




Challenges in the Management of Mining Waste [†]

Wojciech Kaczan ^{1,*} , Herbert Wirth ¹, Jan Kudelko ¹ and Cezary Sroga ²

¹ Department of Mining, Faculty of Geoengineering, Mining and Geology, Wrocław University of Science and Technology, ul. Na Grobli 15, 50-421 Wrocław, Poland; herbert.wirth@pwr.edu.pl (H.W.); jan.kudelko@pwr.edu.pl (J.K.)

² Polish Geological Institute-National Research Institute, Lower Silesian Branch, Aleja Jaworowa 19, 53-122 Wrocław, Poland; csro@pgi.gov.pl

* Correspondence: wojciech.kaczan@pwr.edu.pl

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Abstract: The article aims to summarize the current challenges for tailing piles and ponds geological-mining projects focusing on the waste deposited in southwestern Poland.

Keywords: tailing piles; environment; raw materials; challenges; circular economy; exploitation



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1. Introduction

The discussion on mineralization potential and relevant policy concerning anthropogenic deposits in Poland is coming back every few years. In recent years, those types of sites are becoming gaining more worldwide attention in scientific and practical terms, mostly because of geological inflation and the rising demand for raw materials but also due to the increasing environmental awareness [1]. The most crucial questions in this matter are how high the potential of the raw material is in tailing piles and how significant its impact on the environment is. It seems that scientists and researchers working on this issue should provide a specific answer.

The article aims to summarize the current challenges regarding the possible utilization of the materials deposited on tailing piles and tailing ponds in south-western Poland. Authors highlight the important aspects regarding environmental impact and technical solutions for the whole life-cycle, the economy of the investment, and the social license to operate. Moreover, the authors aim to bring circular economy thinking before the potential project planning.

2. Current Knowledge about Waste Management in Poland

In European regulations, the awareness of the need to neutralize the negative impact of waste on the environment has been noticeable for many years [1]. Recent years have also brought increased awareness of the possible use of waste to meet the raw material demands. In Poland, there are also noticeable trends of greater emphasis on documenting the generated and deposited waste. An example of an activity is the database on products, packaging, and waste management launched in 2018 [2]. Additionally, tasks related to the full use of waste are mobilized, which was highlighted in the Polish circular economy roadmap and in the policy of European Union [3,4].

In the context of the generated waste, the mining industry and the processing of raw materials are undeniable leaders. As mentioned above, the current monitoring allows for the documentation of the amount and location of this waste. In recent years, the Polish Geological Institute–National Research Institute has undertaken the difficult task of making a digital inventory of former mining waste storage facilities in the Sudetes [5]. The result of the institute's work is a base of 568 tailing piles and ponds. Considering that it is the

beginning of the work, this shows the scale of the amount of mining and processing waste deposited in Poland [5,6].

These objects, due to the specificity of the materials deposited in them, pose a potential environmental threat. At the same time, further research will allow to assess their potential in the context of obtaining valuable raw materials, such as copper, silver, cobalt, lead, and zinc. A holistic approach to the possibility of using these facilities seems inevitable in the face of the growing trend of implementing the circular economy [3].

3. Challenges for Potential Investments

The authors qualitatively defined the challenges in five mine areas (economical, environmental, social and governance, legal, technical) of tailing piles that appear at each stage of the geological and mining project life (current state, exploration, development, exploitation, processing, closure, reclamation) (Table 1). The census was based on the experiences gathered by the Polish Geological Institute in the geodatabase *Hałdy*, the authors' experiences, and a review of the scientific literature. The issue of the operation of tailing piles and ponds combines aspects of environmental protection, waste management, mining, and processing. Many of the challenges facing a possible investment relate to best practices in these areas. There are, however, additional issues that need to be addressed for the deposited mining and processing waste. These are, amongst others, an inventory of existing sites, technical aspects of the exploration of heterogeneous geological media, assessment of the economic sense of this type of geological and mining investments, and the need to use the principles of circular economy management.

In the next stage, the significance of the given aspects was assessed in individual phases of the project. The environmental impact during the most impactful mining phases and the economic potential of obtaining raw materials at the exploration phase were identified as key challenges. Proving the possibility of obtaining profit and the simultaneous restoration of the environment gives a probability of making the investment sensible.

Table 1. The current challenges in the management of mining waste in every phase of the geological-mining project.

Phase/Area of Challenge	Social and Governance	Environmental	Economical	Legal	Technical
current state	Social protests due to the hazardous impact of tailings; informal exploitation; local authorities involvement	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; conducting environmental impact assessment	Costs of the environmental impact assessment, monitoring and technical expertise; land use	Environmental requirements for existing sites; different perpetual ownership	Environmental impact monitoring; technical works securing the heaps (slope stability, geotechnical works, good practices application)
exploration	The reluctance of the local community to the possibility of changes in their region; employment of specialized staff; ensuring the safety of employees and the community; ensuring process transparency (local authorities and local community)	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; conducting environmental impact assessment; drilling and other works impact	Economic potential assessment; small- and medium-sized business interest in tailing piles mining projects	Obtaining permits to carry out works in areas with different perpetual ownership; meeting the requirements of the law; requirements of the licensing authorities	Selection of prospecting and exploration methods for a significantly heterogeneous deposit; selection of methods to identify possible threats;
development	Employment of specialized staff; the reluctance of the local community; safety of employees and the community; use of the services of local entrepreneurs; overexploitation of existing infrastructure (buildings, roads, facilities); conducting public consultations; ensuring process transparency (local authorities and local community)	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; the impact of the urban mining	Optimization of the mining and processing processes for small, dispersed deposits (location of infrastructure, processing plant); identification of recipients for all products (circular economy); designing the economics of short-term mining activities; expenses for satisfying claims	Change in land use (e.g., tourism, education or geological sites); problems concerning the anthropogenic deposits concessions that are not included in the Geological and Mining Law; arising of claims and their compensation (damage to infrastructure); meeting the requirements of the law	Designing an appropriate method of development; limiting the negative impact on the environment; adapting the infrastructure to the type of investment (roads, buildings).

Table 1. Cont.

Phase/Area of Challenge	Social and Governance	Environmental	Economical	Legal	Technical
exploitation	Employment of specialized staff; ensuring the safety of employees and the community; the possibility of using the services of local entrepreneurs; ensuring process transparency (local authorities and local community)	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; the impact of the urban mining	Generating income from investments, feeding the local budget; expenses for satisfying claims	Meeting environmental requirements; arising of claims and their compensation (damage to infrastructure); meeting the requirements of the law	Designing an appropriate method of operation for tailing pile exploitation project; limiting the negative impact on the environment
processing	Employment of specialized staff; ensuring the safety of employees and the community; the possibility of using the services of local entrepreneurs; ensuring process transparency (local authorities and local community)	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; the impact of the urban mining; utilization of chemicals and waste	Generating income from the sale of products and waste; expenses for satisfying claims	Meeting environmental requirements; arising of claims and their compensation (damage to infrastructure); meeting the requirements of the law	Adaptation of known treatment methods to the characteristics of the waste; development of new green processing methods; design of processing technology concerning the Circular Economy (without leaving waste at the site); testing new ways of use for by-products
closure	Ensuring the safety of employees and the community; ensuring process transparency (local authorities and local community)	Harmful dusting; water and soil pollution; gas emission; land use; potential risk during anomalous weather phenomena (landslides, liquefaction); fauna and flora threat; assessment of the state of the environment after closure and before reclamation; designing monitoring	Decommissioning expenses (securing or liquidating of the mining workings, equipment, and plant facilities)	Meeting environmental requirements; arising of claims and their compensation (damage to infrastructure); meeting the requirements of the law	Designing of monitoring methods (observation and measurement points equipping)

Table 1. Cont.

Phase/Area of Challenge	Social and Governance	Environmental	Economical	Legal	Technical
reclamation	Designing the appropriate direction of land reclamation, considering the needs of the local community; ensuring process transparency (local government, local community); including the recovered sites in the spatial development plan	Leaving the area without any impact on the observed environment before the investment; conducting environmental impact assessment after reclamation; environmental monitoring; site decontamination	Incurring the costs of reclamation and reducing environmental hazards; costs of environmental monitoring and assessment; cost of decontamination of the site; generating income from the sale of the decontaminated site	Meeting environmental requirements; meeting the requirements of the law;	Environmental impact monitoring; selection of technologies allowing for the elimination of environmental threats

4. Case Study—Waste Deposited in the Area of Old Copper Basin (Poland)

An example of a potential investment opportunity is the tailing piles and tailing ponds deposited in the Old Copper basin (Lower Silesia, Poland) (Figure 1) [5–7]. The potential of the deposited waste was estimated to even 0.3% of Cu and 13.7 g/t Ag. The occurrence of metals such as Au, Pt, and Pd was also documented [8]. The current environmental impact was estimated as a potential threat for humans, fauna, and flora [5]. The possible exploitation was part of the interest a few times in history, but it did not finish as an active project, which was mainly related to the lack of economically justified processing method (extraction of metals and the utilization of residue) [7–9].

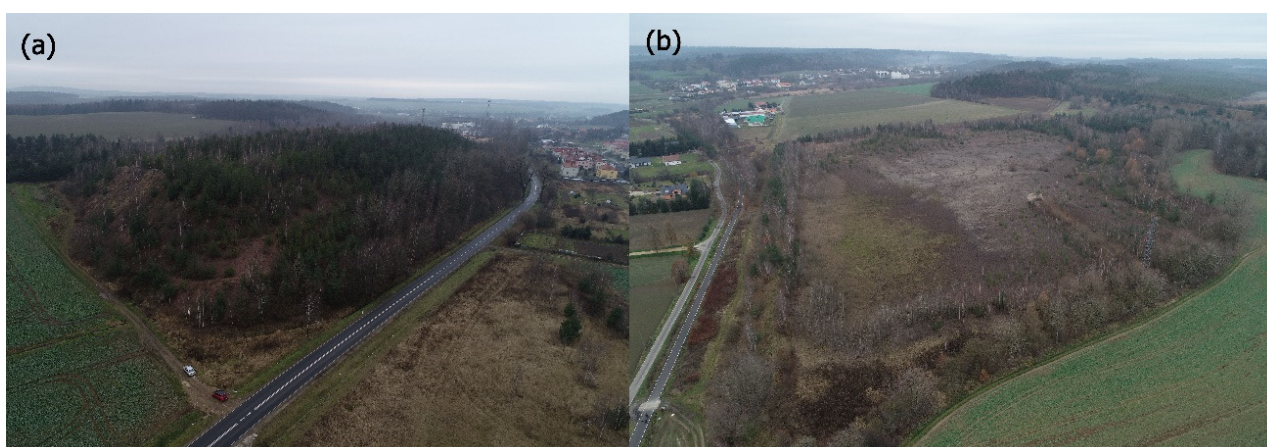


Figure 1. Examples of the current state (2020) of tailing pile (a) and tailing pond Iwiny (b) in the area of Old Copper Basin (Iwiny).

5. Conclusions

As the awareness of the potential of the raw material of tailing piles and ponds is growing, there is a need for determining the possible obstacles for geological-mining projects. The work conducted by the Polish Geological Institute showed the scale of deposited waste in south-western Poland. That results and the example of waste deposited in Old Copper Basin shows the opportunity for scientific and business activities; however, beforehand, the challenges have to be distinguished and considered by decision-makers. In this study, authors analyzed the current potential barriers and determined the most significant ones: the assurance of the environmental protection through the project life cycle, and the development of the circular economy implementation with the simultaneous economic justification.

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