The assessment of the sludge lagoons reclamation plans in the area of the uranium deposit Rožná

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Abstract: The article is aimed at an assessment of the reclamation plans of the sludge lagoons K1 and K2, which arose as a result of mining and chemical treatment of uranium ore in the deposit area Rožná. The area was explored and soil samples were taken from the locality of the sludge lagoons and near surroundings in the autumn of 2012. Then the samples were analyzed in the geological laboratory. An interesting succession of vegetation of different ages was found in the K1 and K2 area, so it was recommended to let the part of this vegetation stand to be developed, without human intervention (reclamation). Results of the laboratory biochemical analysis showed the sufficient microbial content in the soil samples from stands with succession of vegetation. On the other hand, low nitrogen content in the mineral form was detected for all the studied surfaces. The reclamation proposal should include filling the sludge lagoons with an inert material, building a cover layer and isolating the layer of bentonite and subsequent grass seeding and planting shallow-rooted shrubs. After the examination of the reclamation proposal documentation, the project was assessed as appropriate with some comments on the choice of shrub species and the project realization. It is also important appropriately to integrate the sludge lagoons body into the landscape. A possible future "social" use of the area after reclamation, for example public recreation or educational trails, was also suggested.

Key Words: sludge lagoon, reclamation, deposit Rožná, uranium ore, soil sample

Introduction

The sludge lagoons named K1 and K2 arose as a result of mining and chemical treatment of uranium ore in the deposit area Rožná. The deposit is located close to the town of Bystřice nad Pernštejnem, in Bystřice nad Pernštejnem micro-region (Vysočina Region, the Czech Republic). The deposit exploration and mining began in 1956. Rožná is currently the only uranium ore deposit being mined in Central Europe. [2] Its share in the world production of uranium was 1.3 % in 2003. The most important uranium deposits are located in Canada, the United States of America, Australia and South Africa. [4]

The sludge lagoon is a natural or artificially created area on the earth's surface, which is used for permanent or occasional storage of mainly hydraulically deposited sludge. In the sludge lagoons, solid matter (sludge) with the water used in production cycle is stored.

Land reclamation includes different measurements and adjustments, which are necessary for the renewal of soils devastated by natural or human activities. This usually includes a technical and biological phase. The biological phase has the task to create production land that would facilitate the plants growth and fauna life in the shortest possible time. [11].

Closing technology of K1 and K2 is the same in principle and consists of reshaping and filling the sludge lagoon body to the designed shape, building of a sealing layer, covering the layer and biologically appropriate layer (soil) over the entire body, and grassing and planting shallow-rooted shrubs. The sludge lagoon closure and overlap aims at removal dustiness, shield gamma radiation, decrease of radon consumption rate, significantly reduces the infiltration of rainwater into the sludge lagoon body, and finally integrate the anthropogenic structure into the surrounding landscape. Insulation and covering layers are:

mineral seal bentofix, geotextile, drainage layer, cover layer of an inert material, biological layer (soil or pond mud). [15]

The subject of the study is to assess the reclamation plans of the above mentioned sludge lagoons. The basis for this assessment is reclamation plans documentation study, field survey in the locality and an analysis of the collected soil samples.

To realize a research of the published knowledge of uranium ore mining and subsequent reclamation was the first goal. The second objective was aimed at the study of the K1 and K2 reclamation plans documentation. The work deals mainly with biological reclamation proposals and with the impact of this reclamation on the environment. The third objective consisted of an evaluation of the field survey and a realization of soil samples from the sludge lagoons locality and near surroundings, where, successional processes are in progress for a number of years. The fourth objective was found in the laboratory analysis of soil samples (soil physical and biochemical properties) and their appropriate statistical evaluation.

Material and Methods

The field research in the area of mines and sludge lagoons was performed in the autumn of 2012. Soil samples were taken from the sludge lagoons K1 and K2 and near surroundings. A mixed soil sample was taken from places on the K1 dam, where successional vegetation with white birch (*Betula pendula*) and Scots pine (*Pinus sylvestris*) was found, specifically a soil sample from the place covered with white birch and another soil sample from the spot covered with Scots pine. One sample was also taken from the place where the reclamation experiment was in progress. Other soil samples were taken from the K2 locality, specifically one sample from the place overgrown with grass - mostly Wood Small-reed (*Calamagrostis epigejos*), and one sample from the white birch standing at the K2 dam. Also, one soil sample was taken from agricultural land under K1. At all the sites intact soil samples for the determination of soil physical properties were also taken. The following soil properties were studied: content of nitrate (μg $NO_3 \cdot g^{-1}$), ammonium nitrogen (μg $NH_4 \cdot g^{-1}$) and microbial carbon ($mg \cdot g^{-1}$); the protease (μg L-tyrosine$\cdot g^{-1}$), urease (μg NH_4-N$\cdot g^{-1}$) and catalase (ml $O_2 \cdot 5\ g^{-1} \cdot\ 15\ min^{-1}$) activity, pH, density ($g \cdot cm^{-3}$), water and dry matter content (%), porosity (%) and maximum capillary capacity (%).

Laboratory analyses were performed according to the methods available in the literature. [13, 17] For statistical analysis of laboratory data three repetitions of the same sample were always performed, so it enabled using of average values and also creating graphs of divergence by means of Statistica software.

Results and Discussion

Interesting successional vegetation was found on the K1 and K2 dams. The artificial reclamation was not recommended, but leaving the succession locations and monitoring their (where it is possible). However, there is also an expansion of expansive Wood Small-reed (*Calamagrostis epigejos*) visible, which extrudes other types of herbs. The oldest stand logically occurs on the lowest terrace of the dam, while the grass species dominate on the upper terrace. Among the trees there is a continuous grass cover.

Results of the laboratory analysis showed a sufficient microbial content in the soil samples. The presence of microorganism in anthropogenic soil is necessary for starting the biochemical and biological processes relevant to plant growth. Sufficient content of microbial biomass was demonstrated by the authors, who have dealt with a different type of sludge lagoon in Třinec (Moravian-Silesian Region, the Czech Republic). The authors evaluated the presence of microbial biomass as high to very high, the highest in the oldest terrace of the dam. [9] The author Lencová [7] evaluated in her study higher content of microbial biomass in grassy areas that were mowed compared to not mowed areas, which can suggest that the controlled succession (management) is better for the microbial activity in the soil. The results of this work, however, can not confirm nor deny this trend. The controlled succession can be recommended in the areas left without artificial reclamation and regular lawn mowing in the areas with reclamation.

In all areas examined, however, low content of mineral nitrogen was found, which is used in large volume by plants, but its source is essentially only degradation processes of organic matter in the soil. According to Králová et al. [5] low content of ammonium nitrogen is found in the surface soil layers, especially in winter. Low detected ammonium nitrogen values could therefore be supported by the late sample collecting and the small depth. The low nitrogen content is logically followed with low content of ensyme urease in all the samples. This corresponds with the results of analysis carried out on the sludge lagoon in Třinec (another type of sludge lagoon), where a very low ureolytic activity on all the terraces was found. [9] On the monitored sites steep decline in dependence on the content of ammonium nitrogen and nitrate towards the youngest terrace was noticeable. According to the author team it can be said that ureolytic activity is directly dependent on the quality of the vegetation cover and humus content. This corresponds again to the results presented, where the oldest stand on K2 with apparent developed continuous vegetation contained the highest ureases values. The urease activity may be easily affected by contamination by foreign substances, pH, substrate concentration, temperature and agricultural management, so it is not very appropriate for determining the quality or degradation of soils. [10] Studies have shown that ensyme urease is sensitive to toxic concentrations of heavy metals. Other studies of soil samples collected from various horizons showed a decrease in urease activity with increasing soil depth. The differences were attributed to the decline of organic matter in the soil with increasing depth. Generally, the activity of urease increases with increasing temperature. [8] The urease bound to soil organo-mineral complexes is more stable than the urease in the soil solution. These complexes are highly resistant to denaturing agents, for example extreme temperatures. On the other hand, urease in soil solution can be rapidly proteolytically degraded. This suggests that much of the soil ureolytic activity is included in urease, which is stabilized by the organic and mineral colloids. A higher content of soil colloids means increment of ureolytic activity and vice versa. [1] Low urease activity in the surveyed areas could be partly related to the late collection (low temperature), insufficient soil colloids content or heavy metals content, which have not been subject of the analysis, but we can assume this content on the sludge lagoon K1 and K2 location.

The analysis also showed adverse properties of the reclamation substrate without vegetation (reclamation experiment), which should be seeded as soon as possible to avoid soil degradation. The activity of catalase in soil samples was assessed as medium to high, except of the reclamation experiment.

The protease activity was assessed as high, except of the reclamation experiment, where the values were five to ten times lower, which supports the autor's statement that the values of protease activity are at a low level in areas without vegetation or with only sparse vegetation. However, the given values can not confirm nor deny the autor's argument of the proteolytic activity independence on stand age. The statement that the proteolytic activity is higher in areas with at least partial plant cover can be agreed.

The physical parameters showed that the examined soils are generally structurally satisfactory and water-holding but actual water content of the samples was relatively low. Areas without continuous vegetation cover may suffer from desiccation. The agricultural land soil sample (we can say the most natural sample, but also human-influenced) showed no major differences from the other samples in the monitored parameters. Biochemical and physical parameters of anthropogenic soils are, of course, different from natural soils but over time can lead to a "succession" in the soil, and these values may begin to equalize.

Table 1 Nitrate content in soil samples

Sample	Nitrate Content (μg $NO_3 \cdot g^{-1}$)	Nitrate Content Evaluation [14]
1 (K1 birch)	0,110	low
2 (K1 pine)	0,088	low
3 (field)	0,163	low
4 (reclamation experiment)	0,089	low
5 (reclamation experiment)	0,137	low
6 (K2 grass)	0,036	low
7 (K2 grass)	0,087	low
8 (K2 birch)	0,093	low

Recommendations for practise

First, the main insulating layer will be constructed, which is necessary to avoid environmental contamination. That is an inescapable fact and therefore it will not be possible to leave the locality covered with succession vegetation or plant trees (forestry reclamation), because tree roots would destroy the insulating layer. It is only possible to plant shallow- -rooted shrubs and grasses (meadow grass species). Nevertheless, there are also spots where the insulating layer is not required (foreground of the sludge lagoon K1), so it was suggested not to reclaim artificially, but to leave some areas evolve. This conclusion was supported by the laboratory analysis, which showed high microbial activity in the soil on the successional stands.

In the reclamation plan six species of shrubs for planting were proposed, namely hazel tree *(Corylus avellana*), common privet (*Ligustrum* *vulgare*), barberry (*Berberis vulgaris*), black currant (*Ribes nigrum*), European Spindle tree (*Euonymus europaeus*) and blackthorn (*Prunus spinosa*). [12] Hazel tree and common privet were recommended as appropriate to plant on the location. Other species were not recommended, due to either climatic or other reasons (demands for land quality or tendency to expansion). On the contrary, other shrubs were recommended, specifically dog rose (*Rosa canina*) and hawthorn (*Crataegus laevigata*). These shrubs are appropriate with climate and soil on the locality, and in addition they can fulfill an aesthetic function. Dog rose is frost-resistant and can withstand dry habitats. Hawthorn is climate undemanding, and able to withstand dry and acidic substrates. Thermophilic species are not appropriate for the site due to a colder climate. Expansive or not indigenous shrubs are not appropriate, either. [16]

In the case of areas intended only for biological reclamation (foreground of the sludge lagoon K1), where the insulating layer is not needed, it is possible to agree with Grohmanová [3], that during the reclamation some perspective places should be left to the succession, because the occurrence of rare and interesting species of plants and animals is documented there by biomonitoring.

Lacková [6] proposed the sludge lagoon reclamation plan as a “socio-ecological” plan, which combines nature conservation requirements and social requirements, which may be considered suitable objectives that should guide proposed K1 and K2 reclamation in Rožná.

Pic. 1 Sludge lagoon K2 (source: author's archive)

Conclusion

Uranium industry can be understood as a certain controversial topic due to the potential risk arising from the operation of nuclear power stations and nuclear weapons production. But if we consider only the Rožná deposit and consult on this issue purely as a resident settled in the region, we can see the mining which is not devastating hundreds or thousands hectares of our land, but we can see a significant employer in the region, for whom currently approximately one thousand employees work. We can expect an increase in unemployment in the region, when the mining is reduced and terminated in the end, so we can also expect some negative social effects.

It is true that the natural landscape of the area was changed by human activities, we can say it is agro-industrial landscape now, with an intensive human use. The largest share of that is apparently carried by inconsiderate field uniting in the second half of the last century and the uranium mining in the area at the same time. Uranium ore mining certainly has some environmental influence, but it does not currently have any major impact on the worsening of environment quality, because the legal limits on the releasing water, dust and other risk factors are respected, and there are also preparing decontamination and reclamation works being prepared.

The sludge lagoons, which arose as a result of mining and chemical treatment of uranium ore in the deposit area Rožná, are really an important consequence of human activity in the landscape. Their negatives and positives were mentioned in this article. These water surfaces mean unquestionably some risk, but they also contributed to the increase of biodiversity in the landscape, there are a lot of species of birds and some rare species of plants. Their dams are covered with successional vegetation of herbs and trees, but most of these places will have to be destroyed because of technical and biological reclamation. In fact, it will be necessary to build isolation and covering layer over the entire body of the sludge lagoon to avoid contamination of the environment. In areas where the isolation is not necessary, it was proposed to leave some areas for controlled succession (reduction of expansive Wood Small-reed etc.). This is supported by the laboratory analysis, which showed a high microbial content in the soil samples from stands with succession of vegetation. It would be wrong to destroy a lot of years of succession on the surface and in the soil.

The analysis further showed, inter alia, a low content of mineral nitrogen, which is used in large volume by plants, but the source is essentially only degradation processes of organic matter in the soil. Plants from the *Fabaceae* family could help increase the content of nitrogen that is acceptable for plants. Analysis also showed adverse properties of the reclamation substrate without vegetation, which should be seeded to avoid soil degradation as soon as possible.

The sludge lagoons reclamation, which will progress in several phases in the following years, will be completed after the end of mining deposits and will be one of the last very important activities in the area. Precise and correct realization of the reclamation is necessary to avoid the environmental contamination. However, the sludge lagoons K1 and K2 will remain officially water constructions of the 2nd category and will be continuously monitored and maintained. Reclamation proposals of K1 and K2 are prepared and were analyzed in detail in this work. Other tree species for biological reclamation were recommended, while some of the proposed species were not recommended. Some important principles for proper planting were also recommended. The possible social use of the locality in the future was also outlined, for example recreation or nature trail. With respect to the environment and landscape engineering it is particularly important to avoid all the environment components contamination, to use appropriate indigenous trees, to ensure stability of the entire body enclosed sludge lagoon and appropriate integration of these anthropogenic structures to landscape.

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