One Step Forward: Automating Advanced Heap Leaching Irrigation Techniques

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ABSTRACT

Optimizing heap leach irrigation directly increases production and thus, profit. Only a handful of efforts have proven to automate this process in order to properly apply state-of-the-art irrigation techniques. Although these approaches have been a matter of usual discussion, industrial scale applications are yet to be developed.

A series of experiments were carried out in a pilot plant to test an automated double circuit system to perform non-conventional irrigation techniques for process optimization. The methodology and the results of those tests are discussed in this paper, featuring the new functionalities of the industrial Leachtrol® system, a smart automated monitoring and control system that enables advanced process management.

The resulting feasible instant irrigation rates of the cells determined by the automated calibration procedure show a high correlation between repetitions when using the same circuit since slight deviations were observed within the group. Also, the procedure properly discriminates between different hydraulic conditions of the circuits. An overall average error of 3.10% between the setpoint irrigation rate and its corresponding measured instant flow indicates that the procedure can effectively determine the feasible range of instant irrigation rates and operate within it thereafter. Additionally, compliance levels in excess of 96% were attained when running low-rate irrigation programs by means of double circuit equipment, in terms of time-average irrigation rates and programmed flow.

Being able to operate an automated double circuit system with calibrated rates enables to adapt to different geometallurgical units and address a wide variety of leaching challenges such as uniform leaching for low percolation ores and creating a suitable environment for effective bacterial leaching.

In perspective, the future should hold an increasing incorporation of automated double circuit irrigation in industrial heap leaching as it is a versatile and reliable approach to optimize production by the means of advanced irrigation techniques and, consequently, to increase process profitability.

Keywords: heap leaching; automation; irrigation; pilot plant; Leachtrol.

INTRODUCTION

The heap leaching pad is an extensive area subdivided into cells that traditionally requires the presence of operators on site to control and monitor the process. Low or no instrumentation in the cells significantly differs from mining process standards and limits the capacity to detect operational deviations and provide timely responses, thereby affecting process profitability. Traditional operation methods expose the already scarce personnel to risky and difficult-to-track activities with a high probability of human error. Furthermore, reports or records allowing control or further analysis are usually non-existent. To address this deficiency, the industry is making efforts to automate the understanding, monitoring and control of the heap (Chavez, 2014; Ghorbani, 2014).

Moreover, the increasing complexity of minerals makes it even more necessary for the industry to adopt state-of-the-art irrigation techniques in order to enable processing. As means of example, it can be mentioned: the use variable irrigation rate, double circuit irrigation, on/off cycles, application of different solutions and irrigation ramps. Although these approaches have been usually discussed (Bernal & Velarde, 2004; Carretero & Harvey, 2006; Silva, Picarte & Patiño, 2012; Van Staden, 2007), they are yet to be properly scaled to an industrial level.

Hypothesis

Nowadays, there is available technology that allows a versatile use of heap leaching irrigation equipment in order to address the challenges of this process.

General objective

Using a pilot plant context to study the new functionalities of the Leachtrol® system as a tool to improve the versatility of industrial irrigation equipment and to enable advanced irrigation techniques. This is a continuation of the work undertaken at Compañía Minera Cerro Colorado to automate, monitor and control the wetting process.

Specific objectives

- Evaluating the empirical automatic procedure of the Leachtrol® system for determining the feasible instant irrigation rates in which installed equipment can operate, according to its site-specific conditions of available pressure and hydraulic design. This, to assimilate topography, cell size and inherent variability of the irrigation equipment which provide each cell with specific operational conditions and also to establish initial conditions for subsequent performance evaluation.
- Evaluating irrigation programs executed by the Leachtrol® system which, by coordinating the use of two irrigation circuits and varying its instantaneous application rates, allow for uniform low-rate irrigation over time. This, among other things, to handle the increasing amount of fines and clays present in the ores that significantly hinders solution percolation through the heap producing ponding and saturation. Also, allow air replenishment by maintaining low dynamic moisture for bioleaching operations.

METHOD

Pilot plant setup

A pilot plant was designed and built at Biohydro.cl Headquarters located in Iquique, Chile in order to carry out the experiments. The fundamental design criteria were to meet flow requirements per cell to deliver a standard irrigation rate for industrial heap leaching operation, i.e. 25-80 m^3/h.

This plant operates a pumping and recirculating circuit that achieves flows designed to feed three cells, each with double circuit irrigation equipment. To limit the space for this plant, a condensed emitter configuration was utilized. For instance, spacing between drippers was reduced to less than 3 cm while irrigation lines were placed along the main pipe only 5 cm apart. By these means, a typical industrial cell irrigation area of 3 200 m^2 can be reduced to an area of 20 m^2. Each circuit is designed to deliver a nominal rate between 6 and 9 $L/h/m^2$ considering the equivalent area.

The automation of this pilot plant is performed by the Leachtrol® system using a Remote Device capable of controlling both irrigation circuits simultaneously on each cell.

Table 1 Cells configuration details

	Cell 3		Cell 4		Cell 5	
Circuit	A	B	A	B	A	B
Tag	C3MA	C3MB	C4MA	C4MB	C5MA	C5MB
Emitter	Misting sprinklers 23 L/h	Drippers 2 L/h	Drippers 2 L/h	Drippers 2 L/h	Drippers 2 L/h	Drippers 2 L/h
# emitters	968	13 300	13 300	13 300	13 300	13 300
Nominal flow (m^3/h)	22	26	26	26	26	26
Debris collection pipe	No	No	Yes	Yes	No	No

The Leachtrol® system

The Leachtrol® system is a smart automated monitoring and control system that enables advanced process management. It consists of three primary components that support its operation: a Base Station, a Repeater Station and Remote Devices.

The Base Station is the system control center where the operator has access to the HMI (Human Machine Interface) which handles programming, control and irrigation monitoring. The user has the flexibility to easily program irrigation cycles of varying complexity for each cell. Particularly, the system is capable to manage one or two irrigation circuits per cell.

Once the program is generated, instructions are sent by radio frequency to the Remote Devices located on the heap. These units are energy independent and run the irrigation program reporting to the Base Station both their status and pressure and flow measurements in the cell on a minute-by-minute basis. Pressure measurements are performed immediately after the control valve of each circuit with piezoresistive pressure transmitters. For each cell, input flow is measured using insertion electromagnetic sensors.

The Repeater Station enables communication between the Base Station and the Remote Devices acting as liaison between them. Its convenient location allows for extended communication coverage or overcoming topographic obstacles, thereby completely encompassing the leaching area.

On-line monitoring of process information for each cell takes place at the Base Station, where early detection alarms are triggered should there be any deviation. Also, program compliance and alarm reports are produced by the system and all historical process information is stored in a database.

Figure 1 Pilot plant view

Experimental Design

Evaluation of the automatic procedure to determine the range of feasible instant irrigation rates

The instrumentation and software that constitute the Leachtrol® system allow it to recognize the flow-pressure relationship of the cell by means of an automatic procedure which constructs a calibration curve for the installed irrigation equipment; hence, determining the feasible instant irrigation rates that can be achieved for each circuit of the cell.

The objective of this experiment is to evaluate the repeatability, discrimination capability, and validity of this automatic procedure to determine the range of instant irrigation rates. Repeatability is to be defined as the capability of the procedure to obtain similar results under the same hydraulic conditions, discrimination capability as the competence of the procedure to differentiate between diverse hydraulic conditions and validity as the correct determination of the range of instant irrigation rates of the cell.

Executing the procedure three times in the same cell and comparing calibration results will help to evaluate repeatability. Three hydraulic configurations are considered: C3MA, C4MA and C5MB. Discrimination capability will be evaluated comparing calibration results of the different hydraulic configurations, considering the three repetitions for each. Executing an automatic irrigation program will be used to evaluate validity. A random sweep of six evenly spaced operation points within the range of instant irrigation rates is performed. Each operation point is programmed for 20 minutes to verify that the system is capable of operating reliably in all of them.

From the operational information that the Leachtrol® system stores in its database, values of instant irrigation rate setpoint, real instant irrigation rate, cumulative flow and calibration curves are utilized.

Evaluation of repeatability and discrimination capability is done by a graphical analysis of the calibration curves. For validity, the absolute average error between instant irrigation rate setpoint and its corresponding measured instant flow are analyzed when performing the random sweeps.

Evaluation of the execution of time-average low irrigation rate programs

The Leachtrol® system can execute irrigation programs at very low rates since it combines the effects of three independent factors: applying controlled instant irrigation rates, scheduling on/off cycles and using double circuit equipment alternately. The results achieved by performing on/off cycles are equivalent to lowering the nominal flow of the emitters, but without increasing the probability of plugging. A double circuit arrangement features two main pipes which splits the input flow, but maintains the total number of emitters. Nevertheless, as the spacing between emitters is preserved and the circuits are operated alternately, low rate irrigation is achieved without generating non-leached areas.

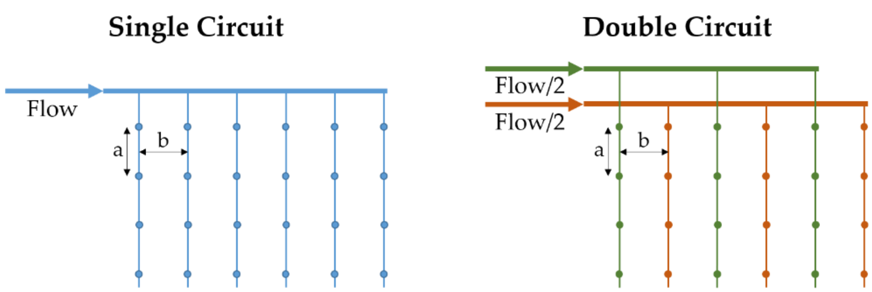

Figure 2 Single and double circuit arrangement

The objective of this experiment is to evaluate compliance of a series of low-rate irrigation programs which combine the factors mentioned above. Compliance is defined as the adhesion of the execution to the irrigation program. These experiences do not consider metallurgical results as performance indicators, as the possible benefits of these strategies depend on the specific conditions of an industrial scenario.

Using cell 4 equipped with irrigation circuits C4MA and C4MB, three different irrigation programs are designed and performed to meet the same time-average irrigation rate: 5 L/h/m2. By using both circuits, an effective irrigation area of 6400 m2 is considered. Details regarding the irrigation programs are shown in the following images.

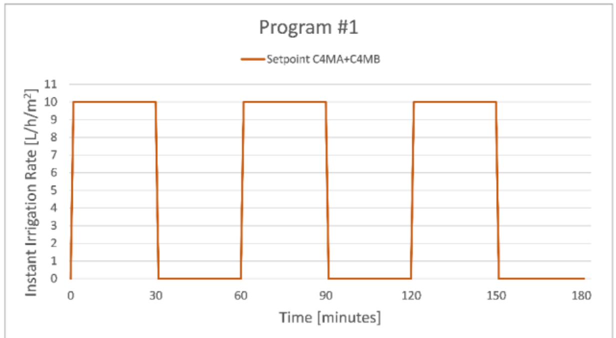

Figure 3 Program #1 On/off irrigation cycles with simultaneous operation of circuits. Both circuits simultaneously operate to deliver a total instantaneous rate of 10 L/h/m2 while performing cycles consisting of 30 minutes of irrigation followed by a 30 minute rest period

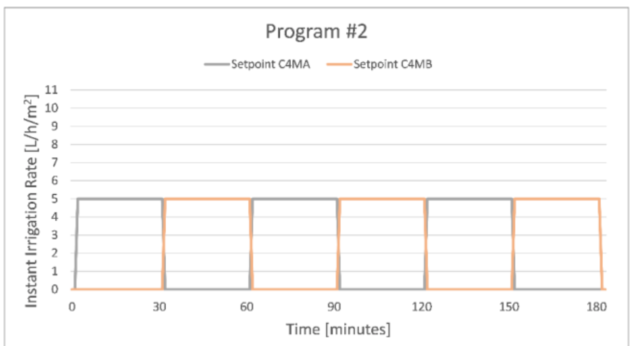

Figure 4 Program #2: Continuous irrigation while alternating the operation of circuits. Each circuit operates to deliver an instantaneous rate of 5 L/h/m2 while performing cycles consisting of 30 minutes of irrigation followed by a 30-minute rest period. Circuits operate in coordination to achieve continuous irrigation

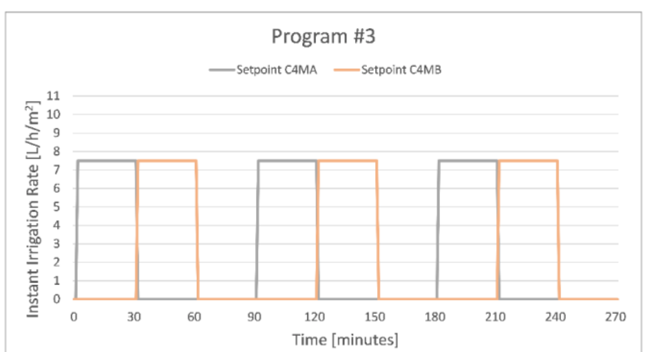

Figure 5 Program #3: On/off irrigation cycles while alternating the operation of circuits. Each circuit operates to deliver an instantaneous rate of 7,5 L/h/m2 while performing cycles consisting of 30 minutes of irrigation followed by a 60-minute rest period. Circuits operate in coordination to perform a total cycle consisting of 60 minutes of irrigation and 30 minutes rest

From the operational information stored in Leachtrol® system's database, values of instant irrigation rate set point, real instant irrigation rate and cumulative flow are used.

To evaluate validity, Mean Square Error (MSE) between programmed instant irrigation rate and real instant irrigation rate is analyzed. Also, the percentage difference of the total programmed flow vs. the real cumulative flow is considered as an indicator.

RESULTS AND DISCUSSION

Evaluation of the automatic procedure to determine the range of feasible instant irrigation rates

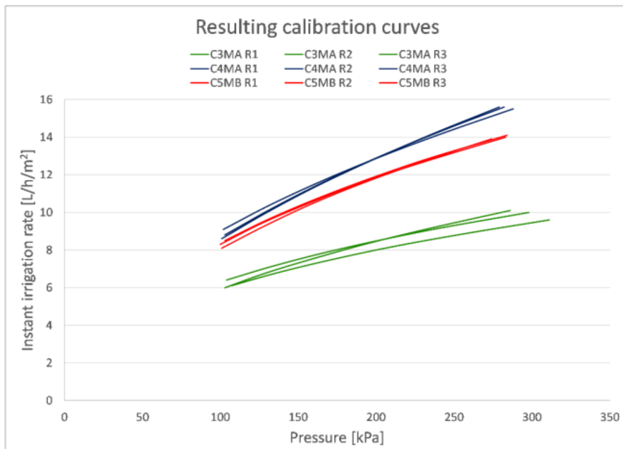

Figure 6 Calibration curves resulting from the process to determine the feasible instant rate range and its relation with the inlet pressure to the circuit. Each color brings together the three repetitions performed for the three cell configurations used. Results of C4MA in blue, C5MB in red and C43MA in green

Repeatability: The resulting calibration curves for the same circuit show high correspondence between repetitions since slight deviations are presented within the group, thus proving that the method is consistent when repeated under the same hydraulic condition.

Discrimination capability: Differences between groups of results are significantly higher than the highest difference within a group of repetitions. This demonstrates that the procedure properly discriminates hydraulic conditions of the circuits.

Table 2 Absolute fit error of instant irrigation rate sweeps

Cell	Repetition 1	Repetition 2	Repetition 3	Cell Average
C3MA	4,58%	4,28%	2,09%	3,65%
C4MA	3,99%	3,60%	4,00%	3,86%
C5MB	2,07%	1,64%	1,7%	1,80%
			Overall average	**3,10%**

Validity: The analysis of the absolute average error shows that calibration curves consistently fit the experimental results of the instant irrigation rate sweeps. Considering all repetitions, errors were always below 4.58%. In general, an overall average error of 3.10% indicates that the procedure can effectively determine the feasible range of instant irrigation rates of the cell and operate within it thereafter.

Evaluation of the execution of time-average low irrigation rate programs

Figures 7, 8 and 9 present the execution results of the three time-average low-rate irrigation programs defined for this study.

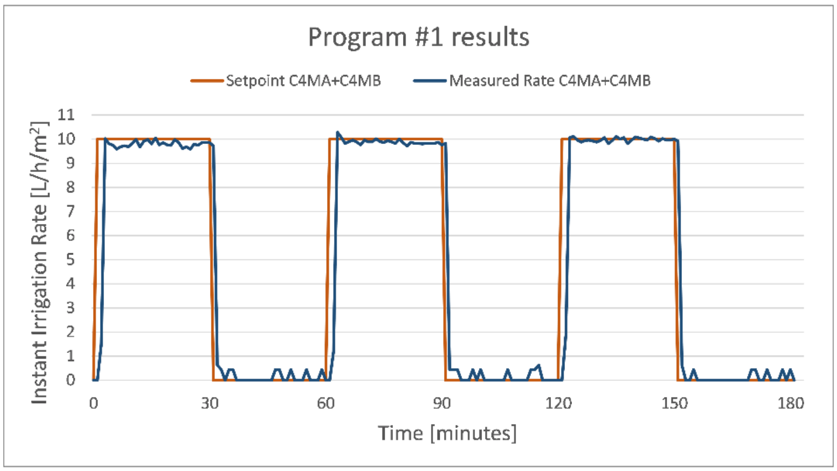

Figure 7 Execution results of Program #1 to achieve time-average low-rate irrigation. In blue, the measured total instant rate and in orange its setpoint

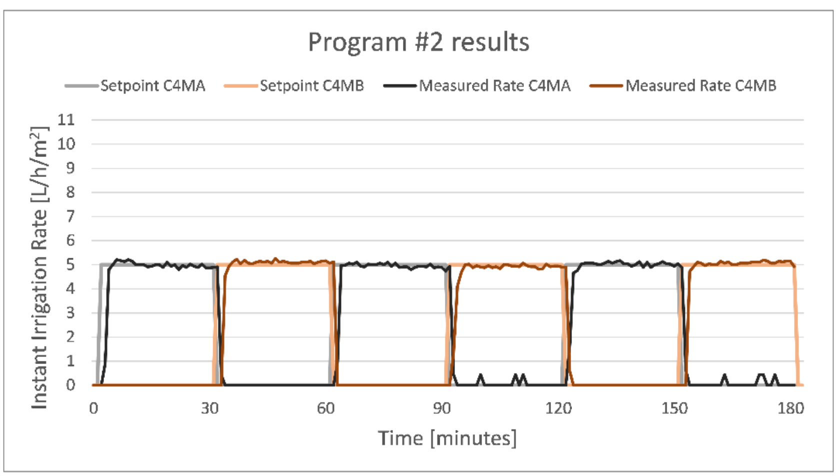

Figure 8 Execution results of Program #2 to achieve time-average low-rate irrigation. In black and red the measured instant rates of C4MA and C4MB and in grey and light-orange their setpoints

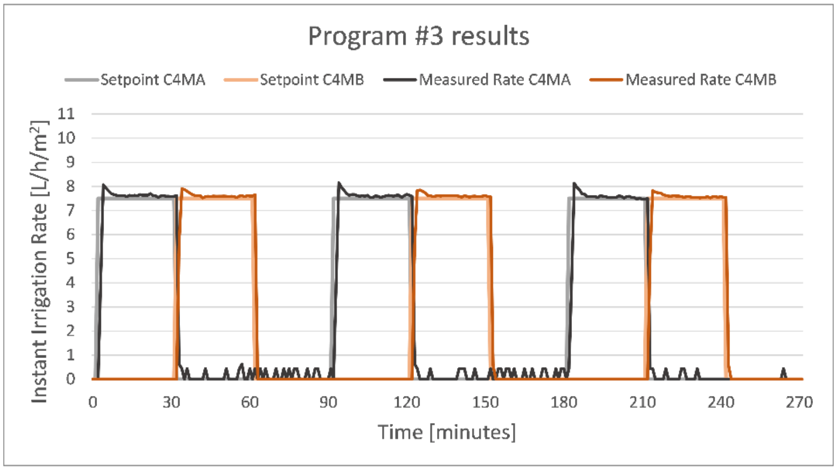

Figure 9 Execution results of Program #3 to achieve time-average low-rate irrigation. In black and red the measured instant rates of C4MA and C4MB and in grey and light-orange their setpoints

Table 3 Summary of performance indicators

	Program #1	Program #2	Program #3
Instant rate MSE	0.328	0.319	0.117
Programmed flow (m^3)	96	96	144
Real flow (m^3)	94.51	99.36	145.15
Flow difference	1.6%	3.5%	0.8%

Compliance: The analysis of the MSE for each of the three low-rate irrigation programs shows minimal deviation between execution and setpoint in all cases, which indicates a high level of compliance. This translates to very low differences between programmed flow and real cumulative flow for every instance, all below a maximum of 3.5%.

The time gap that can be seen between irrigation rate setpoints and the real irrigation rate is due to inherent latency characteristics of the communications among the Base Station and the Remote Devices of the Leachtrol® system. Also, the occurrence of slight executions deviations is due to the internal set of control parameters. If necessary, these parameters can be modified to optimize the execution control within the entire range of irrigation rates.

CONCLUSIONS AND FUTURE PERSPECTIVES

In the light of the results, the procedure carried out by the Leachtrol® system to determine the feasible instant irrigation rates proves to be a reliable tool given its repeatability, discrimination capability and validity. Also, the high level of compliance observed in the execution of the time-average low-rate irrigation programs corroborates the capacity of this technology to properly carry out this task.

For the industry, this indicates that it is possible to:

- Determine the operating range of each cell according to its site-specific hydraulic conditions.
- Operate at different rates with the same irrigation equipment either to modify it during the leaching cycle of a cell or to adopt different strategies according to the characteristics of the metallurgical units.
- Industrially execute reliable uniform low-rate irrigation programs with different strategies in accordance to the specific needs of each operation, such as: handling the increasing amount of fines and clays to reduce ponding and saturation and allowing air replenishment for bioleaching operations, among others.
- Evaluate the performance in time of the irrigation equipment at any operational condition.

Future work considers implementing and executing this and other advanced double circuit irrigation techniques in industrial heaps in order to analyze the impact on metallurgical results. This, as a complementary line of work regarding the industrial implementation of the automated wetting procedure using the Leachtrol® system in Compañía Minera Cerro Colorado.

In perspective, the future should hold an increasing incorporation of automated double circuit irrigation in industrial heap leaching as it is a versatile and reliable approach to optimize production by the means of advanced irrigation techniques and, consequently, increase process profitability.

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