

Article

Examining Sustainable Transition and Post-Mining Management in the Ruhr Region and the Prospective Evaluation of Knowledge Transfer to Kosovo's Mining Sector

Kemajl Zeqiri ¹, Tansel Dogan ², Stefan Möllerherm ² and Sara Kasmaeeyazdi ^{3,*}

¹ Faculty of Geosciences, Department of Mining Engineering, University "Isa Boletini" Mitrovica, St. "Ukshin Kovacica", 40000 Mitrovica, Kosovo; kemajl.zeqiri@umib.net

² Research Center of Post-Mining, TH Georg Agricola University, 44787 Bochum, Germany; tansel.dogan@thga.de (T.D.); stefan.moellerherm@thga.de (S.M.)

³ Department of Civil, Chemical, Environmental and Materials Engineering, University of Bologna, Via Terracini 28, 40121 Bologna, Italy

* Correspondence: sara.kasmaeeyazdi2@unibo.it

Abstract: Despite the long tradition of mining activities in Kosovo, there is still the a lack of policies for post-mining. Specifically, focusing on coal mining, this research analyzes the sustainable transition and post-mining management in the Ruhr Region, exploring the potential for knowledge transfer to enhance mining practices in Kosovo. The research aims to identify transferable strategies for sustainable mining transitions by examining environmental, social, and economic dimensions. Through comparative analysis, the study assesses the applicability of Ruhr's experiences in fostering environmentally responsible mining practices in Kosovo and beyond. Similarities and possible challenges are discussed based on the environmental and socio-economic points of view. The findings contribute insights into effective post-mining strategies, facilitating knowledge transfer to regions undergoing similar transitions and thereby fostering sustainable mining practices globally.

Keywords: post-mining; abandoned mine site transition; environmental remediation; coal mine remediation



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1. Introduction

In the development of the European nations, mining has often been an important factor and is therefore a part of European history. Raw materials such as fossil fuels, copper, iron, silver, potassium, rock salt, coal, bauxite, and uranium provided the basis for technological and social progress all along this path. Probably the most important and impressive innovation in mining was the mass production of coal, which was closely associated with the technical revolution and industrialization in the 19th century [1].

The extraction of these raw materials from the surface or subsurface leads inevitably to an intervention in the landscape and in the natural environmental compartments of air, soil, and water, as well as in biodiversity and habitat change, even in the social surroundings and in the life of the local population. Depending on the technology in use and the management practices adopted, mining and raw material processing can cause considerable environmental degradation, industrial pollution, loss of vegetative cover, land degradation, and ecosystem disruption. Mining dumps and tailings are frequently the principal source of solid waste as well as liquid waste pollution, affecting public health and social community development. Mining, concentration, and refinement processes may also cause the contamination of ground and surface waters with toxic chemicals and metals. An example is air, water as well as soil pollution detection around the mining waste area of the Rio Tinto Mining District located in the southwest of Spain [2]. Excess copper, nickel, mercury, cyanide, zinc, lead, and cadmium all have negative biological effects on the human body and other beings in the food chain, while the dust and water in the mining

environment can make it a hazardous workplace. An example of this case is the red mud dust waste in a bauxite tailings dam (red mud), located near Podgorica in Montenegro [3]. In addition, inefficiencies related to underutilized capacity, equipment malfunctions, a lack of reagent controls, irregular operating regimes, and the use of high-sulfur fuels contribute significantly to adverse environmental impacts. The management of the environmental impacts of extraction during operations can help minimize these impacts and the future cost of environmental management. However, with the cessation of the mine, these adverse environmental impacts will not stop; in contrast, they remain existing. Most of the environmental issues at closed mine sites, both open-pit and underground, are the same as those at active sites. The only major difference might, but does not have to be in the grade of severity and overall extent of the impact. In the social dimension, post-mining facilities, including waste dumps, strongly grow into the landscape and social awareness.

On the contrary, the mining industry is commonly linked with a myriad of adverse effects on a global scale, encompassing environmental degradation, social impact, and economic setbacks.

In general terms, the mining of mineral resources comprises three main stages: (i) exploration of the mineral resources, in which studies are undertaken to determine the technical conditions and economic profitability of a certain mineral deposit, usually ending up in a feasibility study for the mineral deposit. (ii) The second stage follows up by mining the valuable mineral resources. This stage lasts for a long time and is expected to end after mineral reserves are depleted; however, in practice, excavation of mineral resources might be stopped before reserves are depleted for many reasons (e.g., economic crises, socio-environmental issues, etc.). (iii) The third stage is the so-called “post-mining” stage, which consists of post-closure care and maintenance. Since the impact of mining on the environment as well as on the community is multidimensional and hard to predict, the end of the post-mining phase cannot be foreseen. Community, safety, economy, environment, and efficiency are the dimensions of sustainable mining practices that should be considered before, during, and after mining operations, since economy, environment, and community represent the pillars of sustainable development [4]. Furthermore, the United Nations declared that a raw materials policy can only really be sustainable if it also includes post-mining issues [5]. There are successful examples where post-mining led to extra opportunities for the local inhabitants. For instance, the so-called “potentials” of mining regions are defined by Wirth et al. as legacies of mining activities. Mining areas could be valued after mineral extraction for their natural and cultural potential. Natural potentials are post-mining landscapes, renewable energies, and thermal water. Cultural potentials are artificial relicts such as technical structures, buildings, and infrastructure, as well as the traditions of miners. It makes sense to distinguish between them because the two categories are valued differently [6].

Kretschmann et al. emphasized that, as mining can lead to consequences that have a permanently adverse impact on people and the environment, they have to be managed as best as possible. In Germany, the tasks to be faced at the post-mining stage of hard coal mining are called “perpetual obligations” or “perpetual tasks”, pointing out they have to be coped with almost endlessly [7].

One challenge is that since mining activities during centuries had many ups and downs, closing–returning based on social-economic and technological developments, there are no precise statistics of post-mining and their exact environmental worldwide consequences [8]. However, the post-mining transition is still a key area for research, policy, and practice, in part due to the increasing number of mines closing and expected to close in the coming decades around the world [9]. It is also important to note that, generally, there is a poor track record of mine closure [10] and that many mines close unexpectedly [11]. Moreover, opening new resources should be carried out in respect of all promising environmental standards regarding post-mining management, such as reuse, recycling, re-cultivation, and remediation activities [8].

Regarding the post-mining situation in Western Europe, Wirth et al. highlighted that the lack of European and national support as well as the inconsistent forms of multi-level governance and local obstacles can obstruct innovative and successful forms of regional management, trying to involve new ways of using post-mining potentials to promote development [6].

The purpose of this paper is to discuss post-mining transition challenges by focusing on the Ruhr Area in Germany as a successful example, aiming to transfer knowledge to the Kosovo and Western Balkan Regions, which in the next few decades will have to cope with similar post-mining challenges. The successful transition in the Ruhr Region is studied, and possible challenges are presented to clarify necessary considerations from environmental, economic, and social points of view. Since the post-mining topic is quite wide, this paper's focus is on general lessons learned from Ruhr Area transitions and possibilities to simulate similar factors in Kosovo and the Western Balkan Region.

2. Overview of the Research Sites

2.1. Mining and Post-Mining Practices in the Ruhr Area

In Germany, industrial underground mining of hard coal began in the early 19th century. In a period roughly 200 years ago, several hundred mining companies of different sizes existed, mostly located in the Ruhr Area and in the Saar Region, where Germany's largest hard coal deposits can be found. By the end of the 1950s, the German coal mining industry produced 150 million tons of hard coal per year in 170 collieries with 600,000 employees. At that time, 70% of the primary energy demand of the Federal Republic of Germany was covered by domestic coal [7].

Coal was the driving engine of the iron and steel industry in the Ruhr Area, supporting the growth of national economic development. At the end of the 1950s, approximately 13% of the gross domestic product was still attributed to the Ruhr, which accounted for 8% of the population of West Germany [12]. Due to the rise of oil as a source of energy, cheap coal imports from countries such as the US, and the increasing availability of less-expensive steel on the global market in the 1960s and 1970s, the Ruhr's core industries—coal, steel, and related industries—began to collapse, and the region witnessed a sharp industrial decline and rising unemployment. Because of this, in the 1980s, the Ruhr Area lost more than 10,000 industrial jobs, which was reflected by an unemployment rate of more than 15% in 1988. By the 1990s, about two-thirds of coal, steel, and related industry jobs were gone. Without a doubt, this situation has resulted in socio-economic problems, which is why the regional industry needed a sustainable restructuring and transition [13].

Converting former coal mining and industrial sites for new economic activities indeed presents significant challenges due to remnants of prior use, such as soil and water pollution, mining shafts, and outdated infrastructure. These challenges require substantial investments in site conversion. In Germany, over the last three decades, urban renewal initiatives have encouraged socio-economic transition in old industrialized locations, promoting new forms of urban tourism and converting closed factories into heritage sites to enhance destination attractiveness and foster entrepreneurial activities in tourism and services [14]. The Ruhr Regional Association (RVR) has been a key player in driving the transformation of the Ruhr Area since its establishment in 1920. Through its role in coordinating efforts and fostering collaboration among municipalities, the RVR has been instrumental in repurposing former industrial sites into cultural and leisure hubs [15]. Furthermore, it must be pointed out that Germany has a long tradition of solving environmental problems from mining activities, since there is a very good interaction among mine authorities, mining companies, and the mine workers' union.

In 1968, the remaining mining companies in the Ruhr Area merged their coal activities under the supervision of the Ruhrkohle AG, intending to create a healthy economic and social basis for the coal industry and its employees. Furthermore, hard coal production received state subsidies to ensure the supply for domestic power generation and coking coal, as well as to maintain jobs in mining. In 1997, Ruhrkohle AG was restructured and

renamed RAG Aktiengesellschaft (RAG AG). The operation of mines was step-by-step separated from other business units to optimize funding opportunities and to draw a line between profitable and subsidized business activities. In 2007, the federal government, the state governments of North Rhine-Westphalia and Saarland, the trade union for mining, chemistry, and energy, and RAG AG agreed to discontinue subsidized support of hard coal mining in Germany by the end of 2018 in a socially acceptable manner. Based on this agreement, the RAG Foundation was established on 26 June 2007, to liquidate the German hard coal industry in a socially acceptable way and to finance the perpetual tasks of hard coal mining [16,17].

Following the end of hard coal mining, three perpetual tasks must be dealt with: mine water management, polder measures, and groundwater purification. The related activities are collecting the underground mine water with powerful pumps and pipes; discharging this water into watercourses like the Ruhr River; regulating surface water in subsided areas; draining and purifying contaminated groundwater; and regular monitoring of groundwater. These tasks have to be carried out for an indefinite period of time; all of them concern the management and control of water, as given in Figure 1.

The RAG Foundation is responsible for financing these perpetual tasks. In addition, it funds projects in the fields of education, science, and culture in the former mining regions along the Ruhr and Saar Rivers as well as in Ibbenbüren, a smaller mining area in the northern part of North Rhine-Westphalia [18].

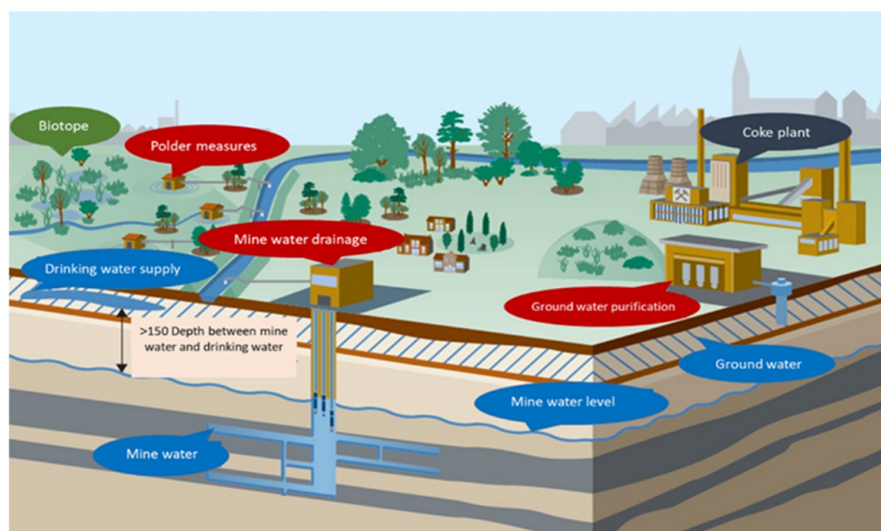


Figure 1. Eternal tasks of former hard coal mining in the Ruhr Area [19].

The income side of the foundation's model is based in part on a mix of diversified capital investments with broad risk diversification, comprising shareholdings, government and corporate bonds, managed funds, and equity investments in medium-sized enterprises and real estate companies. However, the foundation generates most of its regular income with the help of its strategic equity investments in Evonik Industries AG, VIVAWEST Wohnen GmbH, and its holding company RSBG SE, as shown in Figure 2 [20].

The German strategy for mine closure consists of the reduction of social impacts, economic beneficiation, and mine heritage preservation. Thus, it aims to commit the mine companies to collaborate closely with responsible institutions on national, state, and regional/local levels, as well as political parties, municipalities, and trade unions, for a sustainable post-mining transition. The closure of hard coal mines as well as the related transition have taken place for years in Germany, bringing a wide range of tasks that have to be fulfilled. Table 1 summarizes the socially acceptable adjustment of the hard coal industry.

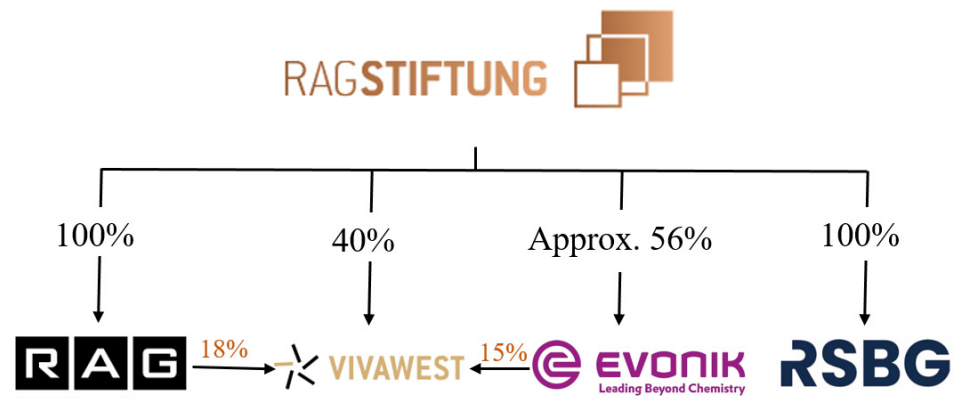


Figure 2. The structure of the RAG Foundation [21].

Table 1. Socially acceptable adjustment of hard coal industry in Germany [22].

Years	1957	1968	2018	2022
Employees	607,000	254,000	4124	650
Collieries	173	69	2	0
Production (MT)	150	112	2.6	100 million m ³ water (perpetual task)

Campbell highlighted that today, the Ruhr has become one of the key centers for the environmental protection and preservation industry, technology, and research in Germany. Local firms, universities, research institutes, and environmental agencies are cooperating closely together.

Furthermore, former mines, mining areas, and steel factories are currently used for other purposes such as museums, exhibitions, modern event locations, nature conservation areas, eco-tourism, education, science, and research institutions, as well as commercial real estate, housing estates, and alternative energy production, thus forming the perfect example for the successful transition of a whole area. Colliery Zollverein, for example, having been one of Europe’s largest industrial coal complexes, as seen in Figure 3, has now been a UNESCO World Heritage Site since 2001. The Ruhr Museum, which opened in a former coal washing plant at the Zollverein, has been the regional museum of the Ruhr Area since 2010 [13,23].

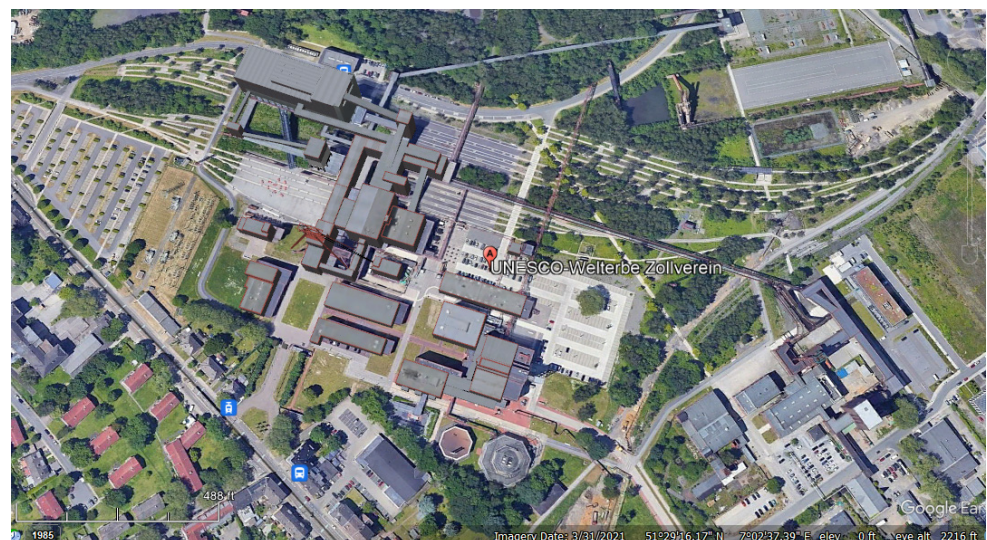


Figure 3. Usage of former mines and mining areas in the Ruhr Area UNESCO World Heritage Site Zollverein (Google Earth Image, date: 2021).

Another example is the project MARK 5107. By closing the first mines in the second half of the 1950s, it was realized that new industries beyond coal and steel were missing in the Ruhr Area. Negotiations between representatives of the state government as well as the city of Bochum and Adam Opel AG, which was looking for a production site for the newly developed small mid-size car, started. Finally, Opel's largest European factory was built on the site of the former Dannenbaum Mine Site (active from 1859 to 1958), and it brought new jobs to the city of Bochum. At the beginning of December 2014, the Opel Plant in Bochum was closed, and a new chapter began with the MARK 51⁰⁷ at this site: the construction of an industry, technology, and knowledge campus, which will generate more than 10,000 jobs as well as find a new role for the former mine workings [24,25].

Since there is no particular act on mine closure in Germany, the actual laws, regulations, and guidelines regarding mine closure and post-mining in the EU, Germany, and NRW are listed in Figure 4. The EU itself is neither a conventional international organization nor a federal state; it is a supranational organization of twenty-seven member states with its own integrated legal order, which means that the member states share responsibility with the EU for ensuring that EU laws are effectively and properly executed. The EU has the power to enact legislation binding all member states and has the mandate to enter into international agreements. A directive is a type of legislation that has to be implemented in the national legal orders of member states in such a manner as to guarantee that the objectives prescribed in it are attained in that state. Member states have a choice or discretion as to how this is ensured [26–28].

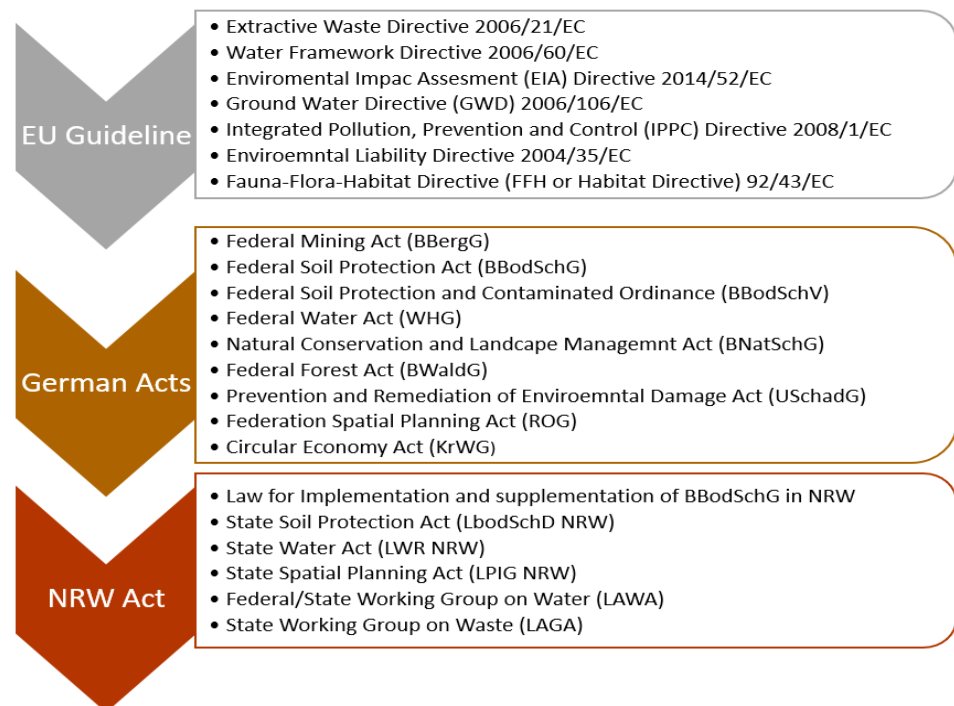


Figure 4. Legislation framework for post-mining [26–29].

The German Federal Mining Act (Bundesberggesetz-BergG) is the basis for all national directives and administrative acts applicable to the mining industry. It covers all mining activities, from the exploration phase to the production and processing of mineral resources up to the after-care phase and the re-utilization process for abandoned areas. The obvious advantage is that there is only one authority for permissions that is familiar with the dynamics and site-specific situations in the mining industry, which is the mining authority. All framework plans can only be approved by this mining authority if it is assured that the environment is not unduly affected and that unavoidable impairments connected with mining are kept to the necessary minimum. This has to be stated by the environmental

impact assessment study as the most important part of the framework plan [29]. Since Germany is a federal republic, the states are entitled to define the general terms of the federal legislation. The mining authorities' control will only end when no more dangers from the decommissioned mine can reasonably be expected. Once it is assumed that the former mining site presents no hazard to the environment or the public, the mining authority will release the site from its surveillance. This, however, only means that, as of this date, the general supervising authority, the regional department for mining and energy, will now control the site. All legal requirements will now be handled by this authority instead of the mining authorities. If problems should arise, the offender—that is, the former owner of mine or the person who committed the acts leading to the pollution—will be held responsible for securing or safeguarding measures. If an offender is no longer in existence or cannot be identified, the state will have to step in, which the state, of course, tries to avoid or at least postpone for as long as possible because of financial reasons. For example, in NRW, for the surface openings (shaft and adit entrance), which do not have any legal succession, the Arnsberg Regional Government's Department of Mining and Energy is responsible [30].

Regarding the mining legislation framework, as shown in Figure 4, the German legislation is in line with EU directives and policies. What should be highlighted is that the German legislation framework, regarding post-mining (e.g., abandoned mine sites and mining legacies), is more progressive. In this context, the German experience considering the Ruhr Area's case on transfer and post-mining is specific; its experience and knowledge can be used to the benefit of other countries with similar mining challenges, such as Kosovo.

2.2. Mining in Kosovo

Kosovo has a long tradition of mining mineral resources. The Trepca Mine was mentioned for the first time in literature in 1303 based on documents found in the archives of Dubrovnik in Croatia [31]. Until now, different kinds of mineral resources have been exploited in Kosovo, including lead, zinc, silver, gold, cadmium, magnesite, nickel-cobalt, bauxites, and chromite, as well as lignite, which supplies 90% of the electricity generation in the country.

Pruchnicka and Zeqiri emphasized the positive impact of mining on the country's economy and social well-being; nevertheless, unfortunately, this impact is hard to measure and estimate [32]. For example, as given in Figure 5, between 1930 and 1980, three artificial lakes in different places in Kosovo and the water channel from Lake Ujmani in the north part of Kosovo to the coal-fired power plant in Obliq were constructed as a result of the mining industry's development (power plant, flotation, smelter). Today, these lakes serve as a drinking water supply for many cities as well as being used for agricultural purposes. Therefore, mining's impact on the economy and social well-being is fascinating but not easy to recognize, especially its indirect impact.

Despite a long mining tradition, the huge exploitation of mineral resources in Kosovo started after the First World War and reached a production maximum after the Second World War between the 1970s and the 1980s of the last century. Between the 1970s and 1990s, the mining industry contributed about 50% of the country's GDP (gross domestic product) and was the country's main employer, with more than 30,000 employees. Currently, the mining industry has about 17,500 employees and is struggling with a lack of investment, followed by mining legacy and socio-environment issues.

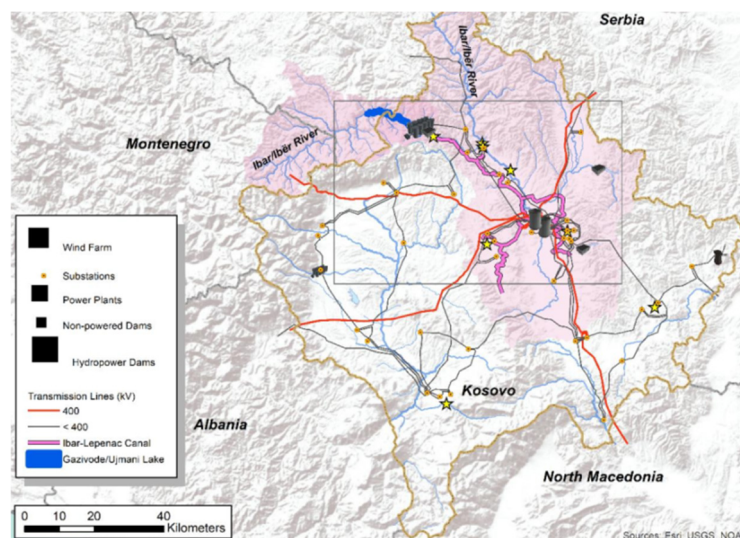


Figure 5. Mining industrialization and its impact on the development of infrastructure [32].

3. Materials and Methods

This article is based on the use of a comparative method. Within the framework of the DAAD Program “East-West Dialogue: Higher Education Dialogue with Western Balkan Countries 2023”, the Research Center of Post Mining at the TH Georg Agricola University in Bochum orchestrated a significant academic event. This initiative took the form of a summer school-themed “Post-Mining Challenges in Former Mining Areas”, catering to participants from diverse Western Balkan countries. Facilitated by experts deeply entrenched in post-mining dilemmas, particularly within the Ruhr Area, it offered a program with case study presentations followed by intensive discussions, fostering invaluable exchanges of experiential knowledge among attendees in the context of post-mining challenges in former mining areas, tailings dumps, mining legacy, and abandoned mines. Augmenting these dialogues were insightful site visits, affording students and researchers firsthand exposure to the intricate dynamics of post-mining landscapes. Through this immersive experience, participants garnered practical insights into effectively managing multifaceted post-mining challenges, spanning mining transition, remediation-reactivation strategies, land and water management, policies and legislation, social and stakeholder dialogue, mining legacy preservation, developing educational institutions and protocols, as well as fostering in-situ sustainable development initiatives and grappling with socio-economic ramifications intrinsic to the post-mining paradigm. This knowledge and experience will foster their research work and, as part of experience and knowledge transfer, enable them to share their knowledge with colleagues in other countries facing similar challenges. Experience exchange on similar mining challenges followed by a focused literature review aiming at sustainable development goals set in a UN report in 1987, which is quite well known as the Brundland Report, was the key driver for this research work [33].

Kosovo is suffering similar environmental challenges as Western Balkan countries such as Albania, Bosnia and Herzegovina, Macedonia, Montenegro, and Serbia, which are resulting from mining industrialization [34]. Air, soil, and water are contaminated, as proven by a large amount of research and investigation. The huge mining production in these countries has resulted in the creation of a massive amount of industrial waste, causing tremendous environmental and social problems for a relatively long period of time [35]. Depending on the strategies as well as mining policies used and applied in the Ruhr Area, effective, applicable, and suitable strategies should be created for an environmentally, socially, and economically sustainable post-mining concept in Kosovo.

Although in Kosovo the status of post-mining activities is not as good as in Germany, there is important support for investments. Recent attention to the economic benefits, reusing, and recycling of mining wastes has caused specific attention to the mining wastes

and post-mining activities in Kosovo. As an example, lower mining production and devastation of mineral resources, the specific attention of local industries, job vacancies for local society, and respecting European environmental standards can be highlighted in Kosovo [8].

The mining industry in Kosovo can be divided into three categories: (i) mining under operation, (ii) postponed mining operations, and (iii) abandoned mining sites. The environment is suffering from all of these mining categories and quarry mining as well. There are about 60 million tons of mining waste located in nine tailing dams. Three of them are still active, and the rest of them are not remediated, thus causing permanent environmental contamination and social risk, as seen in Figure 6. Furthermore, there are two ash dams with 40 million tons of waste as a result of energy production based on lignite (with a carbon content of around 25–35%).



Figure 6. Mining tailing impact-tailing sites and acid mine drainage (AMD) [33].

Despite the progress that has been made in mining policies and legislation frameworks, there is still a lack of mining regulation, especially on abandoned mines and integrated remediation plans, whereas post-mining and transition processes are still a new concept and are not yet subject to mining legislation. Not only for post-mining, but in some important mining operations, sole legislation is still missing. such as the lack of a regulatory basis for near-miss incidents (NMI), which is a progressive and sustainable regulation [36]. According to the Ministry of Economic Development of the Republic of Kosovo, the country is committed to the rational utilization of its mineral resources to achieve responsible development of the mining resources [37]. Since any raw materials policy can only really be sustainable if it also includes post-mining issues, Kosovo will embrace the post-mining and transition concept very soon, having to face its current lack of experience and expertise in this area. Thus, approaching concerns through an economic lens entails considerations not only of environmental sustainability but also of broader societal implications, encompassing comprehensive social welfare, thereby safeguarding a prospective outlook on social dynamics, including education and cultural preservation, while concurrently safeguarding the integrity of mining heritage.

3.1. Challenges of Mining Industry in Kosovo

In this part, the challenges of the mining industry in Kosovo are presented. Focusing on coal mining can lead to sustainable solutions for post-mining, similar to the post-mining activities in the Ruhr Area. There are various sources of governmental support and funding available for the post-mining process. As an example, UN support was given to treat Gracanica tailings with a capacity of 11 million tons from the processing of lead and zinc. These residues were environmentally harmful for the adjacent areas, as seen in

Figure 7. There were various environmental problems in the area; highly surface water contamination closely to the Paddock dam; Regarding the groundwater contamination due to a high concentration of arsenic; high arsenic concentration in soil nearby the Gracanica River, high metal concentrations in soil and in vegetables [38].



Figure 7. Gracanica lead-zinc tailings, surrounding cities, and lake nearby (Google Earth Image, date: 2022).

The plan was to remediate eight tailing areas and rehabilitate the processing plant, including the concentrators and smelting facilities. Similarly, for the Ruhr Area, the following steps were considered [38]:

- Studying the surface water quality to find out possible contamination;
- Studying and analyzing the groundwater quality;
- Check and analyze the soil for possible contamination near the Gracanica River;
- Vegetation analysis near mining sites to detect the high metal concentrations.

Other aspects in order to reduce the environmental impacts in the Gracanica area are geotechnical investigations of the tailings area and dams, controlling the lead-contaminated dust spread by wind, reducing and controlling the hazardous chemicals used in the processing plants; and acid mine drainage control and treatment [38].

Another example is electricity production based on lignite. Ash waste, with a capacity of more than 40 million tons of ash, is a source of pollution for vegetation and agricultural lands nearby. Moreover, there are reports about population health among people who live close to the dumps [39].

There are similarities between the lignite resources in Kosovo and former hard coal mining activities in the Ruhr Region. The similarities start with the economic and social effects of coal mining [39].

The sole operational coal mine is situated within the Kosovo basin. This open-cast coal mine is situated atop the former underground mines of Hade and Sibovc. Additionally, historical records indicate the existence of two underground mines, namely Dardhishta and Babush (Lipjan), which were closed about fifty years ago and can be treated as abandoned mines. Many of the mining operations started between 1952 and 1957, such as Hade and Babush (Lipjan) mines, and have been considered for coal processing and coal-powered thermal power plants. There are several zones nearby with populations that are surely affected by lignite mining activities both positively (economic development) and negatively (environmental and health impacts) as given in Figure 8. As an example, the productive part of the Kosovo basin covers a surface area of approximately 300 km².

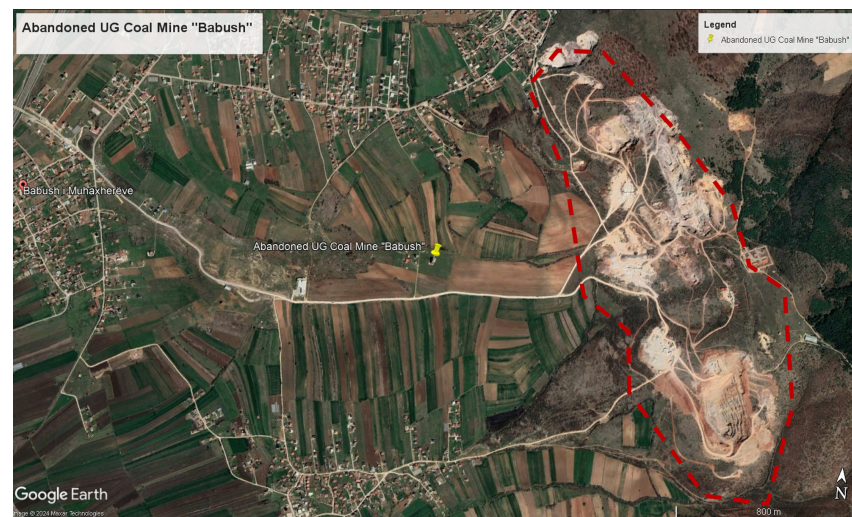


Figure 8. Abandoned coal mine of Babush in Kosovo in red dashed line (Google Earth Image, date: 2022).

Just in the Kosovo coal basin, there are around 68 settlements, including five municipalities such as Vushtrri, Kastriot, Fushë Kosova, Prishtina, and Lipjan [37].

Another example of a coal basin, Dukagjini, has more complex morphological-tectonic structures. The surface of the Dukagjini basin covers 1700 km². This basin is providing good infrastructure like railways and roads, which can be helpful for post-mining facilities. Moreover, on the surface of the Dukagjini coal basin, there are about 19 settlements belonging to Istog and Klina municipalities [40]. Hence, it is fundamental to consider and learn from Ruhr Area challenges. The main points will be as follows:

- Well-addressing the social legacy and considering the safety of the future occupation;
- Precise environmental monitoring based on past problems and respecting European standards.

Since recent mining activities have been performed by international companies, there are some remediation plans for the ash dumps, such as the following:

- Re-cultivation and agricultural use of the areas in which there are no mining operations anymore;
- Financial anticipations for the post-closure activities of the mining fields [40].
- There are several studies focusing on “environmental impacts” that try to connect the mentioned mining areas based on similarities to post-mining operations. Normally, these studies try to anticipate possible environmental effects. For instance, there is the possibility of filling past exploited mining areas with overburden materials from mines. Other agricultural uses and creating new landscapes in the area are suggested by operating companies as post-mining activities. Finally, several studies have been conducted for mine water drainage, analyzing soil contamination around mining sites, and measuring dust emissions during mining operations. However, based on the experiences of the Ruhr Area, more detailed studies should be done on technical aspects (e.g., sampling from water, soil, vegetation, and air; sample analysis and quantitative maps) while considering the social-economic benefits of the local communities (how to include locals, needed facilities, etc.).

3.2. Recommendations from Learned Lessons in the Ruhr Area

Based on the post-mining challenges review of the Ruhr Area, some recommendations can be proposed by the authors. One of the recommendations relates to the mining plan strategies. It means that at the time of the mid-term plan of mines, when companies are providing regular operation conditions such as the geotechnical, public safety, and economic efficiency of mining, it is fundamental to review the post-mining conditions as

well. Land use, environmental standards, and re-structural considerations (e.g., sport halls, nature conservation areas, and cultural locations) are significant factors to be considered beforehand, based on successful examples such as the transition of the Ruhr Area.

In addition, possible new facilities in the area will lead to the repopulation of the area in question and the return of local societies. The mining facilities (railways and roads) can help communities develop new land uses for both settlements and new business activities, as well as tourism, leisure, and cultural events.

Then, it is important to provide various funding resources (private and governmental), not only for exploitation activities during the mining operations but also for future remediation activities, and to have a far-reaching vision for socio-economic developments at the local scale. Another lesson from the Ruhr Region is water monitoring, which can be used in Kosovo to enhance water and electricity security. It is important to upgrade the current water infrastructure and perform water monitoring systems at the mine sites. Finally, a revision of past mining projects can create the possibility of respecting environmental goals and re-establishing public safety.

4. Results

The research revealed a lot of similarities in the mining industries in the Ruhr Area and Kosovo. As mentioned above, the mining industry is contributing to economic growth and social well-being not only in Europe but all over the world.

In any case, the tremendous mining exploitation, in addition to economic growth and social well-being, was also accompanied by severe environmental impacts. These were followed by the decline of the mining industry, resulting from a variety of reasons such as external transformative pressures, increased competition, pollution, etc. Therefore, coal mining in the Ruhr Region has faced a transition since the beginning of the 1960s. It might be concluded that the only options in question were sustainable transition or transition without prior measures. At this point, the government of Germany decided to manage the mining transition in the Ruhr Area through sustainable mining policies. The German government passed the law on funding the termination of hard-coal mining, followed by just policies such as reducing social consequences, economic beneficiation, sustainable land management, and mine heritage preservation. To sum up, the success of Ruhr transitions was based on: wide collaborations of governmental and local authorities and including private industries to cover required investments; considering the socio-economic aspects of the local societies; long-term monitoring of the environmental impacts (air, soil, water, etc.); and above all, performing a well-structured legislation framework to cover all necessities of a post-mining sustainable transition. Therefore, Ruhr coal mining was transformed to the post-mining phase, which even nowadays is continuing to aim for just transition and is being evaluated as successful worldwide.

Kosovo's mining industry needs to embrace practical sustainable development and establish sustainable mining policies for transition and post-mining. In this regard, German experience and knowledge might be useful for Kosovo. Especially the case of Ruhr Area's coal-mining transition to post-mining is fascinating. Kosovo needs to strengthen and develop human resources for the subjects of transition and post-mining. This human potential would enable Kosovo to face the difficulties of mining transition and post-mining through a suitable legislation framework based on sustainable mining policies in the next decades (e.g., the German case, "Coal Policy Agreement of the Federal Government").

5. Discussion

The results of this study are based on comparing investigations between coal mine activities in Kosovo and the transition of the Ruhr Area. There are many similarities between Kosovo coal mining and the past Ruhr conditions. Coal mining in Kosovo, similarly to the Ruhr Area, has an outstanding role in the socio-economics of the area since it provides a high percentage of the country's electricity. Therefore, the transition to renewable energy needs appropriate investments, long-term consideration for job opportunities, and

new resources for local authorities. The challenge of finding appropriate investments arises here, which highlights the different situation in the Ruhr Area. The existence of heavy metals causing soil and water pollution is another similarity between the Ruhr area in the past and current Kosovo coal areas (for instance, the Dukagjini coal basin and the Gracnica tailings area). Following a similar environmental monitoring framework for the Ruhr Area can be helpful to overcome this challenge in Kosovo. Finally, new sustainable applications for the abandoned mines in Kosovo should be taken into account, this time not following the Ruhr Area but considering the needs of the local economy and social well-being.

Considering the current situation, it is fundamental to follow the applicable EU directives on environmental impact assessment. Many examples show that there are significant challenges and uncertainties caused by new strategies of mining companies, economic changes, and market variations of raw materials. Besides environmental aspects, the re-projection of mining dumping and the long-term vision of post-mining should be considered. This point should be considered to establish a robust strategy for post-mining activities, since within the Raw Materials Act, published by the European Commission, there is an important trend to re-open mining activities in Europe for new raw materials and specifically critical raw material resources [41].

An important point is that in active mining areas, the post-mining operations have a longer history and many successful examples. For instance, in Australia, there are already several representative establishments responsible for post-mining designs and performance. The Centre for Social Responsibility in Mining (CSR) and the Mine Closure Hub (MCH) are some of the examples. CSR reviewed 141 examples of post-mining land use globally in 2020 and classified the examples into 10 categories, such as forestry, alternative health, agriculture, light industry, lake or pool, construction and intensive recreation, education and research, non-intensive recreation, conservation and ecosystem services, and community and culture. In such areas, it is easier to find important mine re-use examples and collaborations between industry participants, local-region communities, and national economies [42].

6. Conclusions

The objective of this work was to integrate post-mining successful stories of Ruhr area from different aspects, discuss the challenges, and connect them to possible cases in Kosovo. Several lessons are learned, such as:

Post-mining, including closure and rehabilitation, should be planned and designed across all mining stages and operations. Land use is a fundamental issue in post-mining, which should be based on sustainable regulations depending on the size, type, nature of the mine, and local needs. To achieve a successful result, it is recommended to create a direct collaboration between landholders, communities, traditional owners, governmental institutes, and various investors, which still requires many years of monitoring.

Before sustainable mining, it is recommended to develop sustainable mining policies followed by a suitable legislative framework. As shown by the concept of the Brundtland Report, land management and environmental and socioeconomic care are the pillars of sustainability. The Ruhr Area's case shows how the development of sustainable policies and proper legislation can lead to multi-stakeholder engagement and commitment to the process of post-mining and transition, which in the case of the Ruhr Area has transformed an industrialized and polluted region into a green metropolis, ensuring economic perspective and social well-being. In this regard, mining heritage has been preserved, and good conditions for higher education have been developed, especially regarding the science used for the topic of sustainable mining. All of this could only be achieved through close collaboration between mining authorities, companies, regional citizens, worker's unions, and universities.

The post-mining and transition case in the Ruhr Area might be used as an example to manage Kosovo's mining industry. There will be many challenges, such as finding appropriate funding sources, defining economic advantages at the end of work, integrating

local communities, and well-defining their needs and requirements. Hopefully, some steps are being taken (quantifying the environmental impacts on water, soil, etc.) and more understanding about missing parts is being achieved. The framework of the Ruhr transition can also be followed by countries all over the world that want to manage sustainable mining transitions and post-mining.

Future research activities should focus on the potential for remediation and re-utilization of at least one of the Kosovo coal basins, for instance. All presented parameters (economic, social, environmental, etc.) are categorical indicators for detailed studies and the discovery of practical processes, including the timing, costs, and potential risks and uncertainties in the selected area. An appropriate, comprehensive perspective on mine re-use should be estimated. Possible regulations should be performed based on the published Raw Materials Act (European Commission) in line with local needs and decisions.

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