The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2023

Volume 26, Pages 341-347

IConTES 2023: International Conference on Technology, Engineering and Science

Geophysical Techniques for Monitoring of Integrated Mine Waste Storage Facility: Case Study of Southeastern Bulgaria

Maya Tomova
University of Mining and Geology

Abstract: The extraction of mineral resources usually generates varying amounts of extractive waste, which require appropriate management. Extractive waste management is complicated and difficult process. It encompasses a lot of actions and many different competences. Here must be taken into account the mining excavation method, processing methods, beneficiation and overall mineral treatment. The results obtained from these study provide an important basis for the quantification and management of environmental impacts of the Integrated mine waste facility (IMWF) at the "Ada Tepa" gold mine. The aim of this research is to monitoring the process of internal water drainage into constructed cells of the facility. This task is performed using geophysical method based on electrical resistivity measurements made on the ground surface. Electrical resistivity tomography is commonly used to solve mining and engineering issues, because it is efficient and environmentally sound. This study demonstrates the efficiency of electrical resistivity tomography in detecting the saturated zones in the IMWF.

Keywords: Waste management, Electrical resistivity tomography, Water drainage, Monitoring.

Introduction

Bulgaria has old traditions in mining and processing of gold-bearing ores. Gold mining and processing in the Bulgarian territories has been practiced since ancient times. Currently, the main gold mining in Bulgaria is realized from copper and gold-bearing ores from the "Chelopech", "Elatsite" and "Asarel" deposits. Gold-bearing ores are available in "Khan Krum", "Chala", etc. deposits (Grigorova & Nishkov, 2016). The mining industry is witnessing an epochal revolution due to the metals growing demand (copper, iron, aluminum, nickel, gold), industrial minerals and energy resources (oil, uranium) all over the world and especially in the currently developing economies such as China, India and Brazil.

"Ada Tepe" gold mine is the oldest gold mine in Europe. It is located near Krumovgrad, on the summit of the Ada Tepe ridge and has operated from 1500 to about 600 BC. The region is part of the Eastern Rhodopes Massif, which hosts the eastern portion of a large metamorphic terrain. Gold and silver mineralisation in the Krumovgrad area is mostly identified within the Shavar Formation proximal to the unconformable fault contact or detachment with the underlying basement rocks of the Kessebir core complex. Base on the information from several drillings in the investigated area the following rocks are observed: clay, breccia conglomerate, breccia conglomerate with quartz inclusions and metamorphic clasts (Grigorova, 2020).

Open-pit method of mining is proposed for the "Ada Tepe" gold mine. It is used drilling and blasting works followed by loading by hydraulic excavators and haul trucks for the transportation of the extracted material. Conventional processing methods, including crushing, grinding, and flotation processing are employed for extracting gold at the "Ada Tepe" gold mine. Mineral processing generally is focused on extracting the most valuable components from the ore, while the rest of the material is disposed at the tailing ponds. Mining and ores beneficiation generate waste that have to be properly managed to reduce environmental risks. Plenty authors (Tayebi-Khorami et al., 2019; Yankova, 2020; Yankova, 2021), emphasize the key problems with

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

mining and processing waste along with particular tailings storage, mining waste amount reducing and safe storage. Effective waste management is the basis of sustainable development. Many experts contend the present stage of mineral-raw material industry evolution is describing by mineral deposits with complex mining-geological conditions, difficult for mining, low grade ores with complex processing, which leads to considerable waste quantities formation. Waste proper storage is critical to the planet and human health.

Extractive waste management is usually part of the overall ore extraction and the treatment of minerals. In the "Ada Tepa" gold mine for waste deposition is used Integrated Mine Waste Facility (IMWF). The idea behind the IMWF is to place thickened tailings into cells constructed from mine rock, because they provide strength required for overall stability and also internal drainage. It is known that tailings tend to have a lower vertical permeability than horizontal permeability and the IMWF exploits this characteristic fully by depositing the tailings into cells and the berms acting as dewatering pathways. The underdrain system collects and convey the rainfall and the excess pore water from the consolidation of the tailings. A two zone filter system will be placed to prevent tailings being carried through the outer rock berm (Diaz, 2014).

The aim of this research is to monitoring the effect of internal water drainage into constructed cells. For this purpose, is used popular non-destructive geophysical technique – electrical resistivity tomography. The investigation is performed in period of six months and has to evaluate the progress of water drainage into constructed cells during this period.

Description of the Technology

Generally speaking, mineral treatment consists of two main steps (Grewal, 2016; Kauppila et al., 2013). The first step, the comminution, is to reduce the size of the extracted materials and prepare the ore for the next step. Comminution consists of crushing, grinding, screening and classification steps. During that stage of the process, the ore is transformed into a granular material with a specific grain size depending on the mineral. The grain size is selected to allow the liberation of the targeted minerals during the beneficiation stage. The second step, the beneficiation, is to separate the valuable mineral resources from the rest of the ore, known as the gangue, in order to concentrate one or more targeted mineral resources in a product, also called concentrate. Beneficiation can be achieved using one or a combination of different types of processes - sorting, gravity concentration, magnetic separation, electrostatic separation, flotation processes, leaching processes and dewatering.

The gold ore is processed in dressing plant, involving a crushing and milling followed by froth flotation to produce gold and silver concentrates. Mineral processing waste, the gangue, are thickened to paste and disposed in Integrated Mine Waste Storage Facility, along with waste rocks (Grigorova, 2020). It is important to understand the stages in the process of ore preparation and processing at their basics, because the gangue and the non-valuable mine rocks are the core of the Integrated Mine Waste Facility. Their chemical composition and structure are important for the strength and stability of the facility and also are essential for the internal drainage.

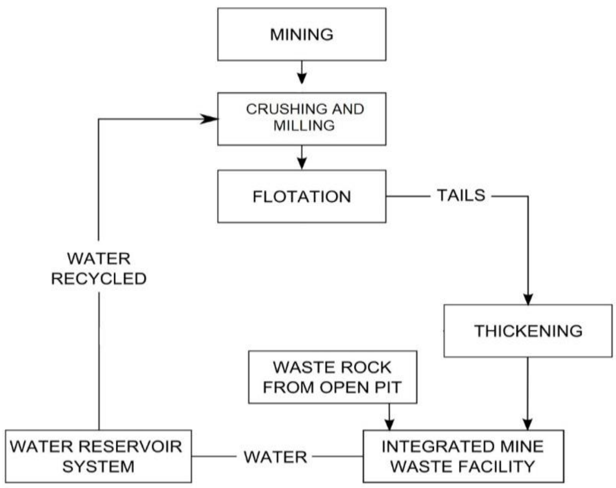

Figure 1. Overall flowsheet

The extraction of mineral resources may generate different amount of extractive waste, which require appropriate management. According to White et al. (2020) the mining method used at the Ada Tepe gold mine is a conventional open pit, drill, blast, load and haul operation, using hydraulic excavators and haul trucks to mine the material. Ore is processed by crushing the mined ore in the primary jaw crushing circuit, grinding in a semi-autogenous grinding ("SAG") milling circuit followed by a further secondary grind in a vertimill circuit. Tailings and waste rock material from the mine are placed in an Integrated Mine Waste Facility ("IMWF") (White et al., 2020).

Mine waste rock and tailings are typically the two major waste types at mine sites. In the process of mining operation, the mine rock is trucked from the open pit to the IMWF, dumped and spread to construct containment cells for the tailings. Tailings are then thickened in the tailings thickening plant to the maximum practical amount (between 56-68% solids), and then conveyed by pump and pipeline to the containment cells. The IMWF is design to be a fully drained facility without a water pond during its operation. A system of underdrains is constructed along the axis of each small surface water channel in the footprint of the IMWF and these drains are prompted to discharge to one of two sumps located at the toe of the facility. Water reporting to the underdrain is pumped to the Raw and Process Water Reservoir ("RPWR") located southwest of the open pit. The underdrain system will collect and convey the rainfall and the excess pore water from the consolidation of the tailings. Water draining from or through the IMWF is collected and treated in the existing wastewater treatment plant (Diaz, 2014). The fast drainage of water is important for the faster consolidation of the tailings leading to better operational sequence as it is of crucial meaning (Eldridge et al., 2013). For this problem to be mitigated and to be better managed Aleksandrova et al. 2021 suggested that the critical path method (CPM) can be used.

Initial mine waste characterisation is essentials for any planning of the management of mine waste. It may be used for the classification of extractive waste, i.e. inert, non-inert non-hazardous or hazardous. Only if this background work is done properly appropriate management measures can be applied. Quality assessment and monitoring is performed using electrical resistivity tomography method. It is geophysical technique, which inject electrical current into the ground surface and couple of electrodes to measure the resistivity of the media. Electrical tomography method has the potential to provide fast and reliable information for observed area based on electrical resistivity (Dimovski et al., 2017).

Field Measurements and Results

The precise location of the geophysical surveying lines in the area of Integrated Mine Waste Facility is illustrated in Figure 2.

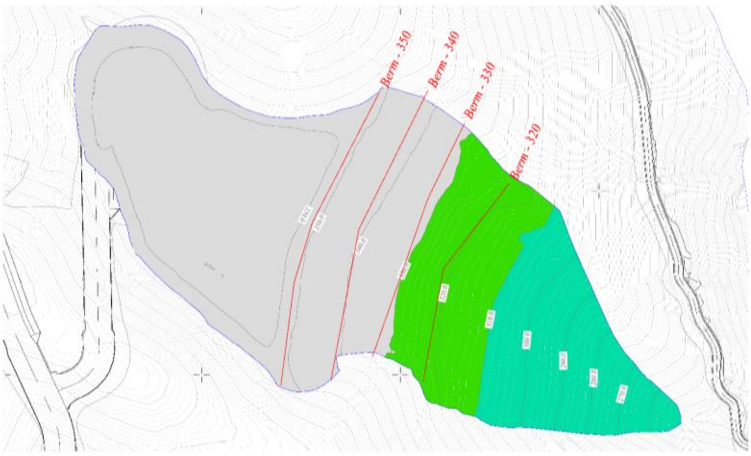

Figure 2. Field measurements situation plan

The ERT field measurements were performed along 4 lines. The total length of the measured profiles is 740m, and their exact location is presented in Figure 2. The aim of electrical resistivity survey is to measurethe resistivity distribution in the subsurface by conducting measurements along the ground surface. Apparent resistivity data were collected with a Wenner-Schlumberger array and distance of 10m between the electrodes (a total of 24 electrodes per arrangement). Electrical resistivity tomography data was process and analyzed using RES2DINV software. This computer program automatically determines the 2D resistivity model for the observed data (Griffiths, 1993). This study demonstrates the efficiency of application of electrical resistivity tomography (ERT) in detecting the saturated zones in the IMWF. This research will help in sustaining the berm stability via indicating the position of water saturated zones and water pathways.

Table 1. Total length of each line of integrated mine waste facility

Line	Berm - 350m	Berm - 340m	Berm - 330m	Berm - 320m
Length, m	210	210	170	150

The comparison of interpreted ERT sections is presented on Figure 3 to Figure 6.

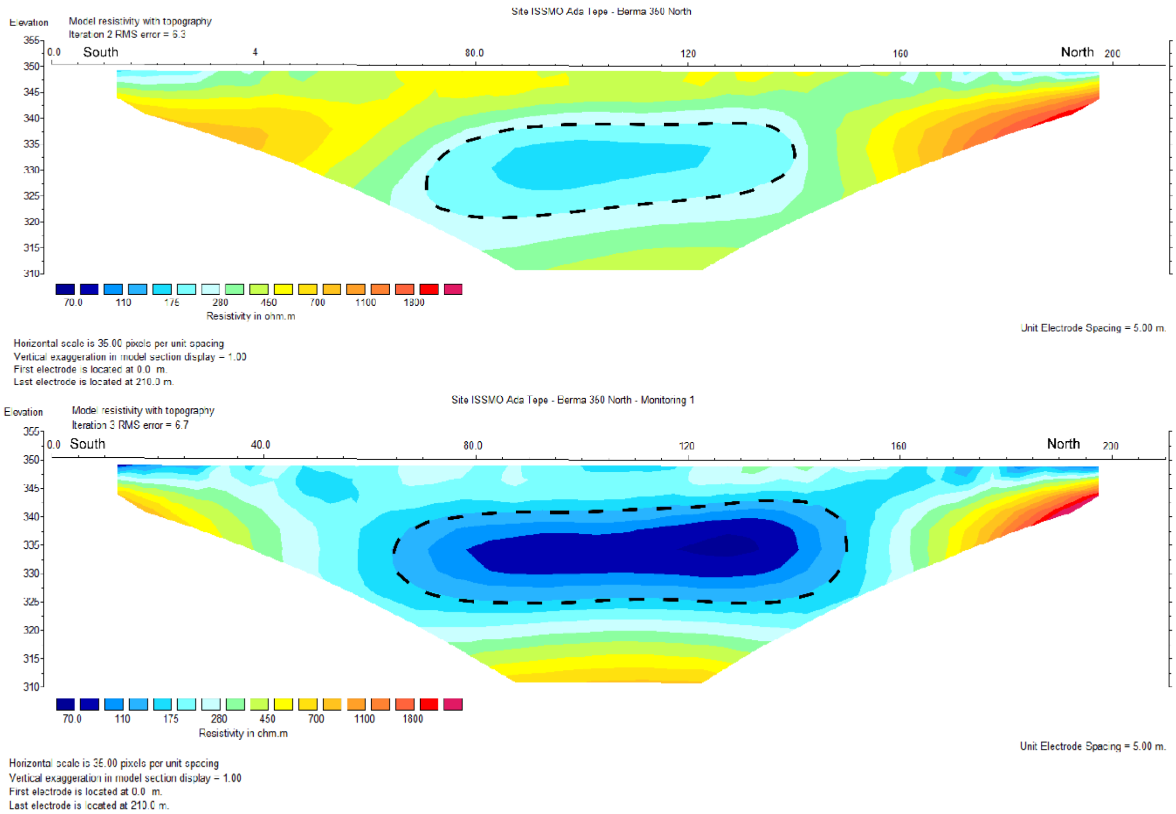

Figure 3. ERT section along Berm 350m measured in February 2020 and again in July 2020

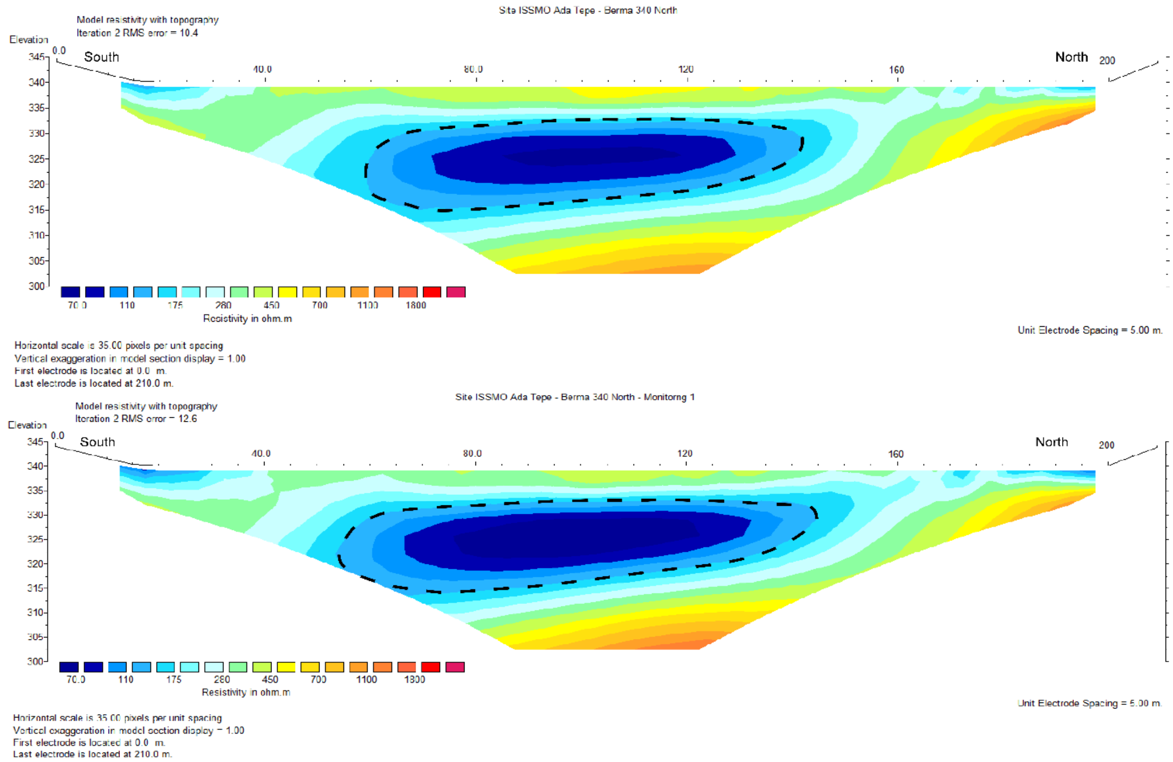

Figure 4. ERT section along Berm 340m measured in February 2020 and again in July 2020

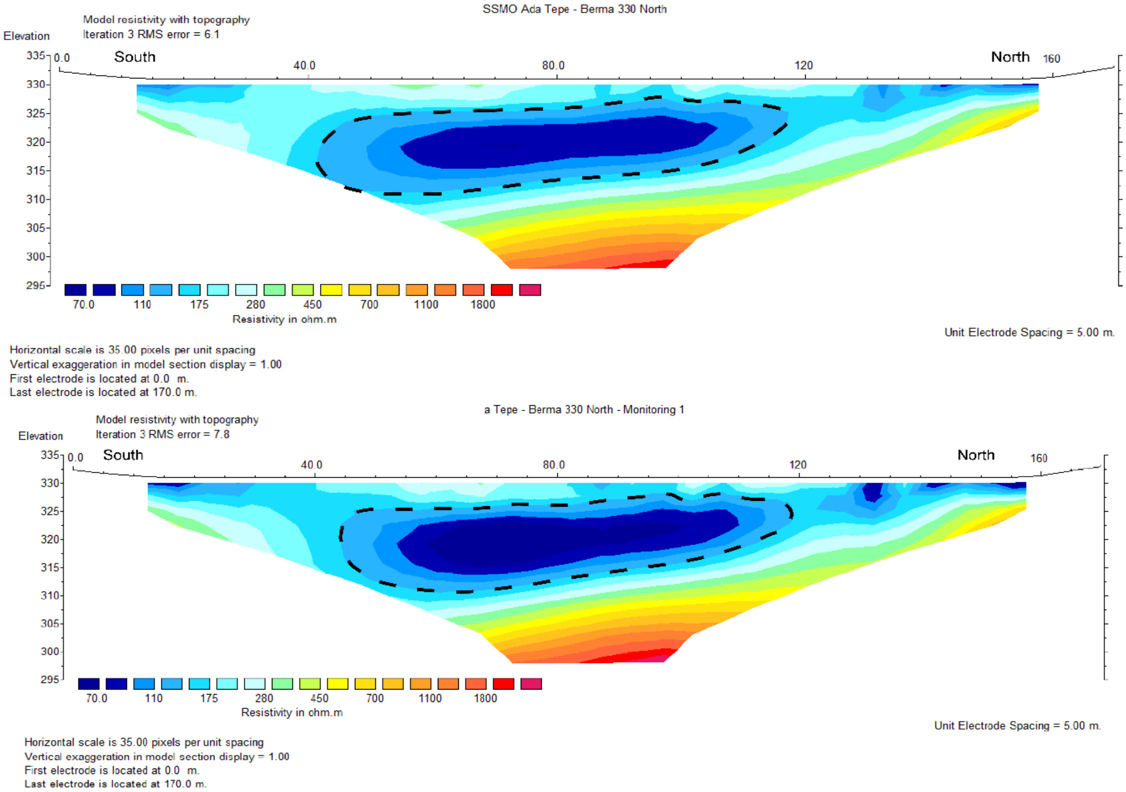

Figure 5. ERT section along Berm 330m measured in February 2020 and again in July 2020

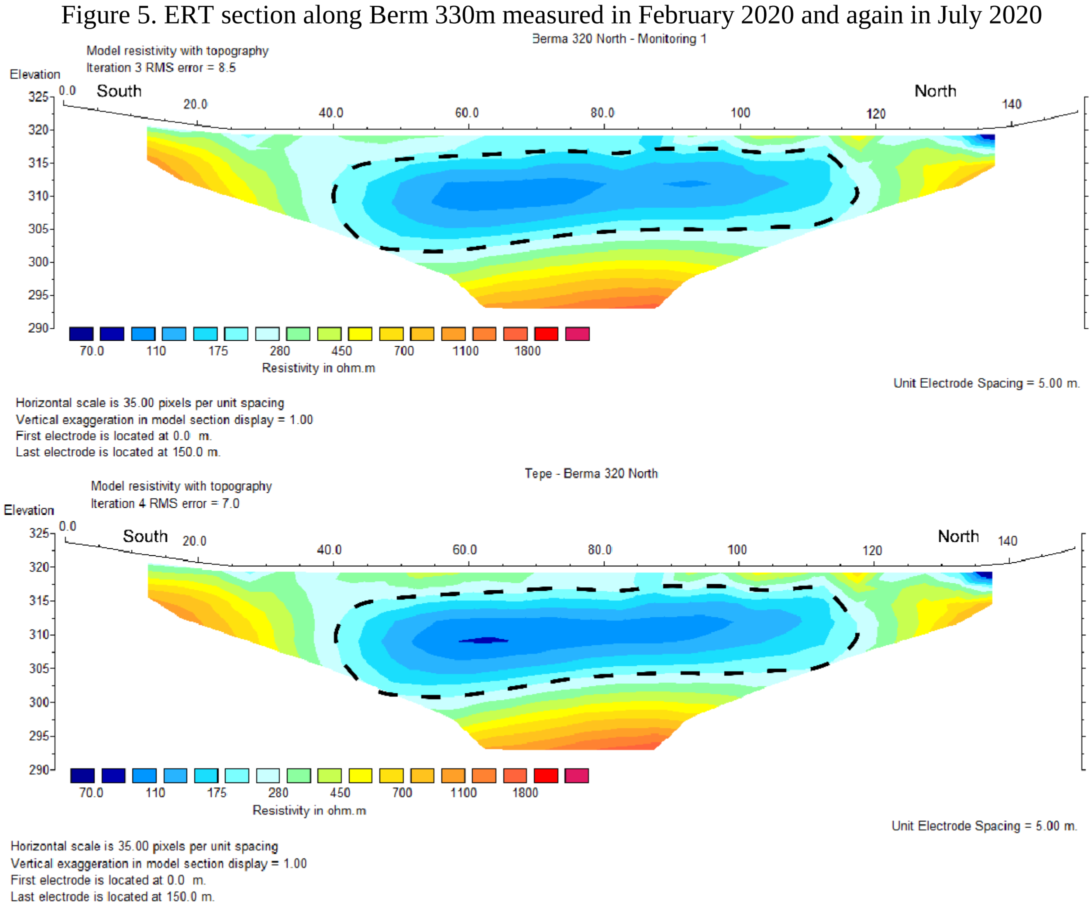

Figure 6. ERT section along Berm 320m measured in February 2020 and again in July 2020

From the comparison of the results between ERT measurements made in February and in July, can be drawn the following conclusions about the behavior of the zones that mark the spatial distribution of a zone with increased water saturation due to the incomplete drainage of the deposited material:

- The comparison of the electrical resistivity distribution on the ERT section along Berm 350m (Figure 3) shows that the area is currently much better defined with reduced resistance values. This is most likely due to the mining waste deposition during the period February - July in a cell with a design bottom of 340 m;
- The comparison of the electrical resistivity distribution on the ERT section along Berm 340m (Figure 4) shows that the area is currently similar in its electrical resistivity distribution, but with a slight increase in the southern direction, which corresponds to the slope of the natural terrain.
- The comparison of the electrical resistivity distribution on the ERT section along Berm 330m (Figure 5) shows that the area is currently similar in its appearance. There is a slight decrease in the electrical resistivity values, due to partial drainage of the deposited material.
- The comparison of the electrical resistivity distribution on the ERT section along Berm 320m (Figure 6) shows that the area is currently similar in its appearance. There is a very slight decrease in size, also suggesting slight drainage of the deposited material. This is also confirmed by the small increase in electrical resistivity values in the central part of the zone.

Conclusion

Mine waste treatment is a complex process. The effective and safe deposition of extractive wastes presents technical and environmental challenges. Each integrated mine waste facility is tailor-made and a sound approach is needed to ensure that the extractive waste management is safe and environmentally sound while also economically viable. Many efforts have been made in the last few decades by the extractive industries to prevent, reduce and minimise as far as possible the negative impacts as a result of the management of extractive waste and the extraction activities.

An integrated mine waste facility is considering to occupy a smaller footprint compared to a conventional slurry tailings impoundment due to an increased maximum stacking height and higher densities than can be achieved by conventional methods. The monitoring of the process of dewatering is essential to ensures the effectiveness and long-term stability of waste and tailings. The integrated waste mine facility in "Ada Tepe" gold mine deposit significantly reduces the mine footprint and also facilitates mine closure in the future. Construction and operation monitoring, management and quality assurance of the risks that tailings storage facilities pose to the environment and society is very important for the proper functioning of the mining sector at all. The question of how mine waste facilities can be effectively managed to avoid unwanted effects is essential for the long-term development of the industry.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Technology, Engineering and Science (www.icontes.net) held in Antalya/Turkey on November 16-19, 2023.

References

Aleksandrova, E., Dimitrov, L., & Kaykov, D. (2021). Operational sequence for constructing a combined mine waste facility. *XVI International conference of the open and underwater mining of minerals* (pp. 7-13). Varna.

Diaz, M. (2014). Evaluation of liner requirement – Krumovgrad integrated mine waste facility (A150-14-R2243). Retrieved from https://s27.q4cdn.com/486073686/files/doc

Dimovski, S., Stoyanov, N., Tzankov Ch.,& Kisyov, A. (2017). Application of electrical resistivity tomography for studying fissure-karst water-bearing complexes, Proceedings of the *9th Congress of the Balkan Geophysical Society,* 1-5. Antalya, Turkey.

Eldridge, T., Kissiova, M., Wickland, B., Ahmed, I. B., & Laurin, J. F. (2013). Integrated mine waste storage facility, Krumovgrad gold project, Bulgaria. *XV Balkan Mineral Processing Congres*s. Sozopol.

Grewal I. (2016, Jun 1). *Mineral processing introduction*. Retrieved from http://met-solvelabs.com/library/articles/mineral-processing-introduction.

Grigorova, I., I. Nishkov. (2016) *Technogenic raw materials processing and recycling*. Annual of University of Mınıng and Geology. Sofia, Bulgaria: St. Ivan Rilski",,

Grigorova, M. (2020). Geophysical and mining technologies for increasing efficiency in Han Krum open pit mine, Bulgaria. *20th International Multidisciplinary Scientific GeoConference SGEM 2020, 20*(1.2), 111-118. Albena, Bulgaria

Kauppila P., Räisänen M. L. and Myllyola S. (2013). *Best environmental practices in metal ore mining.* Finnish Environment Institute

Tayebi-Khorami, M., Edraki, M., Corder, G., & Golev, A. (2019). Re-thinking mining waste through an integrative approach led by circular economy aspirations, *Minerals, 9*(286), 1-12.

White, G., Olden, K., Patrick, G., Kuzmanova, P., O'Connor, M. (2020). Technical report – mineral resource and mineral reserve update. *Ada Tepe mine (NI 43-101).*

Yankova, T. (2020). Mineral processing waste utilization. *XX International Multidisciplinary Scientific GeoConference SGEM, 20*(1-1), 219-226. Albena, Bulgaria.

Yankova, T. (2021). Mining damaged landscape reclamation study, *XXI International Multidisciplinary Scientific GeoConference SGEM, 2*(1-1), 383-390. Albena, Bulgaria.

Author Information

Maya Tomova
University of Mining and geology “St. Ivan Rilski”
Sofia, Studentski grad, prof. Boyan Kamenov", Sofia 1700
Sofia, Bulgaria
Contact e-mail: *maya.grigorova86@gmail.com*

To cite this article:

Tomova, M. (2023). Geophysical techniques for monitoring of integrated mine waste storage facility: Case study of Southeastern Bulgaria. *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 26,* 341-347.