Environmental Management Strategies in Mining Industry in Chile

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Sustainable development in the mining industry is a critical concern for companies because it covers multiple environmental, social, and economic approaches. The principal aim of sustainable development is to find the equilibrium between environmental, social, and economic aspects to maintain the system's stability. In this sense, defining mining sustainability is a complex task because of the multidimensional definition of sustainability. However, the primary concern of the environmental sustainability of the mining industry is to avoid and reduce environmental impact at different stages of the mining life cycle, where the mining industry needs to anticipate possible negative effects that its operations may generate. The mining industry faces diverse challenges to maintain sustainable production, particularly regarding critical water and energy supplies. As a significant player in the copper mining industry, Chile has become a global reference. The most prevailing strategies involved implementing Environmental Management Systems, which allow organisations to define, implement, and track their specific goals and standards.

mining industry | mining challenges | social license to operate | environmental strategies

1. The Mining Industry in Chile

There are various challenges that the mining industry in Chile needs to deal with. One is the atmospheric pollution caused by the smelting processes. Mining companies have invested significant money to improve emission control technologies and reduce their annual emissions, especially sulphur dioxide and arsenic [1]. Another pertinent issue is the impact on land use. The various landscape modifications caused by mining operations, erosion, and soil pollution can adversely affect human health and biodiversity.

In this regard, due to current legislation through the environmental evaluation system in Chile, companies must present an adequate closure plan for the mining operation, in which all stakeholders must participate, and new projects cannot be approved without this closure plan [1][2]. However, in Chile, water availability is one of the most critical challenges that the mining industry must face since it is not directly dependent on the actions that companies can develop. Hence, they should find the solution with the participation of all stakeholders [1][3][4].

Geographically, most mining industries are in the country's north, with a high water risk due to competition for water use among various stakeholders. Additionally, various water pollution problems have occurred in an area caused by a lack of environmental regulations before 1994. Besides water competitiveness and pollution problems, there is also a lack of rainfall in the zone, an issue caused by climate change that has affected the whole country [3].

Energy challenges, like water, are highly relevant for the Chilean mining industries since there is a high dependence on the national energy distribution system, which they do not control. The energy matrix system in Chile mainly uses fossil fuels, including oil and natural gas, which are not available in the country and must be imported [1][5]. Moreover, hydroelectric energy has significant relevance in the energy power generation in Chile. If there is extreme drought, such as the one that occurred in 2007, there could be a reduction plan in using electricity during that year [1].

The industry is searching for more sustainable practices to address significant challenges concerning water resources and high energy consumption rates [6]. Water, a critical resource for the copper mining industry, is used in many stages of the mining process [7]. Based on projections, total water consumption for copper mining in Chile will be 23.3 (m^3/s) by 2031, representing an annual average increment of 2.1% [8].

The increase in water consumption is due to two main reasons. The first is a change in the production matrix because of an increase in the treatment of sulphide minerals. Sulphide minerals must be processed through flotation, which requires a much more intensive process in using water than oxide minerals. The second reason is a drop in ore grade. Because of that, the extraction process requires processing a more significant amount of minerals to obtain a ton of acceptable copper [8]. Indeed, energy consumption will rise around 33.6% by 2031, representing a 3.05% annual increase [9].

Many factors influence the need for mining companies to improve their efficiencies, such as a decrease in ore grade, an increment in energy costs, water conflict between different stakeholders, or water scarcity. In these cases, water and energy challenges are a relevant concern for the mining industry in Chile because of the need to reduce water consumption and boost the electricity generation capacity to ensure sustainable operation [8][9].

2. Initiatives for Water Challenges and Their Benefits

For instance, because of the drought in May 2020, Teniente had reduced copper processing [10]. Hydric scarcity affected the mining industry and agricultural sector in Chile [3]. Water supply must be reduced for the mining industry to cope with agricultural demand. This situation is described as 'water grabbing', in which there is direct competition between different water users [11].

Water pollution is another matter that is highly relevant for companies because they have developed various plans to ensure compliance with national regulations and reduce negative social impacts and prejudicial effects on water sources [12]. Water pollution from the mining industry is not a recent issue [13]. Examples from China, Finland, Papua New Guinea, Australia, and Canada showed that failure in managing effluents has resulted in groundwater contamination.

EMIs related to water challenges allow the organisation to reduce the hydric stress, ensuring enough water supply for the operation. They can increase resilience in facing an unexpected event. An example is the case of Los Bronces in 2014, whereby it had lost productivity because of extreme drought. However, the company have improved its water recirculation system, reducing freshwater consumption and dependency [14].

Seawater use is one of the most dominant activities, with projections showing that this resource will increase by approximately 289.9% by 2028, with the concentrations process using the most amount [8]. The desalination strategy has also been used globally. As of June 2015, there were 18,426 desalination plants, providing more than 86.8 million m^3 per day worldwide [15]. For the Chilean companies, using seawater is more costly compared to traditional water sources, i.e., around USD 3.5/m^3 more. However, since water is scarce in the north of Chile, most of the companies rely on some alternative sources. They relate most of the costs to electricity consumption, which contradicts reducing energy consumption [16][17].

Some alternatives to reduce operational costs are necessary to achieve a more cost-effective desalination process [18]. However, it needs more effort to reduce energy costs, and a shared supply network between different companies might be an alternative for reducing the energy prices [16][17]. The high operating costs of desalination may result in low water production, such as in Spain [19]. Some desalination companies were only operating at 10% capacity due to high costs. Another option is to adapt processes to use seawater without desalination, as in Antucoya or Sierra Gorda.

Community Strategic Plans are another initiative that companies have used, in which the dominant strategy is cooperatively improving the drinking water system [20]. Improved drinking water access is also one of the new Sustainable Development Goals (SDGs), and it is essential to be realised [21]. This action can help reduce the hydric stress condition in the influence area, improve the relationship between stakeholders, and enhance the SLO [22][23]. With management systems, most of the base is on the ICMM Framework and risk system, which might support companies in setting concrete plans and goals. With audits, it is possible to generate ongoing reports and evaluate the fulfilment of the commitments made. Some organisations use water balance in management systems to determine water consumption for different stages, identifying potential issues [24].

Monitoring programs are another dominant EMI, which allows organisations to test water quality in different extraction points. One strategy is working with communities. One example is Pelambres's plan, which developed representative participation of diverse stakeholders, resulting in an online website that enhances the transparency and legitimacy of the monitored information [25]. Ghana's government has undertaken the same initiative to manage the country's groundwater resources. More field monitoring activities are taken to control pollution, illegal mining operations, and water body encroachment while monitoring the water quality [26]. A new method to assess the water life cycle, called the water footprinting method, has been developed by the Water Footprint Network. This method has been used to identify the potential environmental impacts of water in the mining industry [13].

Water recirculation is an important initiative for the mining industry to face hydric scarcity, with a global recirculation of around 70% [27]. There are different methods in which the most common sulphide minerals are thickeners and pumps to reuse water from tailing dams into the process [8]. In the strategies studied, it is possible to highlight the use of Thickened Tailings technology, which allows tailings to have a substantial percentage of around 67–70%, maximising water recuperation. This technology can provide other significant benefits, such as stabilising the tailing dam and reducing its evaporation [28]. However, water recirculation is complex and has its disadvantages [29]. Long-term recirculation increases the chemical concentration in flotation and the accumulation of microorganisms, which may harm the environment and social aspects of a leak in the water recirculation plant.

Despite the companies' efforts to acknowledge the challenges, there are some challenges that they have considered minor compared to others in their EMIs. For example, glaciers' management is the least considered, where CODELCO Andina and Antofagasta Minerals include glaciers into their operational planning, even though glaciers are critical water sources, and adverse effects on these ice masses can reduce water availability [30]. Currently, there is a discussion about the Glacier Protection and Preservation Law (GPPL) in Chile, which seeks to enhance the glaciers' preservation status because of their relevance in water supply, biodiversity, and tourism. The first draft of the GPPL was in 2006. However, there is currently no approved law due to a lack of agreement in some specific landform classifications and issues with conflict of interest [31]. A study regarding the proposed GPPL showed that if this law project is approved, copper production will reduce by around 22.5%, affecting the operations of some crucial companies such as Andina, Teniente, Los Pelambres, and Los Bronces [32].

3. Initiatives for Energy Challenges and Their Benefits

The most common strategies for the companies studied are the use of NCRE, Optimisation of processes, Management Systems, Energy Efficient Plans and Innovation projects.

The initiatives address most of the energy challenges. Management systems can provide a guideline to generate goals and common standards for the organisations, where most companies focus on climate change and energy efficiency. It is essential to highlight that some companies such as Teck have an Environmental Management System that covers water and energy challenges. Conversely, some companies have these topics separate, such as Anglo American. However, both strategies have integrated water and energy aspects into the decision-making process.

Innovation is a relevant aspect of the mining industry because it can generate competitive advantages and better use of current resources. There are several innovations into the initiatives , such as the conveyor belt capable of generating around 10% of total energy in Los Pelambres, the trucks tested with hydrogen in El Salvador, the electric vehicle used in CODELCO, and the hybrid LHD in Teniente, among others. The innovation is not only limited to the use of new machinery but also includes remote operation [33]. One example is Remote Operations Centres (ROC) in the mining operation to control mines, ports, and railways. In this sense, all innovative projects need the collaboration of different actors, with research playing an essential role in finding innovative solutions for energy challenges [34].

In the case of the optimisation process and the energy efficiency plan, it is possible to identify their connection because some energy efficiency programs can generate guidelines for seeking opportunities to reduce energy consumption [35]. Although both strategies might deal with four energy challenges, it is less common that these actions could reduce fossil fuel dependency. One reason might be that the strategies focus on modifying current processes to reduce energy consumption rather than generating changes in energy sources. Within the optimisation strategies studied, it is possible to highlight the VOD developed in Andina and Chuquicamata, where this strategy reduces 20 to 30% of the energy consumed by the ventilation process through automation of air distribution based on demand [36].

The most common NCRE strategy is solar energy, reducing the dependency on fossil fuels and GHG emissions. Besides Chile, other mining countries have executed solar projects in their mining industries, such as Ghana, Australia, Eritrea, the

United States, and Canada [37]. However, renewable energies do not mean an energy consumption reduction or improvement in the energy efficiency indicator (energy consumed per ton of mineral produced), as renewable energies replace conventional sources [38].

Companies need to foster both energy efficiency strategies and the use of renewable sources to achieve sustainable production [34]. There are two types of strategies that are possible to identify within the initiatives. First, some companies have created alliances to install their solar thermal plant, such as Gaby [39]. Secondly, there are also other companies that have signed the agreements with energy suppliers to ensure that energy comes from renewable sources. For instance, Zaldivar is trying to become the first company to produce copper solely with renewable energy by 2020 or QB2, attempting to ensure the use of NCRE at the beginning of its operation [40]. Different companies such as Collahuasi, Centinela, Escondida, Spence, Chuquicamata, and Carmen de Andacollo seek to reduce their GHG emissions from scope 2 by agreement, which ensures to supply energy from renewable sources.

The advantages of using renewable energy can be multiple, such as improving the corporate reputation, obtaining the SLO, and reducing GHG emissions [41]. Renewable energy sources also can reduce operational costs in the long term. For instance, Centinela saves around USD 2,000,000 in diesel per year by implementing the solar thermal plant [25]. From the environmental aspect, the utilisation of renewable energy may improve polluted mine sites [42].

However, the reduction in fossil fuel dependency is the least discussed issue compared to the decrease in energy costs, which is the most addressed in strategies where companies seek to increase the efficiency of copper production [41]. Some initiatives aim to decrease fossil fuel dependencies, such as NCRE agreements with energy suppliers, process optimisation, and electromobility. These initiatives may face climate change issues, a topic frequently discussed by companies because they are currently seeking to reduce their GHG emissions [38]. However, although renewable energy helps reduce fossil fuel consumption, avoiding them is a difficult challenge for companies, especially when thermoelectric is the primary energy production source in the national electric system [38].

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