

CYANIDE MANAGEMENT IN THE GOLD INDUSTRY

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The cyanide leaching process, introduced to the gold-mining industry about 120 years ago, was at the forefront of the technological revolution in the industry that saw global gold output rise tenfold in the first half of the 20th century.

The cyanidation process, which was cheap and very efficient, allowed even lower-grade ores to be processed economically, even in the era of gold price fixing at the US\$35/oz standard. Its only drawback was its extreme toxicity, but even this aspect was managed effectively, and the gold industry boasts a remarkable safety record, with very few recorded deaths from accidental ingestion of this potentially dangerous chemical.

Until quite recently, the widely accepted practice for handling cyanide in residues was to deposit the gold plant tailings slurry in large dams, and wait for nature to do the work of detoxifying the water.

The cyanide ion is thermodynamically unstable in water and breaks down slowly through a natural sunlight-catalyzed, air-oxidation process, producing harmless cyanate ions. This proved to be a cheap and effective method of dealing with waste cyanide for almost a century, and was quite acceptable during an era of less stringent environmental management in most parts of the world.

However, this situation began to change in the latter part of the 20th century, and a slew of highly publicised incidents (such as bird and small mammal fatalities from drinking tailings dam water, as well as several tailings dam breaches) have led to the imposition of increasingly onerous environmental regulations.

CURRENT TREATMENT

Today, in most mining jurisdictions around the world, cyanidation plant tailings must be treated with chemical oxidants on the site of the metallurgical operations, and cyanide (as well as most metals) has to be removed from solution to very low levels, before deposition in tailings dams or any other such storage facilities.

The cyanide ion oxidants that have gained widest acceptance in the gold industry are hydrogen peroxide, chlorine (or hypochlorite ions), and sulphite ions in combination with atmospheric oxygen (the so-called SO₂/air process).

Ozone and Caro's acid (a mixture of hydrogen peroxide and concentrated sulphuric acid) are also effective, but more expensive, and are therefore not commonly used.

The SO₂/air process is the most popular choice in most gold plants around the world. It generally meets the required environmental standards and invariably turns out to be the cheapest method of destroying cyanide.

But cyanide oxidation is expensive, whichever method is selected, and the cost of destroying cyanide is invariably as high as the cost of purchasing the original cyanide.



This observation, coupled with the fact that gold orebodies are becoming more complex and consuming increasing amounts of cyanide, is forcing the gold-mining industry to examine more effective ways of managing cyanide in its plants.

The best alternative is to recover cyanide from the tailings and recycle it to leaching. In many cases, the cost of recycling cyanide is significantly lower than the cost of destroying cyanide in the tailings and purchasing new cyanide.



CYANIDE RECOVERY

A number of processes for recovering cyanide from gold plant barren solutions or pulps have been developed. Most of the processes require that the recoverable cyanide is first converted to the highly toxic hydrocyanic acid gas (HCN), and concern with the handling of this compound has presented the greatest impediment to implementation of these processes.

The earliest experience in the mining industry with cyanide recovery from tailings was the Acidification, Volatilisation and RENEUTRALISATION of cyanide process (AVR), which was practised at the Pachuca silver mine in Mexico and at the Flin Flon mine in Canada more than 60 years ago.

AVR is still used today and has recently been installed at several other mines around the world. The process involves acidification of the gold plant tailings with sulphuric acid, to lower the pH from around ten to less than seven. Acidification converts the free cyanide to HCN gas, which is then volatilised by passing a vigorous stream of air bubbles through the tailings pulp or solution.

The air/HCN gas stream is scrubbed in a caustic solution to convert the HCN back to free cyanide ions for recycling. Scrubbing in a lime scrubber has been tested but has not been installed at any of the operating plants, mainly owing to concerns about scaling. The scrubber solution is recycled to leaching, and it is possible to build up the cyanide concentration in this solution to the solubility limit of the sodium or calcium cyanide salt, although a practical limit of ~100g/L CN is usually used.

AVR can be applied to solutions or pulps, although solution treatment has been preferred in all the recent commercial installations.

A more recent development is the Sulphidisation, Acidification, Recycling and Thickening of precipitate process (SART).

This is an adaptation of the AVR process, and was developed to treat gold plant tailings solutions that contain high concentrations of copper cyanide.

An increasing proportion of world gold production is coming from orebodies that contain both copper and gold, and most copper minerals react readily with cyanide, potentially leading to very high cyanide consumption.

High cyanide consumption associated with this reaction can render the gold leaching process uneconomical unless measures are taken to recover the copper and recycle the cyanide.

The SART process involves adding sulphide ions to the gold tailings, along with acidification of the tailings from about pH10 to pH4.5. Under these conditions, the copper cyanide complex breaks down completely, releasing its cyanide as HCN gas and converting the copper to the mineral chalcocite (Cu_2S).

The Cu_2S is recovered by thickening and filtration as a high grade, fairly pure copper product (~70% Cu), which can readily be sold to generate extra revenue.

The HCN can be recovered as a high-grade solution by volatilisation and

neutralisation (as in the AVR process) or as a low-grade solution for heap leaching, by direct neutralisation and recycling of the SART liquor.

The SART process has been successfully commercialised at three plants in the last five years, and several new plants are under construction.

NEW DEVELOPMENTS

All of the commercial AVR and SART processes treat solution tailings rather than pulp, and therefore the cost of solid liquid separation must be added to the costs of cyanide recovery.

This can be a significant capital-cost burden if the tailings pulp is difficult to separate into solid and liquid components (as occurs with high clay, slimy or viscous ores).

Anion exchange resins can play a valuable role in these situations by their ability to extract cyanide and metal cyanide complexes directly from gold plant tailings pulp via a resin-in-pulp (RIP) process. The RIP process is a well-developed, industrial process, which is used for gold and uranium recovery, and is readily adaptable to cyanide recovery, thereby circumventing solid/liquid separation processes. Moreover, conventional, commercial strong-base resins are well-suited to this application.

The most common cyanide species in gold plant tailings are free cyanide anions (usually 100-500mg/L) and the tricyano



copper complex, both of which can be extracted directly from pulps by anion exchange resins.

As in the SART process, ion exchange resins present the opportunity to not only recycle the cyanide associated with the copper complex, but to generate revenue via the sale of the copper itself. This revenue will offset the operating costs of the cyanide recovery plant in most cases, and the technology has the potential to transform uneconomic orebodies into viable mines.

When the loaded resin is treated with sulphuric acid, copper remains in the resin phase as a precipitate of the compound, CuCN, and only two moles of cyanide are released per mole of copper. This fairly unique chemistry has been turned to advantage in the Augment and Hannah processes, wherein CuCN is intentionally precipitated in the pores of a conventional strong base resin and, in this form, produces a regenerated resin that is an efficient adsorbent for free cyanide ions and soluble copper cyanide.

This chemistry has been known for more than 50 years, but the technical challenge in the early days was to find a way to economically strip some or all of the copper off the resin so that the amount of copper coming into the plant (as copper cyanide in the tailings) was the same as the amount leaving the plant (as a strong copper cyanide resin eluate). This technical hurdle has been overcome in the Augment and Hannah processes, both of which incorporate novel and proprietary copper elution processes.

CUTTING COSTS

Cyanide recovery can have a significant impact on the economics of processing high cyanide-consuming copper-gold orebodies. When cyanide destruction is practised in these situations, the operating costs associated with cyanide alone will amount to more than US\$2/kg of cyanide used in the process.

This cost can be converted into a new revenue stream of up to US\$0.50/kg of cyanide used in the process when cyanide is recycled from the tailings and credits from the sale of a Cu₂S precipitate are taken into consideration.

In addition, the various unit operations needed for a cyanide recovery plant (by ion exchange) require simple equipment, operated under ambient conditions.

It is expected that the capital cost will be relatively low, with a short pay-back time of less than two to three years in many cases.

COST/REVENUE ITEM	CYANIDE DESTRUCTION	CYANIDE RECYCLING
	\$/kg NaCN	\$/kg NaCN
H ₂ SO ₄ consumed (1.2kg H ₂ SO ₄ / kg NaCN)		0.15
Lime consumed (0.90kg / kg NaCN)		0.25
NaSH consumed (0.20kg / kg NaCN)		0.1
Resin losses, labour, power and maintenance		0.5
Copper sulphide credit (0.4kg Cu / kg NaCN)		-1.5
New cyanide purchase (per kg NaCN)	1.5	
Cyanide destruction cost (quoted by Inco for SO ₂ /air)	0.65- 2.40*	
TOTAL COST	2.15- 3.90	-0.5

* The wide range of costs for the Inco process takes into consideration variable CN- in the tailings (in the range 100-800 mg/L CN) and the variable cost of different SO₂ sources. Other CN destruction processes are generally more expensive than the Inco process.

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