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KU LEUVEN

MATERIALS ENGINEERING

SUSTAINABILITY ANALYSIS IN THE MINING SECTOR: A SUSTAINABILITY ASSESSMENT OF NEW RECYCLING TECHNOLOGIES FOR SULPHIDIC MINE RESIDUES VALORISATION

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Introduction

Sulphide tailings are residues of the mineral extraction from the valuable fraction of an ore. They are usually composed by pyrite and pyrrhotite, and they are stored in the form of slurries (mixture of mineral particles and water) in big ponds. Sulphide tailings may rise significative environmental concerns worldwide, especially in the areas where mine sites are located. In fact, the tailings ponds can be a source of percolation and the leaching of many heavy metals such as Co, Cr, Cu, Mn, Ni, Pb and Zn, that may become a serious source of damage when they reach the surrounding soil, surface, and ground water, and can decrease biological diversity[1].

Mine tailings in European countries can be a source of valuable metals and a good material for the building and construction sector. The benefit derived from the reprocessing of mine tailings can be many[1]. First, the reduction of environmental impacts and economic profitability. Secondly, new, and efficient processes may allow to extract metals and critical elements. Finally, European countries could be less influences by the fluctuation of the metals' prices, determined by extra European countries.

The goal of this study is to understand the potential environmental, economic, and social benefits of the metals recovery from sulphide tailings, to assess the sustainability of the mining sector. As a case study, this paper presents the sustainability assessment of a bioleaching technology to recover metals from nickel sulphide, proposed by Mondo Minerals within the Mondo Minerals nickel sulphide project[2]. The main steps of the nickel sulphide plant are the bioleaching and the iron and arsenic removal processes. The bioleaching process consists in the solubilisation of the metals in the sulphide tailings due to the presence of microorganisms, that allow the extraction of valuable metals. The iron and arsenic removal process enables the remotion of iron and arsenic from the remaining material, that can then be safely impounded without the risk to have environmental liabilities in the future.

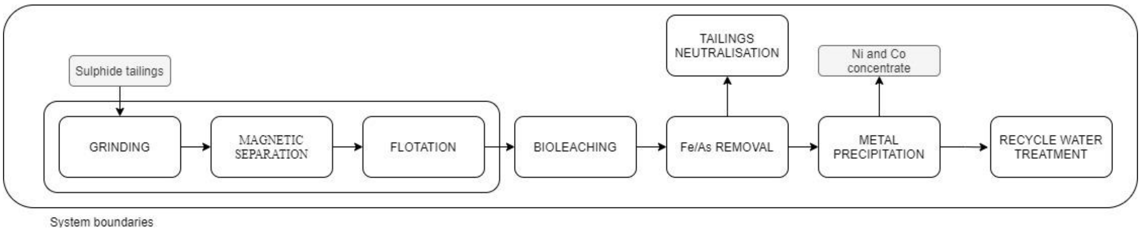

Figure 1: System and system boundaries

The methodologies used for the sustainability analysis are Life Cycle Assessment (LCA) for the environmental analysis, Life Cycle Costing (LCC) for the economic analysis, and Social Life Cycle Assessment (S-LCA) for the social analysis.

The aim of LCA is to quantify and assess which are the most relevant activities and processes, implied with the analysed good or service, that are relevant for the environment, such as the extraction of the raw materials, manufactory, transport, and distribution, recycle, upcycle and disposal. Social Life Cycle Assessment aims at assessing the potential social and socio-economic impacts of product or service during the entire life cycle (UNEP Setac Life Cycle Initiative, 2020). Life cycle costing, or LCC, is a compilation and assessment of all costs related to a product, over its entire life cycle, from production to use, maintenance and disposal.

Results

To perform the analyses, the data regarding the resources consumption and waste flows were collected.

Environmental analysis

The results of the environmental analysis are shown in Figure 2. In the graph are presented the contributions to different impact categories of each process considered in the study.

For most categories, there is a greater negative impact, meaning that the avoided impact is higher than the caused impact. An example is given by the Global Warming Potential (GWP) impact category. The avoided production of nickel concentrate from new resources constitutes the 60% of the avoided impact for the GWP impact category. For

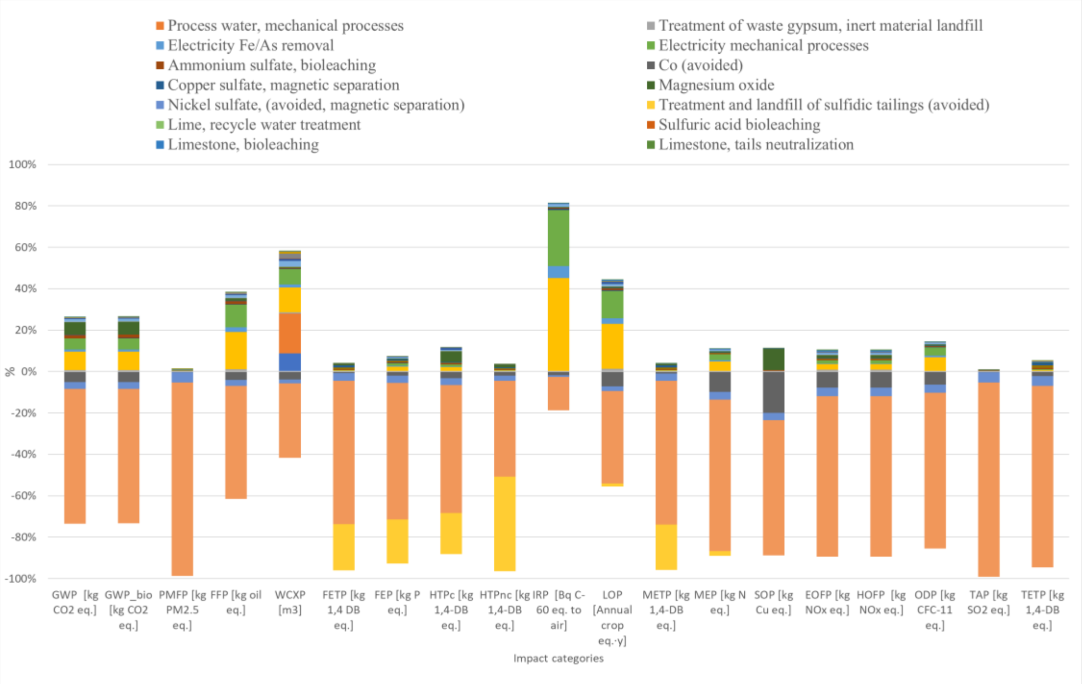

Figure 2: LCA results, normalised to 100% in absolute value for each category.

the same category, the electricity consumption of the mechanical and bioleaching process contributes for almost the 20% of the caused impact. Instead, ionizing radiation and freshwater consumption present opposing results.

If we look at the contribution of the single processes with a positive impact, the energy consumption gives the highest contribution in all categories, from the mechanical processes and the bioleaching process. For the freshwater consumption and ionizing radiation categories, the electricity consumption contributes respectively to almost the 90% and the 50% of the caused impact.

The use of magnesium oxide in the metal precipitation process is responsible for the caused impact in the impact category Stratosferic Ozone Depletion (SOP) and contributes for the 10% to the GWP impact categories.

If we look at the avoided production of nickel concentrate from new resources, it has the highest negative contribution in all graphed categories. It constitutes for example the 90% of the avoided impact for the Fine Particular Matter Formation (PMFP) impact category.
A significant negative contribution is also given by the avoided landfill of the sulphate tailings for the categories freshwater ecotoxicity, freshwater eutrophication, marine ecotoxicity and human toxicity, where it contributes up to the 40% of the avoided impact.

A minor negative contribution to the avoided impacts is given by the avoided production of cobalt concentrate, especially to the impact category metal depletion, where it represents the 20% of the avoided impact.

Economic analysis

The results of the economic analysis are shown in Figure 3. The graph represents the contribution of the costs sustained by the company to the total OPEX (Operational Expenditure) in a year.

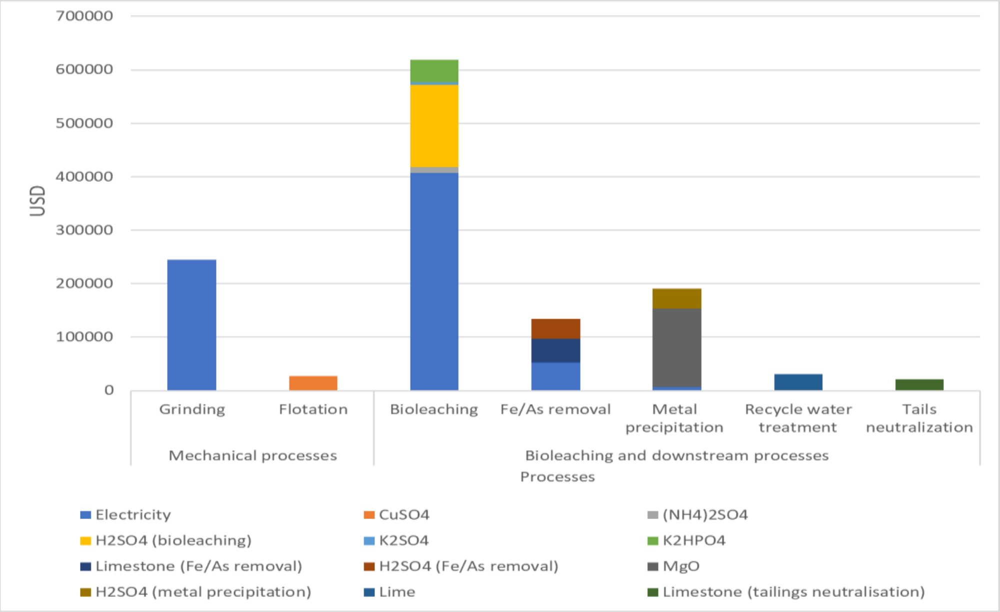

Figure 3: LCC results

As shown in the graph, the biggest cost for the company is represented by the electricity required, especially for the bioleaching process. The costs due to the purchase of chemicals represent 46% of the total operational costs.

Overall, the bioleaching process is the one that requires the major cost for the company, contributing to more than the 50% of the overall electricity cost. In this graph is not possible to represent the capital costs of the project, that is estimated to amount to 13-15 million USD (Neale et al., 2015). The nickel and cobalt product is estimated to pay approx. 16.000 USD/tonne.

Social analysis

A preliminary analysis of the project's social impact was conducted. The Social Life Cycle Assessment analyse the impact on 4 stakeholder categories: local community, society, value chain actors and workers. For each stakeholder category there are many social impact categories. The most relevant social impact categories affected by the project are the ones presented in the graph (Figure.4).

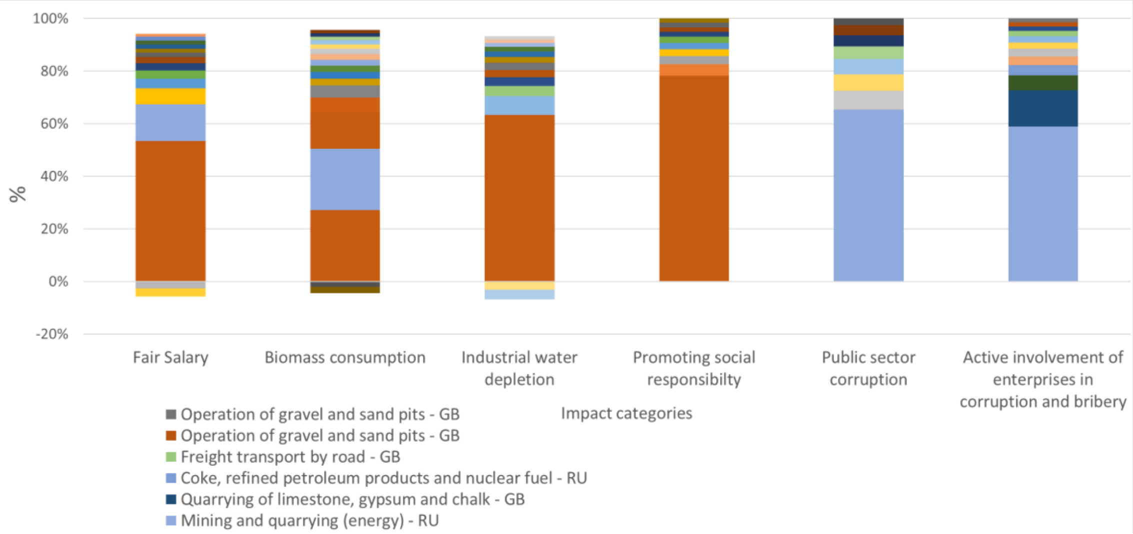

Figure 4: S-LCA results, normalised to 100% in absolute value for each category

From the social analysis emerged that the most relevant social impact categories are Fair salary, biomass consumption, industrial water depletion, and public sector corruption.

The processes that contributes the most to all the categories considered are the chemical manufacturing and the mining and quarrying. For the category fair salary (related to the worker category), for example, the chemical manufacturing contributes for more than the 50% of the total impact. The mining and quarrying process contributes for approx. the 25% for the same category. This process contributes for the 60% to the public sector corruption and the active involvement in corruption and bribery. The avoided mining of nickel and cobalt concentrate does not seem relevant, compared to the impacts caused.

Conclusions

The analysed case study aims at valorising the residual mine tailings from the talc production in the Sotkamo mine (Finland). The results of the sustainability assessment show the potential benefits of the bioleaching process to recover metals. The bioleaching process can help avoid the mining of new mineral resources for the extraction of nickel and cobalt. Moreover, it reduces the amount of landfill material, avoiding the risks of leaching and percolation of metals in the areas surrounding the mine site. The electricity consumption is the process that impacts the most to many impact categories in the LCA and represents the highest cost. Considering using a renewable source of energy, for example, may further reduce the environmental impacts of the project.

From a social point of view, the most critical issues associated with the Mondo Minerals bioleaching project are related mostly to the chemical sector and the mining and quarrying processes, for the impact categories considered. Further studies on these processes can be done, to pinpoint the relation between the mineral sector and the stakeholders considered and identify the key element that contributes to the social impact of the sector.

References

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