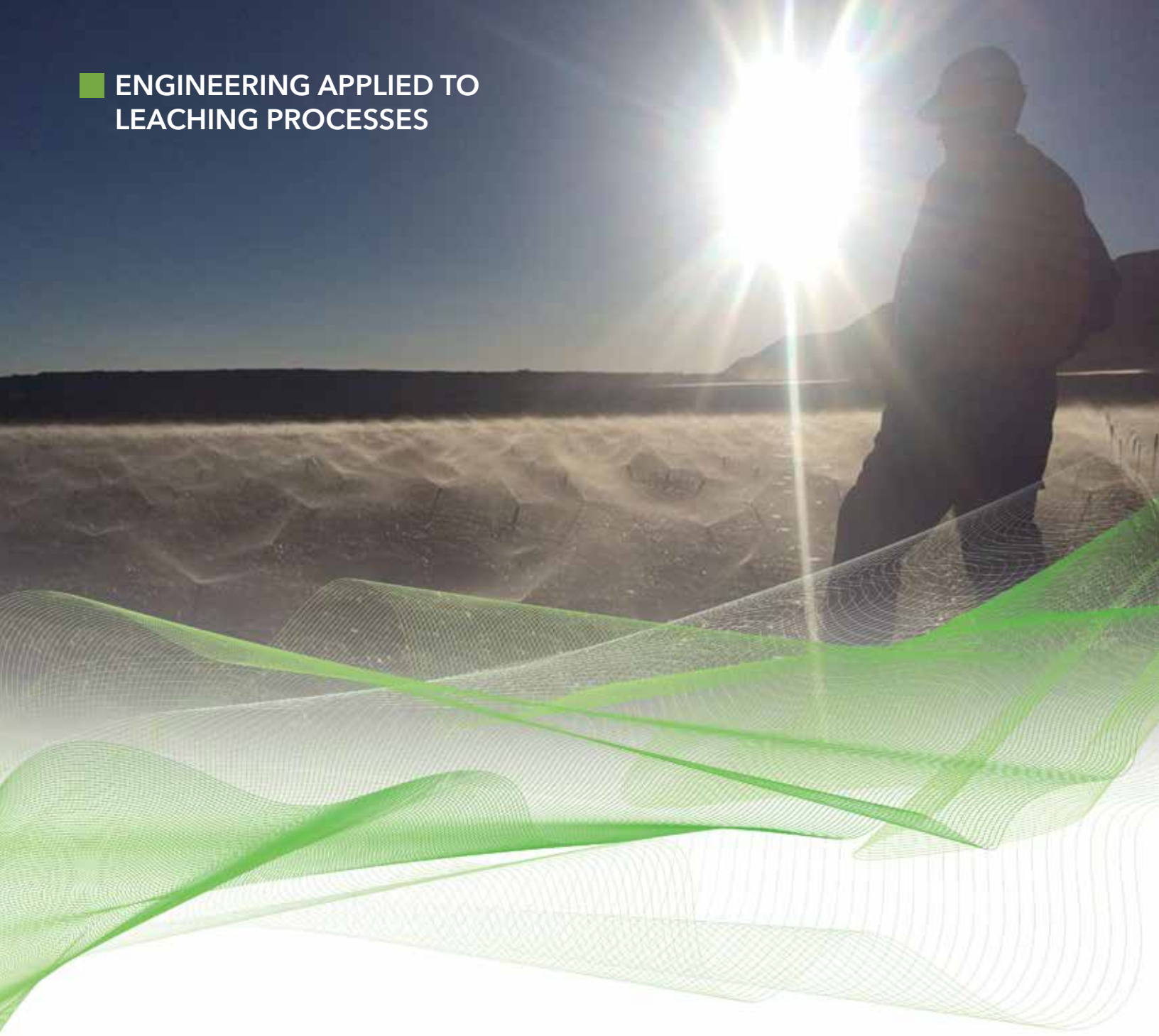


ENGINEERING APPLIED TO
LEACHING PROCESSES

INGENIERÍA DE PROCESOS DE LIXIVIACIÓN

Biohydro.cl

Our passion...

For innovation...

Because it takes paradigm-breaking courage to address the unresolved challenges of the industry, as well as sound technical know-how of the process.

For profitability...

Because we are convinced that the basis for a successful business is increasing your profit margin by reducing costs and growing your revenue from extra production.

For service...

Because honoring delivery deadlines and our unwavering commitment to the quality of our solutions speaks of our pledge to build constructive, mutually beneficial and long-term relationships with each of our customers.

INGENIERÍA DE PROCESOS DE LIXIVIACIÓN

Biohydro.cl

Biohydro.cl, a success story of team work

Our engineering team with a vast experience in hydrometallurgy, jointly with our customers, comes up with practical and innovative solutions to add value to heap leaching operations.

Designing and implementing substantial improvements in irrigation, air injection, thermal lining, drainage systems, and control & automation projects in hydrometallurgical processes at several mining operations is a testament to and the cornerstone of our success.

Change and innovation have been our hallmark since 1996 under the name Servicios Asociados A.M. some of our breakthroughs have become industry standards in leaching, such as:

• Increasing temperature, reducing water loss due to evaporation and preventing dripper sulfation by using our FilmTherm2.

• Reducing dripper plugging by flushing debris accumulated inside irrigation lines.

• Reducing costs of air injection by replacing expensive high pressure pipes with corrugated pipe with a smooth inner lining.

We have driven the development and improvement of a number of management support tools for our customers, such as:

• Smart automated control in irrigation management using Leachtrol®, an industrial automation tool that ensures the irrigation schedule will be met while minimizing operator exposure to risk.

• Compensated air injection system with an Anti-Clogging Belt (patented) and perforations varying in diameter.

• Improved thermal performance, support system and installation of FilmTherm2+padding.

• Doing away with ponding and maximizing equal application of solution across the heap by way of localized irrigation with punched drippers.

• Sub-surface irrigation applied to both slopes and tops for treating heaps with high fines content.

Improving dripper life

Each dripper supplies the reactants required to produce the chemical reaction and the liquid flow that removes the solubilized metal. Sediment present in irrigation solutions gradually plugs the drippers, thereby preventing the expected recovery, since the area immediately underneath the dripper is not irrigated and, as a result, unavailable for extraction.

Precisely in order to address this issue, in 1996 we introduced the leaching industry to debris collection pipes and a flushing procedure to remove the sediment built up at the end of irrigation lines, thereby increasing dripper life.

Our Flushtrol system is used to minimize the need to have operators working on the heap, turning previously manual operations into automated ones both in terms of frequency and duration.

Enabling efficient and safe slope irrigation

Slopes account for at least 2% of the stacked ore, but they are not irrigated because conventional top irrigation systems are not suitable for them. Poor execution may affect heap stability causing toppling and solids entrainment to the SX plant.

We have designed slope irrigation systems for several leaching operations in Chile and Peru, which minimize toppling by way of pressure regulators, punched drippers and other components, resulting in localized and equal irrigation delivery that makes it possible to efficiently leach slope-stacked ore.

Increasing heap temperature

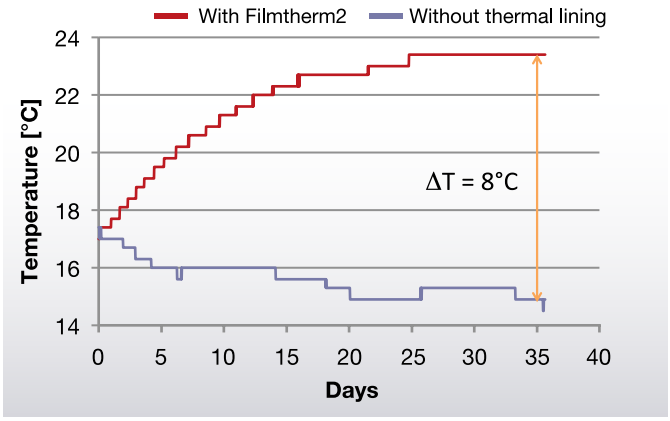
The predominant environmental conditions near bioleaching operations prevent heaps from reaching the temperature required by bacteria to thrive, thus hindering recovery kinetics and, consequently, the effectiveness of the process taking place inside this bioreactor. Although this effect tends to be more noticeable in biochemical operations, it also affects strictly chemical operations, such as acid or chloride oxide leaching.

In 1997 we developed our thermal lining FilmTherm2, which eventually became an industry standard for covering the heap top in order to cost-effectively reduce heat loss attributed to evaporation and radiation at night.

The subsequent development of FilmTherm2+ padding (patent pending), which also reduces convective heat loss, has allowed for additional temperature increases. Yet another development is the improved fastening system used to attach it to mains and debris collection pipes (patent pending) in order to minimize displacement.

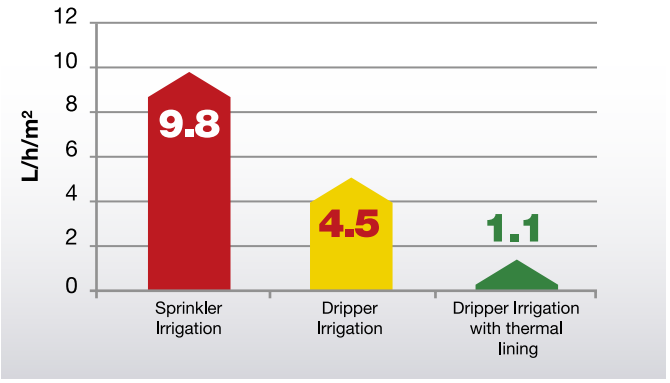
This solution has yet another advantage, i.e., it minimizes water loss due to evaporation and dripper sulfation.

Temperature inside the heap, with and without thermal lining



The chart clearly shows how using the FilmTherm2+padding increases heap temperature by 8°C at a depth of 1.5m, compared to an uncovered heap. Measuring this variable is one of the many services provided by Biohydro.cl.

Evaporation Rate



According to a paper presented by Lomas Bayas at HydroCopper 2011, the combination of thermal liners and drippers for irrigation can bring about a 76% reduction in water loss due to evaporation.

Efficient and reliable aeration of leach pad

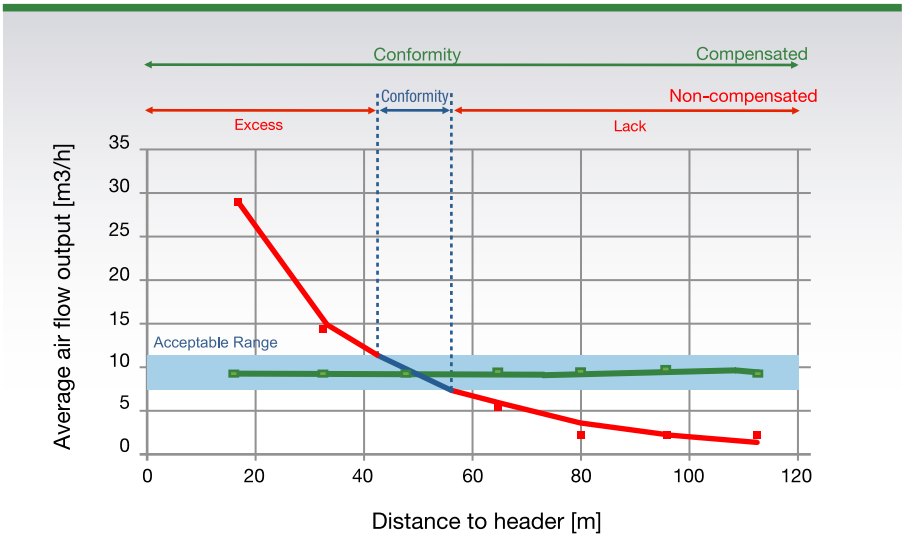
Oxygen is one of several reactants required for complete copper dissolution in leaching operations, particularly bio and chloride leaching. Although a certain amount of oxygen does enter the heap naturally, either dissolved in the solution or through molecular diffusion, it is not sufficient to dissolve the copper fast enough to be economically profitable. Therefore, forced convection is used to artificially inject air. The size and conditions of these systems pose a significant design challenge when it comes to evenly distributing the air during the entire leaching cycle.

In order to address such challenge our company designs pneumatically compensated air injection systems, which provide reliable and efficient aeration through different-sized holes for even air distribution, while our patented Anti-Clogging Belt prevents these openings from being clogged by residue entrained during irrigation.

"our company designs pneumatically compensated air injection systems, which provide reliable and efficient aeration"

Air Flow vs. Distance

Compensated arrangement vs. non-compensated arrangement



Field measurements of non-compensated aeration systems (in red) performed by the Biohydro.cl engineering team provide clear evidence of uneven air distribution of up to 100%, thus creating heaps in which less than 50% of their volume is adequately aerated. Whereas, a compensating system designed by Biohydro.cl (in green) ensures even aeration in excess of 90%.

Enabling irrigation without ponding on irregular or low-percolability surfaces

Irregular top surfaces during stacking are a common occurrence. Traditional irrigation lines with integrated drippers do not deliver the drop adequately because the solution runs along the pipe. The ponds left behind are even more detrimental if the stacked ore has a low percolability. This non-equal irrigation pattern results in inadequately leached areas due to lack of irrigation under some drippers or excess irrigation under others, which also creates an unsafe environment for operators working around the heap, and increases the likelihood of heap toppling.

Our localized irrigation systems are available for irregular surfaces or for low percolability ores. They provide safe and equal irrigation delivered through punched drippers or these attached to microtubes for sub-surface irrigation, thereby minimizing the risk of ponding and dry areas.

Reducing aeration CAPEX and OPEX

Air injection systems require a significant investment. These capital expenditures typically include substations, transmission lines, blowers and respective civil works, as well as the main pipes for air conveyance, while operating expenditures are earmarked for distribution pipes and the energy consumed by the blowers.

At Biohydro.cl we are currently working on Airtrol, an automated aeration control system that can be operated from a control room where operators regulate the air supply and manage blower operations during leaching cycles. This innovation will allow us to reduce the number of blowers (CAPEX) required at the plant and their total energy consumption (OPEX).

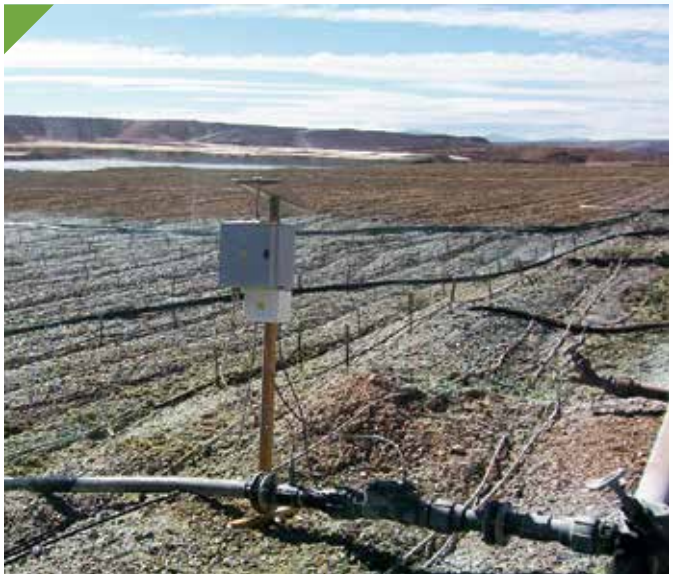
Smart automated monitoring and control of the leaching program

Leaching heaps are vast areas traditionally requiring the presence of operators for irrigation control and monitoring. The lack of or limited instrumentation employed at leach heaps is a far cry from the degree of standard automation featured in the rest of the mining process.

For instance, in combined wetting and leaching procedures, operators regulate the solution flow by opening and closing valves and because valve cycles vary in length and frequency, already understaffed operations expose operators to risky and difficult follow-up activities. The latter makes it impossible to thoroughly record the process and subsequently analyze results.

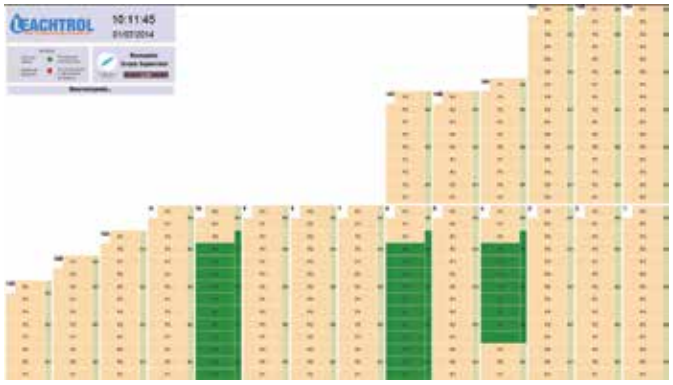
The lack of monitoring and control tools limits troubleshooting and problem solving in the heap, thereby affecting process profitability.

Remote unit for automated irrigation control operating at Compañía Minera Cerro Colorado (BHP Billiton Pampa Norte).



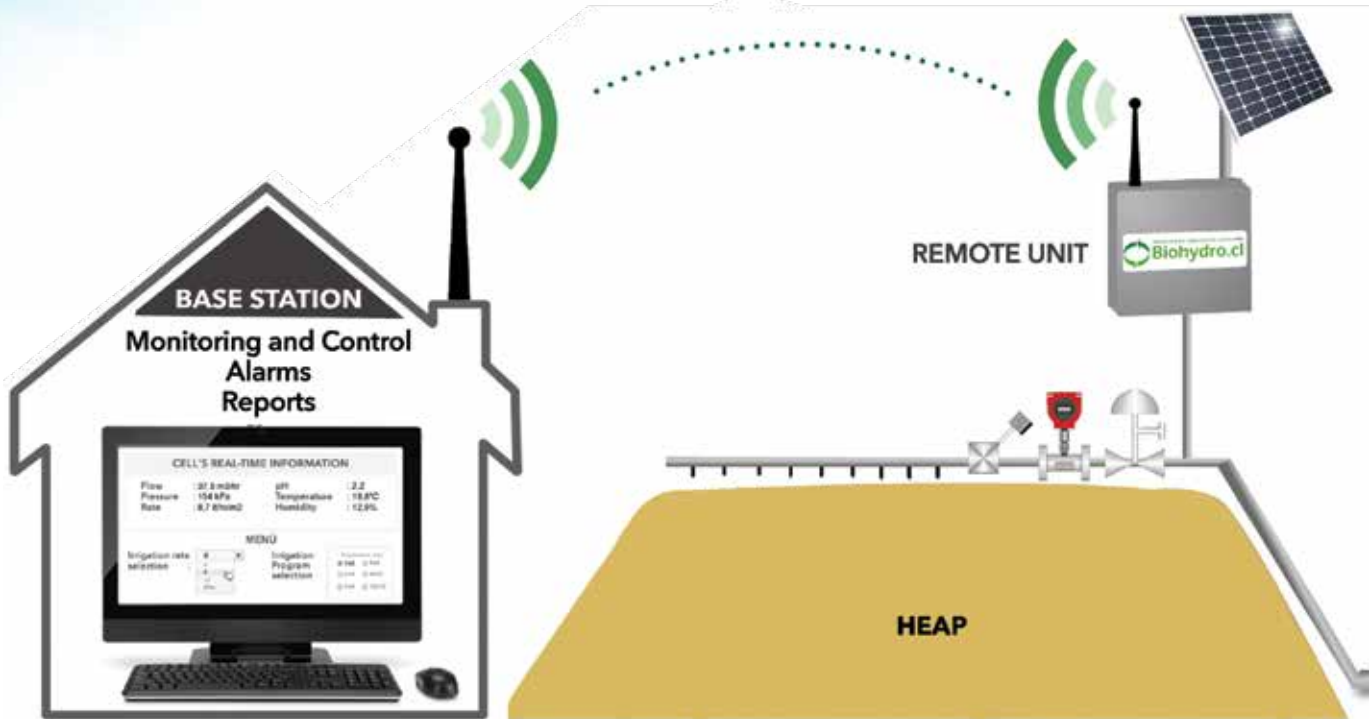
Thanks to our expertise and process knowledge, at Biohydro.cl we have successfully developed, tested and implemented our proprietary Leachtrol® system for smart automated monitoring and control of the leaching program.

This system features a base station and wireless remote units with an independent power supply. The irrigation program is housed at the base station and sends operating instructions to the remote units, which act accordingly and then send back the field readings taken by their sensors.



Control display of our proprietary software tool Leachtrol®, which adapts to each operation providing detailed information on wetting zones and their status.

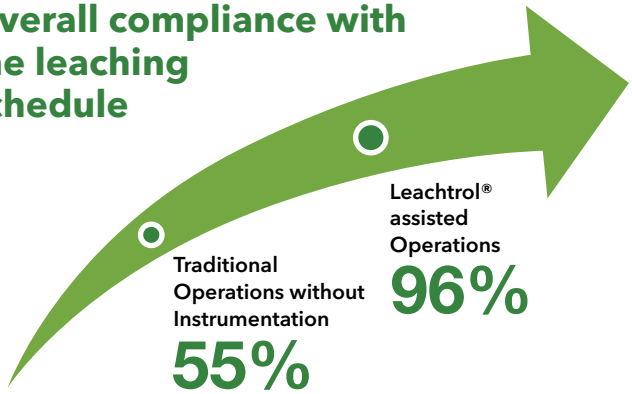
LEACHTROL



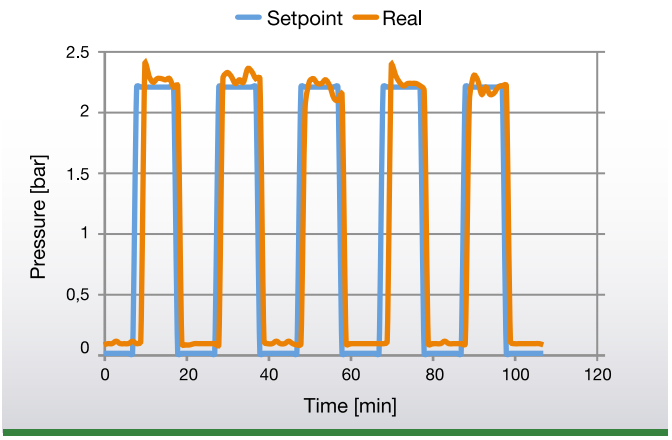
The Leachtrol® system is able to:

- Ensure compliance with the leach schedule as designed, according to irrigation timing and rates in order to maximize recovery.
- Keep management control by issuing reports and early warnings in the event of deviations.
- Store operational history in a database for future analysis.
- Adapt to and be used with all kinds of operations and irrigation protocols, even tests.
- Introduce leading technology for intelligent automated control with the degree of precision required for each process.
- Make operations safer by minimizing operator presence on the heap.

Overall compliance with the leaching schedule



Controlling Operating Variables



Adding technology to the leaching process by using the Leachtrol® system for automated and smart monitoring and control of the leaching process, significantly increased overall compliance. Levels of up to 96% were achieved, considering: operating pressure, scheduled openings and closures, and circulating flow. On-line information and recording allowed for responding to alarms early on and conducting quantitative assessments on the process.

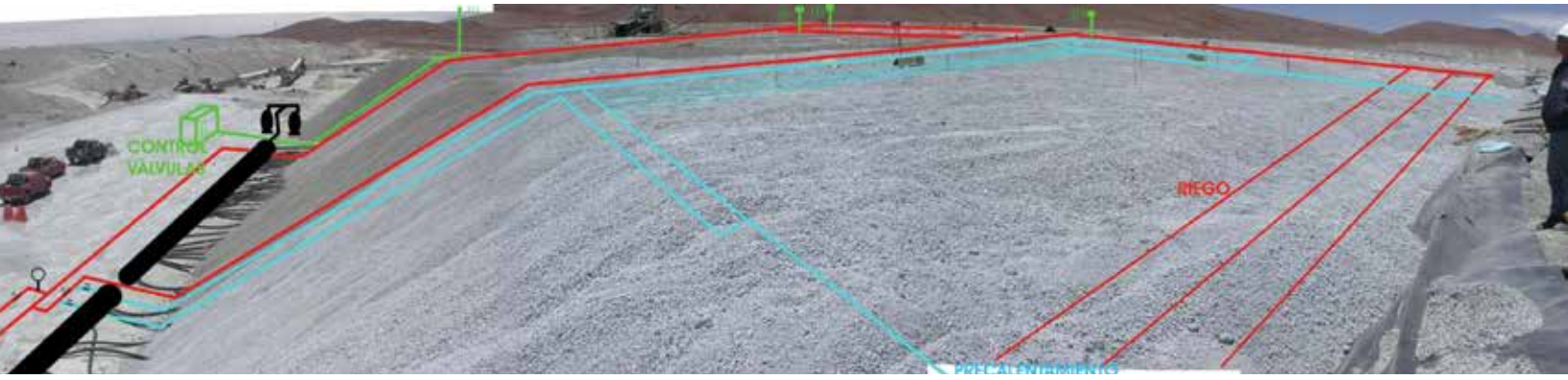
Engineering projects

Since 1996, Biohydro.cl has been providing its customers with Engineering (E) and Engineering and Procurement (EP) services for irrigation, thermal lining, drainage, and automation projects. The scope of such projects has involved:

- Prefeasibility Engineering
- Feasibility Engineering
- Detail Engineering
- Procurement
- Commissioning

Our customers are, among others:

- BHP Billiton - Minera Cerro Colorado
- BHP Billiton - Minera Spence
- Minera Escondida
- Teck - Quebrada Blanca
- Tintaya
- Codelco - Radomiro Tomic
- Codelco - Minera Gaby
- Codelco - Chuquicamata
- Minera Doña Inés de Collahuasi
- Caserones
- Barrick Zaldívar
- Lomas Bayas
- El Tesoro
- PCS Yumbes



Scaling up

We design and scale up lab/pilot plant conditions for irrigation, aeration, thermal lining, drainage and automation systems for industrial heap applications.

Consulting, assessments and audits

Our team of professionals uses assessments, hydraulic and pneumatic surveys, mass balances and stoichiometric data to provide operational support to our customers' continuous improvement programs and detect process vulnerabilities.

We provide specialized methodologies to measure, analyze and assess:

- Heap oxygenation
- Equal irrigation and uniform aeration
- Bed temperature
- Pressure availability

Training and education

Appropriate operation of the systems controlling leaching processes calls for a qualified workforce, both in theory and practice. Our training and education programs can be held at our customer's facilities or at our premises located in Iquique and Santiago. Topics covered, among others, include:

- Hydraulic and Pneumatic Systems
- Thermodynamics
- Installation and Operation of Biohydro.cl Solutions

What is your challenge?
Contact us

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