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THE RECYN PROCESS -
CHANGING THE NEGATIVE PERCEPTION OF CYANIDE

By

Malcolm Roy Paterson

PT Green Gold Engineering, Indonesia

Presenter and Corresponding Author

Malcolm Paterson
malcolm@greengoldengineering.com

ABSTRACT

Cyanide is firmly established in the gold mining industry as the overwhelming choice of solvent for gold and silver recovery from ores. Several niche applications for alternative reagents have been proposed, but it's unlikely the superiority of cyanide will be seriously challenged for some time.

The reason alternative solvents are widely sought is due mainly to the negative connotations of cyanide in the public arena; and its poor reputation has been further harmed by several catastrophic tailings dam failures in recent years.

This paper describes a development that can help change the negative perception of cyanide in gold plant processing and, at the same time, substantially improve the economics of its use.

Known as the RECYN Process, it is a resin based technology that allows for the economic recovery of cyanide from gold/silver plant tailings. The process is also used to recover dissolved base metals and gold/silver cyanide complexes. The combination of recovery steps overcomes any need for further detoxification of the tailings, changing a nett cost to a positive return.

Gold projects incorporating the RECYN Process can reduce the purchase and shipment of cyanide by 50%, reduce the overall cost of cyanide usage, and produce a fully decontaminated tailings stream from the process plant. These advantages, both economic and environmental, can help change the negativity associated with cyanide.

The Mirah Gold Project in Central Kalimantan, Indonesia has, for over two years, successfully operated a commercial scale plant (1Mtpa ore) for the recovery and recycle of cyanide on a continuous basis. An average of 1t/day of NaCN has been recycled at a cost of 50% of new cyanide, with no further detoxification of the tailings required to meet environmental compliance levels.

A second project is presently under construction, designed to recycle 1.5t/day NaCN, incorporating many improvements in operation and efficiency acquired from the first project.

We believe the RECYN process is now sufficiently robust for wider international commercialisation and will become a standard part of the gold process plant flow sheet.

Keywords: Cyanide, carbon, tailings, resin, detoxify, recovery, environmental.

INTRODUCTION

The widespread use of cyanide in gold ore processing is a fact of life. Up to 1M tonnes are consumed each year in thousands of gold mines around the world. In many countries illegal miners obtain cyanide on the black market to process hand mined ores. The leach effluent is discharged directly to the nearest river.

Unfortunately, this practice is not limited to small mines: Some larger operations discharge effluents intentionally, some in a catastrophic unintentional accident. These incidents simply help perpetuate the cyanide myth.

Cyanide is hazardous; but it is the best and cheapest known solvent for gold and silver.

The present recommended compliance levels for discharge to TSF impoundments are not always guaranteed to protect wildlife, and the cost of detox can be a deterrent to good practice.

The simple answer is to solve the problem at the source, i.e. by thoroughly detoxifying in the process plant to prevent downstream problems.

Today, there are numerous processes that involve partial recovery or destruction techniques, but they come at a significant cost, and don't always give satisfactory results. Some processes also add metals such as copper or zinc to the circuit.

This paper describes a commercially proven process for solving this problem, a process that can provide significant environmental and operational cost benefits.

THE CASE FOR CYANIDE, CARBON AND RECYN

Cyanide is an excellent solvent, not only for non-refractory gold and silver, but also for some copper minerals. This has been seen as a negative attribute, especially for high copper ores where cyanide consumption is increased and it complicates the detox process. If the copper can be economically recovered, along with the cyanide, then being non-selective can be turned to an advantage.

Gold/silver ores rely on a good solubility for both metals, which is favored by high cyanide levels, particularly for silver. Often cyanide levels are restricted to keep down consumption and detox costs, but this can also reduce metal recovery levels. By eliminating detox costs, cyanide levels can be increased to better suit metal recovery economics.

The effort to find a replacement for cyanide has persisted for over 100 years. The hope has been to find a less problematic solvent, which is more publically acceptable.

No acceptable alternative has been found, failing due to being less efficient, less economic, not environmentally better, or often a combination of all three deficiencies.

We can more easily accept the superior efficiency of cyanide if we solve the environmental concern and turn its non-selectivity to an advantage.

An adjunct to the non-selective "problem" of cyanide is the search for a selective adsorbent.

Carbon is partially selective and has a fairly complex elution process. For most gold circuits, carbon is currently considered the best choice. It has a proven performance record and robust treatment methods.

The most common alternative is a gold specific resin, but this is also not so applicable to gold/silver ores, or if copper is to be simultaneously recovered.

Resin is the best alternative if preg-robbing ores are processed or problem levels of mercury are encountered.

Having chosen a non-selective solvent and partially selective adsorbent we are left with the challenge of cleaning up what is left solubilized in the tailings. Here the answer is more obvious, a non-selective **resin**.

The **RECYN** process not only adsorbs all the problem solubilized metals, but has the added advantage of recovering free cyanide for reuse.

RECYN HISTORY

The core resin technology is not new, having been first noted in South Africa in the 1950's by Eric Goldblatt. It was reinvented in the late 80's by a Canadian group called Tallon, and known as the Vitrokele Process. Several commercial operations, based on gold recovery, were constructed with varying operational success, until a combination of circumstances occurred in the mid 90's to once again put the technology into hibernation.

The author of this paper has been involved in the development of the resin technology for the last 30 years, initially with the Vitrokele process. This is a classic case of the challenges of technology commercialization. The answer has been persistence.

Vitrokele

A serious attempt at commercialization of a resin based system was undertaken by Tallon and Signet Engineering in the 80's and early 90's. The technology, known as Vitrokele, was focused on the replacement of carbon for metal recovery.

A major effort was applied to continuous piloting of the technology at mine site locations in Australia and Canada. The results gave confidence in the process and chemistry prior to commercial application.

A total of four commercial applications were constructed over a five year period:

- The technology was first applied very successfully at Connemmara in Zimbabwe on a gold heap leach project. It was successful because the ore did not have any significantly soluble base metals.

- The second commercial project for Vitrokele was the MayDay project for Jason Mining. This was a small vat leach project that also had high soluble copper levels. Many aspects of the technology were proven at this project, but copper again proved to be the downfall. There was an inadequate copper removal circuit, even though this was a standard part of the technology, proven at pilot plant level. Again the focus was on gold recovery. The focus on metal recovery consequently had a major negative impact on Vitrokele technology.

- The third commercial application was at Avocet's Penjom project in Malaysia. Penjom had encountered significant preg-robbing ore, causing a dramatic reduction in gold recovery in their CIL circuit. The addition of kerosene overcame the pre-robbing, but contaminated the carbon. Resin was not affected by kerosene and was therefore a good substitute for carbon. Signet Engineering converted the CIL circuit to an RIL circuit using Vitrokele resin. The conversion was carried out using the existing carbon circuit equipment with a single elution step. The resin proved impervious to kerosene, but not to copper. The copper occupied gold sites and substantially reduced the resin activity. Penjom then changed to a gold specific resin having been convinced that resin was a practical viable alternative.

- The fourth and final attempt at commercial application of the technology was in 1998 at the Mirah Gold/Silver Project in Indonesia. In this instance the focus of the technology was reversed and cyanide recovery and detoxification became the main objective. Carbon was retained as the primary metal recovery process. The introduction of a cyanide recovery process made the project economically viable, as it was previously marginal. Unfortunately for the technology, the Mirah Project was not commissioned as scheduled due to the 1998 Asian Financial Crisis. It was two months away from commissioning, but then sat in the Borneo jungle for the next 14 years.

These factors, combined with the untimely passing of two of the main protagonists of the technology, resulted in the Vitrokele technology being abandoned.

ALTERNATIVES

For the past 15 years, other research groups have persisted with resin based variants of the Vitrokele process, but no commercial process has eventuated.

There has been a similar focus on finding alternatives to cyanide, in the hope they will be more environmentally acceptable. Again nothing has emerged as a serious contender.

So what is the answer?

Simply accept cyanide as the superior solvent and address the concerns: Hence, the RECYN process.

COMMERCIALISATION OF THE RECYN PROCESS

Finding an alternative to cyanide is like bashing your head against a brick wall: You get a sore head. To find a more specific gold adsorbent is like kicking the wall, less painful, but does not solve the main problem.

GreenGold has taken a different approach by bypassing the wall.

Carbon is satisfactory for metal recovery in most cases, so it is better to focus on the real problem, which is the negative reputation and impact of cyanide.

The RECYN process totally solves this problem, reducing operating costs and increasing revenue.

By turning the technology around and focusing on cyanide recovery and detox elements, the true value of the resin process can be realized. For the time being, gold and silver recovery is left for carbon: The two processes cannot be carried out simultaneously.

The crucial step is commercialization. Many laboratory processes do not translate practically or economically to the real world. Even if they are heralded as definite winners, it still takes a willing mining company to take the risk of serious financial, environmental and social impact in the event of failure. Many fledgling technologies stumble at this crucial phase.

As noted above the core technology has a long history of development, with varying degrees of success in commercial application. The reasons for the initial failures are well understood and building on the successes has been the way forward.

The following case histories demonstrate the relative maturity of the RECYN process, although it still needs to be implemented commercially over a much wider spread of ore types to be considered a standard part of the gold process flow sheet.

In addition to the examples below, there is an increasing pipeline of projects considering implementing the RECYN process for their existing operations to replace conventional detox methods.

The Mirah Project

Engineering companies are entrusted with the task of designing and constructing process plants reflecting the best available technologies. In this capacity, they have an advantage in persuading mining companies to implement new technology to enhance project economics. Historically a major risk was arguably borne by the engineering company, especially when undertaking lump sum projects with performance guarantees. This was the case with the Signet's Mirah gold/silver project, a 1Mtpa project built in 1998 for $13M.

Depressed gold prices in the early 90's were not favourable for the Mirah Project, which was relatively low grade (2.3g/t Au), high silver (70g/t Ag), low Reserve (250koz) and very high strip ratio (15:1).

The feasibility study showed a marginal project, which on balance was not attractive for funding. Introducing a cyanide recovery process with economic detoxification allowed the Mirah project to get across the line and become an economic proposition.

As previously mentioned, the project came to within two months of commissioning when it succumbed to the 1998 Asian Financial crisis.

The gold price recovered in the mid 2000s, and the project was revisited. Luckily, 10 years in the Borneo jungle had no serious effect on the plant and it's equipment - a testament to the quality of construction and equipment selection.

The Mirah Gold/Silver project was finally commissioned in 2012, but the cyanide recovery section was not brought online until 2015. Again, this demonstrates the focus on production over new technology.

SMBS was used as the detox method. This proved expensive and destroyed not only the cyanide, but also the steel work. The incentive to commission the resin plant became imperative.

The cyanide recycle plant was commissioned in early 2015 and has operated continuously ever since, recovering on average 1t/d of NaCN.

No detox has been necessary since commissioning the cyanide recovery plant

The Mirah project has relatively low soluble copper levels and the compliance level for discharge into the TSF is <50ppm WAD Cyanide. Although a metal recovery section is included as part of the resin plant, it has not been utilized after commissioning due to soluble copper levels being less than 30ppm. Removal of free cyanide is sufficient to meet compliance levels. A programme to recommission the metals section is now underway to test the base metal recovery efficiency with different eluants.

A major benefit of recycling cyanide has been the ability to increase levels in the leach to 1000ppm NaCN resulting in a substantial increase in silver recovery, up to 90%. Gold recovery averages 96% from a 2.5g/t head grade.

Classic advice states that a high silver ore requires a Merrill-Crowe recovery circuit. This is attributed to the much higher carbon treatment levels for the high metal content. Signet Engineering built several process plants, including the Mirah Project, using carbon for metal recovery where silver levels were over 100g/t. The application has proven to be very successful and has shown increased silver recovery where preg-robbing occurs.

The Mt. Muro Project

Following its success at the Mirah project, the RECYN Technology has now been applied to a second project: the reborn Mt. Muro project which is also located in Central Kalimantan. This project has a similar mineralization to Mirah being a high silver, low sulphidation, epithermal, narrow vein ore body.

Many of the lessons learned with the Mirah RECYN plant have been applied at Mt. Muro, which has a 50% larger throughput than Mirah, for recycling 1.5t/day of NaCN.

A note for the record: Part of the plant modification at Mt. Muro entailed converting the recovery circuit from Merrill-Crowe to carbon, in spite of the +100g/t silver levels. Also, a much simpler electrowinning circuit has been installed, another myth overturned.

The Third RECYN Project

This is for a large gold project located in Sumatra, Indonesia. It has been operating for several years using a conventional sulphide detox process to achieve a WAD compliance level of <50ppmm WAD CN for discharge to the tailings dam. It also has a sophisticated detox plant for water discharge to the environment.

The mine is discussing with GreenGold the possibility of providing a RECYN process plant to replace the existing detox system and to be expandable to replace the water treatment facility.

The economics show a 12 month payback period for capital investment. Some of the existing equipment is reutilized in the RECYN Plant.

Most interestingly, a new potential advantage has emerged for this project, which may be applicable to other projects.

The mine has a significant resource with increasing copper levels with depth. The resource cannot be converted to reserve below a certain depth due to the higher copper levels; this would mean consuming excessive cyanide, leading to negative economics. Using the RECYN process, the copper can be economically recovered potentially leading to a substantial increase in reserves.

APPLICATION

Each project is unique and has a specific solution depending on the ore type and environmental compliance conditions. The economics will vary with plant size, free cyanide levels, and solution chemistry.

There is no simple answer, but our experience of the last 30 years has shown that most projects can be accommodated using the RECYN Process for cyanide recovery and tailings detox.

There are three parts to the evaluation process: free cyanide recovery, detoxification, and metal recovery:

- **Cyanide recovery** is simply an economical consideration, although often it will overlap with detox requirements. The two commercial applications in Indonesia are based on free cyanide recovery; but they find this also satisfies detox requirements, resulting in substantial cost savings and recovery benefits. The capital cost is easily justified and usually results in payback periods of less than one year. Economics are more favorable for larger projects and higher cyanide levels.

- **Detox** is a more complex evaluation because it involves detailed solution chemistry and compliance requirements. The same adsorption plant can be used for detox, but a metal recovery section must be added. The detox evaluation generally splits into two areas, compliance for tailings dams and compliance for river discharge. Either level can be accommodated with the RECYN process. The cyanide code level of <50mg/l WAD cyanide for discharge to tailings dams is easily achieved, usually just by free cyanide recovery. For river discharge, the levels are more country specific, but can also be accommodated with the RECYN process, usually by including a metal recovery stage.

- **Metal recovery** is sometimes required for the detox of tailings, but can be assessed on a stand-alone economic basis if there is no detox requirement. For the recovery of copper a positive economic result can usually be achieved.

A preliminary evaluation requires a few basic details to be inputted to an evaluation model that gives capital and operating costs and cost benefit information. The assumption is that no capital benefit is derived from existing plant equipment.

The GreenGold website has a template for preliminary assessment. www.greengoldengineering.com

TECHNICAL PERFORMANCE

The RECYN process has proven through laboratory, piloting, and commercial application that it can satisfy both requirements of:

- Economically recovering free cyanide for recycle, and

- Detoxifying tailings streams to compliance levels.

The resin bead has proven to be robust in an industrial application, particularly in a pulp application where it is subject to contamination, wide pH swings, large scale pumping, screening and general process plant operator abuse.

For a purely cyanide recovery role the solution chemistry is less critical than the mechanical design. Large volumes of resin are moved through the adsorption and elution stages, which requires special design considerations. Slurry mixing, pumping, screening and continuous elution processes are critical design areas that differ from conventional carbon circuit designs.

Recovery efficiency is based on economic considerations, and don't usually target very low free cyanide levels. Recoveries of about 90% to 95% are considered sufficient.

The following are typical solution values obtained in the Mirah recovery circuit, which targets a CN WAD of <50ppm.

	CN Free	CN WAD
CIL Tailings	350	360
RECYN Tailings	20	30

For detox applications the chemistry becomes important and depends on whether the target level is to satisfy TSF limits (typically <50ppm CN WAD), or more stringent levels for river discharge.

For TSF levels often the removal of CN Free is sufficient, unless soluble base metal levels are high.

If excessive CN WAD is caused by base metals such as copper, a small metal recovery circuit is also added.

When the detox process is required to achieve river discharge quality, more attention is paid to the number of adsorption stages and the metal recovery circuit. The same mechanical detail applies.

For river quality, it is more economical to simply treat the water to be discharged with the RECYN Process as this entails a lower water volume and treating a solution. Cyanide and metal levels will already be low in the tailings dam, because they've already been treated in the plant.

Designs must take into account the changing properties of ore bodies as they get deeper, and where varying oxidation and mineralogy properties are encountered. This applies to detox as much as primary metal recovery.

ECONOMIC IMPLICATIONS

The economic benefits of the RECYN process are wide ranging and substantial. It can provide a step change in project feasibility, making marginal projects economic and economic projects even better.

- Firstly, the ability to recycle 50% of the cyanide added to the leach circuit at a much reduced cost is easily measured. Capital cost is generally equivalent to, or less than, a conventional detox circuit, the difference being that there is usually a payback period of less than 12 months for the recovery circuit.

- Secondly, the use of a recycle process eliminates expensive conventional detox circuits. Detox costs can be up to $3/t ore treated.

Other benefits more difficult to measure are:

- The cyanide recycle eliminates the need for tailings thickeners, which can have a negative effect on the metal circuit due to viscosity problems when flocculent is recycled to the milling and CIL circuits.

- The lower cost of cyanide makes it more economical to increase the cyanide levels in leaching to improve gold and silver recovery.

- Recovered base metals can provide a significant income stream, especially at high solution levels.

CONCLUSION

The benefits of the RECYN process are significant:

- Cyanide is economically recycled.

- CIL plant tailings are economically detoxified.

- Metal values such as copper are economically recovered.
- Gold and silver recoveries can be increased.
- It can add reserve value and extend mine life.

Perhaps the most significant benefit is the starting point for this paper, “Changing the Negative Perception of Cyanide.” Tailings dams are no longer considered toxic due to cyanide; and public perception of environmentally damaging gold projects changes 180º: It ceases to be an issue.

The new gold standard.