POSSIBILITIES FOR THE RECLAMATION OF MINING AREAS USING GREEN INFRASTRUCTURE

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1. Introduction

Over the last century, the landscape has changed significantly as a result of human activity, and it continues to do so. Since the dawn of civilisation, humanity has needed, and continues to need, a range of natural resources to satisfy basic needs and support further development. Mining activity, or extraction, refers to the anthropogenic process of obtaining natural raw materials through surface or underground mining. Mining is carried out primarily to secure resources for industry, energy production, or other necessary purposes. In 2023, the area affected by mining in the Czech Republic amounted to 52,333.6 ha (approximately 0.7% of the country's total area), with the largest areas affected by mining activities located in the Moravian-Silesian Region (42.5% of the areas affected by mining in the country), the Ústí nad Labem Region (22.3%), and the Karlovy Vary Region (14.1%).[1] Historically, mineral extraction has been most closely associated with the North Bohemian, Sokolov, and Upper Silesian coal basins, where it has significantly altered the landscape.[2] The most important raw materials mined in the Czech Republic include construction materials, especially building stone, gravel, sand, and limestone, and energy resources such as brown and black coal and, to a limited extent, natural gas and oil.[3]

2. Regulation of the negative impacts of mining activities

The extraction of raw materials entails a number of negative socio-economic and environmental impacts that significantly and irreversibly modify the Earth's surface, including original natural habitats. Mining activities therefore represent a significant destructive intervention in the landscape. According to Section 4(6) of Act No. 114/1992 Coll., on the Protection of Nature and the Landscape, the consent of the nature conservation authority is required for such significant mining interventions in the landscape. Raw material extraction itself has several life-cycle phases. In general, mining activities can be divided into the preparatory phase (involving exploration of the area and rocks, project activities, and the opening and preparation of mining works), the mining-technical phase (the actual mining and

[1] MŽPA. *Souhrnná zpráva o životním prostředí v krajích ČR 2023*. Praha, 2024.

[2] HAVRLANT, Jan. Devastace a rekultivace krajiny na Karvinsku. *Geographia Cassoviensis*. 2015, vol. 9, no. 2.; VRÁBLÍKOVÁ, JAROSLAVA. Rekultivace území po těžbě uhlí na příkladu severních Čech. *Životné Prostredie*. 2010, vol. 44, no. 1.

[3] MŽPB. *Zpráva o životním prostředí České republiky 2023*. Praha, 2024.

extraction processes, including the handling of soil and rock), the terminal phase of mining (termination of mining activities), and the post-mining, or eco-technical, phase, which is further divided into the technical phase (various forms of terrain modelling) and the biotechnical phase (the use of natural forces, sowing methods, etc.).[4]

This article focuses on the terminal phase of mining activity, when the actual process of mineral extraction has been completed and the reclamation of the affected area begins. Reclamation can be understood as a process leading to the restoration of an area affected by mining, with the aim of restoring the usability of the land.[5]

In the Czech Republic, the legal obligation to remediate and reclaim mining land after the end of operations arises in particular from Act No. 44/1988 Coll., on the Protection and Use of Mineral Resources (the Mining Act), as amended. Section 31(5) of the Mining Act (as amended on 1 July 2025) states that: *„The organisation is obliged to ensure the remediation and reclamation of all land affected by mining. For the purposes of this Act, remediation means bringing the area affected by mining activities to a stable and safe condition that will allow reclamation to be carried out in accordance with other legal regulations."*

Other legal regulations in this context refer in particular to Act No. 334/1992 Coll., on the Protection of Agricultural Land, as amended, and Act No. 289/1995 Coll., on Forests and on Amendments and Supplements to Certain Acts (the Forest Act), as amended. The basic document for subsequent reclamation as part of post-mining landscape restoration is the remediation and reclamation plan.[6]

Reclamation is crucial for the aesthetic restoration of the area and, above all, for ensuring an ecologically stable landscape. Areas affected by mining activities can be restored through several types of reclamation. These include agricultural reclamation (aimed at restoring agricultural activity), forestry reclamation (aimed at reforestation and the restoration of forest management), water-management, or hydric, reclamation (aimed at hydrotechnical measures, the creation of water features, and adjustments to the water regime), and other types of reclamation.[7]

Other types of reclamation have significant potential to support local civic amenities. These include, for example, areas for recreation and accommodation (restaurants, residential buildings, hotels, etc.), commercial and industrial use

[4] VRÁBLÍKOVÁ, JAROSLAVA. *Rekultivace území po těžbě uhlí na příkladu severních Čech*.; VRABLIKOVA, Jaroslava, Eliska WILDOVA and Petr VRABLIK. Sustainable Development and Restoring the Landscape after Coal Mining in the Northern Part of the Czech Republic. *Journal of Environmental Protection*. 2016, vol. 07, no. 11. DOI: 10.4236/jep.2016.711125

[5] HAVRLANT, Jan. *Devastace a rekultivace krajiny na Karvinsku*.

[6] AVČR. *Přírodě blízká rekultivace dolů a lomů* [online]. 2025. Available at: http://www.avcr.cz/cs/veda-a-vyzkum/avex/.

[7] VRÁBLÍKOVÁ, JAROSLAVA. *Rekultivace území po těžbě uhlí na příkladu severních Čech*.; HAVRLANT, Jan. *Devastace a rekultivace krajiny na Karvinsku*.

(solar power plants, production halls), educational and cultural facilities (schools, libraries, environmental education centres, botanical and zoological gardens, etc.), sports and leisure areas (playgrounds, shooting ranges, golf courses, riding schools, gardens, etc.), other elements of green infrastructure (public green spaces, parks, landscape elements, orchards, etc.), as well as elements of grey infrastructure (roads and paths, parking areas, garages, and parking houses, etc.).

A combination of different types of reclamation is an appropriate solution that can provide multiple benefits at the same time. Interesting examples of recreational urban reclamation include the ‚Rezidence Diorit' residential development in a former diorite quarry in the Komín district of Brno and Lamacentrum Hády in a former quarry, which focuses on environmental education and animal husbandry.

3. Reclamation of mining areas

Although the area affected by mining activities has been declining since 2001,[8] a significant proportion of mining land has still not been reclaimed and will likely require attention in the near future. Based on 2024 data from the Czech Geological Survey, the area affected by mining activities that has not yet been reclaimed covers 534.26 km².[9] The method of reclamation depends mainly on the specific conditions of the site concerned and the size of the reclaimed area. In the Czech Republic, larger areas have been used mainly for hydric reclamation (the Velká Amerika quarry, the Medard-Libík quarry, Bílá voda near Chodov, etc.), while smaller areas have more often been reclaimed for forestry or agriculture.

At present, exclusively technical reclamation is being abandoned and replaced by spontaneous natural processes. The use of natural succession is not only economical, but also helps to mitigate the effects of climate change.[10] The primary use of natural forces in reclamation is also enshrined in Czech law. According to Section 32a(1) of Act No. 44/1988 Coll. (the Mining Act), miners (legal and natural persons) and mining organisations examine the possibility of reclaiming land through nature-friendly restoration of areas disturbed by mining. In the restoration of the landscape after mining, green infrastructure thus becomes the basis for the successful reclamation of the affected area.

According to Section 10(1)(c) of Act No. 283/2021 Coll., the Building Act, green infrastructure is understood as a planned, predominantly continuous system of areas and other elements of vegetation, water and water-management features, of a natural and semi-natural character, which, in their target state, enable

[8] MŽPB. *Zpráva o životním prostředí České republiky 2023*.

[9] MŽP. Rekultivace | Envirometr. In: . 2025 [accessed 13.11.2025]. Available at: https://www.envirometr.cz/data/rekultivace

[10] AVČR. *Přírodě blízká rekultivace dolů a lomů*.

or significantly support the fulfilment of a wide range of ecosystem services and functions, including the territorial system of ecological stability of the landscape.

Green infrastructure in post-mining landscapes provides a range of ecosystem services, such as support for biodiversity, improvements in soil fertility through natural processes, reduced soil erosion, positive effects on climate and air quality, recreational and cultural use, and the provision of food sources, biomass, and other resources.[11] In order to exploit the full potential of green infrastructure, it is necessary to coordinate it comprehensively with spatial planning (including the territorial system of ecological stability and ecological corridors) and surrounding landscape management.

The introduction of green infrastructure has become a key element of soil regeneration and is considered a suitable solution for the restoration of degraded sites and brownfields.[12] The use of green infrastructure in the restoration of post-mining areas contributes to sustainable development, environmental improvement, economic support, and good living conditions for the population, and an increasing number of countries are adopting this approach in practice. Examples include neighbouring Germany, especially Saxony,[13] and Poland, especially Silesia.[14]

[11] MATHEY, Juliane et al. Brownfields As an Element of Green Infrastructure for Implementing Ecosystem Services into Urban Areas. *Journal of Urban Planning and Development*. 2015, vol. 141, no. 3. DOI: 10.1061/(ASCE)UP.1943-5444.0000275; WIRTH, Peter et al. Green infrastructure: a planning concept for the urban transformation of former coal-mining cities. *International Journal of Coal Science & Technology*. 2018, vol. 5, no. 1. DOI: 10.1007/s40789-018-0200-y

[12] MOFFAT, Andy J. Green infrastructure and regeneration of brownfield land. In: SINNETT, Danielle, Nicholas SMITH and Sarah BURGESS, eds. *Handbook on Green Infrastructure*. Edward Elgar Publishing, 2015. DOI: 10.4337/9781783474004.00030; MATHEY, Juliane et al. *Brownfields As an Element of Green Infrastructure for Implementing Ecosystem Services into Urban Areas*.

[13] WENDE, W et al. Integrating green infrastructure strategies in post-mining areas. In: *Land Reclamation in Ecological Fragile Areas*. CRC Press, 2017.; WIRTH, Peter et al. *Green infrastructure*.

[14] KANTOR-PIETRAGA, Iwona, Aleksandra ZDYRKO-BEDNARCZYK and Jakub BEDNARCZYK. Importance of Blue–Green Infrastructure in the Spatial Development of Post-Industrial and Post-Mining Areas: The Case of Piekary Śląskie, Poland. *Land*. 2025, vol. 14, no. 5. DOI: 10.3390/land14050918which is characterized by a substantial impact on the cultural heritage of mining and industry. The case of Piekary Śląskie shows the consequences of deindustrialization, which leads to the degradation of urban space and requires innovative revitalization strategies considering the principles of sustainable development and the concept of blue–green infrastructure. Archived topographic maps and current interactive maps of the study city were used in a spatial data analysis. The aim was to determine the directions of the spatial development of post-industrial and post-mining areas using the example of a medium-sized city located in the core of the Katowice conurbation, while considering the role of blue–green infrastructure in the revitalization process. Integrating blue–green infrastructure into the city's planning documents may serve as a model for other urban areas, highlighting the synergy benefits between urban development and environmental protection. Such solutions support the development of a green economy to improve residents' living conditions and increase the city's competitiveness in the region. The specific examples of the revitalization of the areas in the Andaluzja and Julian mines and the reclamation of the brickyard in the area of Kozłowa Góra in Piekary Śląskie show that a multifunctional approach to revitalization contributes to the harmo-

According to Wirth,[15] the four main advantages of using the green infrastructure concept are a systematic and highly objective assessment of the impacts of mining on the ecosystem, free from commercial and other individual interests; facilitation of the integration of municipalities' sustainable development goals; an individual approach that takes local landscape characteristics into account; and compatibility with landscape-planning tools and regional policy, including strategic environmental assessment (SEA).

An important aspect of landscape restoration is the involvement of the public, especially local residents, who can significantly support the land-reclamation process through their visions for the use of green infrastructure elements.[16] The creation of habitats with green infrastructure elements in nutrient-poor post-mining landscapes can significantly contribute to the fulfilment of European policy objectives, in particular Regulation (EU) 2024/1991 on nature restoration, i.e. the Nature Restoration Law.[17]

From the perspective of nature and landscape conservation, exposed and open areas left behind after mining activities can represent unique biotopes that provide refuge for a wide range of rare and protected plant and animal species. In the domestic cultural landscape, which is highly homogenised and focused on productivity, post-mining sites represent islands for the colonisation of organisms as part of natural succession.

The restoration of target vegetation communities in mining areas through spontaneous succession is feasible and can be fully achieved within approximately 25 years, although everything depends on the specific conditions of the site.[18] In the Czech Republic, most reclamation approaches focus on subsequent production functions and land use, but there is no regulatory framework to support non-productive areas.[19] Such retained non-productive areas can therefore become crucial for the survival of many organisms and significantly support biodiversity and habitat heterogeneity in the landscape. Hendrychová et al.[20] state that, as part of the reclamation of the North Bohemian Brown Coal Basin, productive habitats

nious development of urban spaces.","container-title":"Land","DOI":"10.3390/land14050918","ISSN":"2073-445X","issue":"5","journalAbbreviation":"Land","language":"en","page":"918","source":"DOI.org (Crossref

15 WIRTH, Peter et al. *Green infrastructure*.

16 WENDE, W et al. *Integrating green infrastructure strategies in post-mining areas*.

17 AVČR. *Přírodě blízká rekultivace dolů a lomů*.

18 TRNKOVA, Romana, K ŘEHOUNKOVÁ and Karel PRACH. Spontaneous succession of vegetation on acidic bedrock in quarries in the Czech Republic. *Preslia*. 2010, vol. 82, no. 3.

19 HENDRYCHOVÁ, Markéta, Kamila SVOBODOVA and Martin KABRNA. Mine reclamation planning and management: Integrating natural habitats into post-mining land use. *Resources Policy*. 2020, vol. 69. DOI: 10.1016/j.resourpol.2020.101882; AVČR. *Přírodě blízká rekultivace dolů a lomů*.

20 HENDRYCHOVÁ, Markéta, Kamila SVOBODOVA and Martin KABRNA. *Mine reclamation planning and management*.

significantly exceed non-productive habitats, which accounted for less than 10%. It is precisely the surface of mining sites that plays a key role in supporting biodiversity. a nutrient-poor substrate containing no organic matter allows rare organisms to survive and develop; once nutrient levels increase, competition among organisms begins.[21]

In the context of the current nutrient-rich cultural landscape, this may represent a rare biotope. From the point of view of legal protection, these sites may become subject to nature conservation, for example in the form of small protected areas. Examples include the Rudice-Seč Natural Monument, the Křtinský Lom Natural Monument, the Zlatý kůň National Natural Monument, and the Pískovna Erika National Natural Monument. Another example is the Czechoslovak Army Quarry, covering an area of 12.3 km², which was declared a national natural monument by the Ministry of the Environment in October 2025, where 269 specially protected and endangered species of plants and animals have been recorded.[22] According to Section 4(6) of Act No. 114/1992 Coll., on the Protection of Nature and the Landscape, areas disturbed by mining where nature-friendly restoration is taking place can also be protected by registration as significant landscape features with the nature conservation authority.

Significant landscape features registered in this way are protected from damage and destruction. Areas of high value from a nature-conservation perspective require specific maintenance and management, which should always be consulted on and based on independent expert assessment. a combination of forestry and agricultural management, known as agroforestry, appears to have considerable potential for the regeneration of degraded habitats, landscape restoration, and the preservation of open habitats together with green infrastructure elements.[23] In particular, silvopastoral agroforestry, a combination of livestock grazing and tree cultivation, can assist in the reclamation and subsequent maintenance of valuable habitats.

Landscape restoration after mining activities and the establishment of green infrastructure elements can be financed from various sources and subsidy schemes. According to Section 37a(1) of Act No. 44/1988 Coll., mining organisations are required to create cash reserves to ensure the remediation and reclamation of land affected by mining and the settlement of mining damage. Another option is to use current subsidy programmes and support schemes. For the purpose of reclaiming areas affected by mining and related brownfields, establishing green infrastructure, or providing subsequent care, it is possible to use, for example,

[21] TROPEK, Robert et al. Spontaneous succession in limestone quarries as an effective restoration tool for endangered arthropods and plants. *Journal of Applied Ecology*. 2010, vol. 47, no. 1. DOI: 10.1111/j.1365-2664.2009.01746.x; AVČR. *Přírodě blízká rekultivace dolů a lomů*.

[22] AOPK ČR. NPP Lom ČSA. In: *Národní přírodní památka Lom ČSA* [online]. 2025 [accessed 19.11.2025]. Available at: https://aopk.gov.cz

[23] FAO. *Agroforestry for landscape restoration*. Řím: FAO, 2017. DOI: 10.4060/i7374e

the Just Transition Operational Programme provided by the State Environmental Fund of the Czech Republic,[24] the Integrated Regional Operational Programme,[25] the Operational Programme Environment,[26] and the National Recovery Plan.[27] The specific conditions and requirements for individual support schemes are set out on the websites of the relevant institutions.

4. Conclusion

The extraction of mineral resources has a significant negative impact on the environment and landscape. It is important to realise that anthropogenic activities associated with the extraction of raw materials can fundamentally transform soil and landscape in a relatively short period of time, much faster than it took for the extracted raw material itself to form. The establishment of new mining sites should therefore respect the principles of caution and restraint. Where possible, it is advisable to locate mining sites close to places where mining has already taken place. In areas where mining has already occurred, compensatory work to restore the landscape and ecosystem functions should begin without delay.

The concept of using green infrastructure as part of nature-based restoration can assist land reclamation, support biodiversity, and appears to be an appropriate approach in the context of the challenges posed by current climate change. The use of green infrastructure in post-mining landscapes has a number of ecological, economic, and social benefits. a comprehensive and professional approach will be necessary to support nature-based landscape restoration.

Public education is also an important element, as it plays an irreplaceable role in landscape restoration and the implementation of green infrastructure; a proactive public approach can have a significant impact in this regard. In order to facilitate the introduction of green infrastructure elements in the form of nature-based restoration, it is advisable to review and integrate the current legislation relating to reclamation and post-mining activities in areas affected by mining.

[24] SFŽP ČR. Operační program Spravedlivá transformace. In: . 2025 [accessed 19.11.2025]. Available at: https://sfzp.gov.cz/dotace-a-pujcky/operacni-program-spravedliva-transformace/

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[27] MPO ČR. Zelená tranzice NPO | Investice do zelené energie. In: . 23. 9. 2024 [accessed 19.11.2025]. Available at: https://planobnovy.gov.cz/hlavni-pilire/fyzicka-infrastruktura-a-zelena-tranzice/

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Abstract

This article examines the reclamation of areas affected by mining through the use of green infrastructure and nature-based restoration. It argues that post-mining landscapes can support a broad range of ecosystem services, including biodiversity conservation, erosion control, improved soil fertility, biomass production, and climate-related benefits. The article also highlights the legal framework governing reclamation in the Czech Republic and points to the need for a more integrated and publicly inclusive approach that would better support the restoration of post-mining areas in line with contemporary environmental objectives, including the Nature Restoration Law.

Key words

Mining; land reclamation; green infrastructure; nature-based restoration; post-mining landscape; ecosystem services

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