abstract	Underground laboratories provide a unique environment for various industries and are the perfect place for developing new technologies for mining, geophysical surveys, radiation detection, as well as many other studies and measurements. Unfortunately, working in underground excavations is associated with exposure to many hazards not necessarily encountered in surface laboratories. Therefore there is a strong necessity of continuous development of monitoring systems, support technology etc. to provide and ensure conditions which will fulfil all H&S requirements. Within this document, some proposals of pre-investments plans will be presented.

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. The aim of this activity is the development of 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

Underground environment is a very specific and, from the science and research point of view, very valuable place. At the same time, the working conditions in underground space are extremely harsh. Lack of fresh air, internet and GSM connection makes such facilities like Underground Labs

Within the scope of A. 4.3. of BSUIN project the short description of possible improvements and in result, potential pre-investment plans were prepared. The solutions presented here will not only 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.

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2. 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 and safety.

Baltic Sea Underground Innovation Network (BSUIN) is a collaboration project between 14 partners from 8 Baltic Sea Region (BSR) countries. In addition to the project partners, 17 associated partners contribute to achieving project goals. BSUIN includes five existing underground laboratories around the BSR. Moreover, one UL prototype will be developed within BSUIN activities. During the project, the ULs will be characterized both from infrastructural and operational points of view. As a result, the UL's within the network will be more appealing to potential customers, providing important practical and preliminary information on the location and services. The UL's are looking to attract customers, to develop innovative activities and increase the usage of these underground laboratories.

The main outcome of the project is to create a sustainable network organization, which will collect, describe, and distribute knowledge on designing, building, and maintaining of these kinds of facilities.

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

All Underground Laboratories of BSUIN project has a great experience maintaining and developing of underground space for their needs. As it was presented in WP4 report - Health & Safety in Underground Environment (Fuławka et al., 2020a). Each facility are well managed and employees, researchers and visitors are continuously reminded of *Safety First Rule*. In result, despite the harsh environment, and numerous hazards, there is no many accidents observed in abovementioned objects. Still, there is always room for improvements.

Similar conclusions may be a draw when analysing the accessibility of UL to new entities or new projects, not always related to their core activates.

3.1. General classification of UL in BSUIN Project

The basis for the development of pre-investment plans was to report about possible facility improvements (*WP4 report - Health & Safety in Underground Environment*) (Fuławka et al., 2020a). 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) with regards to the profiles of the specific UL and corresponding legal regulations.

As it was already mentioned, there are five existing facilities in 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). The scope of activity of each laboratory is quite different, and thus we have analysed objects related to tourism (Ruskeala, Reiche Zeche), Laboratories aimed to 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. Two of Laboratories are located directly below the ground surface (Ruskeala, Callio Lab), Two facilities are situated at mid-depth of several hundred meters (Reiche Zeche, Äspö HRL) and finally, two objects are located in the deep underground mines, where maximum depth below the ground surface reached the value of 1,470 m in case of Callio Lab and 1280 in case of CUPRUM UL Prototype.

3.2. Possible Improvements in terms of safety and monitoring

Underground Laboratories of BSUIN project are characterised by well-established management of the underground space in terms of its monitoring and maintaining 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 with the use of rockbolts, meshes and shotcrete for underground maintenance. The bolting pattern depends on rock strength parameters and purpose of each working. In general, chambers where working staff rest, are characterised by additional support in comparison 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. In 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.

Wham analysing the situation in Khlopin radium institute, it was decided that due to the shallow location and small size, most of the technologies utilised in the mining industry are unsuitable. 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 case Reiche Zeche Mine, Underground Lab development by KGHM Cuprum R&D centre and Ruskeala Mining Park. All these facilities are located in active or abandoned mines. The large scale of the mined-out area and complexity of rock mass disintegration and workings geometry makes these ULs a 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 summarized in Table 1.

Table 1. Suggestions for improvement on general safety issues, regardless of the area of use

Problem	ULs		
	CUPRUM	REICHE ZECHE	RUSKEALA
A warning system for potential instability of life support systems	Instrumented rockbolts with permanent data transfer and danger indicator	Implementation of a ground control monitoring systems (Instrumented Rockbolts/ inclinometers etc.)	Setting up of an integrated monitoring and warning system based on instrumented rockbolts and fibre-optic Internet technologies are being discussed
Type of emergency signalling	Ventilation - Individual emergency indicator (information about the necessity of evacuation) Ground Control- flashing light, buzzer of rock bolt recorder in case of exceeding the safe levels	Ventilation - Individual emergency indicator (information about the necessity of evacuation) Ground Control - temporal closing of the endangered area	Ventilation - Individual emergency indicator (information about the necessity of evacuation) Ground Control- temporal closing of the endangered area
Communication system with a dispatcher	Expanding the range of mobile transmitters to cover the whole area of Conceptual Lab	Increase the data access network, and	Setting up of an integrated monitoring and warning system based on fibre-optic Internet technologies is being discussed
The system controlling the number of people currently underground	Individual positioning system, gates to UL opened/closed with ID card	N.A.	RFID Tags on helmets IN ADDITION to (not replacing) counting to monitor the exact location of visitors

Of course suggestions depend on the features and detailed characteristics of each facitlity. 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*". For the Cuprum and Reiche Zeche facilities, an improvement is proposed in this position.

In the case of Ruskeala underground laboratory, the creation of new tourist routes is under development. Expansion of the UL area it will require the additional work-related to 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 specialized 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 of 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).

3.3. Organizational matters

Concerning organisational matters, it was decided that there are some key activities which may be implemented in all six facilities. Low costs and high efficiency, makes 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,
- organization 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).

3.4. 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.

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 works changes from basic mining technology development, thru food production ending at astrophysical measurement. Such attitude provides diversification of incomes and is strongly desired when talking on about reuse of underground facility.

UNDERGROUND LOW BACKGROUND LABORATORY OF KHLOPIN RADIUM INSTITUTE

The opposite situation, when comparing to Callio Lab and Reiche Zeche mine, may be observed in Khlopin laboratory where such diversification of projects is at the moment 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.

Conceptual Underground Laboratory Development by KGHM Cuprum

In the case of Conceptual Laboratory developed by KGHM Cuprum, a lot of effort need will be required. As it was mentioned in one of WP 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, will be in form of one underground chamber intended typically for physical and astrophysical research. Creation of such facility will be related to the necessity of excavation of large underground chamber, with the creation of at least two main drifts for ventilation and escape routes. Still, development of such 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 excavation of workings, creation of safety chambers, preparation of safety and ventilation routes, development of 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.

Ruskeala

The situation at the Ruskeala laboratory is still developing. This object is in constant development. Expansion of the territory and 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 of tour guides was carried out in connection with a profound revamp of the route logistics of the Mining Park. Nearly complete is the construction of 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.

There are also many activities related to the development of a new speleo route "Underground Ruskeala" provides for investment cooperation and various forms of partnership, including with KarRC RAS. This effort will encompass the following activities:

- research of non-flooded mine workings (in parts closed for tourists), with a view to arranging and putting 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 on the basis of 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 realized in the nearest future. Among them following should be mentioned:

- Creating the photo exhibition and website “Underground worlds: paths, mysteries, discoveries”. Key mission: to visualize 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). Within three to five years it will turn into a guidebook to underground tour destinations in Russia and other countries. The project’s information partners are Russian Geographical Society, 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 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, and according to early unofficial reviews, they can (and some already have) become learning tourism and ecotourism destinations in the nearest future. There is the demand for comprehensive monitoring of the sites, and investors, economic actors and local authorities require expert advice on using underground spaces.

Äspö Hard Rock Laboratory

Äspö HRL is the facility which has been continuously updated during its almost 30 years of operation to meet the highest international standard when it comes to safety and accessibility for research and technical development (for details see the SKB questionnaire in 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 geoenergy, 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 of the collected data one may conclude that the safety and availability of UL depend on the characteristics and state of the geological environment at the current moment, as well as its predicted future state. Also, the area of use of UL plays an important role. Therefore, it is also necessary to take into account the conditions under which the UL has been created.

Preferably, the future uses of the mine should be addressed in parallel with the design and construction Underground Laboratory in example within the area of waste rock. Such an approach will be base for 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 BSUIN project are good examples of reuse of mining workings and its 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. 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 the 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

1. 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),
2. 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)
3. 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)