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Environmental effects of coal mine closures in the Lower Silesian Coal Basin, Poland

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ABSTRACT

The study addressed the problem of hard coal mine closures in the Wałbrzych coal mining area and its effects on the natural environment and landscape functioning. Coal mining resulted in the degradation of the natural environment and losses on fixed assets caused by the surface subsidence. The purpose of the study was to identify the aspects of the restructuring process of the Wałbrzych hard coal mines concerning the state of the natural environment and landscape, evaluated from a multi-decade perspective. The study also examined environmental changes and the directions of post-mining land use. In the period of performing mining operations coal mines, the coking plants and heat distribution plants in Wałbrzych and Nowa Ruda emitted 69.90% of particulate matter and 51.12% of gases produced by all plants in the Wałbrzych voivodship. The volume of industrial waste, harmful to the environment presented a large decrease regarding the amount of onerous waste in the period 1988–2018. The state of the natural environment improved significantly as a result of coal mine closures. It was found that the ambient air pollution was mostly caused by the industrial and heat distribution plants. Further development of post-mining areas should, by all means, be continued and the good condition of the already reclaimed areas should be maintained. In the areas located near residential developments it is essential to continue searching for alternative uses of these waste heaps.

Keywords: coal mine closures, state of the environment, development of post-industrial sites, Lower Silesian Coal Basin, reclaimed areas.

INTRODUCTION

Coal has been the primary energy carrier in Europe since the mid-19th century and throughout the 20th century. As a result, European coal basins, such as the Ruhr, Saar, Donetsk, Yorkshire, and Northumberland, as well as the Upper Silesian and Lower Silesian basins in Poland, became some of the largest industrial regions in Europe. Currently, coal is still mined in 41 regions across 12 member states of the European Union. This industry provides employment for approximately 185.000 people, with additional jobs created in associated sectors (Dias et al., 2018; Pietrzykowski et al. (Eds.), 2022). Despite the development of alternative energy sources, coal remains one of the most important energy resources, particularly in developing countries and in the regions where the access to other energy sources is limited. According to the International Energy Agency (IEA, 2023), coal accounted for approximately 27% of global energy production in 2023, serving as the most important source of electricity in countries such as China, India, and Indonesia. Its significance is also evident in Europe, where some countries continue to rely heavily on coal, despite the efforts to decarbonise their economies.

Currently, the largest producer and consumer of coal in the world is China, accounting for more than half of global coal production and consumption. A similar situation exists in India, where the economy also heavily relies on coal, with

its extraction being a crucial employment sector. For China and India, domestic coal production has long been the cornerstone of energy security policy. In recent years, both countries have struggled to keep the lights on during the periods of high electricity demand even before these shocks owing to coal shortages and high prices. As a result, both governments have intensified the efforts to increase coal production since October 2021 (IEA, 2023a). In the United States, although the importance of coal has declined due to the development of shale gas extraction technologies and the rise of renewable energy, it remains a significant energy fuel. In Eastern and Central Europe, including Poland, coal continues to play a significant role. Although the European Union strives to reduce greenhouse gas emissions, coal remains a primary energy source in some member states. Poland is one of the largest producers of hard coal in Europe, and its extraction has been a foundation of the country's industrial development, particularly in Upper Silesia and the Wałbrzych region.

Government follow the phase-down of coal-mining sector in Poland. The reason for this is that most of hard coal consumed in Poland is produced domestically (in 2015 Polish mining sector produced 72.2 mln tonnes of hard coal while Polish economy consumed 71.9 mln tonnes) (Baran et al., 2018). Current energy policies are directed towards low emission economies. The traditions of hard coal mining in Wałbrzych and Nowa Ruda regions in Lower Silesia, Poland (Fig. 1) go

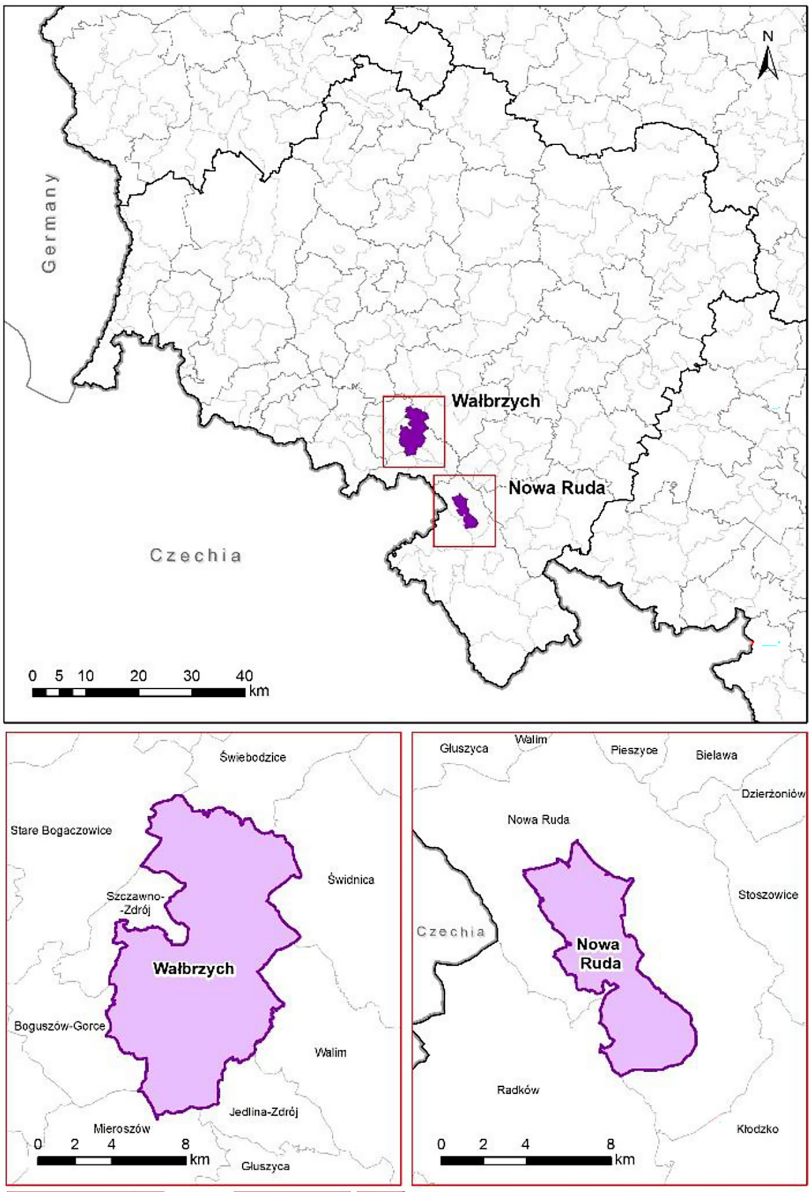

Figure 1. Location of the analyzed cities

many centuries back. The first records about coal mining in this region appeared as early as 1536, and in 1794 – the famous "Fuchs" adit was established. The intensification of mining industry development was recorded in the 19th and 20th centuries. The introduction of steam machines in industry resulted in large demand for coal; however, the absence of possibilities to transport it from the Wałbrzych region at an industrial scale acted as an incentive for the entrepreneurs representing various industry sectors to establish factories in the discussed area, thus reducing the costs of coal transport from a mine to a factory. As a result, many production plants were opened in Wałbrzych (Kosmaty, 2010). Lower Silesian Coal Basin covered the area approx. 60 km long and 25–33 km wide.

Since the 19th century, the economy of Wałbrzych was dominated by heavy industry – hard coal mining. Until 1989, coal mining in the Wałbrzych Basin was subsidised by the state (Hutnik and Jastrząb, 2015). In October 1990, an agreement was signed in Warsaw between the government and the representatives of mining "Solidarity" in Wałbrzych regarding the restructuring of the Wałbrzych region. By order of the Minister of Industry No. 49/org/90 dated October 23, 1990, hard coal mines in the Wałbrzych region went into liquidation. The "Wałbrzych Hard Coal Mines" enterprise, established in 1993, concentrated all the hard coal mines in the Wałbrzych area under one technical and administrative management (Piątek, 2007).

The closure of coal mines was supposed to take about 10–15 years at the expense of 1 trillion 200 billion PLN at that time. The plans were to follow Belgian experiences, where the coal mine closures and restructuring of the mining regions were carried out. It was planned to divide Wałbrzych miners into groups. The most resourceful ones were to receive funds to create new jobs, also for their colleagues who were dismissed from the liquidated mines. The less resourceful former miners were to be offered retraining courses in order to acquire new qualifications, useful on the labour market.

Internationally, there is a well-established expectation by industry, financiers and practitioners alike that mine closure planning should be an intrinsic element of the entire life cycle of mining from initial project design to assessment for mining approval purposes; continuing through implementation, decommissioning, as well as final rehabilitation and closure (Sweeting and Clark, 2000, Morrison-Saunders et al., 2016).

Ultimately, the government shortened the period of mine closures to just five years and each consecutive year reduced the subsidies allocated to the region. Government is the regulator of the mining industry and should act as responsible mechanism to serve the public's interest to ensure a safe and healthy environment (Swart, 2003). Mine closures have generally left behind a legacy of polluted areas, abandoned mines and ghost towns (Ackermann et al., 2018). The most intense cessation of horizontal and vertical excavations was carried out in 1991–1994. In the restructuring process covering the Wałbrzych mines, 31 new business entities were established (Kosmaty, 2011).

As Piątek (2007) reports, the disintegration of the underground structure of excavations aimed at the production concentration in the area of Julia-Sobótka shafts, the closure of mining operations and excavations in the Jan, Teresa, Chwalibóg mining areas and the target closing date of the "Julia" (Thorez) mining plant operation in 1994. The deadline for operations closure in the Julia area was set for October 1996 (Piątek, 2007). The Victoria mine was closed in 1993, the Wałbrzych mine in 1994, and the Thorez mine in 1996 (Borówka, 2010, Kosmaty, 2011, Wójcik, 2018).

In 1990-1995, the employment in the Wałbrzych Hard Coal Mines fell from 6991 to 2054 workers. Hard coal production dropped from 693 139 tonnes in 1990 to 215 043 tonnes in 1995. In the last quarter of 1995, the exploitation was carried out only within the Julia and Sobótka bottom pillar. Coal was mined using explosives. In September 1996, the last mine – "Julia" (Thorez) – ceased mining coal and only the final decommissioning works of mine excavations were carried out (Fig. 2).

Mine closure, whether temporary or permanent, is an issue that needs to be addressed with responsibility towards all stakeholders, including the mining community and the labour force (Digby, 2016; Ackermann et al., 2018). The restructuring process resulted in economically disastrous effects; however, there were numerous benefits to the natural environment.

Coal mining caused degradation of the natural environment and losses on fixed assets resulting from land subsidence (Czocher et al., 1978, Jońca and Kacperkiewicz, 1986). The Wałbrzych coal basin closure, so far assessed as exemplary particularly by the government institutions, in

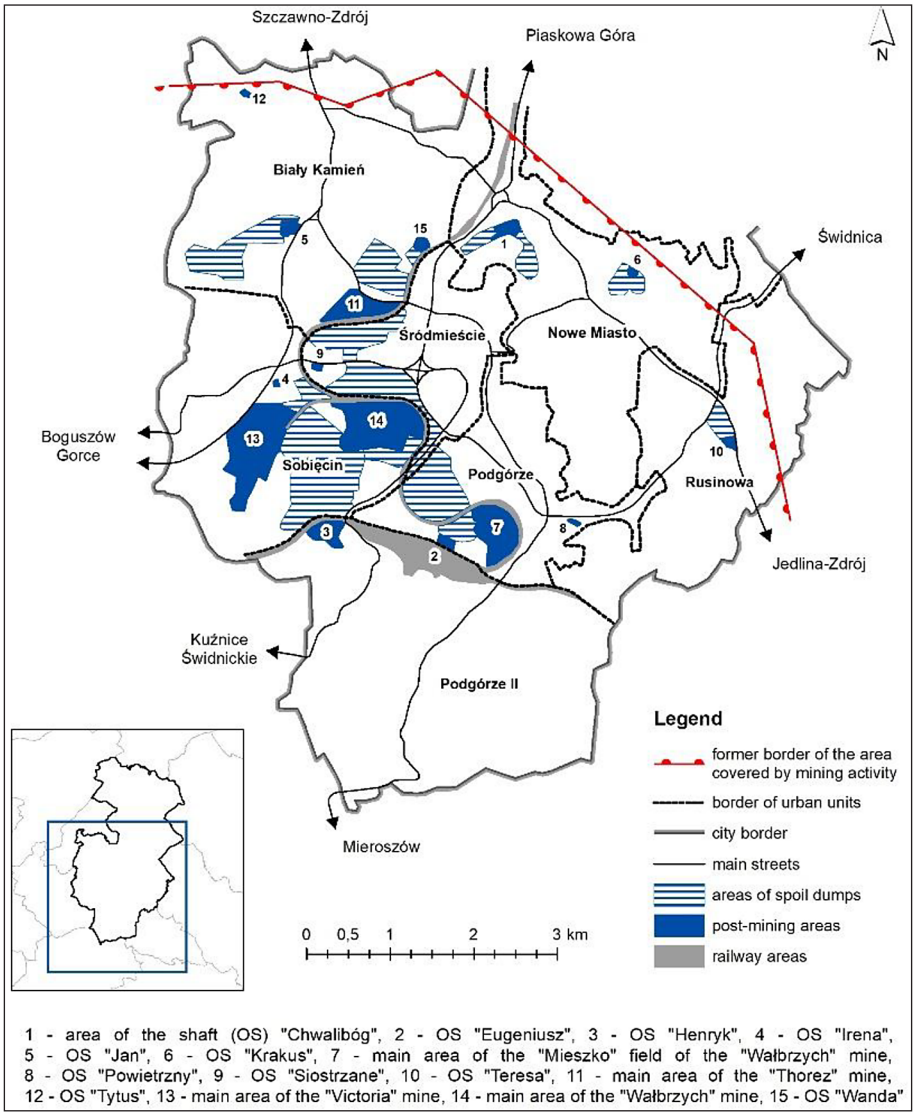

Figure 2. Location of post-mining areas in Wałbrzych in 2012, highlighting spoil heaps, post-mining sites, and the locations of mines and shafts (Dołzbłasz and Mucha, 2015)

practice did not appear to be that optimistic: high unemployment, depopulation of cities, tardiness in removing mining damage, in many cases negligence causing the destruction of individual objects, including the historic ones, remained the negative consequences of the liquidation process (Kosmaty, 2011). In addition, mine flooding turned out highly risky. As Razowska-Jaworek (2003) also reports, mining activities result primarily in the disruption of water balance in a given region, lowering the groundwater table causing depression cones and the reduction of water resources, complete drainage of some water-bearing layers, disappearance of water sources, drying up of farm wells, municipal intakes and surface watercourses as well as changes in the quality of surface and underground waters. Mine closures have consequences taking the form of further changes in the entire aquatic environment.

In the light of the aforementioned considerations, the authors pose a question whether there are any positive aspects of coal mine closures in the mining area of the Wałbrzych Hard Coal Basin for the state of the natural environment. Robb (1994) has written on the environmental benefits of coal mine closures. In recent years, with the shifts in climate policy, a number of publications have emerged on the replacement of fossil energy sources with renewable energy.

The literature extensively addresses the social and economic consequences of the closure of lignite and hard coal mines (Kolde and Wagner, 2022). Numerous publications discuss the process of mine closures in Wales, analyzing the

experiences of industrial restructuring, its impact on the regional economy, and the effects on local communities. According to Brauers (2021), the literature on the German coal phase-out deals with the decline of coal use (Lerch 2007), the roles of the relevant stakeholders in this process (Ortwin and Marshall, 2016; Weber and Cabras 2017), and the impact of the changed situation in the mining regions on their spatial and economic development (Schulz and Dörrenbächer, 2007, Brauer, 2021). Other scholars investigated past coal transitions in other countries (Caldecott et al., 2017).

The purpose of the study was to identify aspects of the restructuring process of the Wałbrzych hard coal mines concerning the state of the natural environment and landscape, evaluated from a multi-decade perspective. The research highlighted the negative consequences of coal mining operations, based on observations of environmental conditions, including the emission of harmful substances into the atmosphere and the presence of non-reclaimed landfills, mining waste dumps, dumping sites, and sedimentation ponds. The study also examined environmental changes and the directions of post-mining land use.

RESEARCH METHODOLOGY

The study was focused on identifying the consequences of mine closures approached in terms of the state of the natural environment and the landscape. The historical data published in the statistical yearbooks of the former Wałbrzych voivodship from 1988 (1989), the data provided in the Statistics Poland database and the Local Database covering 1998, 2008 and 2018 were used in the conducted analyses (Statistics Poland, bdl.stat.gov.pl).

The research area includes the closed coal mines in the Wałbrzych region and the municipalities of Wałbrzych and Nowa Ruda.

The encountered problem was a different system of statistical data registration in the period after the political transformation in Poland. In the course of the conducted research the following analyses were carried out (research stages):

- collecting information about the beginnings of hard coal extraction and mine closures in the Wałbrzych region;
- defining the purpose, methodology and the research area based on the location of mines closed in the Wałbrzych region;
- collecting historical data on the state of the environment in 1988;
- collecting and analysing the available data on the state of the environment in 1998, 2008 and 2018;
- post-mining land development analysis;
- summary and verification of the adopted assumptions.

The following research hypotheses were formulated in the study:

- H1: the closures of hard coal mines and the associated coking plants resulted in reduced emissions of pollutants into the environment.
- H2: the closures of hard coal mines resulted in the increase of green areas in the Wałbrzych region.

RESULTS

The state of the environment during the functioning of the coal basin

Among all production plants located in the region of Wałbrzych and Nowa Ruda, the largest volumes of ambient air pollutants were emitted by power generating plants (combined heat and power plants) and hard coal mines. The table below lists the industrial and heat distribution plants posing main risks to the ambient air in the region under study at the end of 1988 – shortly before the decision of mine closures (Table 1).

The hard coal mines, coking plants and also combined heat and power plants in Wałbrzych and Nowa Ruda, listed in the table, emitted 66.59% of the total equivalent of particulate matter and gases presented as sulphur dioxide (SO_2) produced by the industrial plants throughout the Wałbrzych voivodship. This chemical compound is a by-product of burning fossil fuels, thus contributing to the atmospheric pollution (smog). The activities of the aforementioned industrial plants resulted in the emission of 69.90% particulate matter and 51.12% gases produced by all plants in Wałbrzych voivodship. "Victoria" Hard Coal Mine in Wałbrzych was the record holder in the emission of particulate matter, whereas in terms of gas emissions "Wałbrzych" Coking Plant in Wałbrzych was ranked as the leader (12 945 tonnes/year).

According to Petlovanyi et al. (2020) in Ukraine, when mining 1000 tons of coal, the waste rock yield is 500 tons. Along with the

Table 1. Industrial and heat distribution plants posing main risks to the ambient air in 1988 (Statistics Poland Wałbrzych Voivodship Yearbook, 1989)

Name of the plant	Emission (tonnes/year)					
	Equivalent to particulate matter and gases presented as SO_2	Particulate matter		Gases		
		Total	Including fly ash	Total	Sulphur dioxide	Carbon monoxide
Total in the former Wałbrzych voivodship	205214	35269	28592	41635	18833	9874
"Victoria" Hard Coal Mine in Wałbrzych	65745	20342	20342	5564	4890	181
"Wałbrzych" Coking Plant in Wałbrzych	60583	3220	-	12945	2155	3661
Voivodship Combined Heat and Power Plant in Wałbrzych	5067	597	597	1820	1028	79
Wałbrzych District Gasworks	2874	56	56	170	20	33
"Nowa Ruda" Hard Coal Mine in Nowa Ruda	2388	441	441	786	391	314

negative consequences of stock-piling the rock on the surface, its delivery from the mine requires the diversion of certain lifting equipment capacity. The waste rock accumulation occupies valuable agricultural lands, leading to environmental pollution, and requires the owner to pay an environmental tax for the storage of each 1 ton of waste (Petlovanyi and Medianyk, 2018; Khorolskyi et al., 2019).

A separate problem related to coal mining in the Wałbrzych region is the huge amount of waste resulting from difficult geological and mining conditions of coal exploration (low thickness of coal seams from 0.5 m to 1.0 m, maximum up to 3.0 m). Within the boundaries of Wałbrzych city, the surface of mining waste dumps increased by 157.3 ha in the post-war period. Mining waste was generated below the surface in the process of coal mining or drilling excavations, but also on the surface of coal mines in the coal processing plants (Wójcik, 2011).

The table below lists the industrial plants with the largest amount of waste accumulated till the end of 1988 (see Table 2). The table includes the coal mines which operated in the cities of Wałbrzych and Nowa Ruda.

Deeper deposits of hard coal were mined in the subsequent years; therefore, the initial rate of waste generated by a mine amounted to 1 Mg of the extracted coal, in the years 1960-1975 the average rate reached 1,6 Mg, whereas in the last years of mine operation it presented the level of 2.0 Mg (Wójcik, 2011). The area of non-reclaimed landfills, mining waste dumps and dumping sites, at the end of 1988, amounted to 407 ha in the entire

Table 2. Industrial plants with the largest amount of waste accumulated till the end of 1988. (Statistics Poland Wałbrzych Voivodship Yearbook, 1989)

Name of the plant	Waste in thousands of tonnes					Area of non-reclaimed landfills, mining waste dumps, dumping sites and sedimentation ponds at the end of 1988
	Accumulated in industrial plants at the end of 1988	Generated per year				
		Total	Including economically used	Including conditioned waste	Including stored within internal and external areas	
Total in the former Wałbrzych voivodship	112641	5945	2411	116	3418	407
"Victoria" Hard Coal Mine in Wałbrzych	37427	869	284	-	585	63
"Thores" Hard Coal Mine in Wałbrzych	25103	611	133	-	478	51
"Wałbrzych" Hard Coal Mine in Wałbrzych	19309	823	107	-	716	49
"Nowa Ruda" Hard Coal Mine in Nowa Ruda	14622	1481	429	112	940	65

Wałbrzych voivodship, of which 228 ha (54%) was the consequence of the functioning of four mines: three in Wałbrzych and one in Nowa Ruda. Major part of the accumulated waste was already developed at that time; however, the increasing in size mining waste dumps were observed as a disturbing phenomenon. After initiating the Wałbrzych Hard Coal Basin closure, there were still 7 active mining waste dumps and a few inactive ones where post-mining waste was no longer stored.

Mining waste heaps are potential investment sites. A few years ago, the heap on Moniuszki Street was considered as a potential source of aggregate, and investors also expressed interest in leasing the 'Wiesław' heap. Aggregate from waste heaps has previously been extracted for road construction in Nowa Ruda. This raises the question of alternative waste management strategies. According to Gawron (2014), the environmental impacts in question may be reduced by the recovery of coal from coal mining waste dumps. According to the data from companies that recover coal from mining wastes, it is possible to reduce the volume of the dumps up to 45% via recovery of coal and selling part of waste rock as aggregates.

Changes in the state of the environment in 1988–2018

After 1990, as a result of the systematic closure of large plants and a decline in the size of industrial production, the share of this economy sector in air pollution decreased significantly, similarly to the other indicators showing the state of the natural environment. According to Rocha-Nicoleite and her team (2017), long-term monitoring is needed because of environmental risks associated to pollution; however, distinct targets should be established for different restoration phases. In Brazil, all areas under restoration must to be monitored at least for five years and the responsibility is of the same company (or the government) that has to conduct restoration. After this time, an evaluation is made and if the indicators (considering water, soil, flora and fauna) are not at the levels required by law, the area is maintained under monitoring. The basic volumes of discharged sewage, air pollution and industrial waste generation in the municipalities of Wałbrzych and Nowa Ruda are presented in the table below (Table 3).

A significant decline of the ambient air pollution emitted by industrial and heat distribution plants was recorded in the analysed years. In 1988, 24 692 000 tonnes of particulate matter was emitted in Wałbrzych annually, whereas in 1998 only 1 068 tonnes. A similar situation was observed in Nowa Ruda, where a decrease in air pollution emissions from production plants was recorded. The data on gases emitted by production plants in Wałbrzych also show a rapid drop in pollution from 21 659 000 tonnes in 1988 to 132 007 tonnes in 1998. The volume of industrial waste harmful to the environment, accumulated on the plant grounds in Wałbrzych and Nowa Ruda, in the years 1988–1998, practically did not change, or even increased. However, the data covering

Table 3. Basic data about the state of the environment in 1988, 1998 and 2018 in the municipalities of Wałbrzych and Nowa Ruda. (Statistics Poland: bdl.stat.gov.pl)

Specification	Unit	Wałbrzych	Nowa Ruda	Wałbrzych	Nowa Ruda	Wałbrzych	Nowa Ruda	Wałbrzych	Nowa Ruda
		1988		1998		2008		2018	
Industrial and municipal waste water, requiring treatment, discharged into surface waters	Total [dkm^3]	27 884	3640	No data	No data	4 659	641	3 988	608
	Total per 1 km^2 in dkm^3	328	108	No data	No data	55	17	47	16
Ambient air pollution by industrial and heat distribution plants	Particulate matter [tonnes/ year]	24 692 000	490 000	1 068	178	No data	No data	141	2
	Gases [tonnes/ year]	21 659 000	1 265 000	132 007	87 674	No data	No data	300 562	6 784
	Including sulphur dioxide [tonnes/ year]	8 396 000	503 000	2 278	266	No data	No data	173	33
Industrial waste harmful to the environment accumulated on the plant grounds [status at the end of the year]	[thousand tonnes]	82 100	14 633	82 816	20 905	No data	No data	8 538	1 259
	per 1 km^2	966	396	1.27	0.45	0.5	0.0	0.5	0.02

2018 show a strong downward trend in the volume of waste harmful to the environment, both in thousand tonnes and per 1 km^2. A significant decrease in the volume of industrial wastewater discharged into surface waters was also observed.

The negative environmental, economic and social impacts of mining industry waste indicate that the industry needs to rethink waste management methods and implement new solutions. One effective option in this direction is to reduce mining waste through the implementation of the advanced coal mining technologies and the use of more powerful equipment, as well as maximizing the use of waste rocks already accumulated in waste rock dumps as raw material for other branches of industry and agriculture (Kostenko et al., 2023).

Development of post-mining areas

The closure of both Wałbrzych and Nowa Ruda hard coal mines was the first process of this type carried out at such a large scale in Poland, which was also the main reason for many irregularities and ill-considered decisions in the course of its implementation. Poorly coordinated and chaotic activities were predominantly limited to coal mine closures. Mining industry liquidation resulted, among others, in extensive city areas, so far used by coal mines and coking plants, losing their previous function. The issue of reusing post-mining areas remains one of the most important problems in Wałbrzych, the solution of which should be considered essential in terms of the opportunities for the city spatial development in a coherent and harmonious manner, in accordance with the principles of spatial order (Dołzbłasz and Mucha, 2015). Landscape connectivity and ecosystem resilience have been considered important features for the definition of priority areas for restoration (Stefanes et al., 2016, Rocha-Nicoleite et al., 2017).

In the case of Wałbrzych, the process of coal mine closures brought about significant transformations in the city landscape. It was the effect of extensive changes within the Wałbrzych industrial areas, where individual coal mining plants were located. After abandoning coal excavation, the majority of surface constructions, belonging to these enterprises, were either dismantled or demolished. They most often presented poor technical condition or, because of their specificity, could not be adapted for other purposes (Płonka et al., 1999).

The current development condition of the Wałbrzych post-mining areas is very diverse in terms of both their functionality and the conducted business activity. The developed post-mining grounds in Wałbrzych covered 1.94 km^2. Currently 0.88 km^2 of this area (45%) is a wasteland, 0.6 km^2 (31%) performs industrial functions and 0.46 km^2 (24%) plays service, educational, tourist, recreational and residential roles. Allowing such space to remain a wasteland is a highly unfavourable situation from the city development perspective and needs to be changed. In order to minimise the unused land, an extensive reclamation of the largest areas of this type should be performed and focused on increasing the investment attractiveness of such land. It should also be emphasised that a vast part of these areas is located in the immediate vicinity of the city centre (Dołzbłasz and Mucha, 2015, Wójcik, 2018).

In addition to mining infrastructure areas, the post-mining grounds are also characterised by the, so-called, mining waste dumps (spoil-heaps, settling tanks). At present, the best situation refers to coal dust settling tanks, their embankments have been, for decades, covered by forests and have almost entirely blended in with the mountain landscape of the surrounding terrain. In turn, the situation of the mining output dumping grounds is less favourable, and these areas constitute more than half of the Wałbrzych post-mining sites. Their reclamation had already been neglected in the period of mining activity, even though it should have been performed on a regular basis.

After coal mine closures, numerous works related to levelling heaps, planting trees or building drainage systems were carried out. It is worth highlighting that the processes of revitalisation and reclamation in post-mining areas aim at allowing their re-use, usually by introducing new functions (Dołzbłasz and Mucha, 2015). In addition to mining waste dumps, also settling tanks were formed as an effect of the mining process. For several years after mine closures, the extraction of secondary raw materials and coal sludge was still continued on these sites (alternative fuels – a settling tank contains a dozen or so percent of coal). Table 4 presents the methods of mining waste dumps development after mine closures.

Since 1996 the existing mining waste dumps were predominantly reclaimed into forests. The steep slopes of some spoil-heaps were covered with turfing and shrubs. During the reclamation process, the top cover of spoil-heaps was often levelled and the slopes were terraced, which limited the intensity of mass movements and erosion.

Table 4. Reclamation method of mining waste dumps and dumping grounds after coal mine closures in the area of Wałbrzych and Nowa Ruda

Name of the plant	Name of the mining waste dump	Reclamation orientation	Current owner	Form of land use
"Victoria" Hard Coal Mine in Wałbrzych	"Victoria" mining waste dump	Forest	State Treasury	Forest
"Thores" Hard Coal Mine in Wałbrzych	"Wiesław" mining waste dump	Forest, partly recreational	State Treasury	Motor rallies and off-road car motocross races are held at the mining waste dump
	"Krakus" mining waste dump	Forest	State Treasury – State Forests	Forest
"Wałbrzych" Hard Coal Mine in Wałbrzych	"Matylda" mining waste dump	Forest	State Treasury	Forest
	"1-go Maja" mining waste dump	Forest	State Treasury – State Forests	Forest
	"Moniuszki" mining waste dump	Recreational	Wałbrzych Municipality	Forming recreational facilities playgrounds, bike paths, communication roads and routes, viewpoints
	"Staszic" mining waste dump	No data	Wałbrzych Municipality	No data

Once priorities are established, restoration activities usually focus on tree species diversity, and they may include both passive restoration and many types of active interventions (Chazdon, 2008, Omeja et al., 2011, Rodrigues et al., 2011, Rocha-Nicoleite et al., 2017, Ignatyeva et al., 2020). Such activities also aimed at adopting these forms by making them similar to the neighbouring natural hills in the area, covered with forests. It improved the landscape aesthetics of the Wałbrzych Upland slopes, where the previous spoil-heaps are currently similar to the hills of natural origin. Since the moment mining waste dumps were no longer used, favourable conditions for plant succession were created. Moreover, the reclamation of mining waste dumps has also contributed to a significant reduction in the ambient air dust levels caused by these forms. The reclaimed spoil-heaps are currently owned by the State Treasury, State Forests Administration and the city of Wałbrzych (Wójcik, 2018).

For post-mining areas in the North American Great Plains, the mining companies are obliged to keep records on restoration activities for ~50 years, which also facilities adaptive management to achieve the desired target (Rinella et al., 2016). In the case of forest restoration, the time to achieve the structure of reference ecosystems can be very long (Rocha-Nicoleite et al., 2017). Changing the form of using mining waste dumps constitutes, beyond any doubt, a positive aspect of coal mine closures (Fig. 3, 4). However, some of the post-mining areas within the Wałbrzych Hard Coal Basin still remain the post-industrial wastelands.

The immediate surroundings of Wałbrzych are valuable both in terms of nature and culture – it is worth mentioning the Książ Landscape Park, the palace complex in Książ, and the "Former Mine" Museum of Industry and Technology founded based on the surface industrial constructions of the closed Thorez mine (Julia). The important factors affecting tourism development opportunities are the city good transport connections with the capital of Lower Silesia and the international routes to the Czech Republic and Germany passing nearby.

Each country creates its own scenarios for the development of the energy sector, which aim to identify different directions of development, which are feasible, and moreover, which support the formulated policy objectives (Kochanek, 2021; Krann, 2019; Snoek, 2003). The governments of most countries have changed their energy mixes through supporting power generation from renewable energy sources and production in combined cycle gas-fired units. as a result, global coal consumption has decreased (Kaszyński et al., 2020). Following the mining industry, the Wałbrzych region was left with vast deposits of waste rock. Thus, reducing the technogenic burden of waste rock dumps on the environment by increasing the level of utilisation of solid coal-mining waste is an urgent scientific and technical task (Kostenko et al., 2023). The current primary approach of land management – afforestation – is

Figure 3. Post-mining landscape in the area of the heap of the "Wałbrzych" Coal Mine, Podgórze district

Figure 4. Reclaimed post-mining areas in Wałbrzych

the simplest but does not always yield the desired outcomes. It is necessary to consider alternative methods of managing waste heaps, including their use for construction purposes, road building, and other applications.

The conducted studies revealed that re-using the post-mining areas still remains a significant problem in the Wałbrzych area. The analyses, however, indicate a positive direction of the ongoing transformations. Bearing in mind that the focus of the analysed area development is placed on tourism, the existing mining facilities could be opened to tourists by creating a thematic trail of industrial heritage. The new usage of the area under study should primarily take into account the historical traditions and cultural heritage. Some of the remaining mine shafts, classified as technical relics of the past constitute, among others, a specific attraction of the describe landscape. The elements left behind from the former mines and the entire natural potential (landscape and cultural resources) should be taken advantage of for the benefit of Wałbrzych tourist development. In addition, view platforms and towers could be placed on the spoil-heaps. If properly managed, the latter can also perform recreational and leisure functions. Improving the aesthetic appearance, more extensive afforestation or setting tourist trails and bike paths are just a few of the possible options for the dumping grounds development. The slopes of large spoil-heaps, along with natural sloping surfaces, can also be adapted for practising such sports as skiing, sledging or mount biking. Utilizing mining-waste dumps for various purposes will definitely upgrade the tourist attractiveness of the area. As a result of such actions, the city could be promoted through carrying out both cognitive and educational projects related to the industrial heritage of the region.

CONCLUSIONS

The conducted research confirmed the formulated research hypotheses: H1 regarding the reduction of pollutant emissions to the environment resulting from the liquidation of hard coal mines and the associated coking plants, as well as H2 referring to the increase of green areas in the Wałbrzych region. On their basis, both general and specific conclusions can be presented and addressed to the local authorities and the state government responsible for the restructuring of the Lower Silesian Coal Basin:

1. The biggest greatest with the restructuring of the Lower Silesian Coal Basin was the lack of knowledge and experience of the institutions responsible for the implementation of this undertaking within the scope of the tasks entrusted to them.
2. The grounds after the liquidation of mines represent degraded sites, strongly transformed by a man, nevertheless still valuable in terms of nature, landscape and culture, which are currently being developed for the purposes of nature, recreation and leisure oriented functions.
3. Further development of post-mining areas should, by all means, be continued and the good condition of the already reclaimed areas should be maintained. Properly reclaimed mining waste dumps blend well into the mountainous forest-covered landscape of Wałbrzych.
4. Waste heaps (composed of waste rock) remain hazardous. Alternative solutions should be explored to restore the landscape to its natural state, especially in the areas located near residential developments, due to issues such as sinkhole formation, slope instability, and the composition of the heaps. Therefore, it is essential to continue searching for alternative uses of these waste heaps.
5. The state of the natural environment, in the analysed period of 1988 – 2018, improved significantly as a result of coal mine closures. It was found that the ambient air pollution was mostly caused by the industrial and heat distribution plants.

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