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Water consumption assessment in mineral processing integrating weather information and geometallurgical modeling

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Highlights

- Geometallurgical modeling applied to mineral processing plants and tailings facilities performance.
- Water consumption in mineral processing is assessed using simulation.
- Integration of meteorological variables in estimating water consumption in mineral processing.
- Water consumption as part of the mine planning process.

Abstract

Water is essential in mineral processing. Because water is a limited resource and many mining operations are located in water-scarce areas, proper water management is crucial. An alternative to facing water scarcity in mining is its reuse in the process. Water recirculation is limited because there are water losses associated with the plant operation and the tailings facility. Tailings composition and particle size affect the losses related to entrainment and rewetting. These parameters can be estimated by simulating the plant using geometallurgical models. Weather variables such as radiation, temperature, wind speed, and the fraction of possible sunshine, impact the evaporation expected in the tailings facility. The variability of weather conditions throughout the year implies that evaporation depends on the season. This information is used to assess the water balance in a tailings facility located in a specific region, estimating the water consumption for a given operation. Water consumption can be economically valued and included in the mine plan. This methodology is used to provide examples where a mine plan is optimized incorporating water consumption and using efficient water management criteria.

Introduction

The mining industry requires a significant quantity of water to operate, with mineral processing being the stage with the highest water consumption. Fig. 1 shows the projected water consumption by process and water source for the Chilean copper mining industry over the next decade. It is expected that water consumption will reach 20.9 [m^3/seg] in 2032, while mineral processing is expected to go from 65% in 2021 to 78% in 2032 of the total water requirement (Comisión Chilena del Cobre, 2021b). By 2020, the Chilean mining industry achieved 74.1% of water recirculation in concentrator plants (Comisión Chilena del Cobre, 2021a), an average of 0.52 [m^3] of makeup water per ore ton treated, and estimated water demand of 11.4 [m^3/s] for the concentration process (Comisión Chilena del Cobre, 2020).

Several mining operations are located in arid or semi-arid areas where water is scarce and must be shared with other human activities. In Chile, the General Water Directorate has implemented stricter regulations on water extraction, specifically targeting mining companies. The authorities are encouraging the use of seawater or desalinated water, particularly in the northern regions of the country. These measures aim to protect water resources and promote sustainable practices in the mining industry (Toro et al., 2022). In this context, water management becomes crucial and alternatives for saving freshwater resources arise, like the use of seawater and water recycling. The use of seawater involves other problems such as material corrosion and a drop in flotation performance (Li et al., 2019, Moreno et al., 2011, Ramos et al., 2013). On the other hand, water recirculation has been a common operative solution to face water shortages (Di Feo et al., 2021, Rao and Finch, 1989). The recycling of water has a positive impact on economic factors, such as lowering the amount of water needed to be sourced as well as reagent savings (Forssberg and Hallin, 1989). However, there is evidence that the quality of recycled water could be affected, which could cause a decrease in the flotation performance (Levay and Schumann, 2006, Liu et al., 2013).

New trends have led to the installation of desalination plants that supply mining operations located in areas of water scarcity. This brings other challenges such as transporting desalinated water from coastal locations to mining operations. Thus, the optimization of water usage becomes crucial because the desalination process and water transport are considerably expensive (Northey et al., 2013). In the Chilean scenario, this means traveling over 100 km with altitude differences of up to 3,000 m. Some examples of these operations are presented in Table 1.

Although water can be recovered from tailings facilities, a significant amount is lost due to different processes. We classify the variables that impact the water loss as internal or external.

Internal variables are related to tailings characteristics and operational parameters of the facility such as tailings composition, mineralogy, particle size, solid content, discharge rate, etc. From the point of view of the operation of the tailings facility, the values that depend on the mineral processing performance can be controlled to a certain extent. Thus, all performance variables within the plan, including those related to water consumption and potential losses, can be measured directly or can be inferred with modeling simulation. This permits anticipating the results and making the necessary changes to optimize the process and minimize water losses.

Geometallurgy is the discipline that combines geological, mining, and metallurgical information to create predictive models in the different areas of a mining system in order to control processes and optimize decision-making. Examples of geometallurgical applications in mineral processing include different stages such as grinding and flotation (Alruiz et al., 2009, Rincon et al., 2019, Suazo et al., 2010). Also, geometallurgical simulation has been applied to evaluate the complete mineral processing plant performance (Moraga et al., 2022). From this point of view, it is possible to use geometallurgical modeling to predict the plant performance and hence the variables that affect the tailings composition, which is an input for water losses assessment.

In contrast, **external variables** that affect water losses are related to weather conditions and therefore can not be controlled but only forecasted or characterized using historical data. This group of variables includes radiation, temperature, and wind speed, among others, and have a major impact on water losses due to evaporation (Granger, 1989, Penman, 1956). Thus, water losses due to external variables could be predicted by knowing the area of water exposed to these weather effects and the respective value of external variables. Because of the seasonal nature of weather conditions, the weather variables can be considered cyclical, making the water losses dependent on the time of year. Also, weather variables depend on location, for example, arid regions have greater water losses due to evaporation because of their higher radiation index, higher temperatures, and lower rain rates.

The correct management of water in the mining industry is essential in a water shortage scenario. In order to find better practices for water management, the use of mine planning is a potential tool to optimize the benefits by including water as part of the economic assessment and also considering water availability. Taking as a starting point the block model of a deposit, the mine plan converts the spatial model into a time series that represents the feed to the plant. Mine planning is generally optimized in order to meet long-term requirements, that is, to meet certain production goals, normally associated with ore tonnage and grade, in order to ensure production to the plant. It is unusual that the mine plan includes other characteristics of the material that may affect the process. Typically, the mine planning is performed considering market values, operational costs, and ore properties and the way they impact the final concentrate value. Variables used in mine planning include mineralogy, ore grades, ore hardness, metallurgical properties, mine and plant costs, and metal price among others (Dimitrakopoulos and Lamghari, 2022, Hustrulid et al., 2007). However, even though water supply is crucial in mineral processing, it is not normally included in the mine planning procedure.

In this work, we develop a methodology to assess the water consumption in mineral processing considering the weather conditions of the mine location and their respective variability throughout the year. For this purpose, simulation tools are used to determine plant and tailings facility performances for the treatment of a given ore. Synthetic ore properties data are generated to run the simulations. Additionally, water losses from the tailings dam are estimated using available models. Then, water recovery can be estimated and the requirements of fresh water for the process calculated. Finally, by valuing the water cost, we use water consumption as part of the mine planning strategy. Also, water recovery is utilized to find the best scenario under water management criteria.

Section snippets

Water consumption assessment methodology

It is important to mention that the availability of the full stream characterization (including compositions, mineral proportions, liberation sizes, particle size distributions, etc.) would be necessary to get the best possible model performance. However, as this thorough characterization is so complex, in practice we will only have access to some of the ore stream characteristics, and this information is used in the methodology. Thus, to assess the water consumption in a mineral processing…

Mineral processing plant simulation

A generic mineral processing plant was assumed to be simulated for different ore types. The plant stages are crushing, SAG grinding, conventional grinding, and flotation (rougher-cleaner-scavenger). A feeding rate to the plant of 96,000 [t/d] is assumed.

In order to simulate the mineral processing plant and evaluate the water consumption response depending on ore properties, five geometallurgical units (GMU) are proposed with different ore grades and ore hardness. The GMUs definition is…

Discussion

The results show that it is possible to estimate water consumption in mineral processing plants through simulation. The simulation approach is appropriate because water consumption depends on several variables such as operational parameters of the plant that define the particle size and tailings composition, ore properties, and weather conditions. The simulation allows the user to test multiple scenarios that account for uncertainty in these parameters. Thus, simulation is a quick and easy…

Conclusions

A methodology to estimate water consumption in mineral processing through simulation was developed. The ore properties and the characterization of the weather conditions of the tailings facility location are crucial.

Water consumption depends on weather conditions which vary throughout the year. Therefore, the values of water demand per month for a specific type of ore can be represented by a water consumption vector.

By estimating the water cost and including it in the economic valuation of the…

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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References (46)

O.M. Alruiz *et al.*
A novel approach to the geometallurgical modelling of the Collahuasi grinding circuit
Miner. Eng. (2009)

C.S. Chang *et al.*
A multi-variable equation for relationship between limiting void ratios of uniform sands and morphological characteristics of their particles
Eng. Geol. (2018)

A. Di Feo *et al.*
The effects of water recycling on flotation at a North American concentrator
Miner. Eng. (2021)

G.S. Dobby *et al.*
Column flotation: A selected review, part II
Miner. Eng. (1991)

R.J. Granger
An examination of the concept of potential evaporation
J. Hydrol. (1989)

Y. Li *et al.*
A fundamental study of chalcopyrite flotation in sea water using sodium silicate
Miner. Eng. (2019)

W. Liu *et al.*
A review of the effect of water quality on flotation
Miner. Eng. (2013)

C. Moraga *et al.*
Process simulation to determine blending and residence time distribution in mineral processing plants
Miner. Eng. (2022)

P.A. Moreno *et al.*
The use of seawater as process water at Las Luces copper–molybdenum beneficiation plant in Taltal (Chile)
Miner. Eng. (2011)

S. Morrell *et al.*
Modelling and simulation of large diameter autogeneous and semi-autogeneous mills
Int. J. Miner. Process. (1996)

View more references

Cited by (1)

The effects of indigenous microorganisms and water treatment with ion exchange resin on Cu-Ni flotation performance
2024, Minerals Engineering

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