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Opinion

Decision Making Analysis to Support Waste Recycling Policies at Different Stages of a Mine Life Cycle

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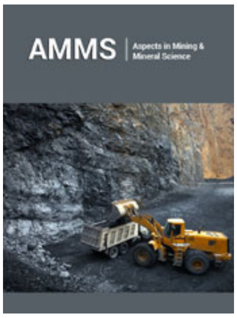

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Opinion

For every single issue that is sensitive to mankind, correct assessment of the involved variables must be attained, before any well-defined decision can be taken. The unique times that Humanity is going through brings many and various changes that affect all economic sectors, leading to behavioural modifications in both industry and society. Mining sector is not an exception in this context. In fact, nowadays, it is critical to find alternative sources of distinct Critical Raw Materials (CRM) of mineral origin, and this issue demands innovation and the establishment of new paradigms, which need to be correctly evaluated and well pondered. The increase of environmental and socioeconomic responsibility in mining activities, as well as research and innovation, are pushing technical and scientific knowledge on the discover of new possible primary and secondary sources of mineral raw materials, and on alternative exploitation scenarios affecting distinct stages of every mine life cycle. In the present context, with circular economy model demanding, mining waste are considered potential metallic and non-metallic resources, and might be managed as Secondary Raw Materials (SRMs). Distinct mandatory tools to evaluate the expected feasibility and potential impacts that may came from the implementation of innovative projects considering mine waste reprocessing are available and include (1) Environmental and Social Impact Assessment (ESIA), (2) Cost/effectiveness analysis, (3) Risk and Decision-Making Analysis (DMA), and evaluation of the impact in the Value Chain(s) of the new generated product(s) through (4) Life Cycle Analysis (LCA). Among these tools, DMA represents a contributively tool that allows to evaluate multiple distinct engineering solutions for a mine site according to a certain stage of its life cycle (operational stage, closure stage, as well as former remediation or revitalization stage). DMA may act as a lever, increasing interest of potential stakeholders and public acceptance. The analysis can be qualitative or quantitative and it must integrate all the engineering, design aspects, and mine entities, and has a strong influence on the features that are under study. The evaluation process can consider a certain specific sector or area of the mine, like the processing plant and its generated mining waste and facilities, or the all-mine site, including water and energy supply and its way out and issues, mainly interconnected with environmental concerns. In both cases, the impacts of distinct engineering solutions (possible alternative scenarios) must be evaluated according to the local and regional conditions, affecting natural environment, social, economic, and land-use development policies, as well as geoethical principles that represent public opinion on the matter. As an example, in [1], six 42 distinct topics are discussed - economics, environmental, technical issues, social, regional development, and geoethics - that must be considered in mine site revitalization processes: economic feasibility of the solution to be implemented, its environmental and social impacts, physical and chemical security conditions (designated as technical issues), regional development and its implications on future land-use and possible economic activities with interest in revitalization process (such as industry, recreational activities, tourism), and, and geoethics, on what issues like the preservation of geological knowledge and mine heritage are aspects to be pondered [2-5].

In the case of evaluating a project for a possible mining waste recycling technology there are some topics to be considered as mandatory. Circumstances, opportunities and, mainly, the economic possibilities of this type of projects may vary significantly according with distinct mine scenarios. For instance, differences are evident if it is intended to process tailings in an ongoing operating mine or in a disactivated mining site. In this last case, financial efforts may inhibit implementation projects' possibilities unless it can contribute significantly to the final revitalization objectives of the site. The expected environmental impacts generated from this new processing activity and its related controlling needs must be carefully evaluated since new needs of water, energy and consumables materials must be considered, and new types and quantities of wastes with distinct danger risk levels will be generated. As an example, Barbosa and colleagues [6] present a case study were distinct alternatives and criteria were established with the aim of reaching a decision regarding the best solution for mining wastes in an old, abandoned São Domingos mine, located in the Portuguese segment of the Iberian Pyrite Belt. These wastes raise a geoethical problem due to their mining-archaeological heritage value to be preserved against, in turn, their high level of generated environmental impacts. Characterization of mining waste must address the conditioning factors of mine waste processing such as mineralogy, texture, granulometry and liberation size. Besides, this characterization needs a Multi-Criteria Decision Analysis (MCDA), considering distinct geoethical alternatives, that was performed under two main possibilities: (1) the permanence of these wastes at the old mining site, in more environmental controlled conditions, without reprocessing them, and (2) the interest in the reprocessing of these waste materials. The advantages and disadvantages of these two opposite actions were balanced according to local conditions. From the MCDA performed it was clear to the authors that the best compromise solution is to remine the mining waste as a component of the environmental reclamation process. This action will allow to improve the expectations of economic sustainability in the short- to medium-term time of the site leading to lower maintenance costs in the environmental post-rehabilitation stage.

Due to the number of topics to be accomplish and its related rating criteria, the selection of the best engineering solutions in mine projects that considers innovative mining waste treatment technologies can be supported by DMA, following a multidimensional matrix model. In this context, in our opinion, the next following nine criteria should be enhanced and prioritized: 1) Circular economy potentialities: i) raw materials to be produced, with respect for economic, social, and environmental impacts of remining activities; ii) expected impacts in distinct value chains (at local, regional, and global level). 2) Impacts on mine waste management strategy: i) potential to transfer and re-use some of the wastes in other mines or other distinct activities; ii) new energy & water consumption rates; iii) new carbon emissions productions; iv) closer proximity to the 4R's, and v) "zero waste production" policies. 3) Environmental impacts and risks: mainly i) geotechnical & environmental impacts; ii) public health, and iii) natural ecosystems; physical and chemical risks. 4) Compatibility of new and future monitoring needs with distinct stages of the mine life cycle (that is, in distinct operational stages and post-mine closure stage). 5) Compatibility of the new and future waste treatment needs with distinct stages of the mine life cycle (that is, in distinct operational stages and post-mine closure stage). 6) Short-, medium- and long-term feasibility due to possible changes in the environmental conditions (such as variations in the piezometric level) effects and their consequent effects, mainly on water, groundwater and soil in operational stages and post-mine closure stage. 7) Public easements and land-use restrictions for the mining site. 8) Future land-use and socio-economic perspectives and interests for the site (public and possible stakeholders). 9) Mine heritage preservation needs and geoethical balance for the site (mainly at post-mine closure stage).

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Authors' Contributions

SB conceived and planned the work. SB and NL wrote the manuscript. NL helped the manuscript review.

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