It’s a bug’s life

HEAP O’ BUGS: the Agnes site in South Africa features Geobiotes technology

For MEI’s Cape Town Bio-Hydro conference, **Todd Harvey*** assesses biotechnology in mining

The use of biotechnologies in the mining industry is not new. Bioleaching of large copper waste dumps has been taking place since the 1950s, though the discovery that acid mine drainage is the result of biological activity is more recent. And the uranium industry pioneered stirred tank bioleaching around this same period. What has changed is that the industry understands the systems better now and has been able to harness them economically.

Biotechnologies in mining generally take one of two forms, bio-oxidation or bio-remediation. The former offers an economical method of treating a range of sulphide ores and concentrates including refractory gold, copper, zinc, nickel, cobalt and any other sulphide type. It offers an environmentally-friendly substitute for traditional processes such as smelting and roasting and can also supplant newer processes like pressure oxidation. These bacteria have been harvested from natural environments and put to work oxidizing metal sulphides in a controlled environment. Meanwhile, bio-oxidation is a cost effective method of treating low grade ores such as copper waste dumps as well as providing savings for the treatment of high-grade concentrates.

Bioleaching can be broken down into several categories. Stirred tank bio-oxidation is the bacterial oxidation of a ground mineral slurry and is carried out in aerated agitated temperature controlled vessels. The reaction vessel can be a mechanically stirred tank with a means of introducing air (used typically for refractory gold concentrates), or an air-agitated pachuca reactor where the air inflow agitates the slurry. Bioheaps and copper dump leaching uses heaps formed by stacking run-of-mine or crushed rock (whole ore) into constructed piles on prepared impervious pads. These heaps are irrigated with acidic solutions and the products are carried away by drains for metal recovery or neutralisation. A heap can not be termed “bio” unless air is provided to the heap though. A variation of this process is the GEOCOAT technology which can treat both concentrates and whole ore in an engineered heap system. These systems can be employed for both refractory gold and base metal sulphide leaching. For in-situ bioleaching, the ore is treated without mining the rock for treatment on the surface. This relies on fracturing the ore to produce voids and porosity to allow free solution flow. Solutions are typically injected through wells into the orebody and collected through either wells or underground sumps and this system is often utilised for base metal sulphide leaching. In vat bioleaching, coarse ore is immersed in an aerated acid solution for all or part of the treatment process within a non-stirred tank. But this is not a very common system due to its lack of flexibility.

Currently there are several stirred tank processes and two heap processes operating for refractory gold treatment. There is currently only a single stirred tank system operating on copper concentrate and several whole bio-oxidation processes for copper. Additionally, there is one stirred tank process producing cobalt.

Bio-oxidation systems can be employed to limit environmental impact from processing. These make the process inherently safer; it generally takes place at near ambient temperatures and pressures. Furthermore, cheaper plastics can be used in construction. Although bio-oxidation has its limitations, it is a viable alternative to existing technologies both economically and environmentally.

Bioremediation is also not very new and was employed on a large scale at the Homestake Mine to treat cyanide effluents in the 1980s. Several new processes, such as BioSulphide, are available for treating acid mine drainage and others for hydrocarbon removal. All of these offer significant potential cost savings over conventional chemical treatments and they exploit naturally occurring processes.

Bio-remediation systems can be employed for long-term projects with less concern for maintenance and operation. These systems tend to be self-regulating, can in many instances be left unattended and be cost effective for very low impurity level contaminants. Although the number of bio-oxidation plants has grown substantially, mainly in refractory gold processing, the technology still has not achieved the penetration it should, particularly in copper and other base metals. There are many reasons for this, some factual and some perceptual and there are hurdles facing the biotechnology field.

Biooxidation Processing Plants

Type	Total Operating	Pending	Closed
Refractory Gold Treatment	9	6	3
Copper Concentrate	1	0	0
Whole Ore Copper	11	1	3
Other Base Metals	1	1	0
Total	22	8	6

In processing refractory sulphide gold concentrates, by far the largest problem faced by all biotechnologies is cyanide consumption. With biotreatment, cyanide consumption can be as much as an order of magnitude higher than other refractory options such as roasting or pressure leaching. The consumption may not be prohibitive economically but the processes could be more competitive with lower operating costs. The reasons for the high cyanide consumption are not well understood, despite significant investigation and while elemental sulphur formation is an obvious contributor, it not the only one. There are many sulphur species in solution plus biomass and various enzymes and proteins, all of which may contribute to overall consumption.

There are not many double refractory ores but several major deposits, namely the Carlin trend in Nevada and to a lesser extent the Ashanti trend in Ghana, do fall into this category. The problem with double refractory ores is that even after bio-oxidation has removed the sulphide refractory portion there remains a significant impediment to gold recovery in the form of “preg-robbing”. Some heap bio-oxidation processes appear to reduce the preg-robbing due to the longer exposure to the bio-oxidation environment (low pH and high iron streams), which fouls the carbonaceous matter. Work is being conducted into regimes capable of both digesting the carbonaceous matter and the sulphide in a single stage but more study is required.

All refractory processes are plagued by the need to neutralise the slurry after oxidation. If sulphides are converted to sulphates then sulphuric acid will be one of the byproducts. Several options have been explored including neutral or alkaline bioleaching and acid lixiviants. Since cyanide is the main method of extracting gold, producing an oxidised product in the neutral pH range would save several process steps. Several researchers have experimented with acidic lixiviants such as thiosulphate but reagent consumption appears to be the limiting factor.

In base metal treatment, the target of bioheap leaching is the ability to fully leach low-grade run-of-mine ore primary copper sulphides in a dump leach environment - quickly. This is the fastest growing application of bioleaching; unfortunately, the results are typically not very spectacular. Consider the Escondida Sulphide Project designed to treat 12 million tonnes/year of 0.52% copper whole ore and only recover 36% of the copper. On top of the poor recovery, the leaching rates of these types of heaps are incredibly slow, taking up to a year or more to reach this level of extraction. Despite all of these hurdles, and a capital cost of US$870 million, the Escondida Sulphide Project looks highly economic though, due to the allocation of waste mining and hauling costs.

The typical low recovery and long leach times of the whole ore systems are the net result of a large number of variables including: the particle size, the solution distribution, aeration, heap temperatures and ambient conditions. However, the areas that can be controlled need to be better managed and research needs to be conducted into heat management of these large heaps. Primary copper sulphide does not leach well except at elevated temperatures and with the low grades of these heaps there is very little energy to waste, though control systems such as HotHeap may provide a heat management mechanism.

A further complication of whole ore bioleaching systems is the acid consumption. The gangue minerals typically cause high acid demand and methods need to be developed to manage acid consumption and to understand the relationships between it and particle size, leaching rates and biological impacts.

The adaptation of any new technology is always going to present engineering issues to be overcome. Oxygen utilisation has always been a factor with stirred tank processes. The difficulty arises from the need to stir the slurry with minimal shear so as not to harm the bacteria but with enough force to distribute air effectively. More recently, higher temperature stirred tank leaching (>60ºC) for copper has found that the oxygen utilisation using air has decreased to such an extent that pure oxygen is required. The problem of diffusion has been compounded by the lower oxygen solubility at higher temperature. The engineering focus is on developing better agitation to increase oxygen utilisation and potentially recycle oxygen off-gas to increase the overall utilisation. In heap systems oxygen utilisation is not a major issue as air is employed as a cheap source of oxygen and delivered at low pressures, though air delivery can be a problem.

Since bioheap leaches can only sustain bio-oxidation if oxygen is present, heap design must ensure oxygen delivery throughout, most often with perforated drainpipes connected to fans. In the past, little effort went into understanding delivery systems and they were not efficient but more care is now taken to ensure that efficiency is maximised. There are precipitation problems near or on the air pipes though while heat balance also needs careful consideration.

Drainage and lining systems require extensive investigation too. Under-heap drainage has been employed for a variety of reasons; to reduce hydraulic head, reduce holdup and control PLS grades through the segregation of streams. Unfortunately, many of these failed due to crushing or scale.

The last engineering hurdle to overcome is the power consumption of stirred tank processes. These have high power requirements, potentially as much as pressure leaching, due to the large low shear agitation required, the potential need for oxygen, long retention times and cooling requirements. These issues are being addressed through the design of more efficient agitators and higher temperature leaching (less cooling) but more development is required.

Overall, the use of bio-oxidation and bio-remediation is growing in mining, with low grade copper sulphide leaching bringing the capabilities and limitations of bioleaching to the forefront. As more projects come on stream, process and engineering issues will be solved, while in bioremediation, it takes the courage to adopt a new technology before it can be optimised.

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