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CONTENTS

KEY NOTE ADDRESS
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THE INTERNATIONAL CYANIDE MANAGEMENT CODE - ADOPTION OF THE CODE AND ITS IMPLICATIONS

By

Edward Clerk

Golder Associates Pty Ltd
Australia

Presenter and corresponding author

Edward Clerk
EClerk@golder.com.au

International Cyanide Management Code for the Manufacture, Transport and Use of Cyanide in the Production of Gold

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UPGRADING, GRAVITY TREATMENT & COMMINUTION

OPTICAL SORTING OF WITWATERSRAND GOLD ORES: AN UPDATE – WASTE ROCK DUMP SORTING AT GOLD FIELDS; RUN-OF-MINE SORTING AT CENTRAL RAND GOLD

By

[1]L von Ketelhodt, [2]LM Falcon and [2]RMS Falcon

[1]CommodasUltrasort(Pty) Ltd South Africa;
[2]The University of the Witwatersrand, South Africa

Presenter and Corresponding Author

Lütke von Ketelhodtark
ketelhodt@commodas-ultrasort.com

ABSTRACT

Automated optical- and radiometric sorting plants treating Witwatersrand gold ore have already been operational in the 1970's and 80's with limited success. Over the last 8 years some gold mines have shown renewed interest in this beneficiation technology in particular to recover misplaced reef from surface waste rock dumps. Acid mine drainage from these waste dumps are an environmental liability. Ever since the discovery of the Witwatersrand basin in 1886 the mining activities have produced over 1 500 Million Ounces (Moz) of gold from the world's largest gold resource and along with it hundreds of millions tonnes of surface waste rock dumps. These waste dumps contain gold at a grade of between 0.5 g/t to 1.0 g/t.

A pilot plant incorporating screening and optical sorting has proven to recover most gold-bearing rocks which are associated with acid-causing iron pyrites. At today's gold prices such operations are not only economically viable with attractive returns on investment but they also rehabiltate these dump sites.

Mining narrow tabular conglomerate reefs especially those of less than 1m in channel width, it is inevitable that there will always be waste rock diluting the grade of the run of mine ore going to the mill and gold processing plant. A range of cost and processing benefits are achieved by removing waste rock with optical sorting as early as possible in the process stream.

This paper describes two separate gold ore sorting applications: one at Goldfield's Kloof Gold Mine, a waste rock dump application; and the second at Central Rand Gold, a run of mine application. In both cases the the gold-bearing quartz conglomerate reef is separated from waste rock by optical sorting.

ALLUVIAL GOLD – SOME SAMPLE, MINE AND PLANT CONSIDERATIONS

By

Ken I Neilson

Kinex Pty Limited, Australia

Presenter and Corresponding Author

Ken I Neilson
knkinex@gmail.com

ABSTRACT

In exploration of Tertiary alluvial gold deposits in Central Victoria, Australia, the sampling and assaying of the alluvial gold ore zone have resulted in assays indicating a gold grade of one fifth of the actual grade – and that more often than not. The reason for this major discrepancy between the sample assay values and the head grade is in part due to the size distribution in the gold particles, the gold malleability and the distribution of particulate gold in the sample, and ways to overcome the analytical problem are discussed in some detail.

The shape and size of the alluvial gold particles, especially with a significant fine gold fraction, are also issues in the treatment of the ores, and this is discussed in relation to a flow sheet for a 115m^3/hour gravity plant.

A 115m^3/hour gravity plant produces almost a million tonnes of tailings annually, with a water circulation of a little less than 2½ billion litres. Environmentally acceptable methods for the disposal of plant water and tailings are paramount for mining to proceed, and a mining pit layout suggestion, the "advancing pit with concurrent rehabilitation" pit configuration incorporating plant water re-use and tailings disposal, have been included.

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LEACHING & RECOVERY

STUDIES ON THE RECOVERY OF SILVER FROM LEAD-ZINC FLOTATION TAILINGS

[1]Michael Rohde, [2]Pau Chieng, [3]Mark Runge, [4]Nursen Guresin, [5]N.W. (Bill) Johnson

[2]hrltesting Pty Ltd, Australia
[3]Rio Tinto Iron Ore, Australia
[4]Snowden Mining Industry Consultants Pty Ltd, Australia
[5]Mineralurgy Pty Ltd, Australia

Presenter and Corresponding Author

Nursen Guresin
nguresin@snowdengroup.com

ABSTRACT

A lead-zinc flotation tailings sample containing silver from BHP Billiton's Cannington Mine was characterised to understand occurrences of silver in the tailings before hydrometallurgical silver recovery testing was commenced. Conventional elemental, X-ray diffraction (XRD) and size analyses were followed by mineralogical analysis with a scanning electron microscope (SEM) equipped with mineral liberation analysis (MLA) software and the use of an adapted diagnostic leach process originally developed for gold containing materials. Cyanide, thiourea, thiosulphate and ferric chloride leach systems were investigated as options to recover silver from the tailings.

The tailings sample contained 67 g/t Ag, 1.8% Pb and 0.52% Zn. The XRD analysis showed that the sample consisted of 74% silicates, 9% sulphides, 11% magnetite and small amounts of other minerals such as fluorite, fluorapatite and rutile. The silver minerals freibergite, acanthite, jamesonite, pyrargyrite and native silver were observed in the mineralogical analysis of the sample by SEM/MLA. The associations of the minerals were intricate and the occurrences of silver were complex. There were finely disseminated silver minerals and also coarser grains of silver minerals in composites with the host minerals. It was estimated that almost 50% of the silver was contained in pyrargyrite, around 14% as native silver and contained in acanthite, 12.5% in galena and around 10% in freibergite and jamesonite.

The silver leach recoveries under optimum test conditions were 50%, 95%, 82% and 60% for cyanide, thiourea, ferric chloride and thiosulphate systems, respectively. The composite particles and the type of the silver minerals present in the tailings limited leaching efficiencies of the silver. The silver recoveries increased with the use of more aggressive acidic thiourea and ferric chloride systems. Major increase in silver recoveries for cyanide and thiosulphate leach systems were obtained only by size reduction to very fine product sizes by wet grinding in a bead mill.

[1]This paper is based on the results of a project conducted for BHP Billiton Cannington Mine at the University of Queensland between 2000 - 2005 while all authors were working or studying in the Minerals Process Engineering Department.

A NON-CYANIDE ROUTE FOR PROCESSING OF REFRACTORY GOLD ORES AND CONCENTRATES

By

Bryn Harris and Carl White

Neomet Technologies Inc., Canada

Presenter and Corresponding Author

Bryn Harris
bryn@neomet.com

ABSTRACT

Despite several attempts to supersede its use, cyanide has been the reagent of choice for the recovery of gold and silver since it was first used in the mid 1800s. However, an increasing number of jurisdictions have banned its use, and relatively recent accidents, such as that into the Danube, are increasing environmental pressures to finding an alternative for cyanide. Chloride solutions are, and have always been, the basis of gold and platinum-group metals refining, but the volumes involved for refining are very small compared to those generated by large mining operations. The reasons that such a process has never been implemented at mine sites is partly due to the non-discriminatory nature of chloride acid attack compared to cyanidation, but mostly because there has never previously been a viable method, both technically and economically, for the recovery and recycle of hydrochloric acid, with the simultaneous control of iron, from such solutions. This paper describes a chloride-based flowsheet, wherein the key unit process is the breakthrough technology for the recovery and recycle of chloride ion. Results of a continuous miniplant run on a low-grade refractory gold ore are presented. It is shown that the chloride-based flowsheet is competitive with the conventional cyanide-based flowsheets, and that it has a number of other advantages.

THE MERRILL CROWE PROCESS VS CARBON IN PULP-PROCESS SELECTION

By

Damian Connelly

Mineral Engineering Technical Services Pty Ltd
Australia

Presenter and Corresponding Author

Laurie Cranston
laurie.cranston@mets.net.au

Introduction

- 1490 to 1900 15,000 tonnes, total now 120,000 tonne
- Merrill Crowe - Original method for gold silver recovery
- Process route- Counter Current Decantation (CCD) thickeners, clarification of pregnant solution, de-aeration of clarified solution using Crowe tower under vacuum, zinc precipitation with lead nitrate, filtration, drying and smelting of precipitate
- Carbon In Pulp (CIP), Carbon In Leach (CIL), Resin In Pulp (RIP)
- Merrill Crowe - Still the only choice for high grade gold ores or high silver ores
- Changes with resins and EMEW cells

THE ROLE OF BIOMINERALISATION PROCEDURES AND ACCOMPANYING GOLD EXTRACTION IN A RANGE OF ORES

By

[1]Leslie C. Thompson and [2]Ian R. F. MacCulloch

[1]Pintails Systems Inc., USA
[2]CooMooRoo Energy Pty Ltd, Australia

Presenter and Corresponding Author

Ian R. F. MacCulloch
rocdoc1945@bigpond.com

ABSTRACT

Biomining is an accepted gold recovery technology finding use worldwide as an alternative process for oxidation of sulphide minerals. Bio-processes, though, have a much larger potential role to play in mineral alteration for affecting both primary and secondary gold recovery.

Pintail Biotechnologies, founded in 1987, has conducted research and development on the role that microorganisms play in the formation, transformation and decomposition of rocks, minerals and metals. The end result is a selection of mineral alteration processes that can affect gold recovery by addressing the principal mineralogical issues that control gold leaching and dissolution. These mineral alteration "tools" include sulphide bio-oxidation, silicate mineral bio-alteration, excretion of alternative bio-lixiviants, production of organic acids, bases and chelating agents and other processes that are applied to unleached, virgin ores or pre-leached ore that is no longer economic to leach with conventional cyanidation processes. As a result of this extensive research, Pintail has created a culture collection of some 5,400 notated examples that are maintained in permanent cryostorage as type cultures for specific mineral alteration processes. The basic development process for each gold bio-recovery project includes:

1. Isolation of native microorganisms from ore and process solutions;
2. Growth studies to determine nutritional classes and requirements of microbes in the ore environment;
3. Bioaugmentation studies to select and improve native microorganism populations and investigate efficacy of archived microbes from similar ore types and environments;
4. Bench-scale gold bio-recovery testing including flask, bottle-roll and small column reactors;
5. Pilot-scale testing including large-scale column tests and field-scale test heaps.

PINTAIL GEOMICROBIOLOGY

The critical elements to success of Pintail's gold bio-recovery technologies include an in-depth knowledge of extreme environment microbiology and the wide variety of microbial processes that control mineral formation, transformation and decomposition. Pintail applies microbial technology that addresses the complex issues affecting gold recovery including gold mineral encapsulation, formation of micro-fractures in ores and excretion of alternative gold bio-lixivients, chelating agents, and organic acids and bases. As gold mining focuses more on lower grades ores, refractory ores (including sulphide and silicate mineral gold encapsulation), and preg-robbing ores, Pintail's bio-processes for gold recovery represent a technical break-through in gold recovery technology.

The focus on the technology development combines the scientific disciplines of geomicrobiology, metallurgy, geology and biochemistry to form Geomicrobiology Sciences. This defines the role that microorganisms play and provides the tools that affect mineral formation, transformation and decomposition. The mineralogical issues controlling gold recovery discussed in this paper will include:

THE BIOXIDATIVE PRETREATMENT OF GOLD BEARING SULPHIDE

By

Meilin Liu, Wenyan Liu, Limei Yang, Jiankang Wen

National Engineering Laboratory of Biohydrometallurgy,
General Research Institute for Nonferrous Metals, China

Presenter and Corresponding Author

Meilin Liu
liumeilinmiss@163.com

ABSTRACT

A moderately thermophilic acidophilic microbial system “MB-1” was isolated from sulfide mineral. The morphological, microbial community structure and biooxidation characterization of strain “MB-1” were studied. The optimum growth temperature is 46□, and the optimum initial pH is 2.0. The strain can grow autotrophically by using ferrous iron or elemental sulfur as sole energy sources. The strain is also able to grow heterotrophically by using trace peptone. The community structure of the microbial system, which was analyzed by using 16S rRNA gene clone library, is composed of ***Acidithiobacillus caldus*** (57%), ***Acidimicrobium ferrooxidans*** (10%), ***Thiobacillus thiooxidans*** (10%) and ***Ferroplasma*** sp. (23%). The results of biooxidation experiments indicate that the strain could oxidize efficiently sulfide concentrate including gold so as to expose the gold for cyanide leaching. The effect of pH, inoculation concentration, pulp density, redox potential, aeration amount and ore particle size on the biooxidation pretreatment process was studied.

KEYS TO SUCCESSFUL GOLD HEAP LEACHING

By

Alan Taylor

ALTA Metallurgical Services, Australia

Presenter and Corresponding Author

Alan Taylor
alantaylor@altamet.com.au

ABSTRACT

Heap leaching is widely applied in the gold industry. It appears to be a deceptively simple technology, which has led to many failed projects, especially in the early days of gold heap leaching in the 1970s and 80s when numerous small to medium sized projects were launched by small companies with limited technical support. This paper identifies the main causes of failure and presents practically oriented keys to overcome past mistakes, learn from past successes, and develop a successful operation.

ALTA 2011
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CYANIDE DETOX & RECOVERY
SYMPOSIUM

ONGOING WATER MANAGEMENT DEVELOPMENTS AT NEWMONT WAIHI GOLD

By

Jennifer Meikle

Newmont Waihi Gold, New Zealand

Presenter and Corresponding Author

Jennifer Meikle
jennifer.meikle@newmont.com

ABSTRACT

Newmont Waihi Gold operates the Martha open pit and the Favona and Moonlight underground mines in Waihi, New Zealand. The site typically receives over 2m of rain per annum, which in addition to mine water and tailings storage supernatant must be treated through the water treatment plant prior to discharge into the Ohinemuri River. The water treatment plant provides two different treatment methods, for both cyanide destruction and metals removal.

In recent years the water treatment plant has undergone a number of improvements, brought about by the expansion of the open pit and the start of underground mining. The addition of a reverse osmosis plant and the implementation of a Sb precipitation step have assisted site in continuing to operate within the water discharge consent conditions.

The development of the Trio underground orebodies has further increased the volume of water requiring treatment on site by necessitating the lowering of the water table for mining access. This posed significant issues in terms of sites ability to treat and discharge the water, resulting in the application for a change to discharge consent conditions and an upgrade to the existing water treatment plant.

The upgrade to the water treatment plant involves the addition of a fourth stream dedicated to metals removal and a mix tank to blend the incoming water sources for metals removal. Provisional designs have also been included for a hardness modification facility and an ammonia removal unit. The improved water treatment plant will enable site to continue to consistently meet discharge consent conditions as well as providing the ability to develop potential new orebodies.

COMPARISON OF THE MMS CN-D™ CYANIDE DESTRUCTION PROCESS WITH CARO'S ACID, SMBS/AIR AND HYDROGEN PEROXIDE OPTIONS

By

Mike Adams

Maelgwyn Australia Pty Ltd, Australia

Presenter and Corresponding Author

Mike Adams
madams@maelgwyn.com

ABSTRACT

Modern gold plants are under increasing pressure to adopt world-class cyanide management practices due to escalating environmental pressures, particularly for signatories to the International Cyanide Management Code. Operations are lowering the levels of weak-acid dissociable (WAD) cyanide reporting to spigot discharge and to any eventual discharges from the tailings storage facility (TSF). Gold operations are increasingly adopting the inclusion of cyanide oxidation processes into their circuits, particularly for greenfields projects. These processes predominantly use sodium metabisulfite (SMBS, or SO_2) with air, Caro's acid (H_2SO_5), or hydrogen peroxide (H_2O_2).

Maelgwyn Mineral Services (MMS) has developed the MMS CN-D™ process, which utilizes the Aachen Reactor™, a high-energy mass-transfer superoxygenation system, in conjunction with an activated carbon-based catalyst, to increase the rate of cyanide oxidation to cyanate, the thermodynamically more stable form. These four processes are compared with respect to stoichiometric reagent costs, chemical reaction efficiencies and risks, as well as logistical, operability, safety and environmental issues, for both remote sites and those close to urban areas. Considerable potential upside benefit is demonstrated for MMS CN-D™ compared with the alternative cyanide destruction processes. Additional potential features of the MMS CN-D™ process are also considered, such as the potential to recover additional gold otherwise lost to tailings, to de-risk implementation and lower capital costs via staged integration of Aachen Reactors™ into existing oxygenation and SO_2/Air equipment and to modify existing plant tankage in CIL trains to become part of the MMS CN-D™ cyanide destruction plant component.

Finally, the current development and commercial status of the MMS CN-D™ process is described. A brief overview is also given of recent pilot-scale and bench-scale testwork conducted at the Maelgwyn Australia testwork facility in Perth Australia. The MMS CN-DTM Process is shown to have considerable potential qualitative upside in comparison to the three most common oxidative cyanide destruction process routes. Oxidative reagent transportation, storage, mixing, dosing and safe handling are clear potential issues for the SMBS/Air, Caro's acid and peroxide processes. Environmental issues such as elevated salt and sulphate loads due to sulphur addition, as well as the risk of corrosive contamination of wildlife habitats on overdosing excursions, are additional factors to be considered when implementing conventional chemical dosing cyanide destruction methods. These factors become particularly important in both remote sites and sites located close to urban areas.

From the reagent cost model outputs for a nominally typical gold plant requiring a comparison of the four options considered in this paper, it is concluded that costs for the Caro's acid route are higher than the other routes; this effect is substantially magnified in the case of the sulphide ore (300 mg/L SCN) as compared with the oxide ore (0 mg/L SCN). SMBS/Air and hydrogen peroxide routes report somewhat reduced reagent costs. MMS CN-D™ reagent costs are significantly lower than those of the other three cyanide destruction process routes considered.

Additional upside potential exists in the case of the MMS CN-D™ Process, given that additional gold leaching is expected in some cases, due to mineral surface cleaning in the high-shear cavitation zone of the Aachen Reactor™, along with enhanced gold adsorption equilibrium onto the CN-D™ carbon, subject to carbon movement. Significant bench and pilot-scale testwork has been completed. The first full-scale MMS CN-DTM plant has been constructed at a gold plant in East Africa and is currently awaiting CIP plant stabilization and commissioning.

THE EFFECT OF PROCESS VARIABLES ON CYANIDE AND COPPER RECOVERY USING SART

By

[1,2]Andrew Simons and [1]Paul Breuer

[1]Parker CRC for Integrated Hydrometallurgy Solutions
CSIRO Minerals Down Under National Research Flagship
CSIRO Process Science and Engineering, Australia
[2]WA School of Mines, Curtin University, Australia

Presenter and Corresponding Author

Andrew Simons
andrew.simons@csiro.au

ABSTRACT

Copper is a problem for gold processing using cyanidation as it causes increased cyanide consumption and creates significant environmental risk. This is due to the formation of toxic copper cyanide species. The SART (sulfidisation, acidification, recycle, and thickening) process is an effective way to overcome this problem as it can recover cyanide and copper as separate products from a clarified tailings stream after cyanidation. This has led to the SART process gaining popularity for cyanide and copper recovery around the world. There is, however, an apparent lack of information on the optimum operating conditions for SART.

Factorial experimentation and economic analysis of the process has been conducted. Screening and factorial design investigations found that SART is largely affected by sulfide to copper molar ratio and cyanide to copper molar ratio. The economic analysis identified the optimum operating conditions for the SART process as a sulfide to copper molar ratio of around 0.56, a pH of 4, and minimised cyanide to copper molar ratio. Price variation of reagents and products has little impact on this optimum but does have a large effect on economics when SART is not operated at optimal conditions.

A REVIEW OF COPPER CYANIDE RECOVERY FOR THE CYANIDATION OF COPPER CONTAINING GOLD ORES

By

[1]Xianwen Dai, [1,2]Andrew Simons and [1]Paul Breuer

[1]Parker CRC for Integrated Hydrometallurgy Solutions
CSIRO Minerals Down Under National Research Flagship
CSIRO Process Science and Engineering
Australia
[2]Curtin University, Australia

Presenter and Corresponding Author

Xianwen Dai
Xianwen.Dai@csiro.au

ABSTRACT

With the depletion of simple cyanide treatable ores, many gold producers are today processing gold ores with increasing soluble copper. Typically, the result of this is a requirement for cyanide destruction to prevent the discharge of copper cyanide into tailings storage facilities. This imposes a significant financial cost to producers from the additional cyanide used to solubilise the copper and the cost of cyanide destruction reagents. Therefore, the recovery of copper as a valuable by-product and the recycle of cyanide to the leach circuit have the potential for significant economic and environmental benefits. This includes enabling the treatment of gold ores with even higher soluble copper. Over the years, a variety of processes have been developed or proposed to recover the copper and/or cyanide including acidification based technologies such as AVR and SART, direct electrowinning, activated carbon, ion exchange resins, solvent extraction, polychelating polymers, and membrane technologies. In this paper, these processes are critically reviewed and compared with particular focus on the advantages and limitations in the challenge of recovering and separating copper from cyanide. Ultimately, there is no universal process solution and the choice is highly dependent on the nature of the stream to be treated and integration with the whole plant.

CYANIDE ATTENUATION MODELING FOR THE NEWMONT GOLDEN RIDGE LTD AKYEM PROJECT

By

[1]Michael Botz and [2]Thomas C Logan

[1]Elbow Creek Engineering, Inc, Billings, Montana USA
[2]Newmont Mining Corporation, Denver, Colorado USA

Presenter and Corresponding Author

Thomas C Logan
tom.logan@newmont.com

ABSTRACT

Newmont Golden Ridge Ltd, the Ghanaian subsidiary of Newmont Mining Corporation, has operated the Ahafo gold mill, a 7.5 Mt/a Carbon-in-Leach (CIL) cyanidation plant near Sunyani, Ghana since 2006. The gold-bearing ore zones range from saprolite to unweathered primary rock. Ores are free milling, although they contain minor amounts of gold-bearing euhedral pyrite. Cyanide consumption is low and residual cyanide in the CIL tailing slurry is typically comprised of free cyanide with slight amounts of weak and dissociable cyanide (WAD) metal cyanide complexes. As a member of the International Council on Mining & Metals (ICMM) and a signatory to the International Cyanide Management Code, Ahafo operates under the mandate to prevent wildlife mortality by operating the milling facilities to discharge less than 50 mg/L weak and dissociable (WAD-remove) cyanide at the discharge spigots into the tailing storage facility (TSF).

CIL tailings slurry feeds a two-stage countercurrent decantation (CCD) circuit. Tailing solids and solution flows are opposed whereby solids advance from the first thickener to the second and then out to the TSF while wash solution (varying proportions of raw water and TSF decant water) is introduced into the second unit and the second thickener overflow is routed to the first thickener and the first thickener overflow is routed to the plant process water pond and is reused. The objective of the CCD wash circuit is to lower the CIL tailings WAD cyanide level to less than 50 mg/l. Actual mill facilities target WAD cyanide discharge concentration is 35 mg/l to allow for circuit upsets. Thus a reduction in the WAD cyanide level of about 60% is achieved.

Natural cyanide degradation in the TSF was chosen as the appropriate cyanide destruction method. Because no cyanide destruction circuit is incorporated into the plant and TSF decant solution is utilized as a portion of CCD wash water, it was crucial to estimate the extent of degradation. Newmont developed a cyanide attenuation model to estimate the residual WAD cyanide concentration in reclaim water After start-up the model was calibrated by comparing model output to actual operating data collected from Ahafo during the period of 2007 through 2010.

A second metallurgical circuit of similar design is under construction at Akyem, located about 120 km northwest of Accra, Ghana. For Akyem, a different TSF design was required that reduced the decant solution retention time, raising concerns that decant solution would contain WAD cyanide concentrations too high to reuse and cyanide destruction would be necessary to meet discharge limits. The calibrated cyanide attenuation model developed for Ahafo has been extended to Akyem to estimate cyanide levels in final tailings and in the TSF decant pond. In this manner, Newmont leveraged operating data from an existing site to estimate performance expected for a nearby similar site. Results from the work suggest final tailings at Akyem will contain less than 50 mg/L WAD cyanide and decant water in the TSF will contain less than 15 mg/L WAD cyanide.

THE ASTER PROCESS: TECHNOLOGY DEVELOPMENT THROUGH TO PILOTING, DEMONSTRATION AND COMMERCIALIZATION

By

Craig van Buuren, Nobuzwe Makhotla and Johan Waldemar Olivier
Gold Fields Limited, South Africa.

Presenter and Corresponding Author

Craig van Buuren
Craig.vanBuuren@goldfields.co.za

ABSTRACT

Environmental legislation associated with the land disposal of cyanidation tailings and water discharge is becoming increasingly stringent world-wide, thus enforcing the treatment or recycling of contaminated water streams. Furthermore, micro organisms used in the bioleaching of sulphide minerals in particular, have a low tolerance to thiocyanate and cyanide species making the recycle of contaminated process water to BIOX® plants impossible. It is predominantly the reaction between residual cyanide and reactive sulphur species which results in the formation of SCN^- up to ~ 5000 mg/L, which renders the upstream recycling of this solution impractical.

The delivery therefore of an improved and integrated water mass balance for subsequent upstream re-usage in BIOX® applications saw the development of the ASTER process, viz., the **A**ctivated **S**ludge **T**ailings **E**ffluent **R**emediation process.

Laboratory and pilot scale testing of the ASTER process in batch flasks and continuous fed reactors at scales of 0.08, 0.8, 2, 6 and 25m^3 showed batch degradation rates of approximately 75 mg/L/hr SCN^- was attainable at 25^oC, while up to 87 mg/L/hr (un-optimised) SCN^- (corresponding to +66% removal) was attainable in the first stage reactor. These derived degradation rates corresponded to batch start test SCN^- concentrations of 1800 mg/L and continuous fed reactor feed concentrations of ~ 2100 mg/L respectively.

The success and process robustness demonstrated during various pilot runs, on different mine tailings solutions prompted Barberton Mines in the Mpumalanga province of South Africa to go ahead with a full scale ASTER plant in 2009. The plant was designed to treat tailings dam solution at their Consort plant for concentrate preparation to be fed to their BIOX® plant. To facilitate the fundamental process aspects, a development program between Gold Fields and the University of Cape Town (UCT) was initiated which draws on advanced microbiological analyses and sequencing techniques. The first phase focuses on optimising the process conditions and effects of heavy metals and cyanide, and a second more fundamental phase involves modelling and characterisation of the microbial consortium.

The Consort ASTER commercial plant has a capacity of 320 m^3/d tailings solution, a design retention time of 12 hours with feed SCN^- and free CN^- concentrations of 120 mg/L and 30 mg/L respectively. To date the plant has been performing well with degradations in excess of 99% being achieved.

This paper discusses the development of the ASTER process through to its first commercialisation at the Barberton Mines, Consort plant. Finally, a further two case studies is described showing how the ASTER process is developing to support projects in the Philippines and Australia.