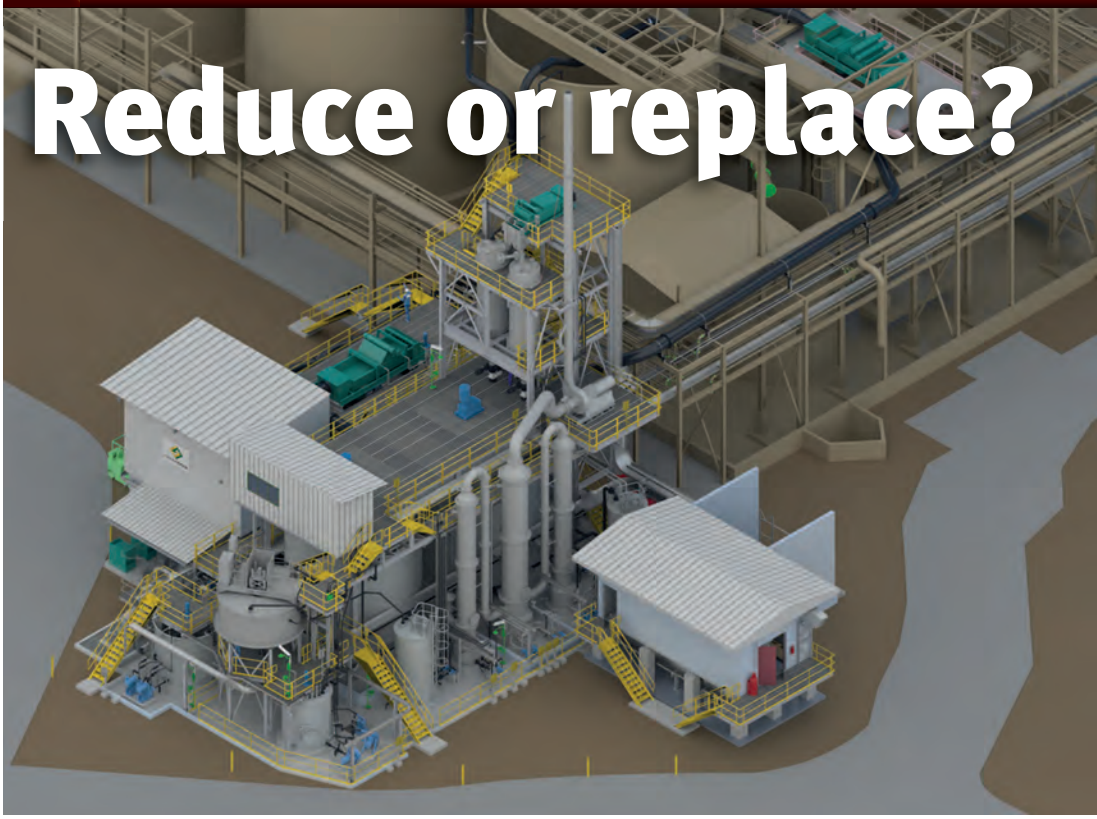
Reduce or replace?



The ReCYN II plant at the Martabe mine in Indonesia will fit into the 5.5 Mt/y circuit and treat around 1.2 t/d of copper, GreenGold's Peter Mellor says

As mining looks to clean up its act in the face of environmental and social governance concerns, the use of cyanide is, again, being scrutinised. Dan Gleeson looks at some technologies eradicating or reducing its use in metal extraction processes

The mere mention of cyanide has, in the last few decades, proven enough to push economically viable mining projects off the development slate.

There are enough stories about cyanide management gone wrong to turn communities against mine developers at key approval stages. This is on top of outright bans on the use of cyanide in countries such as Germany, Czech Republic and Hungary, and states and provinces in North and South America.

For all the financial and operational benefits that come with using cyanide, the industry understands the lixiviant's years are numbered.

This has been highlighted by a number of companies exposed to the chemical making concerted moves away from its use.

Competing with cyanide

EnviroLeach Technologies is helping facilitate such moves, with the Canada-based company coming up with a patented chemical compound that, it says, is "superior" to cyanide and its alternatives and comes with no negative environmental impacts. In fact, the company states the chemistry ingredients are FDA (US Food and Drug Administration) approved for human consumption.

The closed-loop process offers an almost zero environmental footprint, with no off gassing, no water effluent, and no landfilling of any waste materials, according to the company.

Using its non-cyanide, water-based, neutral pH treatment process, EnviroLeach extracts precious metals from ores and concentrates using a proprietary chemistry technology at ambient temperature.

The process is effective on most gold ores and concentrates, the company says, potentially unlocking the value of many deposits located in environmentally sensitive areas that cannot be developed using conventional extraction methods.

Jason Leikam, VP Corporate Development at EnviroLeach Technologies, says the applicable market for the company's technology in mining is vast, which has been proven in test work on real-life ores and concentrates.

"The mining industry is ripe for disruption," Leikam said. "An increased focus on sustainability and social licence to operate, coupled with environmental and social governance (ESG) and Impact investment factors, all contribute to push a mandate for innovation.

"EnviroLeach is uniquely positioned for the evolution of the industry. Our extraction process is not only sustainable, but economically viable. Applying our technology can reduce permitting processes and improve project economics. That means time and money for operators who are subject to inherent cyclical industry risk."

Back in February, the company released results of EnviroLeach test work carried out from 2019 field testing at Golden Predator Mining's Secondary Recovery Unit (SRU™) at its Yukon test processing plant. The SRU is a mobile batch recovery unit for the recovery of gold from its sulphide concentrate, according to Golden Predator.

Eleven test batches totalling around 2 t of a previously announced 5 t test sample from Golden Predator's then-owned 3 Aces gold project, in the Yukon, resulted in 93.17% recovery of contained gold, yielding 132.23 oz of gold doré.

Recoveries improved as the tests advanced with the final five test batches yielding an average of 96.8% gold recovery, according to Golden Predator and EnviroLeach.

Golden Predator said these results confirmed processing and recovering environmentally friendly gold from high-grade sulphide concentrate can be achieved with greater efficiency than cyanide.

EnviroLeach's Leikam went a step further, saying the efficiency and cost-effective nature of the company's technology meant it could put a significant dent in the cyanide sector's metal extraction market share.

"EnviroLeach has demonstrated time and again that our technology leach efficacy is either comparable or superior to cyanide vat leaching," he said. "We achieve high recoveries and, in many cases, are faster than cyanide.

"Our chemistry is also recoverable and recyclable, which translates into chemistry cost reductions over time. We are cost competitive with cyanide vat leaching of gravity and flotation concentrates."

The more EnviroLeach test work carried out, the wider the applicability and more favourable the metal recoveries appear to be, with the Golden Predator program demonstrating the chemistry works well with arsenopyrite concentrates, according to the company.

Leikam, on this development, said: "This can be a game changer for many projects that are otherwise unable to process concentrates with high arsenic values. It broadens our applicability to include an untapped niche market."

Another case in point is the recent agreement

Eleven test batches totalling around 2 t of a previously announced 5 t test sample from the 3 Aces gold project, in the Yukon, resulted in 93.17% recovery of contained gold, yielding 132.23 oz of gold doré, using EnviroLeach's non-cyanide, water-based, neutral pH treatment process

EnviroLeach signed with Golden Predator and enCore Energy Corp that could see its proprietary process become part and parcel of in-situ recovery operations in the future.

The three have established Group 11 Technologies Inc to focus "primarily on non-invasive extraction technology utilising environmentally friendly liquids to recover gold and other metals", they say.

"Group 11's new proprietary process has been tested on high-grade concentrates and is now ready for market and testing on further applications, providing the mining industry for the first time with a commercially viable, sustainable alternative to standard cyanide processes and conventional mining practices which often face community opposition and require slow-moving and expensive regulatory compliance," they explained.

EnviroLeach brings the proprietary water-based leach technology to the company, enCore the proprietary expertise in in-situ metal recovery, and Golden Predator the proprietary mobile recovery unit, SRU.

This agreement takes the environmentally friendly nature of the EnviroLeach process to a whole new level, according to EnviroLeach President and CEO, Duane Nelson.

"This application has the potential to change the way the world mines," he said. "It has the potential to unlock the value of deposits in environmentally sensitive areas and it could also provide a viable solution for thousands of smaller deposits worldwide that don't justify the capital expenditure of current conventional mining methods."

Leikam concluded on EnviroLeach: "Disruption is difficult to achieve. EnviroLeach has proven through test programs it has an industry changing solution. Now the company has to validate it on a commercial scale.

"The opportunities seem to be obvious; industry adoption is the next step."

CLEVR alternative

EnviroLeach is not the only company to have come up with a cyanide alternative for metallurgical extraction of gold.

Dundee Sustainable Technologies' (DST) CLEVR Process™ uses no cyanide and produces no toxic liquid or gaseous effluent, according to the company.

The process uses sodium hypochlorite with a catalytic amount of sodium hypobromite in acidic conditions to put the gold into solution. "Contact time is short and the process operates in a closed loop," DST says, adding that all chemicals are recycled within the circuit and sea water is suitable where available.

The primary benefits of the technology, according to DST, are:

- A short processing time (one to two hours);
- Efficient gold recoveries;
- A closed loop operation (no liquid effluent), thus eliminating the need and environmental liabilities associated with tailings pond;
- Produces a dry stacked, inert and stable cyanide-free tailing; and
- Treats refractory ores and handles base metals.

The technology recently hit a new milestone, with results from metallurgical testing on mineralised samples from a Top Tier gold producer achieving extraction yields of up to 95.6% with the help of the CLEVR Process.

DST received a circa-10 kg sample of material from an operating gold mine in South America, with the company mandated by the producer to conduct a metallurgical test program at its facilities in Thetford Mines, Canada. The objective was to define and quantify the gold extraction amenability of the CLEVR Process on the provided material.

In May 2020, DST completed the metallurgical test program and said the direct application of the CLEVR Process on the producer's sample achieved gold extraction yields of up to 95.6%. Given the low sulphide concentration of the sample, no

oxidation was necessary before proceeding to the CLEVR Process leaching step, it noted.

"The direct CLEVR Process leaching, without any pre-treatment, was successful and demonstrated higher gold extraction yields (>90%) when compared with cyanidation (67.6%) tests conducted on the same material," the company said. "DST's standard CLEVR Process conditions were utilised, which allowed for superior gold yields in a fraction of the time (one-hour leaching time)."

In addition, the solid tailings residues produced by the CLEVR Process met the US Environmental Protection Agency's Toxicity Characterisation Leaching Procedure meaning it may be considered as "non-hazardous waste products", DST explained.

"DST is very excited with the results obtained using the CLEVR Process and the collaboration with the producer," the company said. "The corporation will continue its development efforts with the producer to further develop this promising opportunity and the technical and economic parameters of DST's technology."

In March 2020, DST tested two distinct lots of circa-50 kg and circa-30 kg of representative material from a gold miner's operating mine in the Asia-Pacific region, meanwhile. The laboratory metallurgical test program showed the direct application of the CLEVR Process on oxidised samples achieved gold extraction yields of 93.5% and 94.2%, respectively, for the distinct lots tested.

Testing of the new BIOX MesoTHERM process has taken place at the Fairview operation in South Africa

ATS emerges for Empire

Phoenix Copper has been planning for a lengthy permitting process to extract precious metals at its Empire Mine deposit, in Idaho, USA, but recent test work with a non-toxic cyanide alternative has the company hoping it might be able to launch into production of gold and silver that much sooner.

In late June, the company confirmed precious metals tests performed on samples from the Empire open-pit deposit using ammonium thiosulphate (ATS) reagent had resulted in gold and silver recoveries of 97.8% and 97.7%, and 69.8% and 78.2%, respectively.

Back-to-back bench scale tests carried out at AuRIC Laboratories in Salt Lake City, Utah, showed the reagent consumption and recoveries were comparable to sodium cyanide, according to Phoenix.

Test work on -80 mesh lab-scale (30-250 g) and bench-scale (3,000 g) samples saw the aforementioned gold and silver recoveries, with ATS consumption of some 4% after six hours. By comparison, the sodium cyanide gold recoveries on splits of the same sample over the same time were 97.8% and 97.7%, while silver recoveries were 68.1% and 65.5%. The sodium cyanide reagent consumption for both tests was 6%, the company said.

Ryan McDermott, CEO of Phoenix Copper, said: "The use of ATS, which is much less industrially utilised in the US, but is praised for its non-toxic, environmental friendly, and low cost nature when compared to sodium cyanide, would allow us to time the processing of the Empire precious metals in parallel with the base metals given that we do not need to enter into a lengthy permitting process for the cyanide operation."

The next step for the Phoenix team will be the preparation of a pilot-scale test plant sited in the AuRIC Laboratory scaled to run multiple tonnage leach samples from various locations around the Empire deposit using the ATS reagent.

Cutting consumption

Even in processes where cyanidation is a key component of the metallurgical extraction process, cyanide consumption is being examined.

This is the case for the recently merged **Metso Outotec**'s proprietary bio-oxidation technology, with Jan van Niekerk, Director: Gold Process Solutions, Metso Outotec, convinced the latest updates to the company's technology will prove to be a "step change in the applicability of the process".

The BIOX process, which has been in commercial operation for over 30 years, was developed for the pre-treatment of refractory concentrates ahead of conventional cyanide leaching for gold recovery.

While BIOX has helped produce circa-25 Moz of gold since it originated, the amount of cyanide it consumes has been one of the inhibitors for some of the projects adopting this refractory gold ore treatment technology.

The company explained: "Traditionally, cyanide consumption with conventional bio-oxidation residues is higher than with residues produced through other oxidative technologies."

In late June, Outotec (prior to the merger with Metso) introduced its new MesoTHERM BIOX® process to tackle this problem.

Based on the existing mesophile process within BIOX, MesoTHERM BIOX offers an easy, cost-effective upgrade path that can cut cyanide consumption by as much as 50% compared with conventional bio-oxidation, the company claimed.

"The Outotec MesoTHERM BIOX process enhances the established mesophile BIOX process by combining mesophile bio-oxidation technology with a higher-temperature thermophile oxidative stage to enable an even more effective overall sulphide oxidation step," van Niekerk said.

On top of cutting cyanide consumption by as much as 50% compared with conventional bio-oxidation, MesoTHERM BIOX significantly reduces the formation of thiocyanate – a common and stable cyanide species traditionally formed as a further by-product, the company said.

Solubilised species prevalent in the mesophile stage are decanted off in an inter-stage thickening step between the two oxidative processes, simplifying operation of the thermophile stage, it explained.

This stage stabilises the thermophile process so operators can better control the solution chemistry, according to van Niekerk.

"By introducing the inter-stage step and controlling the solution chemistry, you can get a much higher bacterial activity and more stable operation as well as improve recoveries following the thermophile process," he said.

For existing BIOX customers, upgrading to BIOX MesoTHERM is a "relatively simple process". It involves reconfiguring the circuit with the addition of Outotec High Rate Thickeners for inter-stage thickening and OKTOP® Atmospheric Reactors for the thermophile step.

Testing to verify the process has been conducted at the Fairview operation, in South Africa, according to van Niekerk, with a demonstration ahead of a full-scale installation resulting in the 50% cyanide consumption reduction highlighted.

While Fairview has been the only operation to trial the new process on a continuous basis, batch test work had been completed on several other concentrates, all of which had produced similar benefits, van Niekerk said.

The highest operating cost benefits – brought about by the reduction in cyanide consumption – will be realised at those plants where ores typically require high cyanide doses for effective metal extraction via bio-oxidation, according to van Niekerk.

"We've got some plants with a normal mesophile BIOX plant where the cyanide consumption isn't really that high, so we wouldn't expect to see that level (50%) of cyanide consumption reduction," he said. "Whereas, we have some plants that have higher cyanide consumption than Fairview; that is where you will expect an even higher potential saving."

van Niekerk concluded: "Cyanide consumption has always been considered a negative aspect of bio-oxidation, so I think this will be a step change in the applicability of the process.

"We're also seeing an increase in the number of high sulphur concentrates coming through and being tested, and I think that is really where the technology will find its niche. Higher sulphur concentrates are typically harder to break down and tend to consume more cyanide.

"The new process will have a big impact on the economics of processing those concentrates."

Cyanide recycling

GreenGold Technology's ReCYN process looks to reduce cyanide consumption through an innovative recycling process.

The Jakarta-based company has recently been making waves, with its biggest ReCYN resin-based technology build nearing completion and several new projects on the horizon.

The ReCYN technology reduces cyanide consumption by up to 50% by capturing free cyanide from plant tailings and recycling it back into the leach circuit while recovering metal complexes and making them available for sale, according to the company. In the process, it detoxifies the tailings stream and guarantees 100%-compliant clean water discharge.

Such technology is in serious demand considering the industry's operational cost focus, increased stakeholder pressure around the use of cyanide, the need to recycle and replace as much water as possible, and a necessity to improve project economics through the recovery of all payable metals.

On top of this, new and existing gold projects are becoming difficult to process through conventional means with problems around by-products such as copper often proving the difference between a sub-economic and economic mine development proposition.

The ReCYN process is based on the use of a functionalised resin bead, pre-treated to allow the dual duty of recovering free and complex cyanide ions from solution with a high degree of efficiency. GreenGold works with local construction companies to customise treatment plants for each operation to match the various solution chemistries and throughputs, it says.

"The two areas of cyanide recovery and metal detoxification are balanced to achieve the desired compliance levels," GreenGold says. "Equally applicable to slurries and solutions, the process is technically and economically superior to all others currently available for the detoxification of gold plant tailings."

The company currently has four ReCYN options for clients, according to Commercial Director, Peter Mellor.

ReCYN I is for active (free) cyanide reduction, while ReCYN II has been devised to include detox applications to recover cyanide complexes such as copper. ReCYN III adds gold recovery as a "secondary function" to the mix.

The fourth option (ReCYN IV) includes gold recovery as a primary option, Mellor told ***IM***, explaining that the development of a plant offering in this configuration could remove the need for a carbon-in-leach treatment plant in some applications.

It is a ReCYN II installation the company is currently putting the finishing touches to at PT Agincourt Resources' Martabe gold-silver operation in Sumatra, Indonesia.

The application of the technology, which will detoxify tailings and recover cyanide and copper, was previously estimated by Whittle Consulting to provide a $126.9 million upside to the project.

Speaking to ***IM*** earlier this year, Mellor said the company was just over a month away from completing the plant at Martabe before COVID-19 restrictions hit progress. He was confident the company would be back commissioning it before the end of the year.

By far the biggest ReCYN installation of the technology, the ReCYN II plant at Martabe will fit into the 5.5 Mt/y circuit and treat around 1.2 t/d of copper, Mellor said. It will have benefits in terms of reduced cyanide consumption and reduced cyanide detoxification costs, he added.

While work in Indonesia is currently on hold, the company is making significant progress elsewhere.

Mellor said GreenGold had started detailed engineering for a plant in the Ivory Coast, while it had also completed an economic study on a legacy gold operation in Australia that showed compelling economics and the potential for a ReCYN IV installation for processing gold-bearing tailings.

The company also has some 40 projects it is working on in the laboratory – from Australia to the US – with client awards expected this year.

Sulphidisation, acidification, recycling and thickening (SART) technology also has applications in cyanide reducing projects, with GoGold Resources' recently commissioned SART plant at the Parral tailings facility in Chihuahua, Mexico, a prime example.

The plant is providing important economic and technical benefits to the Parral facility, according to the Toronto-listed company. This includes the recovery of a high-grade saleable copper sulphide product, the re-generation of cyanide – the largest single operating cost at Parral – and an improvement in the leaching efficiency of the heap.

The company announced back in June 2019 that it had retained **BQE Water** to design, construct and commission the SART plant at Parral. This contract followed on-site testing and preliminary assessment of SART integration into the metallurgical process at Parral that BQE completed earlier that year.

Brad Langille, President and CEO of GoGold, said: "Our team at Parral has successfully adapted agglomerated heap leaching to old mined waste at Parral, and the SART is a further optimisation of this innovation."

The SART plant commissioning phase began in late January, and steady production was reached in early March, GoGold said. The plant is currently operating as intended, producing copper sulphide precipitate and re-generating cyanide.

Its introduction reduced the need for purchased cyanide by more than 20%, or around C$200,000 ($140,378) in the month of March, according to the company, with the revenue attributed to the copper sulphide precipitate offsetting the costs of operation of the SART plant. In the March quarter, GoGold produced copper by-product from the SART plant equating to 9,509 oz of silver-equivalent.

More SART plants could be on the way, too.

BQE said in its March quarter results that engineering design for the construction of two new plants to be integrated into the respective gold metallurgical processing facilities for Shandong Zhongkuang Group and Zhaojin Group in China had been carried out.

The company has also submitted a SART plant engineering design for the feasibility study assessment of tailings re-processing using carbon-in-pulp at an existing mine in Mexico, while preliminary technical assessment of integrating SART into an existing gold heap leach operation in Mexico has been conducted.