DROP Project: Leaching process optimization for reducing water consumption in copper mining

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Abstract The growing water shortage in the north of Chile and the projected growth of the mining sector has forced the initiation of efforts to optimize the use of water resources and to minimize water losses. The DROP Initiative, developed by Fundación Chile at a mine company, aimed to reduce fresh water consumption in the leaching process by the optimization of the sprinkler irrigation system. The results of the field tests performed on the leaching pads showed that the solution generated can meet the goal of reducing water losses defined at the beginning of the project of 5 L/s.

Keywords Water losses, leaching process, sprinkler irrigation, evaporation

Introduction

Copper mining takes place mainly in the North of Chile, where the availability of water resources is limited mainly due to low rainfall. This limited availability of water is exacerbated by, the growing increase in water demand from mining in conjunction with the changes in the water cycle caused by global climate change, particularly evident in recent years (Garredeau 2011). As a result of this situation the mining projects in the area, both old and new, are affected by this shortage which has led to the urgent need to develop optimization processes in current mining water consumption(Cochilco 2010). This is how project DROP emerged: an initiative led by the Water and Environment Department of Fundacion Chile alongside a mine company of northern Chile. This initiative is part of the Cluster World Class Provider Programme for the global mining industry, which seeks to encourage suppliers to develop greater technology and management in order to address the challenges that the mining industry has throughout the country and the world (Fundación Chile 2012).

Copper mining in Chile has two operational paths, depending on whether the copper ore is in a sulfide or oxidized state, holding constant the extraction stages. The sulfide milling process, involves; flotation, smelting and electro-refining. If oxidized, it will go through a leaching, solvent extraction and electro-winning process. Mining Company, through this latter process, operates under dynamic heaps, formed by mixtures of oxide-type materials and copper sulfides: representing a proportion of between forty to sixty percent of oxides. The project began by identifying the losses in the leaching process, specifically in the wetting of the heaps under nebulization, in order to achieve the goal of developing and evaluating the nebulized system in order to reduce water consumption by 5 L/s in the leaching process. This improvement was carried out keeping current copper extraction rates.

Operational and environmental critical factors in the process of nebulization:

For the leaching process to develop properly, one must consider a number of operational and critical environmental factors in the process of nebulization. These can be grouped into three categories: operational factors of process, design factors specific to the nebulization step, and environmental factors or (also known as) external factors.

The first category includes the permeability of the material to be leached and the efficiency of contact between the material and the leaching solution. The permeability of the material to be leached, and refining the solution must pass through the entire bed of material and make contact with it. The effectiveness of contact between the material and the leaching liquid depends on the surface area, porosity, particle size and roughness of the surfaces (Mellado, Galvez &Cisternas 2011) amongst other factors. During the application of the solution, refinement is applied as spray. The correct operation prevents water loss by crusting on the surface, avoiding superficial ponding and formation of preferential channels by promoting efficient leaching of ore on the heap. (Avendaño 2004).

The second group of operational factors, relating to the nebulization design, can be identified as: irrigated frame (nebulizers configuration), the height of the nozzle and pressure and nozzle diameter. The frame affects the correct overlap of nebulizers. If nebulizeres are spaced further apart, the dispersion of the cloud caused by the wind is more influential, avoiding a good wetting process. The height of the nozzle determines the residence time of the drop of water in the air, the higher the losses by wind drag and the evaporation due to residence time is greater. The pressure and the nozzle diameter determine the droplet size; smaller diameter, more evaporation.

Finally, in the third category, the environmental factors that promote the loss of water are: a) the temperature, b) air humidity, c) solar radiation, and d) wind flows.

In this research, efforts have focused on optimizing the irrigation matrix of the leaching process. To meet this goal, we studied the water loss in the current configuration, and furthermore each design factorswas studied (eg nozzle height, irrigation frame, drop size and use of cover, among others) individually. Then, we proceeded to optimize these design factors in order to reduce water losses and finally we quantified the effect on water loss of the entire process and also at the level of each design parameters.

Methodology

Experimental Design

Tests for water loss were performed *in situ* in the leach pads on the mine company. This was achieved on a quadrant of twenty meters long and eighty meters wide on a leach pad. The quadrant was divided into a 8-cell study plot of approximately ten by ten meters. Each unit contained seven nebulizers mounted on a triangular design distribution, as used by the mine (Fig. 1).

The evaporation and precipitation rate measurement was made using forty-eight catch cans around the center of nebulizer. Pressure and flow rates were monitored by a pressure gauge and a flowmeter, respectively, both located in the input line to each cell. The evaporation loss value was calculated as the difference between the rate of applied irrigation and water collected at the set of catch cans. Tests were conducted in three different

Fig. 1*.Configuring nebulizers on study plots*

time intervals: 9:30–11:00 am, 11:30am-13:00 pm and 15:00pm-16:30 pm each day in order to evaluate the effect of environmental variables on water loss. For statistical purposes, each test was repeated 3 times.

In addition to the sampling of environmental variables a weather station was mounted in a field at a fixed point of the leaching plant to generate a wind rose to determinate wind behavior and its influence on the losses and water savings achieved in conducted tests.

Optimizing process design parameters – nebulization

In relation to the operational and environmental variables a test matrix was used for evaluating their effects on potential water savings (Table 1).

Note that the current system configuration of nebulization is a 1.8 m separation between nebulizer, a 40 cm nozzle heightand no use cover. A mixture of measurements were also considered in order to verify synergy between them by means of a experimental factorial design 2^4.

Finally, in order to study the droplet size, a nebulizer was mounted inside a covered cell with a droplet size measuring station, which consisted of a 40 cm high nebulizer and water sensitive cards along the wet radius. These cards can capture various droplet sizes by changing from yellow to blue upon contact with the water, registering droplet size with a droplet finger print that is marked on the card. After the test, the cards were scanned and processed in the Steinmaster software that translates every mark and droplet size. Droplet size was measured for the current nebulizer and another alternative nebulizer, similar in operational parameters, in order to quantify the difference in droplet sizes.

Potential solutions	Unit	Test range
Nozzle height modification	Cm	40 - 20
Framemodification	M	1,4 - 1,8
Coversystem	--	Use/No use
Dropsize	μm	190-250

Table 1 *Potential measurementsto reducewater consumption*

Results and discussion

Base analysis

The results presented below are for the time interval of 15:30 to 17:00 hrs, Zone 3, where it was expected to be the most favorable condition for high evaporation.

Framework irrigation

The effect of frame irrigation did not influence the reduction of evaporation losses or drag. It's important to say that although a reduction was not observed in regards to evaporation losses,

There was an overall evaporation reduction, considering that if the distance is reduced between the nebulizers, more are needed in the same area, which consequently means a reduction of the pressure and flow rate to keep a constant flow rate. Taking into account this effect, the overall reduction is positive, which quantifies potential savings. Those savings compared to the rest of the measures are discussed in the following section.

Nozzle Height

The nozzle height did not show a favorable trend in relation to the reduction of evaporation losses and drag. The increase may be explained by wind turbulence on the areas close to the surface as the drops would remain in the air longer.

Covers

The use of a cover to isolate the spray from the environment is a desirable element in terms of evaporation. This can be seen in Fig. 1. Wind speed measurements within the cell showed that the wind reduced by 75 % (in regards to the wind outside), confirming the importance of protecting the nebulizers from the wind due to the influence on the process.

Droplet Size

In Fig. 2, the droplet size shows a difference of almost 10 % between the nebulizer and the alternating current due to the effect of the drop on evaporation. The small drop of the alternative nebulizer is more likely to be dragged due to their weight and increase evaporation due to the high surface area. Although the difference in size between drops was 60 µm, the trend is significant, demonstrating an important sensitivity in this parameter.

Environmental variables

The weather station worked during most of the study, recording data every 1 minute. This data was then processed and the values were reported hourly. This allowed information to be checked in relation to time intevals and to see how this variable influenced water losses. The main parameters are shown in Table 2

As seen in Table 2, zone 3 is the most unfavorable for nebulization due to a low relative humidity anda high wind speed and strong radiation, which is consistent with previous data.

It's important to say the results of evaporation losses from the other two zones were not favorable, because the measurements did not show a positive trend in terms of reducing water consumption.

Integrating Optimization variables.

After a baseline analysis, a new analysis was introduced that integrated operational variables with the previous heap nebulizers results. This analysis was essential to connect the loss by evaporation and drag with the flow rate in order to compare it with the preferred flow rate. In this analysis we integrated the total amount of nebulizers, the flow emitted by each of them, the total nebulization area, the wetting ramp established, among other variables.

Considering this analysis aims to support the reduction of total water consumption, with respect to the four variables described above, the order of importance taking into account the greatest reduction is:

Frame irrigation> cover> height
> drop size

Considering the reduction goal of 5 L/s, four variables were able to overcome it. Of these, 3 are a combination of variables.

Cover + frame irrigation>
frame irrigation + cover + height >
frame irrigation>Frame irrigation + height

If the criteria are the costs associated with

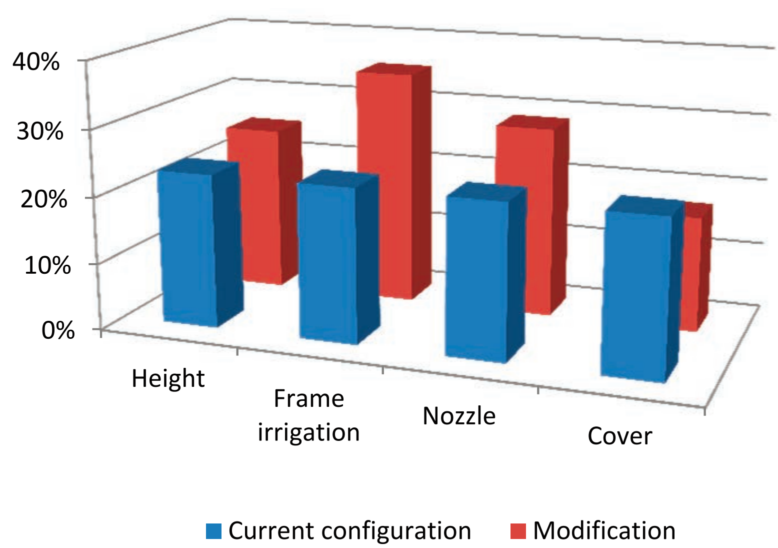

***Fig. 2** Effect of the proposed measures on the total losses*

Topic	Unit	Zone 1	Zone 2	Zone 3
Wind	m/s	1,3	2,5	3,6
RelativeHumidity	%	20	14	14
Radiation	W/m2	20	530	830

***Table 2** Environmental variables and ranges measures on field*

each variable, taking into account the highest cost, the optimized solution would be:

Cover + height + frame irrigation>
walls + height + frame irrigation >
frame irrigation + height> frame irrigation

Taking account the two previous criteria, frame irrigation and height are seen as cost-efficient options to reduce water losses.

Conclusions

From this analysis, the possibility to change the distance between the nebulizers and the use of covers, are the most interesting options with the potential for significant water savings.

The drop size was the most sensitive parameter, demonstrate its importance in terms of evaporation and drag. If the size is known, its possible modifying in order to reduce evaporation.

At the end of this project, Fundación Chile studied and considered the factors in this process comprehensively and articulated a methodology for nebulization irrigation. This provides insights for appropriate solutions to several operational realities, aiming to reduce water losses.

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