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Editorial

Interdisciplinary Studies for Sustainable Mining

Yosoon Choi

Department of Energy Resources Engineering, Pukyong National University, Busan 48513, Republic of Korea; energy@pknu.ac.kr; Tel.: +82-51-629-6562

Mining is an essential sector for economic development, as it provides valuable resources that are crucial for modern living. However, the mining industry has significant impacts on the environment, including land degradation, water pollution, and air emissions. The mining industry should therefore embrace sustainability to ensure that mining activities are environmentally, socially, and economically responsible. The Sustainable Mining collection by MDPI provides a comprehensive view of the challenges and opportunities facing the mining industry in its journey towards sustainability. The collection includes articles from different fields, including engineering, social sciences, and environmental science, providing a multidisciplinary approach to the topic.

One of the critical themes in the collection is the need for effective environmental management practices in mining. Mining activities have significant impacts on the environment, including the destruction of habitats and the contamination of water bodies. The collection includes articles that discuss innovative solutions, such as the use of green technologies, and the best practices that minimize the environmental impact of mining activities.

Huber et al. [1] examined the environmental impact of mining activities in the Monchepluton massif in NE Scandinavia, which is mainly composed of ultramafic and alkaline rocks with mineralization of oxide and sulfide ores. The study found that the area is currently at risk of ecological disaster due to metallurgical plants, acid rain, soil pollution, and uncontrolled mine water outflows. The authors proposed rehabilitation strategies that may be costly and lengthy due to the specific climatic conditions and vegetation in the area. Huber and Iakovleva [2] investigated the environmental impact of the Zn-Pb heap in Ruda Śląska, which is eroding, contributing to the spread of pollutants. The authors used microscopic observations and geochemical analyses to show that the components of the heap are mobile due to the infiltration of meteoric waters, leading to soil and plant contamination. The authors proposed solutions for the reclamation of the heap, including covering it with an isolation layer or moving it to a protected place away from the city center.

Gui and He [3] investigated the effects of dry beach slopes on the sedimentary characteristics of tailings in upstream tailing dams and the effects of internal erosion on the physical and mechanical properties of sedimentary tailings under unsteady seepage. The results showed that a dry beach with a larger slope has more obvious stratification of tailings and that internal erosion caused by heavy rainfall increases the permeability and reduces the shear strength of tailings. The authors also showed that after internal erosion of tailings under heavy rainfall, the average particle size increases, the hydraulic conductivity increases, and the shear strength decreases for downstream, midstream, and upstream tailings.

Pilecka et al. [4] investigated the impact of high energy mining-induced tremors on building damage in the Upper Silesian Coal Basin (USCB), Poland, by analyzing one of the highest energy tremors (E = 4.0 $\times$ 10^8 J). The seismic energy propagation from the hypocenter of mining-induced tremors caused an uneven distribution in the peak ground velocity (PGVHmax) in tectonically complicated structures, and consequently an uneven distribution of damage to buildings located on the ground surface. The directionality of seismic energy propagation is aligned with the focal mechanism acting in the Barbara fault,

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and it has been concluded that a zone with a width of up to about 1200 m along the Barbara fault is the most threatening on the basis of registered building damage in the geological conditions of the USCB.

The collection also highlights the importance of sustainable mining practices that promote social responsibility. Mining activities can significantly impact local communities by disrupting their livelihoods and cultural heritage. The articles in the collection provide insights into the need for mining companies to engage with local communities and stakeholders to ensure that mining activities benefit all parties involved.

Yang et al. [5] focused on constructing an ecological security pattern (ESP) to protect the regional ecological sustainability of the Pingshuo open-cast mining area in China, which has negative ecological effects. The ESP is formed by identifying ecological sources and corridors through the ecosystem structure and function and constructing an ecological resistance surface. The results showed that in 2018, the ESP included 11 sources and 17 corridors, mainly distributed in Taocun Township, Jingping Township, and Xiangyangbao Township, and that land reclamation work greatly promotes connectivity. This study provides a framework for constructing and optimizing ESPs in ecologically fragile coal mining areas and adds new insights to the concept of land reclamation in these areas.

A regional gravity survey was conducted to determine the thickness of quaternary sediments prior to assessing the sustainability of the Muda River basin [6]. The study area is made up of thick quaternary alluvium deposited on top of older basement rock, and previous studies, including drilling and geo-electrical resistivity surveys, have been conducted in the area, but none of them managed to conclusively precisely determine the basement rock type and depth. Gravity readings were taken at 347 gravity stations spaced at 3–5 km intervals, and the gravity data were analyzed to generate Bouguer, regional, and total horizontal derivative anomaly maps for qualitative and quantitative interpretations. The results showed the average depth of shallow and deep bodies to be 0.5 km and 1.2 km, respectively, and that other geophysical techniques such as seismic reflection surveys can be used to more precisely estimate the thickness of Quaternary sediment and the depth of sedimentary formation.

Eight kaolinitic materials from the Lokoundje River were evaluated for their potential suitability as raw materials in ceramics [7]. The samples were found to be predominantly composed of kaolinite and quartz, with a low alkali content that does not favor vitrification. The presence of goethite limits their utilization in white ceramics. Overall, the results indicate that Lokoundje alluvial clays are suitable for the manufacturing of white stoneware tiles.

A study was conducted at the Detour Lake Mine in northeastern Ontario to assess plant community assembly within a reclamation field trial and compare it with reference forested and historically reclaimed sites [8]. The study investigated the influence of soil amendments on plant functional group establishment and growth in mine overburden and explored the amendment properties that best support the establishment and growth of a plant community that resembles the baseline reference sites. The results indicate that the vascular plant community composition present within the historically reclaimed sites and amendment treatments does not resemble the forested reference sites, but fertilizer and biosolid-based treatments have developed a vascular plant community, excluding woody species that are more similar to those present in forested reference sites, in contrast to the peat-based treatments.

Another critical theme in the collection is the role of government regulations in promoting sustainable mining practices. The articles discuss the importance of regulatory frameworks that balance economic development with environmental and social responsibility. The collection also provides insights into why mining companies should adhere to international environmental and social standards.

Borate is a vital compound that is used in various industries, and Turkey possesses around 70% of the world's reserves. The recent development and pursuit of alternative borate-consuming products raise concerns about the sustainability of boron minerals.

Elevli et al. [9] conducted a material flow analysis to update the current data on boron by establishing a system that shows the flow of boron material from extraction to the end use products. The results can help to develop strategies for boron production and sustainability.

The global gold sector faces an imbalance in supply and demand due to increasing demand for industrial electrification and automation. To address this, research must focus on developing processing methods for complex and refractory ores, which are not amenable to standard cyanidation. Recent technological advancements, including sensor-based ore sorting, provide opportunities for refractory resources in proximity to the processing infrastructure within major gold districts. Discrete event simulation (DES) and integrated artificial neural network (ANN) frameworks can be used to model complex mining systems dealing with geological uncertainty and improve decision-making processes. Wilson et al. [10] present calculations based on a generated dataset for sediment-hosted refractory gold systems.

Coking coal remains on the European list of critical raw materials due to its high economic importance and supply risks, despite narrowly missing the threshold of economic importance in 2017. As there are no significant alternatives to the energy-intensive steel industry, the European Union remains dependent on coking coal imports. The Dębieńsko coking coal project in Poland was analyzed using a scientifically proven methodology based on a world-class analysis of coking coal projects submitted for financing to financial institutions [11].

The Forestry Reclamation Approach (FRA) was developed to improve forest health in the Appalachian region through a five-step process that minimizes soil compaction and establishes a productive forest. Phillips et al. [12] attempt to provide a comparison of two reclamation methods: the FRA low compaction method used in the Appalachian region and the conventional scraper-pan (scraper) methods in the western Gulf Coastal Plain (GCP). The results suggest reclamation practices modeled after FRA methods may positively affect tree growth and survival in the Western Gulf.

Finally, the collection highlights the need for technical innovation in the mining industry. The articles discuss the role of technology in promoting sustainable mining practices and the need for collaboration among mining companies, governments, and other stakeholders to achieve sustainable mining.

Pilecka et al. [13] aim to set strength parameters for the stability analysis of open-pit slopes with a developed slide process using the random set method. The four-stage methodology includes site investigations, sensitivity analyses, shear strength reduction analyses, and probability analyses of the factor of safety calculation results. The resultant factor of safety values revealed probable slide planes, and the positions of these planes enabled the design of a securing approach for landslides and the implementation of preventive measures to reduce this risk. Farkaš and Hrastov [14] discuss the implementation of multiple criteria decision-making methods (MCDM) in quarry mine design, which is not commonly used in Croatia's mining industry despite its extensive stone mining operations. The study applied the PROMETHEE II and AHP decision making methods to select the best quarry design contour out of three final designs based on 22 different criteria parameters. The selected model was found to be financially viable and had the least environmental impact.

The occurrence of rockburst is complex and difficult to predict, and it can cause damage to engineering equipment, can disrupt construction progress, and can endanger human lives. Zhang et al. [15] proposed the D-P-transformer algorithm to improve the embedding structure of transformers for specific applications on rockburst data. The proposed algorithm shows significant improvements in error reduction compared to the original algorithm and can be used for coal mine rockburst prediction analyses. Tshitema and Kallon [16] discussed the increase in underground mining activity, the risks involved in hard rock mining for minerals, and the impact of the global steel shortage on mining operations. The paper presents two designs for rock reinforcement systems to prevent fatal rockfalls in underground excavations, including a preliminary design and an improved model of the rock bolt. Laboratory tests were conducted on the improved bolt design,

which yielded an average of 200 kN during dynamic testing and successfully met the reliability and performance requirements. The improved bolt design requires less steel and has the same performance as current rock reinforcement systems.

Measuring gas pressure is crucial for assessing the methane hazard in coal mines; however, existing methods are limited. Skiba et al. [17] used artificial neural networks to estimate the methane seam pressure, developing two models that demonstrated a high correlation with the reference values determined through sorption isotherms. The models had prediction errors of 2.59% and 3.04% for average and maximum pressure values, respectively, with determination coefficients exceeding 0.99. These results indicate the potential for practical application of this method to improve methane hazard assessments in coal mining. Turkiewicz et al. [18] described the results of biomonitoring research at an underground gas storage facility in Poland. The study focused on the presence of hydrogen sulfide- and sulphate-reducing bacteria in reservoir waters and natural gas. The results indicate that microbiological processes, specifically microbial sulfate reduction, were the main cause of hydrogen sulfide formation at the facility, and methods are suggested for controlling and maintaining the hydrogen sulfide in natural gas at a low level.

Liang et al. [19] presented the design of a new type of fiber Bragg grating (FBG) dynamometry bolt with a linear viscoelastic adhesive layer modeled by a standard linear solid model. A shear strain transfer model and instantaneous and quasistatic strain transfer functions of the surface-bonded FBG sensor were established and validated through uniaxial tensile tests and long-term constant load tensile tests. The application of the FBG sensing technology in the field demonstrated successful monitoring of the stress of the rock bolt in a mining area. Ji et al. [20] discuss the development of a kinematic and dynamic model for roadheaders, which includes their obstacle crossing ability, and its use in path rectification planning. Field experiments were carried out to verify the effectiveness of the dynamic model and a roadway grid model was established based on actual working conditions. The authors proposed a path rectification planning and tracking algorithm based on particle swarm optimization, which was verified using MATLAB simulations. The algorithm can provide technical support for the intelligence of roadheaders and unmanned mining and can contribute to the structural optimization and intelligent travel control of roadheaders.

Peng et al. [21] presented a simulation cutting experiment system for a drum shearer using similarity theory. Simulated coal samples were prepared using an orthogonal experiment method, and their density and compressive strength were analyzed using the range analysis method. The results showed that the density and compressive strength of the simulated coal samples were related to the mass proportion of cement and sand and the proportion of cement, respectively. The self-designed simulation cutting experiment system could effectively carry out experiments and obtain cutting condition signals that could distinguish between various cutting modes. Zwierzyński et al. [22] discuss the importance of space mining to solve ecological energy and mining problems and the need for geological surveys using drilling methods to achieve this. Drilling methods are important for studying extraterrestrial objects for geological, life searching, and geoengineering studies. Designing future space drilling missions requires adapting drilling technologies to the space environment and the realities of the space industry, including minimizing the energy consumption and the mass of the coring devices. The authors performed initial drillability tests to determine the possibility of building low mass coring devices with an energy consumption of below 100 W for use in space missions.

Wu et al. [23] proposed a fast calculation method for improving the steering arm of a mining truck with Macpherson suspension. The forces on the steering arm were calculated by quasi-static analyses, and a rigid-flexible coupling model was established to obtain the distribution stress on the steering arm. The simulation results were verified by experiments, and after determining an improvement scheme, the strength of the improved steering arm was nearly doubled. The effectiveness of the improved steering arm was demonstrated by user feedback after it was manufactured, installed, and used.

The methane-bearing capacity is a fundamental parameter to determine the methane hazard level, potential quantities of methane for energy, and harmful emissions. Direct methods, such as the direct drill cuttings method, are commonly used to determine the methane-bearing capacity; however, gas losses during sampling can affect the accuracy of the results. Karbownik et al. [24] performed several experiments, including methane sorption tests, to identify important aspects and propose a new gas loss coefficient for the direct drill cuttings method. The proposed coefficient can improve the accuracy of methane-bearing capacity determination in hard coal seams. Karbownik et al. [25] discuss the feasibility of applying unipore and bidisperse diffusion models to understand the kinetics of methane sorption and its diffusion in hard coal. The study carried out laboratory tests on coal samples with varying petrography and determined the degree of coalification based on measurements of vitrinite reflectivity and volatile matter content. The study identified coefficients that control the course of sorption in mathematical models, allowing for an assessment of the possibility of applying a given model to describe the phenomenon of methane sorption in hard coal.

Weng et al. [26] focused on optimizing predictions of the critical production pressure differential for deep carbonate reservoirs in the Tarim Basin, which is essential for the development of these areas with huge reserves. The paper summarizes the analytical methods for predicting the production pressure differential and establishes a new numerical model based on finite element theory. Laboratory tests were also conducted to obtain input parameters for the simulation, and the results showed that carbonate rocks exhibited brittleness and post-peak strain softening. The Mogi–Coulomb criterion was found to be suitable for evaluating the pressure differential, and the finite element numerical method was confirmed to be accurate in predicting the critical production pressure differential, although some on-site operators may prefer a more convenient analytical method.

Li et al. [27] introduced the Enhanced Geothermal System based on Excavation (EGS-E), as a new method for geothermal energy extraction. The article investigates the initiation and propagation of excavation damaged zones (EDZs) in the EGS-E and the further evolution of surrounding rock stress and EDZs during ventilation by thermal–mechanical coupling. The results show that high temperature damage on the mechanical parameters of granite should be considered and that ventilation of high-temperature and high in situ stress tunnels has a significant effect on the EDZ scale. Additionally, EDZs experience three stages of slow, rapid, and decelerating expansion with increasing cooling time, and a thermal insulation layer prolongs the slow growth stage.

In conclusion, the Sustainable Mining collection provides valuable insights into the challenges and opportunities facing the mining industry in its journey towards sustainability. It is essential for the industry to embrace sustainability to ensure that mining activities do not compromise the environment, community well-being, and economic development. This collection provides a valuable resource for researchers, policymakers, and practitioners in the mining industry to promote sustainable mining practices.

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