The Case for Glycine Heap Leaching

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Introduction

GlyLeach is an emerging metallurgical technology with the potential to solve a number of long-standing industry dilemmas. Alkaline glycine solutions provide a selective leach process where valuable metals including gold, copper, nickel, cobalt, zinc and lead are extracted while most gangue minerals are completely inert. The principle reagent, glycine, is recovered and continuously re-used. Metals are recovered from the leach solution by conventional downstream processes such as SX-EW, sulphide precipitation and carbon adsorption. GlyLeach may be applied in any circuit configuration, including agitated tanks, vats, and in-situ. However, the process has several characteristics that are especially well-suited to heap leaching.

Mining and Process Solutions (MPS) has acquired global, exclusive rights to commercialise GlyLeach. The challenge now is to identify the most promising applications, and to methodically lower the barriers to the first commercialisation event. This may well be a heap leach project, where GlyLeach offers a unique solution to several significant types of copper and gold ore deposits:

- Copper oxide with high acid consumption
- Copper oxide with leachable gold value
- Copper ores with high clay content
- Low grade copper sulphides
- Gold ore with high cyanide consumption due to nuisance copper
- Gold projects where the use of cyanide is prohibited

There are vast mineral resources around the world that have remained undeveloped for these reasons. This article outlines the case for glycine heap leaching and proposes a radical re-evaluation of these resources.

Process Chemistry

Glycine is a widely available bulk reagent with characteristics well-suited to use in the mining industry:

- Non-toxic
- Water-soluble
- Stable
- Non-volatile
- Re-usable

Under alkaline conditions, glycine forms stable complexes with copper, gold, nickel, cobalt, zinc and leach but not with iron, magnesium, or manganese.

Copper oxide minerals leach readily under GlyLeach conditions. Copper sulphides also leach, but at a slower rate, consistent with a heap leach operation.

Gold also dissolves slowly in GlyLeach. The rate may be increased by catalysis with cyanide, or by increasing temperature to around 60C.

Copper/gold ores can be effectively leached by a combined glycine/cyanide solution. Cyanide consumption is a fraction of that required by conventional cyanidation. The resulting solution has much lower WAD cyanide and the cost of detox can be greatly reduced or eliminated.

The common gangue minerals in general do not react under GlyLeach conditions. Silicates and carbonate minerals such as calcite and dolomite are all essentially inert.

As well as the process advantages, glycine is environmentally benign and very safe to work with. It is recycled within the process, leading to low operating cost and no special disposal issues.

Heap Leach Advantages (1) – Physical Properties
For ores with a high fines content, agglomeration is essential to create stable heaps with even solution distribution.

The copper industry has always had to rely on the natural properties of the ore to produce agglomerates. Cement could not be added as it simply dissolved in acid. Polymer binding agents have been tried but generally showed high cost and poor effectiveness.

As a result, there have been numerous projects where copper recovery was dramatically less than that projected from column leach experiments. High clay content is now considered a potential show-stopper for copper heap leach projects.

The gold industry, by contrast, has been very successful in heap leaching a wide range of materials using cement agglomeration in an alkaline cyanide system. The ability to agglomerate with cement makes the process far more robust with respect to the physical properties of the ore, and recovery projections from test results are much more reliable. Finer crushing can be considered without the risk of excessive fines generation.

Cement also acts to raise the solution pH and thereby lowers the lime consumption.

GlyLeach thus enables a fresh look at high-clay copper ores previously considered unsuitable for heap leaching.

Heap Leach Advantages (2) – Reagent Consumption
Glycine is similar in unit cost to sodium cyanide, and reagent re-use is fundamental to the economic viability of GlyLeach. The solution recirculation inherent in heap-leaching makes it ideal for GlyLeach, since there is no extra equipment required for solid/liquid separation or washing.

Theoretical consumption of glycine is zero, as the leach reactions are reversed in downstream metal recovery. However there are inevitably losses arising from residual concentration in the final tails, as well as gradual chemical degradation. Losses are minimised by operating at low solution concentration, just above that required by the leach reaction. A multi-stage heap leach enables fine-tuning of the process conditions to minimise the overall operating cost as well as the working capital. Final spent heaps can be rinsed to ensure losses are kept to an absolute minimum.

Heap Leach Advantages (3) – Leach Kinetics
As with any leach process, GlyLeach kinetics vary according to the dominant mineralogy, as well as grain size and liberation characteristics. Copper oxides such as malachite leach rapidly, while secondary sulphides such as chalcopyrite take much longer. Leaching a complex ore with various minerals can be challenging in an agitated system with limited residence time. Heap leaching enables multiple operating cells with the opportunity to stack different ore types separately. Each cell can be leached until the marginal operating cost exceeds the marginal revenue.

The reaction kinetics seen in GlyLeach systems at ambient temperatures and low reagent concentrations are fairly slow, but steady, with no surface layers inhibiting the later stages of the reaction. The leach rates are well-suited to a heap leach system where gradual extraction over several months is typical.

Project Target 1 – Carbonate-hosted copper oxide
Sulphuric acid is a major cost in heap leaching of copper oxides, and carbonate-hosted copper deposits are often untreatable for this reason. There are a number of potentially rich copper deposits around the world that have been neglected due to lack of a suitable process.

GlyLeach is very effective in leaching copper oxide minerals while ignoring the gangue calcium and magnesium carbonates. Leach solutions can be treated using conventional solvent extraction/electrowinning. For smaller projects or high power cost, sulphide precipitation is a viable option.

Project Target 2 – Gold ore with nuisance copper
Gold ores with elevated or 'nuisance' copper levels are difficult to process by conventional cyanide heap leaching, as the copper causes high cyanide consumption. As well as the direct cyanide cost, this increases the cost of detoxifying effluent solutions. Glycine, used in conjunction with cyanide, greatly reduces the overall reagent cost, speeds the leaching reaction and provides the opportunity to produce copper as well as gold.

Project Target 3 – Copper/gold ores
Ores with significant grades of both copper and gold are difficult to treat by conventional leach processes. Shifting from a low to a high pH is costly and rarely done in practice.

GlyLeach offers the opportunity to co-leach copper and gold using a combined alkaline glycine-cyanide solution. Metal recovery is by conventional SX for copper and carbon adsorption for gold.

Project Target 4 – Primary copper sulphide
Slow leaching minerals such as chalcopyrite present a further opportunity. There has never been an efficient way to heap leach low-grade primary sulphides (chalcopyrite). The most successful acid bioleach systems only achieve around 40% extraction after several years under leach.

GlyLeach test data on primary sulphides is limited but very promising. There may be potential to heap leach chalcopyrite much more effectively than any known alternative.

Development Program
The past 3 years has seen great progress in understanding the chemistry and metallurgy of glycine leaching. Researchers at Curtin University have conducted extensive test programs to understand the behaviour of various mineral systems under glycine leaching conditions, and to adapt downstream process routes to treat glycine leach solutions. However, the particular features of heap leaching require a different approach to research. Specifically, heap leaching treats coarse solids, typically greater than 6mm, and the process takes several months to reach high extractions. To replicate industrial conditions, column leach tests are required on fairly large ore samples, over an extended timeframe. The leach should be run in closed circuit with recycle of barren solution after extraction of metals.

MPS is undertaking a dedicated, 2 year research program into the application of GlyLeach to heap leaching. The program will be a collaborative effort involving Curtin University and several industry partners. The goal is to offer industry a viable, low-cost process for treating gold and copper ores that are now considered uneconomic.

Conclusions
GlyLeach is an emerging metallurgical technology with the potential to kick-start a range of mining projects for which there is no viable alternative. When considered in a heap leach system, glycine leaching prompts a complete reappraisal of mineral deposits previously considered "too hard" for reasons including mineralogy, metal grades, and physical characteristics.

MPS is embarking on a comprehensive research program to develop and de-risk glycine heap leaching. The focus is copper and copper / gold ores, but these are just the first of several target minerals that can be leached with glycine. A successful copper/gold program should greatly lower the barriers to other minerals, notably nickel, cobalt, zinc and lead.