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Editorial

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The latest green and sustainable development of mineral processing and extraction

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The Earth's crust contains mineral resources that must be properly exploited and processed to sustain not only current life standards adopted by modern society but also to support its continuous development and progress. Mineral processing (MP) comprises a chain of unit operations applied to raw materials, named ores, to meet market specifications posed by chemical and metallurgical industries. Typical MP industrial circuits include unit operations of comminution (crushing and grinding), sizing (screening and hydraulic/pneumatic classification), concentration (sensor-based sorting, gravity separation, froth flotation, and magnetic/electrostatic separation), and dewatering (thickening, filtering, and drying). Concentration plays a significant role in the value-adding unit operations because it separates valuable minerals from gangue minerals, yielding concentrates which mainly contain valuable minerals, and tailings which mainly contain gangue minerals. Extractive metallurgy (EM) comprises either hydrometallurgical, such as acid/base leaching and electrowinning, or pyro metallurgical, such as heat-based extraction unit operations that add further value to concentrates yielded by MP. Although both MP and EM are vital activities to produce materials that feed various industries (manufacturing, transport, construction, and technology), they are often associated with significant environmental impacts, including emissions of dust and greenhouse gases and water and land pollution. These environmental issues have led to an increasing awareness in society of the need for sustainable MP and EM.

The latest trend in achieving sustainable MP and EM is the adoption of green and sustainable technologies and processes. An example that contributes to this trend is the shift towards the use of renewable energy sources, such as solar and wind power[1,2]. Although the initial motivation for this shift seemed to be the increasing energy demand and economic aspects, it certainly has the potential to reduce greenhouse gas emissions and improve the sustainability of MP and EM. Nevertheless, optimization and control are key factors in fulfilling the application of renewable energy sources to these vital activities[1]. In detail, outputs of the irregular renewable energy sources require optimization and control by modeling tools, for example, traditional predictive control or those enhanced by machine learning. Besides that, the optimization of the design and operation of equipment (crushers, mills, screens, hydraulic classifiers, hydro cyclones, jigs, magnetic/electrostatic separators, flotation cells, thickeners, filters, and driers) by computational modeling can help to reduce environmental footprint (carbon emissions, energy consumption, space use, and resources required)[3,4]. Additionally, there is an interest in green or eco-friendly reagents (diphosphonic acid as a collector for pyrite and starch as a depressant for hematite) for flotation because of their relatively fast and full degradation, as well as lower toxicity and price[5,6]. Nevertheless, their effective selectivity in different mineral systems, use in a wide range of minerals, and long-term success must be thoroughly investigated.

Another area of interest has been the development of more efficient and environmentally friendly EM. For example, unit operations that use microorganisms to obtain metals from ores, such as bio hydrometallurgy and bioleaching, have been investigated because of their potential to reduce the use of chemicals that cause environmental impact[7,8]. Additionally, efforts are being made to improve the recovery of valuable minerals from mine tailings[9], which potentially reduce the need for MP and EM and minimize environmental impacts. The processing of mine tailing as a secondary source of minerals greatly contributes to overall sustainable/eco-friendly MP and EM. Finally, in addition to practicing the best circular economy methods, the recovery and extraction of metals from secondary sources (e-waste or end-of-life batteries) may be considered a key factor in reducing the demand for primary sources and contributing to a cleaner environment by recycling.

To promote the transition and application of sustainable practices in MP and EM plants, regulatory frameworks and industry standards have been developed. For example, the International Council on Mining and Metals (ICMM) has developed a comprehensive set of 39 performance principles and right-related position statements for sustainable mining, which include a focus on minimizing environmental impacts and promoting social responsibility (website visited on March 2023: https://www.icmm.com/en-gb/our-principles/mining-principles/mining-principles). In summary, the Special Issue "The Latest Green and Sustainable Development of Mineral Processing and Extraction" is aimed at communicating novel research for the reduction of the environmental impact of these activities while maintaining their economic benefits. This research includes significant contributions from existing experimental technologies, new experimental technologies, modeling, data management, machine learning, and others. Research is crucial to understanding the mechanisms behind green and sustainable technologies. When mechanisms are understood, it becomes possible to statistically interpret the technologies and make accurate predictions (using mechanistic models or empirical models such as machine learning). This can lead to automation and control in real-world plant applications. Additionally, this Special Issue is focused on "carbon neutralization" and "peak carbon dioxide emissions", promoting technological innovation in MP. Therefore, constant research and innovation will be required to ensure that sustainability in mining is adopted worldwide and become the industry norm.

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