Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

Reclamation and revitalization of post-mining sites – ups and downs

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How to cite this article:
Biegańska, J., Tora, B., Sinka, T., Čablík, V. and Hlavatá, L. (2023). Reclamation and revitalization of post-mining sites – ups and downs. *Acta Montanistica Slovaca*, Volume 28 (3), 637-654

DOI:
https://doi.org/10.46544/AMS.v28i3.09

Abstract
During the post-mining activities, all the forms of environment degradation are observed. This article refers to the projects of reclamation and revitalization of post-mining sites. The method of studying reclamation project documents was used to evaluate remedial actions. This allows for a comparative analysis of the obtained effects (the analyzed case) with the planned procedures.
It has been shown what the main effects of degradation are caused by surface and underground mining, as well as what procedures are in force for the repair processes (recultivation and revitalization).

Keywords
post-mining site, recultivation, revitalization

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Introduction

As of 2020, the global mining footprint was 57,000 km^2. Mining and mining products are major contributors to national economies, with mining value tripling in the past two decades (Young et al., 2022).

Abandoned or former mine sites are a common feature around the world: estimated that there are approximately 500,000 such sites in the USA, Australia 50,000, and Canada 10,000 (Fields, 2003; Gutiérrez et al., 2016; Gutiérrez, 2020; Abandoned Mines, 2020). Identified 95,320 mine sites in Australia, of which some 89% were inactive (Unger et al., 2012; Werner et al., 2020). Mines and their potential for reuse are an important issue.

Man's industrial activities, especially those related to mining, result in significant consequences (Frankowski
et al., 2012; Haddaway et al., 2019; Morrill et al., 2020; Azadi et al., 2020; Malan, 2021; Sanders et al., 2021; Vidal Legaz et al., 2021; Mononen et al., 2022): they initiate secondary geological processes (e.g., earthquakes), extensive depressions and surface deformations, changes in the direction of water flow and others.

The mining industry (underground and surface mining) also forces the formation of waste dumping grounds and dumps, which cause land surface deformation, a change in the rock mass stresses, and the chemical composition of groundwater. The area's transformation is also caused by the industrial infrastructure accompanying mining operations. The largest transformations of the land surface and of the landscape are found in the area of extractive industry, which is clearly visible in Silesia.

In Poland, about 7% of the country's area, including urban areas, is covered by mechanical land transformations. Numerous grounds taken for the activities mentioned above were degraded and devastated.

Statistical data (GUS, 2022) prove (Fig. 1) that devastated and degraded sites' number and surface area decreased. However, the rate of these changes is not high.

The degree of reclamation and development of devastated and degraded grounds in 2022 accounted respectively for 3.6% and 0.9% of the total area of these grounds, amounting to 62,000 ha.

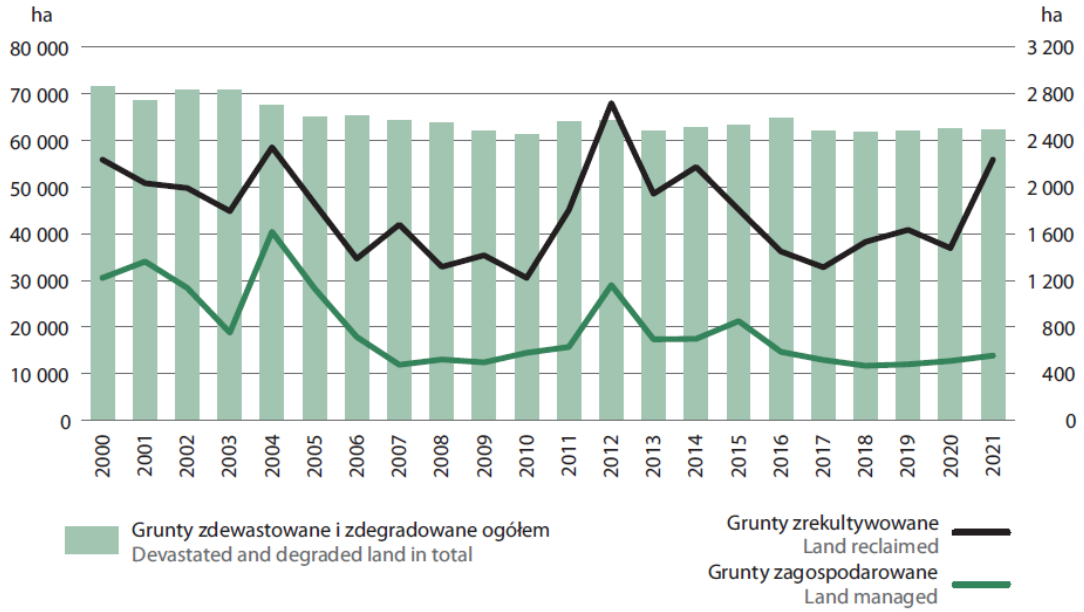

Fig.1. Devastated and degraded land as well as reclaimed and developed land Source: (GUS, 2021)

A reclamation of post-mining sites is associated with compensation for losses caused by mining operations, but in a large number of cases, it can also be a chance to increase the attractiveness of a former mine area (Polek et al., 2018; Sobczyk and Grzebinoga, 2018; Source 7).

The areas situated in the vicinity of the cities in which there is a problem of excessive tourist traffic are of particular significance. Revitalization projects for such areas are special due to their environment specificity. Polish and Vietnamese experiences in this field (Brömme et al., 2007; Łacny et al., 2019) may be an inspiration for use in revitalization projects, but also a warning against making mistakes during their implementation.

Literature review

Transformations of the natural environment make the repair process (recultivation or revitalization) necessary, but it can be difficult and time-consuming. Recultivation is compensation for the environment and is often the beginning of other, more attractive land management of post-mining areas.

It requires an interdisciplinary approach to the engagement of technical, planning, and social stakeholders (Han and Zhang, 2014; WB, 2021). Taking into consideration such relationships ensures a successful recultivation.

Recultivation - from Latin recultivare, recultum, to cultivate again, to make productive again (re-again, cultum-farming).

The term "*reclamation*" was defined in the Polish Act of 3 February 1995 on the protection of agricultural and forestry land (Source 8). Recultivation, more commonly called land reclamation, consists of giving or restoring degraded areas of useful value - carrying out a number of treatments that allow further use of the land in a different way, giving it new social functions.

Thanks to recultivation, i.e., land reclamation, a post-mining site can become an attractive cultural, natural, didactic, recreational place.

Revitalization - from Latin re - back + vita - life = revival, that is, literally bringing back to life.

Despite being widespread, the concept of 'revitalization' was introduced into Polish law at the end of 2015. According to the Act of 9 October 2015 on revitalization (Source 11), it is a process of bringing degraded areas out of the crisis, carried out in a comprehensive manner, through integrated territorially concentrated actions for the benefit of the local community, space, and economy, carried out by revitalization stakeholders based on the revitalization program. Colloquially, revitalization is understood as activities carried out after the reclamation process, conducted in accordance with the local spatial development plan of a given area, if such a plan exists. Unlike recultivation, revitalization is not currently a legal obligation of the mining entrepreneur. When undertaking a revitalization project, it strives to make sustainable use of previously degraded areas and create good conditions for the development of other activities, including, for example, the areas of closed-down mines. In turn, recultivation aims to restore useful and natural values of devastated and degraded areas from various human activities.

The differences in the process of reclamation (recultivation) and revitalization also apply to the territorial scope – a recultivation takes place within the limits of unfavorable land transformation, but a revitalization usually applies to vast areas due to interrelations, and it is not limited only to post-mining sites (Kasztelewicz, 2012).

The recultivation and revitalization of post-mining sites is a serious economic and technical problem. Especially when it concerns so-called land subsidence. Due to the limited financial resources, ad hoc undertaken measures such as leveling the surface, controlling the water circulation patterns, and restoring the soil dominate. Post-mining waste is often used for land leveling, thus creating informal landfills that may have a negative impact on surface and groundwater chemical composition.

Recultivation is the last stage of the mining entrepreneur's activity to which he is obliged by the mining license, but recultivation goals and directions should be subordinated to the methods of subsequent land management (revitalization). Due to the quality of the recultivation process, it is desirable that the entrepreneur (if he owns the land) should deal with further management and revitalization.

Revitalization is considered to be the highest form of restoring useful values to post-mining sites. The sites that require repair are classified as degraded areas if their useful value (mainly agricultural or forestry areas) decreased or as devastated areas if they lost completely their useful value due to, e.g., industrial activities (Source 8).

Degraded area - the area covered by the revitalization program on which there are negative crisis phenomena in the form of a number of harmful and destructive processes affecting the space, technical devices, society, and economy, leading to a degradation of this area (Source 11). Selected indicators should reflect the character of the area and the problems that occur there (Fig. 2).

Recommended determinants (Source 2) (for defining the crisis areas) are as follows:

social:

- high: unemployment rate, poverty level, crime rate, domestic violence rate,
- low: education level, number of social organizations (foundations, associations), voter turnout;

spatial-functional:

- degradation of the technical condition of buildings, including housing estates, insufficient equipment as regards technical and social infrastructure,
- lack of technical solutions enabling the effective use of buildings (regarding energy efficiency and environmental protection),
- lack of access to basic services or their low quality,
- a maladaptation of urban solutions to changing functions of the area,
- a low level of transportation service,
- a deficit or low-quality public areas;

economic:

- a low degree of entrepreneurship and poor condition of enterprises;

environmental:

- exceeding the environmental quality standards, the presence of waste being a threat to life, health, people, or environmental conditions.

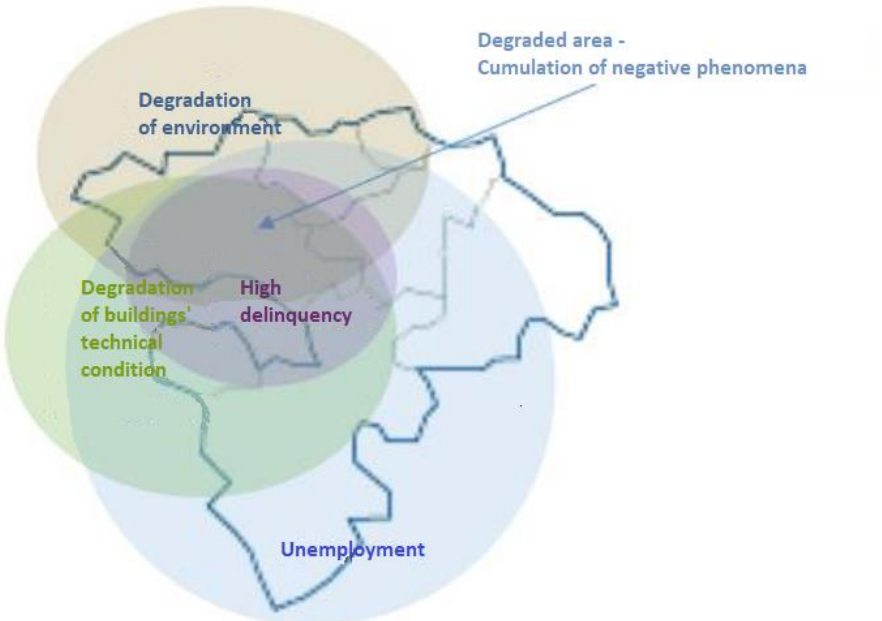

Fig. 2. Example of degraded area Source: (Source 2)

Due to recultivation or revitalization processes, the characteristics of land degradation from the perspective of transformations arising from it are important. In this approach, land degradation may concern the deterioration of the quality of environmental elements (land, soil, water, living organisms) and surface transformations (changes in the landscape).

This often results in depriving or limiting a given area's existing or planned functions.

Special conditions in which the mining industry operates should be considered while undertaking damage repair processes. In the case of quarries, it is possible to take advantage of durable – stable slopes generated during the extraction of seams for the construction of sites for diving, climbing, fishwater ponds, fun-entertainment parks, etc., as an appropriate alternative for land development (Alexander, 1996; Cao, 2007; Lintukangas et al., 2012; Mborah et al., 2016). Agriculture and forestry dominate post-mining site management directions (Miao and Marrs, 2000). Certain literature data (Cuff and Goudie, 2009; Dogan and Kahriman, 2008; Kuter, 2013; Lima et al., 2016; Sphiwe and Amponsah-Dacosta, 2016; Abramowicz et al., 2021) indicate that management of post-mining sites means a return of the function which those sites had before starting the mining processes – natural land.

In the world literature (Bangin et al., 2012; Masoumi and Rashidinejad, 2011; Narrei and Osanloo, 2011; Soltanmohammadi et al., 2010; Hu et al., 2021), the classification frames, which in eight groups put in order the ways of using post-mining sites, are presented:

1. Agriculture: Arable farmland, garden, pasture or hay-land, nursery.

2. Forestry: Lumber production, woodland, shrubs, and native forestation.
3. Lake or pool: Aquaculture, sailing, swimming, water supply.
4. Intensive recreation: Sport field, sailing, swimming, fishing pond, hunting.
5. Non-intensive recreation: Park and open green space, museum, or exhibition of mining innovations.
6. Construction: Residential, commercial (e.g., shopping center), industrial (e.g., factory), educational (e.g., university), sustainable community.
7. Conservation: Wildlife habitat, water supply (surface and groundwater).
8. Pit backfilling: Possibility of landfill (as a last resort).

A less detailed classification was suggested by Dogan and Kahriman (Dogan and Kahriman, 2008), mentioning six usage groups of such sites: Construction (Industry, housing, public buildings), Agriculture (Cultivation, productive grazing, marginal grazing, allotments), Forestry (Economic, marginal), Fishing (Economic, marginal), Recreation (intensive) (Sport, picnic sites, caravan and campsites, car parks, waters capes), Recreation (extensive) (Casual/public open space, country parks) and Wildlife (Casual education, nature conservation/education).

Details of the recultivation process were also presented in numerous publications (Brown, 2005; Hancock, 2004; Hao et al., 2010; Hendrychová, 2008; Miao and Marrs, 2000; Mishra et al., 2012; Parrotta and Knowles, 2001; Skousen and Zipper, 2014; Wiegleb and Felinks, 2001; Wirth et al., 2012; Witt, 2004; Wuppertal Institute, 2022; Source 12), indicating the fact that the recultivation problem differs significantly in relation to the country and to the region, which is subject to such processes.

The most important factors that are considered in selecting the post-mining site management system (Masoumi, 2014; Amaro, 2020) include economic, environmental, technical, and social factors, as well as identification of property rights, type of mining activity, and legal requirements.

The main directions of recultivation are listed in the Act (Source 8), Polish Standard (Source 3), and numerous publications (Maciejewska, 2000; Paulo, 2008; Pflug, 2014; Wójcik, 2018). These are the following directions:

- agricultural, forestry, and other - according to the act,
- agricultural, forestry, communal, water, and special - according to the standard.

In Poland, post-mining areas intended for forest purposes account for about 60%, agricultural areas - 20%, land covered by water recultivation - about 10%, and the same share for other purposes. They are transformed into recreational areas, housing estates, parks, sports fields, etc. (Augustyn, 2013; Chmielewska and Otto, 2014; Krzaklewski and Pietrzykowski, 2009). Such adaptations can be much more, and this requires taking into account the land and the environment analysis in terms of the factors that characterize it.

Considering the dynamic development of tourism and the number of projects related to giving new functions to the facilities/areas after mining activities, they are often created just for the needs of tourism and recreation. Another tendency related to managing post-mining areas, considered by some to be unfavorable, is the multiplication of lofts, shopping centers, and development estates (Kobylańska and Gawor, 2017; Skowron, 2011; Source 12).

Simple recultivation, as well as complicated, costly, and time-consuming land management, can be regarded as revitalization (Ostręga and Uberman, 2010). Revitalization programs require the involvement of local residents to learn about their expectations and preferences (Santarius et al., 2007; Source 11).

In the Ministry of Infrastructure and National Development, assumptions for the 2022 Revitalization Plan were developed, which was not finally created, but its assumptions were implemented by introducing a new act on revitalization (Source 11) and amendments to the acts on spatial planning and development (Source 10) and on real estate management (Source 9).

International situation

The decline of the coal era also has a number of specific impacts, either on the environment or the socio-economic aspects. Each coal-intensive region has its particularities. The multiplicity of terrain, hydro-geological profile, community development, level of technology, level of education, demographics, etc., influence this.

The environmental impact of coal mining is quite serious and long-term. A summary of the main findings on these issues is the TRACER program **(**TRACER-D2.4, 2020; TRACER-D2.5. TRACER-D3.1, 2019; TRACER-D3.2, TRACER-D3.3, 2020; TRACER-D5.2, 2022), which supports nine European coal-intensive regions. The "target regions" of the TRACER project are Lusatia Region (Brandenburg DE40 and Dresden DED2 - Germany), Western Macedonia (EL53 - Greece), Wales (UKL1, UKL2 - UK), Southeast Region (BG34 - Bulgaria), Jiu Valley, West Region (RO42 - Romania), Kolubara region (RS11 and RS21 - Serbia), Donetsk region (Ukraine), Upper Silesia (PL22 - Poland), North West Bohemia (CZ04 - Czech Republic).

The project aims to modify the research and development plan for coal regions to help facilitate the transition to a sustainable energy system.

A TRIM4Post-Mining (TRIM4Post-Mining, 2021) intelligent system/project funded by the Research Fund for Coal and Steel (RFCS) under the European Framework Program H2020 has also been established. This system of state-of-the-art monitoring technologies facilitates the observation of processes occurring in coal dumps. The project aims to support planning for the transition from coal mining to a revitalized post-mining environment.

Transition Information Modelling for the transition from coal exploitation to a revitalized post-mining land (to be completed in 2023). It supports decision-making during the transition from coal exploitation to a revitalized post-mining landscape, enabling infrastructure development for agricultural and industrial utilization and contributing to recovering energy and materials from coal mining dumps.

Degradation types of post-mining sites

Underground mining industry

Such type of exploitation causes changes in land surface on a big area. The method and depth of mining operations, the system of void elimination, and land dewatering impact the range of these changes.

The main effects of degradation caused by the mining industry are as follows:

- land subsidence, as well as associated cavities and subsidence troughs,
- flooding (marshes, wetlands),
- waste rock and coal waste dump sites,
- para-seismic bumps,
- land drying in the area of a depression funnel.

The environmental impact assessment process (EIA), which is closely linked to other permits and procedures (spatial development plan, building permit), is the basic tool for assessing the potential environmental impact of the mining industry. This type of degradation is described in the case study (Lapčik et al., 2018) summarizing the information on environmental factors that may play a role in the underground mining deposit in the Česky Krumlov - Městsky Vrch and in the Lazec - Křenov deposit.

Opencast mining industry

Using the opencast system, mining lignite, sulfur, and other minerals changes all the environmental components in direct mining activity and adjacent areas. The exploitation process causes land surface disturbance changes in the surface and groundwater system, and it generates waste–fly ashes as a result of coal combustion in a power plant.

The main effects of opencast mining degradation are as follows (Kasztelewicz and Zajączkowski, 2010):

- large-scale landscape transformations: external dumping grounds and an excavation working are generated below the initial land level; it causes changes in landscape and microclimate,
- changes in groundwater-to-surface water ratios; there is also an impact on water quality in the external hydrographic network,
- surface deformations due to deep drainage of the rock mass and a disturbance in the original static systems in the rock mass near the mine,
- degradation of land quality in terms of agriculture and forestry, permanent and temporary exclusion from the use of agricultural and forestry land, land transformation, and morphological changes related to a displacement of earth masses.

Chemical hazards associated with devices for exploration and exploitation of crude oil and natural gas, processing plants (located near mines), as well as landfills, and waste dumping grounds are additional factors worsening the condition of the environment. Old surface landfills built without taking into account natural conditions of environmental isolation and specially made insulation barriers have the greatest impact; the largest wet landfills in Poland – Machów, Żelazny Most, Gilów – do not have adequate, previously designed insulation protections.

A risk assessment (Nišić and Knežević, 2018) related to the management of these sites is a very important aspect when creating such landfills. A classification of a waste storage and neutralization facility is one of the first steps of this process.

Procedures in recultivation and revitalization processes

Recultivation is the most important environmental, social, and economic problem. The rational goal of recultivation is not only to create a stable landscape consistent with the aesthetics and surrounding environment but also to consider the intended use for future generations. In this sense, the considered recultivation should take into account the basic objectives, which, according to X. Cao (Cao, 2007), consist of:

- an elimination of threats to health and safety (removal of all the objects and structures that threaten human health and safety),
- bringing back the land and water circulation patterns (re-vegetation and land stabilization to reduce mine drainage or water pollution),
- an elimination of the environmental impact also outside the mine area,
- care for real, self-sustaining future development of the post-mining sites: it concerns environmental and socio-economic benefits (a development of public areas for recreation, historical purposes, goals related to the protection of open space or to the construction of public facilities),
- encouragement for a better use of natural resources.

Mining and land management are closely linked to dynamic and inclusive processes, where a number of environmental, production, aesthetic, land use, and economic aspects related to the objectives of planning the recultivation deal with. This process begins with an opening of the mine and ends with its closure. ICMM Tool 8 from Integrated Mine Closure – Good Practice Guide, 2nd Edition (ICMM, 2019) provides more about risk assessment and management.

Revitalization assumes an optimal use of specific conditions of a given area and strengthening of its local potentials (including cultural ones) and is a long-term process conducted by stakeholders (including entrepreneurs, non-governmental organizations, real estate owners, public authorities, etc.) of this process in cooperation with the local community.

The main features of a revitalization program that meets the requirements of the Guidelines (Source 12) are:

- completeness – full mapping of the minimum content of the document as required by the Guidelines or the Act,
- a comprehensiveness – an integration of activities in individual spheres without omitting any of the areas important for bringing the area out of the crisis. Compliance with this principle can be assessed on the basis of indicators adopted for monitoring changes in the area of revitalization. If the indicators correspond to identified problems and show how they will be overcome, the program is comprehensive;
- a concentration – the program cannot cover areas larger than 20% of the commune's area and inhabited by more than 30% of its inhabitants. Designating a too-narrow revitalization area may result in the risk of achieving no assumed revitalization goals, as it will not be possible to launch and use the local potential.
- a coherence (complementarity) – spatial, problem, procedural and institutional, inter-period, and financial compliance of planned activities.
- an implementation of the principle of partnership and participation – representatives of all the stakeholders are involved in the development and implementation of the program.

Methodology

The object under testing included post-mining sites in Poland, which in recent years were subject to complex transformations connected with processes of recultivation and revitalization. The objects that gained a

new image are presented. The damage repair work was successful – the management gave a positive result and changed the initial condition. Some cases (not many) were taken into consideration, where there was no success due to lack of organized activities and those sites experienced a complete degradation. A comparative form was accepted – imaging of the initial condition of the degraded area, showing the site's characteristics for such a landscape. In parallel, the most interesting effects, which were achieved as the result of recultivation and revitalization, are shown. An accepted assessment form of negative activities – lack or stopping of damage repair activities- resulted from the inspection carried out by the NIK (Highest Control Chamber) and the data in this scope. They also present the results of negative undertakings as regards the environment.

Tests of remediation and revitalization of post-mining sites are conducted on the base of the corrective measures planned in advance. The planned directions of remediation and revitalization consider the conditions in the post-mining sites where the degradation process occurred, resulting from the accepted procedures and elaborations. In the case of the subject matter presented in this article, the method of testing documents was used to assess the degree of corrective measures realization.

Such documents usually contain the scope of tasks accepted for a realization, financial results, a description of realization activities as well as reports on undertaken activities. The method of testing documents enables to conduct a comparative analysis of obtained results (of the case under analysis) with the planned procedures – the accepted effect includes the ups of post-mining site management. Based on some given examples (presented in the chapter "Examples of the development of the post-mining sites – ups), the obtained results are presented. Selected examples are used for imaging remediation or revitalization of post-mining sites.

A detailed analysis of the documents concerning in particular:

- a check-up of an execution of an obligation of a remediation of post-mining sites,
- a reliable determination of remediation conditions in issued decisions,
- undertaking activities (in accordance with legal requirements) in the case of unfulfillment of remediation duties

gives a reply on how the organs of public administration ensured an efficient realization of corrective processes. In the case of a negative assessment, the accepted result includes downs of the post-mining site management. The obtained results are presented in the chapter "Examples of negative land development of post-mining sites - downs" and in other examples.

Results

Examples of the development of post-mining areas - international scope

Examples (Table 1) of mine sites that have been reused in many different ways (Beer et al., 2022):

Table 1: Examples of some re-purposed mines [Beer et al. 2022]

Site	Location	New Purpose
Selby Coalfield	North Yorkshire, UK	Industrial park, business park, waste processing, storage
The Eden Project	Cornwall, UK	Botanical garden/concert venue
Zip World	Wales	Adventure tourism
Louisville Mega Cavern	Kentucky, USA	Mega underground bike park
Green Forests Work (non-profit)	Virginia, USA	Daniel Boone National Forest (restored forest)
White Pine Mine	Michigan, USA	Plant nursery for a biomedical company
Former gold mine at Lead	South Dakota, USA	Physics lab
Former mine in upstate NY	New York, USA	Data storage
Former limestone mine at Boyers	Pennsylvania, USA	Room 48, data storage
Former mine at Boyers	Pennsylvania, USA	Government office
Creekside Mushrooms Ltd	Pennsylvania, USA	Mushroom farm
NRG Dewey Prairie Garden	Jewett, Texas, USA	Farm
Lake Ore-Be-Gone	Minnesota, USA	Artificial lake
Butchart Gardens	Vancouver Island, Canada	Sunken garden
Springhill Mine	Nova Scotia, Canada	Flooded sub-surface coal mine with geothermal energy providing heating to several commercial buildings
White Mountain Publications	Ontario, Canada	Independent bookstore
Former limestone quarry	Dalarna, Sweden	Dalhalla concert venue
Gotland Ring	Gotland, Sweden	Subterranean racetrack
Lefdal Mine	Norway	Data Centre
Zollverein Coal Mine	Germany	Entertainment hub
Salina Turda	Transylvania, Romania	Amusement park

Wieliczka Salt Mine	Poland	Underground spa, museum
Roman Catholic Church	Zipaquirá, Colombia	Salt cathedral
Clube de Braga	Portugal	Soccer stadium
Tianma Pit	Shanghai, China	Shimao Wonderland InterContinental Hotel
Former iron-ore mine	Yanahara, Japan	Hypoxic running track
Kebun Raya Megawati Soekarnoputri	Indonesia	Botanical garden
Fassifern Coal Mine	Fassifern, near Newcastle, New South Wales	Pumped hydro energy storage facility [planned]
Schwenkes Dam	Greenbushes, Western Australia	Wetland habitat
Lake Kepwari	Collie, Western Australia	Recreational facility
Peak Hill Open Gold Mine	Peak Hill, New South Wales	Tourist attraction
Laverton	Western Australia	cARpeT: Reclaiming the Void art project
Hannan's North Tourist Mine	Mullingar, Kalgoorlie, Western Australia	Tourist attraction
Gove	The Gove Peninsula, East Arnhem Land, Northern Territory	Industrial and recreational areas

Former mines are the site of tourist activities such as zip lines and bike trails. They are also used as material recycling sites, part of hydroelectric power systems, and industrial parks. Many projects have been realized with the support of various organizations. They serve for the benefit and development of local society. The process of reclamation and revitalization of post-mining areas is transforming the region. New generations often do not know that these were previously mine sites.

Examples of development of the post-mining sites – ups

Wilson Shaft Gallery in Katowice

In the former pithead and bath of the Wilson Shaft (Fig. 3); area of Wieczorek Hard Coal Mine) the biggest private art gallery was established (Fig. 4) – one of the biggest ones in Central Europe (Pietrzyk-Sokulska, 2017).

Fig. 3. Wilson Shaft before revitalization Source: (Photo.: Pietrzyk-Sokulska E. and Jankowiak M.)

Fig. 4. Wilson Shaft after revitalization Source: (Photo: materials of Wilson Shaft Gallery)

Post-zinc mine heap in Ruda Śląska

On the revitalized zinc heap (Fig. 5) at 1Maja St., Ruda Śląska, the following objects were built (Source 4): an industrial playground, a historical path, a fitness room, a climbing wall, a BMX track, a toboggan hill, and numerous paths with places enabling to relax. The work on the revitalization of the heap started in January 2018, and it is almost completed. After stabilizing the heap surface, a network of walking paths was created (Fig. 6) with the state-of-the-art LED lighting.

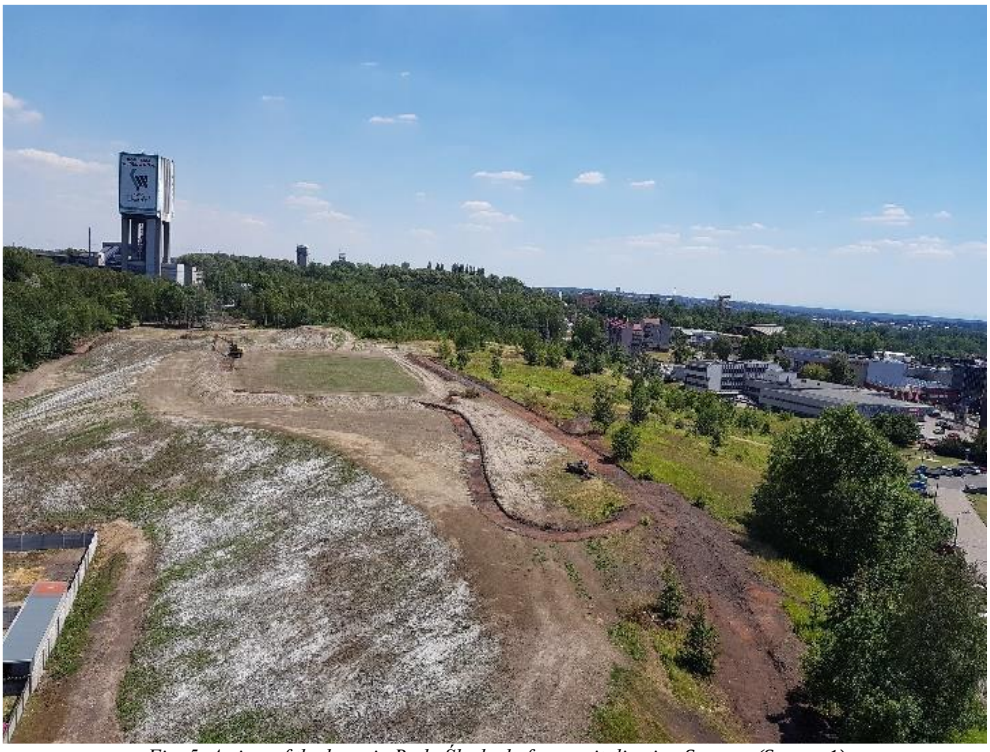

Fig. 5. A view of the heap in Ruda Śląska before revitalization Source: (Source 1)

Fig. 6. Post-zinc heap in Ruda Śląska after revitalization Source: (Photo: Municipal Administration of Ruda Śląska)

Toxic Górka Lake in Trzebinia

The reservoir located near the town center - the toxic Górka Lake in Trzebinia (Fig. 7), belongs to the most dangerous waste dumps in the Malopolskie Voivodeship.

Toxic waste was deposited at the bottom of the old quarry (Source 6). A waste reservoir in Trzebinia, containing 600,000 m^3 of highly corrosive alkaline liquid (pH = 11-13), was classified by the Chief Inspector of Environmental Protection as so-called ecological time bombs and, for several decades, it posed a serious threat to the environment. The reservoir was located above the town, and after heavy rains, several times, the chemicals were close to being spilled through its crown. The reclamation activities (Fig. 8) lasted several years (Source 5).

Fig. 7. Toxic Górka Lake in Trzebinia Source: (Photo: Marek Mędela)

Fig. 8. *Bicycle and recreation path and xerothermic vegetation covering the Górka waste heap after remediation*
Source: *(Photo:* Tomasz Nałęcz)

Examples of negative land development of post-mining sites – downs

The NIK (Supreme Chamber of Control) notes (NIK 2018) that abandoned mines (e.g., gravel pits) are becoming a place for illegal storage of garbage and various types of waste and may threaten safety due to landslides occurring there. In total, 585 excavations were subject, in the years 2013-2017, to monitor the implementation of the remediation obligation; 206 workings (over 35%) were not inspected at all, 213 (over 36%) were visited fewer times than once a year, as required by law. This meant that the local starosts did not know whether the remediation was proceeding in accordance with the law.

Machów S.A. Sulphur Mine Works

"The liquidation program (NIK, 2017) of the Machów S.A. Sulphur Mine Works for the years 2007–2013 "assumed a liquidation of the Piaseczno working" taking into account the adopted recreational development direction". The following activities were planned: sealing of the working (insulation of exposed layers of the chemical series in the liquidated working), profiling the slopes of the future reservoir, making an abrasive (coastal) surface, constructing a drainage system and the sewage system of the surrounding towns, filling the reservoir with water to the level of +146 m ASL. The areas adjacent to the reservoir and the remaining areas were to be remediated in the forest-meadow direction.

Water circulation patterns were not regulated, and the concept of water and recreational use of the Piaseczno working areas was not realized.

A landslide disaster (Fig. 9) in 2011 undermined the possibility of the reservoir's recreational use.

Fig. 9. Fragment of the reservoir, visible effects of land slide disasterSource: (Biernat G. www.parafoto.pl)

Sołtyków Sand Pit – Radom

In the former Sołtyków Sand Mine in Radom, loaded trucks entered the sand pit and returned empty (Ciepielak, 2019). During an inspection, the guards detected a truck with wastes: scraps of sponge, upholstery, and plastic residue from car interiors (Fig. 10). Wastes have been deposited illegally for a long time. It is estimated that there are thousands of tons of waste in the Sołtyków Sand Pit.

Fig. 10. Illegally deposited wastes in Sołtyków Sand Pit Source: (Photo from 2013 (Municipal Guard))

Other examples

In October 2018, policemen from Piotrków Trybunalski in the Lewkówka I Sand Pit, whose remediation should have been completed in 2017, noted an attempt to bury about 100 tonnes of waste of unknown origin (Kubicka-Żach, 2019).

The owner of TRANS-MAJ Company from Cyców bought the working aggregate mine in Włodawa. He intended to store wastes from the Lubelski Węgiel Bogdanka S.A. Mine. Within five years, one million tons of waste were to be deposited in the working - about 50,000 trucks (Barczyński, 2018).

Discussion

The article identifies the achievements of recent years and illustrates them with concrete examples of post-mining land development. The inclusion was carried out on an international and national scale. Interesting results of reclamation and revitalization projects are shown by comparing degraded areas with the new form and function they will serve.

The examples presented show that degraded land can be given new functions through reclamation and revitalization. In many cases, the negative impact on the surrounding environment is reduced.

Remediation activities planned in advance, compliance with the obligation to carry out reclamation, and securing funds for this purpose have led to the success of remediation activities - upswings.

Many reclamation and revitalization projects have been carried out with various organizations' support, which has contributed to success.

The posted examples of failed-uncontrolled activities indicate serious negative environmental consequences.

First of all, all planned activities were not followed - some were not included at some stage. Sites that were supposed to be rehabilitated became illegal landfills, resulting in serious negligence on the part of those responsible for remediation activities. Lack of control over the implementation of reclamation or revitalization activities was the cause of failures - collapses.

Analyzing the causes of ups and downs in the implementation of post-mining land reclamation and revitalization processes, it can be noted that:

- there is still a lack of legal regulations that would unambiguously enforce corrective actions,
- there is a lack of control (investor supervision) of the implementation of the reclamation obligation,
- existing financing mechanisms do not provide adequate funding for remediation activities,
- promotion of rehabilitated or revitalized sites would be an incentive to repair the environmental damage caused,
- the effectiveness of the reclamation process depends on the involvement and support (public participation) of the direct beneficiaries of the repaired area.

Conclusions

In Poland, underground and open pit mining activities have a large share in the destruction of land surface, soil cover, and vegetation cover - not only in the mining area. Waste storage changes the geological structure to a lesser extent than mining. Heaps of differentiated waste always affect adjacent land and groundwater in a disadvantageous way. Irrespective of the exploitation activity, an environmental impact is destructive. In particular, it can be seen in the case of opencast mining, where the effects of a negative environmental impact are instantaneous. Over many years, it can be observed that the number and surface of degraded and devastated grounds have decreased. However, the rate of these changes is not high. The undertaken activities are oriented toward returning useful values to such sites or giving them new functions. A recultivation is included in the mining activity (it is mandatory). The inspections, conducted by the NIK (Highest Control Chamber), demonstrated that during a period of five years, mayors of districts enacted 729 decisions concerning a recultivation, of which nearly 50% concerned a determination of the recultivation direction and over 33% confirming this activity to be finished. The presented examples concerning the post-mining sites show that new functions can be given to them due to a remediation and revitalization. In many cases, a negative impact on the surrounding environment is reduced. However, uncontrolled actions can cause serious negative environmental effects.

Conclusions that can be drawn from the discussion above:

- existing European legislation on reclamation and post-mining operations is still not effective enough to encourage mining companies to do so,
- there are no targeted units that only supervise the reclamation process,
- there is a lack of comprehensive actions, which means that there are still many post-mining areas in forest areas that remain without reclamation. This is due to activities that have an impact on the economic sector and require forest land,
- reclamation activities and positive environmental and social effects obtained as a result of the works are not sufficiently promoted.

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