

Ecosystem Restoration of Brown Coal Open-pit Mines

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Mineral and rock mining carried out for centuries has had significantly negative impacts on the landscape and the environment in the Czech Republic. By size, the most extensive destruction in the whole country has been caused by surface open-pit brown coal mining in the Krušné hory/Ore Mountains Foothills Basin, also known as the North Bohemian Basin. More than 400 km² have been affected by mining and by related infrastructure and industry there. Nowadays, when

a termination of active brown coal mining termination in the Sokolov and Most Basins¹ has been in sight, the future use of the closed quarries is being discussed extensively. Experts have long been aware of the great scientific significance of abandoned non-reclaimed excavations and spoil heaps. Therefore the question of applying ecosystem restoration to the above post-industrial habitats has been even more urgent than ever before.



Figure 1 The mosaic morphology of brown coal spoil heaps is determined by the way they were established and conditions the diversity of habitats created on them. A part of the Radovesice spoil heaps left to natural succession. © Markéta Hendrychová

Remediation and reclamation plans have been compiled for all large brown coal open-pits or quarries. The more progressive ones allow for leaving 10% of the area to spontaneous succession (Fig. 2). In the remaining area, costly technological (hydrological, agricultural or silvicultural) reclamation will take place. The Most-Ležáky and Chabařovice quarries have been remediated and reclaimed this way. In other ones (e.g. the Vršany and Czechoslovak Army Mine – CSA quarry) already a significant area of spoil heaps has been technologically reclaimed and new ones are planned.

Scientific importance of post-mining area

Scientific research into non-reclaimed spoil heaps and active quarries in the past decade has revealed an extraordinary biological potential of these sites. The brown coal mining areas in the Ústí Region, often referred to as the lunar landscapes, are in fact very species-rich, which is especially true in the case of spoil heaps. The different succession stages on them provide valuable habitats for a range of endangered or extinct wild animal and plant species which are rapidly disappearing from the landscape or have already vanished. Surface mines are refugia for these species in the altered agricultural landscape (see e.g. HENDRYCHOVÁ *et al.* 2008, VOJAR *et al.* 2012, 2018, ŠÁLEK 2012, TICHÁNEK & TROPEK 2016, HENDRYCHOVÁ & BOGUSCH 2016, VICENTINÝ *et al.* 2018, BERAN *et al.* 2018a, 2018b).

The importance of post-mining areas for biodiversity can be well illustrated on birds of which we have detailed information. The Tawny pipit (*Anthus campestris* – see Box 1), Northern wheatear (*Oenanthe oenanthe*) and many other legally protected or rare bird species nest in the mining areas, often in high densities. The numbers of some species in the large quarries of the Most area even match estimations of nesting populations for the entire country. Other species nest strictly in large quarries only or have the majority of their population or the only large population there. In general, large quarries are important source populations for many farmland birds, which are among the most endangered and most rapidly declining groups of the vertebrates all over Europe.

The main reasons why brown coal surface mines are so interesting to biota include:

- sufficiently large areas of sparsely vegetated or bare habitats;
- continuous formation of communities in primary succession stages;
- absence of large-scale use of chemicals and therewith sufficiency of food;

BOX 1 The Tawny Pipit: Flagship Species of Large Surface Brown Coal Mines

Due to its specific habitat requirements (low vegetation, sparsely vegetated plots), the Tawny pipit (*Anthus campestris*) has



The Tawny pipit is a cryptically coloured species with a limited voice expression, living covertly. It is therefore very demanding to monitor it. © Michal Porteš

- bedrock variety creating a mosaic of substrates of different trophic value, including phytotoxic spots where succession is blocked for a long time;
- different site ages; due to the long duration of mining, plots in various stages of succession can be found in particular parts of a quarry;
- waterlogging: thanks to the bedrock and various technological interventions in this type of the environment, a varied range of waterlogged plots are found there, from completely dry to arid through intermittently wet areas and shallow pools to larger and deeper water bodies.

Comparison of reclaimed plots and plots left to spontaneous development

The target of financially demanding technological reclamation is to create a cultural forest, agricultural land, a lake with a regulated water level, a recreation area, etc. (PECHAROVÁ *et al.* 2011). The result is an artificial landscape very poor in biodiversity. Including already inundated residual excavations (Lake Most and Lake Milada), non-productive habitats supporting a generally functional landscape and giving priority to ecological or nature conservation functions (tree rows, hedgerows, baulks, forest margins, spontaneously developing spots,

disappeared from the entire Czech Republic, except for populations capable of reproduction preserved in the surface brown coal mines of the Ústí Region. Regular monitoring since 2009, including colour marking, has shown that the Czech population counts up to 200 nesting pairs and is fully dependent on active mining and regular creation of communities in the initial stage of succession (BERAN 2020).

In the past decade, the bionomics of tawny pipit has been intensively studied (geolocation, predation, acoustic activity, nest site fidelity, genetic data, habitat requirements at different types of soil heap surfaces) (BRIEDIS *et al.* 2016, 2020). The studies were a part of a project from the Technology Agency of the Czech Republic, during which also certified management methods were prepared and suitable habitats for tawny pipit and northern wheatear were created in actively mined areas (BERAN *et al.* 2018a, 2018b). The Tawny pipit thus serves as an indicative and umbrella species in the area of large surface brown coal mines.

sands, wetlands, etc.) cover less than 9% of reclaimed brown coal quarries and spoil heaps in the Most Basin (HENDRYCHOVÁ *et al.* 2020). However, reclaimed landscapes are often unstable, requiring long-term or even permanent finances for maintenance.

Ecological restoration applying natural processes allows for gradual colonisation of post-mining areas by pioneer species and subsequently further stages of succession, with which other ecological/functional groups of species (guilds) are associated. Since the onset of individual succession stages in time and space depends on local conditions (subsoil, trophic value, slope, humidity, etc.), which are very variable in a post-mining area (see above), a diverse mosaic is created, from areas lacking vegetation or partly covered by herbs or shrubs to completely closed habitats with a developed shrub layer and scattered trees. Moreover, many ecotones are found in such environments. Early succession stages in cultural landscapes attract, for example, some pollinating insects (TSCHARNTKE *et al.* 2002). An important feature of ecological restoration is its low cost (see Box 3).

Today we have the opportunity to assess and compare areas left to spontaneous development with technologically reclaimed ones at many sites. Numerous surveys have repeatedly confirmed that ecological restoration allows for development of extraordinarily valuable



Figure 2 Brown coal mining in the Czechoslovak Army Mine (CSA quarry) will finish within five years. Large areas, particularly in the NW part of the Krušné hory/Ore Mountains foothills, have not yet been technologically reclaimed. In cooperation with the Czech University of Life Sciences Prague, the Nature Conservation Agency of the Czech Republic has delineated an extensive area which should be left to ecological restoration. © Markéta Hendrychová

habitats inhabited by endangered species at incomparably lower creation and maintenance costs (BEJČEK & TYRNER 1980, HODAČOVÁ & PRACH 2003, HENDRYCHOVÁ 2008, TROPEK & ŘEHOUNEK 2011, JONGEPIEROVÁ *et al.* 2018). From the pedogenetic point of view, non-reclaimed parts of spoil heaps are not far behind in qualitative features compared to the technologically created anthrosoils. Some spontaneously created woodlands show a higher biological soil activity and more efficient decomposition of dead organic matter, while they can also produce more timber, usually around the 25th year of development (FROUZ *et al.* 2008, 2015).

Looking for the target use of large quarries

The completed technological, hydrological, silvicultural and agricultural reclamations (e.g. Most-Ležáky, now Lake Most) have raised the question of their economic effectivity. It is not just that their implementation is extremely expensive (paid by the mining company), but also its subsequent maintenance is costly (paid by the State). For example in the case of the Most excavation, annual maintenance costs amount to an average of CZK 15 million (EUR 0.6 million), of which raising the water level fallen by evaporation costs CZK 8–10 million a year (EUR 0.3–0.4 million). Future revenues from recreation and

sales of land for economic use and development can be expected, but even though many years have passed since the lake was created, a solution for cost-effective use has still been sought. Lake Milada is in a similar situation. There, an architectural-urbanistic-landscaping competition has been started. This experience logically asks for a more sustainable solution for the remaining quarries.

In 2017, the Government of the Czech Republic stated that no target state has been determined for the currently intensively mined brown coal areas, where extensive water bodies are planned according to the current remediation and reclamation plans. It has therefore imposed to explore possibilities of effective exploitation, taking into account operation costs and simultaneously the revenues from their potential development.

Lake and yacht landscape?

In visualisations, the new post-mining ‘lake landscape’ looks fascinating. It is however questionable whether spontaneous inundation of the excavations or pumping water into them from nearby water pipes after mining and the subsequent control of the water level is realistic.

Current studies² show that it is hard to establish a long-term stabilised lake water level when

BOX 2 Memorandum of Cooperation to Identify Suitable Sites for Ecological Restoration after Termination of Brown Coal Surface Mining

The Nature Conservation Agency of the Czech Republic (NCA CR), together with Ústí Fuel Plant Company, State Enterprise and the Czech University of Life Sciences Prague, have declared their will to cooperate on identifying suitable sites for ecological restoration.

Two cooperation objectives were formulated in the joint Memorandum of Cooperation signed 3 September 2019 (NCA CR 2019):

1. Finding a sufficiently large post-mining area suitable to establish a Specially Protected Area of national importance, where the conservation target would be maintaining natural processes, preparing its protection and proposing a long-term monitoring scheme.
2. Identifying smaller areas with concentrated natural values, suitable for ecological restoration and proposing a method of preserving them.

Already in 2019, a joint working group, consisting also of representatives of mining companies of the Seven Energy AG energy group, was established to fulfil the objectives of the Memorandum and started to work.

only inflow from the respective catchment is considered. Moreover, just a small change in the flow rate may cause considerable deviations in level in the future. The assessment included a modelling of flow rates, precipitation and temperature³ for three time levels: the present, the year 2050 and the year 2100. For the initial filling of the lakes, the Ohře River (the Bílina stream was excluded for its insufficient water quality and quantity) was considered as the water source, provided a minimum residual flow rate and water withdrawal downstream is guaranteed. It was demonstrated that this source for the initial filling of the lakes has a sufficient capacity and is reliable. The time (years or decades) it will take to fill the lakes will depend on e.g. the time schedule of mining termination, *i.e.* whether to fill the lakes successively or parallel to the mining.

Controlling the water level achieved by initial filling, without the need of further water pumping (e.g. from the Ohře River) to compensate for evaporation, was shown to be sustainable in the case of the lakes considered at the sites of Bílina and Libouš (possibly connected with the Nechanice water works). Also the level of Lake Milada, which is supplied with groundwater

from overflow wells, should be sustainable. The study assessed the lake considered in the CSA as unusable for water management, as it would only be a part of a water management system with demands for controlling its own balance (compensation for evaporation). For the hydrologically reclaimed site of Most it was confirmed that the water level is unsustainable under the current climate conditions. The current water level will have to be maintained by pumping water there also in the future⁴. Neither for the lake considered at the site of Vršany a solution for a stabilised water level was found in any of the examined ways.

Placing solar power plants in post-mining areas?

Lately, in addition to hydrological reclamation, efforts have been made to use post-mining areas for energetic and other purposes in order to increase the proportion of carbon-free energy sources. In 2020, the potential of reclaimed areas was assessed, including the water level of lakes considered to be used for installing photovoltaic power plants (PVP). It was verified that building these facilities in areas of future reclaimed areas may provide a very significant power potential (maximum production estimated at 4.0–6.8 TWh/yr). Specifically in the CSA, the estimated PVP capacity is 0.66–1.04 GW⁵.

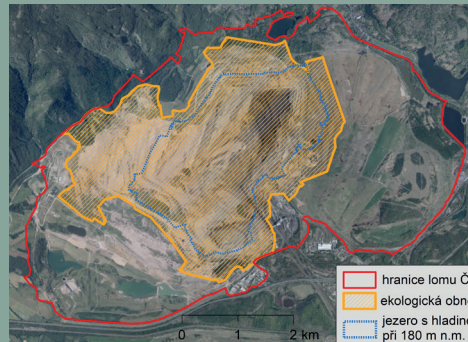
Also the use of these areas for building pumped storage power plants is being discussed. Although the economic assessment is positive in the case of the CSA and Lake Milada, it is necessary to carry out a nature and the landscape impact assessment before a decision is made to work out these plans seriously.

Ecological restoration is a solution

Although a wider application of ecological restoration has repeatedly been proposed by the Nature Conservation Agency of the Czech Republic (NCA CR), scientific institutes and non-governmental organisations, these proposals have mostly only been included in strategic documents. The Implementation Plan of the Strategic Framework Czech Republic 2030 states the necessity to protect near-natural restoration sites in disturbed areas. This is clarified in the National Biodiversity Strategy of the Czech Republic 2016–2025, which states that it is very appropriate to leave strongly disturbed or completely destroyed ecosystems (e.g. surface mining areas) to spontaneous succession combined with suitable management interventions. Near-natural restoration is also mentioned in regional strategies of the Ústí Region.

BOX 3 Applying Spontaneous Succession as an Effective Tool of Ecological Restoration of the Czechoslovak Army Mine (CSA Quarry)

The study by this name summarises the most important scientific knowledge for the application of natural and controlled succession in the reclamation of brown coal surface mines and spoil heaps. It specifically presents the possibilities of applying succession in the Czechoslovak Army Mine (CSA quarry) in two possible ways.



The size of the area suitable for spontaneous development in the CSA quarry is 12.72 km², covering approx. 44% of the quarry (6.03 km², i.e. 21%, when filling the lake to a level of 180 m a.s.l.). © Markéta Hendrychová

One assumes the construction of a lake according to the current remediation and reclamation plan with a water level of 180 m a.s.l. and leaving the remaining half to natural succession, whereas the other alternative even allows for leaving the entire area of the quarry to succession supported by water spontaneously flowing into the area up to a naturally sustainable level. Both alternatives are compared with the current reclamation plan: they provide a direction which is significantly cheaper (saving CZK hundreds of millions to billions), more efficient, to be implemented immediately at a low risk, at the same time having a higher potential for further sustainable use of the area of a considerably higher quality even with regard to climate change. The study emphasises that applying succession to restore an extensive area would – besides a considerable improvement of environmental quality and a contribution to nature conservation in the region – open an enormous potential for scientific research and tourist education and is at the same time in agreement with all applicable strategies at various levels, including the concepts of further socio-economic development of the Ústí Region (HENDRYCHOVÁ *et al.* 2020).



Figure 3 Some parts are being left to spontaneous succession in reclamation, but these are only small areas. The photo shows an area left to natural restoration at the Pokrok spoil heap. © Markéta Hendrychová

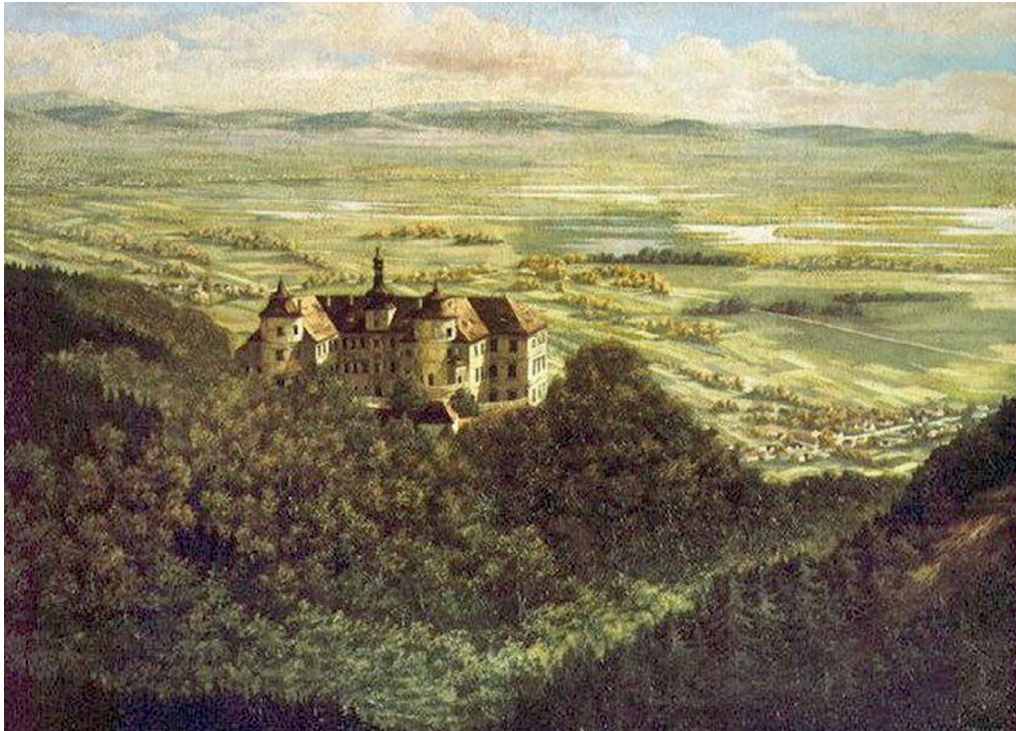


Figure 4 Komořany Lake, which used to cover the site of today's Czechoslovak Army Mine (CSA quarry), started to be drained systematically in 1835 (PECHAROVÁ *et al.* 2011). This picture postcard of the Jezeří Castle shows the state of Komořany Lake around 1880. Source: Archive of the Regional Museum in Most.



Figure 5 Habitats with blocked succession are the most interesting from the nature conservation point of view. They will long host rare early-succession species requiring bare substrates. © Markéta Hendrychová

In the planning and implementation of specific practical measures, ecological restoration has so far only been applied on a small scale, experimentally. In 2018, the NCA CR therefore started

to negotiate actively with the Ústí Fuel Plant Company, State Enterprise and Seven Energy AG energy group about delimiting larger areas for spontaneous development in the CSA and

Vršany quarries. In the end, further steps were agreed and decided on (see [Box 2](#)).

The first aim of the agreement was to select sites extraordinarily valuable for biodiversity and to exclude them temporarily from technological reclamation plans. As agreed, the NCA CR will prepare proposals to register them as Significant Landscape Elements. In updated remediation and reclamation plans, the mentioned sites should then be destined for ecological restoration or special restoration management (blocking certain succession stages).

Another objective is to determine an extensive area affected by mining (5–10 km² in size) to be left to spontaneous development and pursuant to the national legislation to be designated a Specially Protected Area where the specific subject of protection will be the protection of natural processes. For several reasons, an area in the CSA was identified as the most appropriate. First of all, still large areas with ongoing spontaneous succession escaped from technological reclamation and possessing high biodiversity and inhabited by endangered species are found there (see [Fig. 1](#)). An important reason is the fact that most of the land in this quarry is owned by the State, so no problems with ownership relations will arise. A third reason is the low percentage of temporarily excluded agricultural and forest land, because Lake Komořany covers most of the area (see [Fig. 6](#)). Of course also the soon expected termination of mining in the CSA was taken into consideration. The NCA CR therefore requested the Czech University of Life Sciences Prague to prepare a feasibility study for the CSA, which confirmed the feasibility and high efficiency of ecological restoration there (see [Box 3](#)). Its conclusions are transferrable to other sites, e.g. the Vršany quarry.

Background documents elaborated by the NCA CR in cooperation with partners have been incorporated into a document submitted to the Czech Republic Government session by the Ministry of the Environment of the Czech Republic. After decades of debate, ecological restoration has thus become an equivalent restoration option for extensive post-mining areas. It offers the Czech Republic an opportunity to implement its commitments under the EU Biodiversity Strategy for 2030 (EC 2020, PEŠOUT 2020) and an appropriate contribution to the UN *Decade on Ecosystem Restoration*, proclaimed in 2019 (UN 2019, PLESNÍK 2019). The NCA CR now has to define the extent of the territory to be restored by spontaneous processes more precisely, while taking into account other interests and conditions, in collaboration with



Figure 6 In the Vršany quarry, areas have been selected which should not be technologically reclaimed but left to spontaneous development or specifically managed.
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state enterprises Ústí Fuel Plant and Ohře River Basin, mining company Sevens Energy AG and the relevant municipalities. ■

The list of references is attached to the online version of the article at www.casopis.ochranaprirody.cz.

Notes:

¹ The government should decide on this in 2021, based on a recommendation of the so-called Coal Board. It will most probably provide for the termination of active mining in 2036–2038.

² Study of integral water management balance for the inundation of residual excavations after complete termination of brown coal mining in the Ústí Region (Czech Technical University Prague, November 2020); Analysis and assessment of alternatives of interconnected water management systems for completed hydrological reclamations (**Water Management**

Development and Construction Company, May 2020).

³ The studies did not include (due to uncertainties) hydrogeological tributaries and leakage.

⁴ In the period until 2050, the average supplement will amount to 810 thousand m³ annually, then until 2100 to 1,331 thousand m³.

⁵ Analysis verifying the feasibility of solar energy parks in reclaimed areas and areas to be hydraulically reclaimed (Deloitte Advisory, May 2020)