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# Copper-bottomed



Copper continues to experience strong demand and its disinfectant capabilities look set to see its use in the health industry increase significantly. **John Chadwick** examines latest technologies to extract copper

Anything copper-bottomed today is most likely to be a saucepan. This idiomatic phrase has its origins in the 18th century when it described ships that were fitted with copper plating on the underside of their hulls. The process was first used on ships of the British Navy in 1761 to defend their wooden planking against attack by Teredo worms and to reduce infestations by barnacles.

Ironically, the metal known for its versatility in industrial applications from pipes and plumbing in the home to electrical wiring in power cables to cell phone components and much more saw a significant achievement when involved in the rescue of some copper mines. The 33 miners trapped underground last year in Chile were given copper socks to help keep them healthy. Copper's germ-fighting quality helped keep the trapped miners free of foot infections in the warm, humid mine, according to a recent *Mineweb* article.

Now, clinical evidence shows hospitals can reduce infections by using copper touch-surfaces for everything from intravenous poles to over-the-patient tables, bed rails, door knobs and the nurse's call button. With deadly,

drug-resistant bacteria on the rise, researchers have been seeking new ways to fight hospital-acquired infections, the fourth biggest cause of death in the US behind heart disease, strokes and cancer.

Compare the cost of using such copper touch-surfaces with the cost of \$45 billion per year to treat hospital-acquired infections in the US alone, which kill more than 100,000 people a year. The future may indeed be copper-bottomed! Copper, whose anti-bacterial properties have been given certification from the US government, releases ions that penetrate bacteria and bind to their enzymes and proteins, disabling them. Steel, the material used in most hospitals, does not.

At the Copper Hospital in the mining city of Calama in Chile's far north, head nurse Alicia Gutierrez witnessed a sharp drop in infections after copper plating was installed in some intensive care units. "We've seen how these surfaces have helped cut the number of infections here," she said. "I wish everyone could see it and appreciate how it can save lives." A trial at the hospital, which treats Codelco mine workers, showed copper

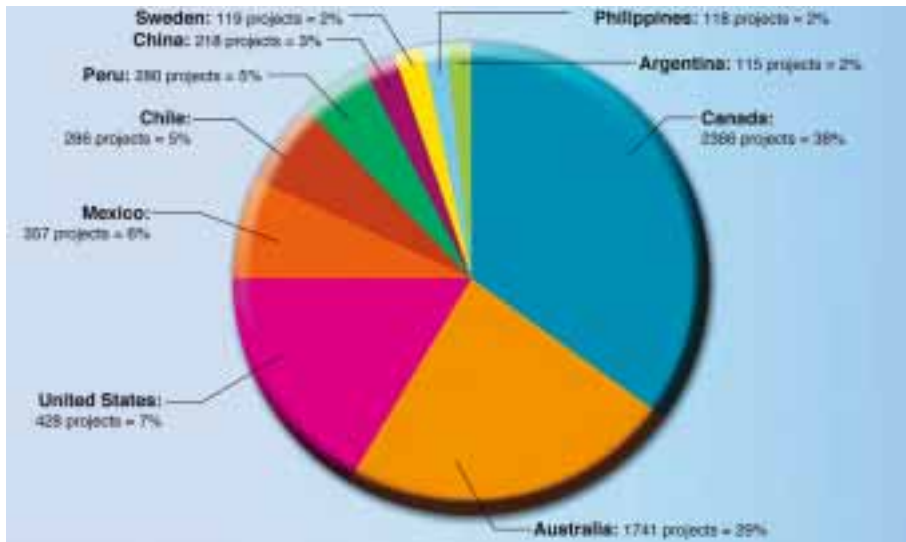
*Construction at Oyu Tolgoi, which will be one of the biggest copper mines in the world (IM, April and May 2011) is continuing toward a projected peak level of activity that is expected to be reached during the third quarter of this year. Commissioning of the concentrator's first production line is projected to begin in the second quarter of 2012 and commercial production is expected to be achieved in the first half of 2013*

surfaces killed over 82% of bacteria within hours. Other studies show copper killed over 90% of bacteria.

Copper producers estimate between 250,000 t to 1 Mt/year in additional copper demand stemming from anti-bacterial uses, or about 5% of world mined copper output. "It's an exciting opportunity for the industry to have applications in hospitals and clinics, but also in public buildings in general," Richard Adkerson, chief executive of Freeport, told *Reuters* in March.

According to Glen Jones (Intierra Resource Intelligence) presentation *Copper: The Project Pipeline* at the International Copper Study Group meeting in April 2011 in Lisbon, Portugal, there are some 7,600 copper projects in the world – see chart of the top ten countries – second only to gold.

According to preliminary International Copper Study Group (ICSG) data, the refined copper market balance for March 2011



From: Glen Jones (Intierra Resource Intelligence)  
Copper: The Project Pipeline

production capacity utilisation in the first quarter of 2011 was around 78% as compared with 79% in the same quarter of 2010.

The average LME cash price for May 2011 was \$8,927.05/t, down from the April 2011 average of \$9,483.25/t. The 2011 high and low copper prices through the end of May were \$10,148 and \$8,536.5/t, respectively, and the average was \$9,147.26/t. As of the end of May, copper stocks held at the major metal exchanges (LME, COMEX, SHFE) totalled 626,651 t, an increase of 58,469 t from stocks held at the end of December 2010. Compared to the March levels, stocks were up at LME and down at Comex and SHFE - [www.icsg.org](http://www.icsg.org).

According to ICSG data, global growth in copper demand for 2011 is expected to exceed global growth in copper production and the annual production deficit, estimated at about 250,000 t of refined copper in 2010, is expected to be about 380,000 t in 2011. In response to prevailing high copper prices and increased end use demand, production increases are expected at operations curtailed following the 2008 economic crisis and, to a lesser extent, from startup of new operations.

Industrial demand in 2011 in all of the major consuming regions is expected to continue the upward trend begun in 2010 and exceed the growth in refined production. Following a year of extraordinary growth (38%) in 2009, China's apparent consumption in 2010 grew by only 4.3% and accounted for more than 38% of global copper demand. In 2011, the growth rate is projected to be around 6%: an anticipated growth in semi-fabricate production and possible restocking of working inventories could be partially offset by greater reliance on direct melt scrap and potential drawdown of unreported inventories that likely accumulated in preceding years.

Project projections taken together indicate

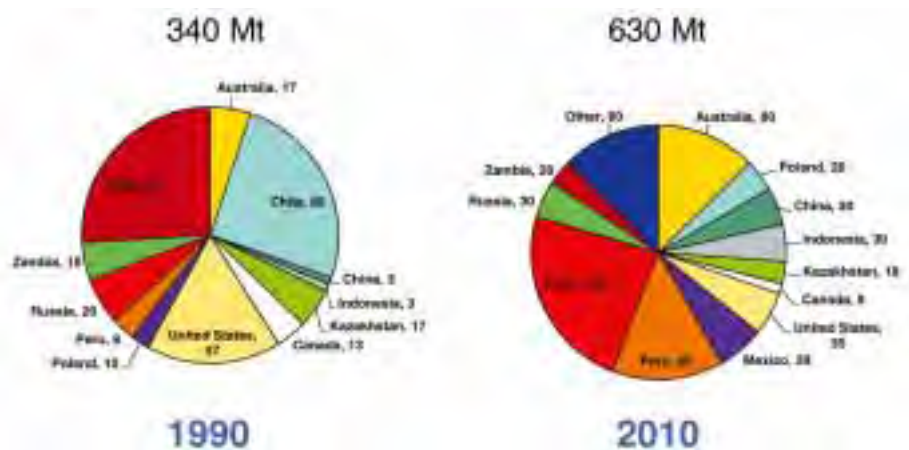
showed a small production surplus of 18,000 t. When making seasonal adjustments for world refined production and usage, March showed a larger surplus of 33,000 t. The apparent refined copper balance for the first quarter 2011, including revisions to data previously presented, indicates a production deficit of 33,000 t (a seasonally adjusted deficit of 16,000 t). This compares with a production surplus of 10,000 t (a seasonally adjusted surplus of about 42,000 t) in the same quarter of 2010.

During the first quarter of 2011, world apparent usage grew by 2.4% compared with that in the first quarter of 2010: A 90% Russian growth and growth of around 4% each in the European Union, Japan and the US were partially offset by a decline of 6% in China's apparent usage. (China's apparent copper usage is based only on reported data (production + net trade ± SHFE stock changes ± industry stock changes, if reported) and does not take into account changes in unreported stocks [State Reserve Bureau, producer, consumer and merchant/trader], which may be significant during periods of stocking or destocking.) China's apparent usage decline in the first quarter 2011 reflects a 31% decrease in refined copper net imports from those in the first quarter of 2010, and the increase in Russia's apparent usage reflected a 65% decline in net refined exports. On a regional basis, usage grew by 2.1% in Africa, 4.6% in the Americas, 10.9% in Europe, and 35% in Oceania and declined by 1.6% in Asia.

World mine production grew by around 2.5% (93,000 t) in the first quarter of 2011 compared with that in the same quarter of 2010:

Concentrate production grew by 3.8% while SX-EW declined by 2.4%. In part, this relative increase reflects operational constraints that reduced production in 2010 in Australia and Mexico. Production in Chile, the world's leading producer, was down by 0.7%. Production was also down in other major producers such as the US (-3.5%), Indonesia (-18%) and the DRC (-16%). On a regional basis, mine production increased by 1.2% in the Americas, 7% in Europe, and 24% in Oceania but decreased by 1% in both Africa and Asia. The mine capacity utilisation rate increased slightly in March and the average for the 1st quarter of 2011 was practically unchanged from that in the same quarter of 2010.

During that first quarter, world refined production grew by 1.5% as compared with that in the same quarter of 2010: Primary output increased by 1.2% and secondary production (from scrap) increased by 2.7%. Production increases of 71% in Australia (recovery from low 2010 level), 11% in China, and 6% in India were partially offset by declines in Chile (-3.5%), the US (-12%), Canada (-27%) and Japan (-12%). Refined



World copper reserves, 1990 and 2010 (Mt). From Dan Edelstein (USGS) presentation Copper Reserves and Resources at the ICSG meeting in April 2011



# WORLD COPPER

Copper in reserves, resources, and past production in major copper discoveries by country, 1999-2010 (Total reserves, resources, and past production of 229.1 Mt)

that mine production in 2011 will increase by about 740,000 t (4.6%); however, it is expected that the actual increase will be significantly lower as production disruptions from project delays, technical problems and labour and political unrest that have become the norm in recent years are expected to continue to reduce output. World refined copper production for 2011 (adjusted for production disruptions) is therefore projected to increase by only about 3.5% to 19.7 Mt. In 2012, it is anticipated that refined production will increase by about 5% following continued ramp-up of projects.

Metals Economics Group's (MEG) recent Strategies for Copper Reserves Replacement: The Costs of Finding and Acquiring Copper study concludes that between 2001 and 2010 the top 23 global copper producers (those that mined at least 145,000 t of copper in 2010) replaced nearly 290% of the copper they produced. Almost all these companies have added enough reserves to keep ahead of production, maintaining strong pipelines of projects to ensure stable or increased copper production.

The major copper producers increased their aggregate annual production by 26% over the past ten years to 11 Mt in 2010 — 68% of world mine production. As of year-end 2010, these companies also held sufficient reserves for 34 years of production at the 2010 rate. However, increasing production has exacerbated their need to add reserves and most major producers forecast further production increases in the coming years. Based on 2010 production, the major producers each need to replace an average of almost 480,000 t of copper in reserves each



year; and if their near-term growth plans bear fruit, this could increase to almost 650,000 t annually by 2016.

Globally, 62 significant copper discoveries (defined as a deposit containing at least 500,000 t of copper) have been reported so far in the 1999-2010 period, containing 229.1 Mt of copper in reserves, resources, and past production. The Americas account for the greatest share of copper in these discoveries, which is not surprising given that the Americas have been the primary focus of discovery-oriented exploration spending.

Although the copper found in the 62 discoveries is slightly more than the industry has produced over the past decade, the economic viability of these deposits relies to a large extent on location, politics, capital and operating costs, and market conditions, which inevitably reduce the amount of resources that will reach production. Considering that just 6% of copper in these discoveries has been upgraded to reserves so far, that many of the larger discoveries are low grade, and that almost half the copper in the discoveries is located in areas of medium or high political risk, the amount of copper available for production in the near term is likely far less than has been found.

Only ten of the 23 major producers have made significant copper discoveries since 1999; of the 62 discoveries made, 24 can be attributed to these ten companies, accounting for 41% of the 229.1 Mt total in-situ value found. Given that just 6% of copper in the 62 discoveries has so far been converted to reserves, it is clear that we know the majors have added almost all of their exploration-derived reserves at existing mines and older projects, but very little of it through new discoveries.

The study addresses key growth strategy issues facing the copper mining industry and compares the relative costs per pound of discovering or acquiring copper in the ground. In addition to an industry-wide review of the copper pipeline, acquisition activity, copper exploration spending, and major discovery successes, the study also provides a variety of metrics for measuring and comparing the relative costs of various growth strategies for the 23 largest copper miners and the industry as a whole.

Bechtel and Xstrata have a strategic alliance for the Standard Concentrator Project. This is a first in the copper sector and aims to speed up project execution and provide costs savings across multiple projects. Xstrata is among the

## COPPER FORECAST TO 2012 ('000 t)

REGIONS	Mine Production			Refined production			Refined usage		
	2010	2011	2012	2010	2011	2012	2010	2011	2012
Africa	1,315	1,428	1,655	857	1,082	1,249	285	277	303
North America	1,915	2,173	2,433	1,690	1,843	1,953	2,182	2,270	2,355
Latin America	7,031	7,383	7,617	3,893	3,997	4,077	632	652	675
Asean-10	1,089	863	844	534	567	601	748	775	806
Asia ex Asean/CIS	1,661	1,750	1,904	7,591	7,930	8,620	11,054	11,601	12,196
Asia-CIS	491	506	532	413	468	515	96	100	104
EU-27	758	790	812	2,613	2,706	2,778	3,332	3,429	3,491
Europe Others	826	843	857	1,053	1,072	1,087	856	865	900
Oceania	1,011	1,097	1,250	417	499	509	128	132	135
<b>TOTAL*</b>	<b>16,097</b>	<b>16,833</b>	<b>17,904</b>	<b>19,061</b>	<b>19,724</b>	<b>20,686</b>	<b>19,314</b>	<b>20,102</b>	<b>20,965</b>

\*Adjusted for primary feed shortage and disruptions

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Hatch is undertaking the feasibility study for Codelco's Chuquicamata underground mine project. Hatch will focus on the basic engineering for the development of access works, environmental studies, human resources, management models, mineral handling, permanent infrastructure, processes, services and supplies, shafts, tunnels and ventilation works. The underground mine is expected to start operating in 2018

world's top five mined and refined copper producers and has approved this strategic alliance with Bechtel to cover a 10-year period. Bechtel International will perform EPCM and or EPC services as required for all Xstrata Copper greenfield projects. The Bechtel alliance provides Xstrata with the proven management, technical expertise and construction management skills needed for development of multi-billion dollar projects.

CiDRA's SONARtrac flow monitoring systems have been chosen as the best technology fit for the critical slurry lines within all five projects, which are Antapaccay in Peru, Las Bambas in Peru, El Pachon in Argentina, Tampakan in the Philippines, and Frieda River in Australia. CiDRA has completed shipment of sonar flow meters to the Antapaccay mine, which is nearing production. Bechtel has designed a standard concentrator that will be used in all of the five projects. The use of a standard concentrator in multiple copper concentrator projects will have significant benefits for Xstrata, including engineering, procurement, vendor submittal, construction and start-up efficiencies, as well as cost savings and reduced operating costs.

CiDRA Minerals Processing's SONARtrac systems have also recently been chosen by Rio Tinto as its preferred technology for use on

slurry lines at Oyu Tolgoi in Mongolia. CiDRA will instrument 30 lines at the new concentrator, where they will provide increased accuracy and reduced maintenance costs. OT is currently constructing a copper concentrator, related facilities and the necessary infrastructure to support an initial throughput of 100,000 t/d of ore. By 2017, an expansion of the concentrator is expected to be completed in conjunction with the ramping up of the Hugo North underground mine. This will provide capacity to process 160,000 t/d for the duration of the operation.

SONARtrac systems were chosen because of the non-invasive design, "which provides exceptionally high reliability, performance, and maintenance-free operation, thus lowering operating costs and total cost of ownership," CiDRA reports.

## Copper flows

To counter declining ore grades, mining companies have looked to increase copper production by improving plant throughput and processing efficiency with larger mill circuit pump sizes. While it is possible to use multiple, smaller pumps to do the job of one large pump, it requires more plant floor space and more maintenance time. Weir Minerals has responded to the need for larger pumps in the market place and has been one of the few slurry pump suppliers willing to invest in expensive rubber manufacturing tooling and presses to produce these large pumps with state of the art rubber lined pump designs. Warman MC pumps are specifically designed for the most severe slurry applications, such as AG and SAG mill cyclone feed. They easily manage large size particles in dense abrasive slurries and are also well suited for use as slurry transfer pumps on arduous applications such as gravel dredging or coarse coal cyclone feed.

The Warman rubber-lined MCR pumps have an outer ductile iron casing which supports replaceable rubber liners. This construction provides the full pressure rating of the pump throughout the service life as the rubber liners wear down and avoids the risk of pump explosion. The rubber linings are lighter than metal wear parts, making maintenance operations easier and safer. Rubber has proven to provide superior abrasion resistance to expensive chrome alloys in mill circuit pumps, which increases pump service life and reduces plant downtime, making them ideal for the demands.

*CiDRA's SONARtrac flow monitoring systems in a copper application*





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*Warman says its rubber-lined MCR 750 is the largest mill circuit pump with moulded rubber liners in the world, and can be used in grinding circuits in large scale ferrous and non-ferrous mineral processing plants, such as copper. These pumps are currently being used at a copper mine in Chile*

Company spokesperson, Robb Clawson adds, "We're seeing strong demand in the market for our rubber lined pumps because site managers are seeing the financial benefit of predictive maintenance and downtime while protecting the significant investment made in the pump and other process equipment. Our customers really appreciate our predictive modelling because it helps a plant manager anticipate equipment maintenance requirements so they can plan downtime, which is crucial to running a profitable business when a mine can lose \$1 million a day for unplanned shutdowns. That can be the difference between a good year and a great year."

Copper producers in southern Europe, such as Somincor in Portugal and Aguas Teñidas in Spain, rely on Metso. These mining companies are not merely looking for a passive equipment supplier – they are challenging Metso to engage in closer co-operation; to share in-depth minerals processing knowhow and to present new mining solutions to improve mine economics.

Both exploit a similar type of fine grained, massive copper-zinc-lead sulphide ore vein with the profile and history of the Iberian pyrite belt. And both companies are in the middle of a series of major investments to expand

capacities and fine-tune their processes.

"Our message to Metso is very simple: we want to mine more tonnes and reach better recovery with the new solutions they propose," says John Andreatidis, Mine Manager of Somincor's Neves-Corvo mine. "During our co-operation, we have already taken several steps towards better energy economy in our grinding circuits. In the future, we see Metso as a close partner, a process knowledge expert, as well as an expert in

*All vibrating equipment at Neves-Corvo, such as this Nordberg TS Series inclined screen from Metso, is painted yellow for safety reasons*



services," comments Manuel Acosta Fernandez, Plant Technical Director of the Aguas Teñidas mine.

Today owned by Lundin Mining, Somincor is investing heavily in the future with a new fine-grinding circuit and a new pre-screening circuit (for this project, Metso has won an order for two VTM 1250 vertical mills and 80 new pumps), and a facility to produce paste for underground backfilling. In 2011, the mine plans to process 2.7 Mt of copper-zinc ore using the drift & fill mining method. Annual copper concentrate production is expected to be some 85,000 t.

The zinc expansion project at Neves-Corvo, designed to produce a minimum of 50,000 t/y of zinc from existing orebodies, is advancing on schedule and on budget. The zinc pre-screen facility, designed to augment zinc crushing capacity, was commissioned in February and is operating with copper ores prior to switching over to zinc ores later in the year. Zinc production is expected to commence in Q3 2011 and reaching the full production rates by the end of 2011. The estimated cost of the project is €43 million and is approximately 90% complete.

The feasibility study of the Lombador project is now expected to complete by the end of Q2 2011. The access ramp down into Lombador continues. It was expected to reach the 300 level (approximately 900 m below surface) by the second quarter of 2012 and this will facilitate the development of an exploration

drive on the 335 level to allow underground exploration of the orebody.

Somincor and Metso have been co-operating for more than 35 years and many Metso crushers, screens, mineral processing machines and pumps can be found. Metso Iberica supplies the mine with wear and spare parts and takes care of selected service tasks.

"We are currently having discussions with Metso on efficient conveying solutions, eliminating dust in screening, and achieving a better recovery percentage in our minerals processing circuits with the Visiofroth system," says Andreatidis. "I do expect Metso to offer us new solutions to help us, in this respect, to achieve a better mine economy," he adds. "Whenever we call Metso, we get professional service," comments António Camacho Valente, Plant Manager at the Somincor mine.

The majority of Aguas Teñidas mine's minerals processing is accomplished using Metso products and solutions. The modern mineral processing system,



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installed mainly in 2007, includes SAG and ball mills, stirred media detritors (SMD), filtration equipment (VPAs) and a good number of pumps from Metso. The mine uses longhole open stoping with paste backfill in its underground operations. In 2010, a total of 2.2 Mt of ore was processed. About half of the production consists of copper ore (2% Cu with a little zinc and silver), and half polymetallic ore (1% Cu, 6% Zn and 2.5% Pb, plus recoverable silver).

Depending on the ore type, Aguas Teñidas runs two parallel grinding, flotation and filtration circuits, both capable of processing 140 t/h. According to Fernández, Metso has also helped the mine to achieve better grinding energy efficiency by finding the best wear parts for the grinding mills. "Thanks to the wide material selection and know-how, Metso provides us with the best solutions and wear materials. A good example is the solution to the SAG mill liners, a combination of rubber and metal (Polymet)," he explains. We believe that Metso designs products that are both solid and reliable during use. In grinding and filtration, our equipment availability is as high as 97%," he adds.

Xstrata Technology (XT) has been in the copper industry in some form for over 30



At Prominent Hill, a rougher concentrate is reduced from over 100µm to 24µm by a M10,000 IsaMill, and is then treated by a Jameson Cell

years, with the development and commercialisation of the Isa Process™ copper EW and ER technology in the late 1970s, as well as the Isasmelt™ top submerged lance

(TSL) smelting process in the early 1990s. Both technologies have had a significant influence, offering low cost copper production from highly efficient and productive operations. However it is in mineral processing that XT believes further gains are still to be made, in particular, in the grinding and flotation fields.

Traditionally mineral processing plants were designed to crush and grind the ore feeding the plant to the liberation size of the required valuable mineral. This approach naturally ground not only the valuable mineral to the required size, but also the gangue minerals – wasting a lot of unnecessary power and effort. A better approach however, is to determine how coarse can the feed stream be ground, and still get good recovery in the first separation stage, i.e.

roughing in the case of flotation. The focus in this case is on the gangue liberation. The next stage in processing is to determine how fine a grind is required to grind down the rougher product to make a high enough grade, where the focus is now on the mineral liberation. By using this approach the whole of the feed stream is not over ground, instead only a small section of the feed is ground

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down to the required size for valuable mineral recovery.

XT has been promoting these types of circuits to a variety of mineral processing applications. Copper circuits, in particular, need this type of grinding strategy, as the head grades of their resources decline, and even more material needs to be processed for every pound of copper produced. In particular, the experience XT has had using its IsaMills, at a range of sites and applications, offers even more energy efficiency to operators who use this type of milling technology in their regrinding circuits. The influence of IsaMill in regrinding is beneficial in two ways:

- High power efficiency. The grinding action in the mill produces attrition grinding from the grinding disc operating at high speed in a relatively small volume of fine media, increasing the chance of high intensity particle media collisions, resulting in very effective use of the available power
- Inert grinding environment. The media used in the mill is ceramic balls, so there are no ferric ions generated in the grinding process, creating relatively inert slurry conditions and contaminant free mineral surfaces, making them ideal for the down stream flotation or leaching processes.

Katie Barnes, Strategy Manager at Xstrata

Technology, said "The development of inert media over the years in grinding circuits has opened up a range of grinding applications for IsaMills™. In ultrafine grinding (UFG) circuits, it is not uncommon to use 1mm grinding media to achieve grinding sizes down to 7µm. However for coarser applications, as we have in some of the copper operations needing to grind down to 40 to 50 µm, larger media of 3 to 4mm is used. The media has certainly developed and improved over the years, along with the size of the IsaMill, so that now IsaMills can handle large scale regrinding circuits".

IsaMills are in a number of copper circuits worldwide, in a variety of applications. The Morenci operation in the US uses a M10,000 IsaMill to produce UFG for its copper pre-leach circuit, while IsaMills treat copper concentrate prior to cleaning at Neves Corvo in Portugal, and Prominent Hill in Australia, which use a M3000 (1.5 MW) and a M10,000 (3.0 MW) respectively.

One of the more recent installations, the copper/gold operation at Phu Kham, Laos, uses a M10,000 in its regrind circuit, followed by a Jameson Cell. In this circuit, coarse rougher concentrate is treated by the IsaMill, which then combines with the fine rougher concentrate, to be treated by a large Jameson

Cell. The Jameson Cell, a self aspirated flotation cell, then scalps out a final copper grade concentrate. The wash water system on the cell allows for the final grade to be achieved, and ensures the fast floated copper minerals to be quickly floated and collected to final concentrate, taking the pressure off the conventional flotation cells that treat the slower floating tails from the Jameson Cell.

This is good example of better circuit design leading to improved efficiency. Conventional cells are good at recovering minerals with slow flotation kinetics, and Jameson Cells are good at recovering fast floating minerals. Putting both technologies together maximises the chance of recovering both types of particles. A similar circuit is operated at Prominent Hill, where a rougher concentrate is reduced from over 100µm to 24µm by a M10,000 IsaMill, and is then treated by a Jameson Cell. A final grade copper concentrate is produced from the Jameson Cell, while the tailings are upgraded by three stages of conventional flotation. The wash water is very important on the Jameson Cell, as not only does it achieve the copper grade, but also eliminates some of the deleterious gangue elements that are present in the ore.

Steve Smith, Operations Manager at XT, said IsaMill technology is playing an important part

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The SART process enhances gold yields and lowers operating costs for copper-gold projects. BioteQ Environmental Technologies has specialized know-how in the design and operation of sulphide precipitation processes, which is essential for successful SART operations

FLSmidth has won a contract worth about \$50 million from Kalumbila Minerals, a wholly owned subsidiary of First Quantum Minerals, for the supply of equipment to its extensive copper development, the Sentinel project, situated in northern Zambia. The order is for the supply of four mills in two production lines, each line will have a SAG mill and a ball mill. The SAG mills and the ball mills will be the largest size installed in the African Continent to date.

in the South American copper industry, with Xstrata Copper's Antapaccay and Las Bambas installing two and three M3000HF IsaMills respectively. The ever present need to efficiently grind was one of the key factors in the selection of this technology for these operations, as well as the small footprint, and the minimisation of over-grinding.

Another Xstrata Copper operation installing IsaMill technology is the Ernest Henry mine (EHM) in Queensland, Australia. While predominantly a copper operation, EHM has recently introduced a magnetite circuit to treat

the tailings of the copper concentrator, as the ore is predominately magnetite based. A M10,000 IsaMill is being installed in the circuit to further enhance magnetite recovery by reducing the size range down to 40µm. The operation is designed to produce 1.2 Mt/y of magnetite concentrate once it is up and running. EHM is only a handful of operations that includes a copper and iron circuit at the same site, and the use of IsaMill technology may offer an opportunity for other sites to establish similar operations that are based upon magnetite hosted orebodies.

## Copper-gold conundrum

Brad Marchant, CEO of BioteQ Environmental Technologies, notes that "as the price of gold continues its climb, demand continues to outpace supply, as investors seek safe haven in a commodity long considered a store of wealth. The widening gap is causing mining operations to consider new development strategies that once may not have been economically viable because of the associated processing requirements and costs. For

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HMS plant at Tiger Resources' Kipoi project

example, many of the known but yet un-mined gold deposits in the world are in areas rich with cyanide-soluble base metals such as copper and zinc.

"While these orebodies can be found throughout North and South America, Asia and Australia, there can be a higher cost associated with the gold extraction process. More specifically, it requires a process known as SART (sulphidation-acidification-recycle-thickening) – a process technology that has only very recently been considered for application in any significant way by the industry.

"SART technology, developed by SGS Lakefield and Teck, has been in existence for a number of years. The purpose of the process is to reduce the metallurgical interference of copper (and sometimes zinc) which can consume the cyanide reagent used in the gold recovery process. It does this by treating the cyanide leach solution to extract and recover the copper and regenerate the cyanide for recycle back to the gold operation. The cyanide associated with the copper cyanide complexes is released by adding acid and treating it with a sulphide reagent to precipitate copper as copper sulphide. The cyanide is then recovered as free cyanide for recycle back to the gold process.

"The SART process has been proven to remove up to 99% of the soluble base metal, producing a saleable high-grade copper concentrate while regenerating up to 95% of cyanide for recycle to the gold extraction process. The process can reduce cyanidation costs, generate incremental revenue from copper, and increase gold yields, changing the project economics for copper or zinc complexed gold ores.

"In addition to addressing the metallurgical challenge of copper or zinc in gold processing, SART can also improve the environmental footprint of gold operations that generate cyanide waste. The presence of copper in tailings supernatant tends to stabilise cyanide in a form harmful to wildlife and one that is less amenable to the natural degradation process. As a result, cyanide waste can require specific and expensive disposal processes. By removing the copper from the cyanide solution, SART can help to reduce the impact of cyanidation and the

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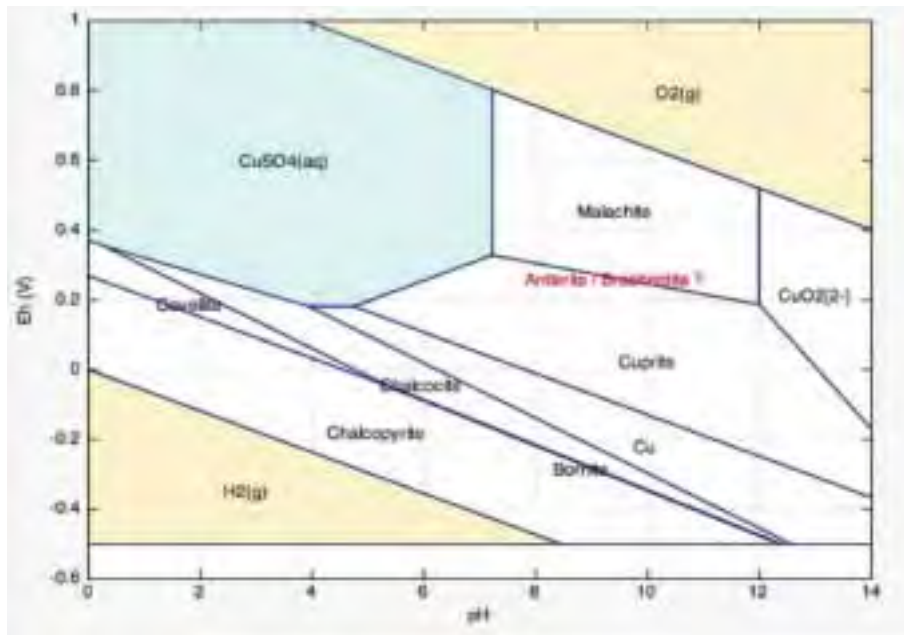
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Pourbaix diagram for copper in presence of Fe, S and Si. Copper oxides readily dissolve in acid conditions, in contrast to sulphides which require oxidising to dissolve conditions. An optimum acidity region is found at pH 4. The diagram shows an increase of the expected solubility in the upper-left corner of the diagram, i.e. in acidic and oxidizing conditions. From van der Lee

associated destruction costs

"Until now, SART has not been considered for most gold mining operations. This is in part due to the fact that metallurgical interference from copper or zinc is not always an issue at gold mining sites. To date, SART has been applied at sites in Australia, South America, Mexico, and Turkey, in geographical belts where gold ore is affected by these metals.

"Widespread adoption of SART has historically been constrained by two main factors. First, SART adds capital costs for process equipment, which can impact the cost of gold production. Mining companies must assess whether this additional capital cost is justified by the cost savings for cyanidation and the incremental revenue from increased gold yields and copper recovery.

"Second, SART requires specialised knowhow in sulphide precipitation processes, which is not common in the mining industry. This second constraint can be addressed by working with specialists in sulphidisation, such as BioteQ." He goes on to explain that his company "has spent more than a decade designing and operating sulphide precipitation process technologies for the selective recovery of metals in mining wastewater. This knowhow is being applied to SART projects, and the company is now considered one of the world

leaders in SART design and operation. BioteQ designed and operated the first SART plants in North America and western Asia, and most recently was contracted by Kinross Gold to assist in the commissioning and start-up of a new SART plant in Chile.

"The rise in gold prices has put SART in the spotlight for some mining companies, who are now considering properties that have not been mined in the past because of the presence of copper or zinc. Now the opportunity is there to bring new properties into development and increase gold yields.

"While the number of operations who have invested in SART technology to date is small, interest in the technology is growing considerably due to the successes of recent projects. With gold prices moving beyond the \$1,400 an ounce range, the industry is now in a position to consider investing in technologies to support these extraction processes to fulfil demand. As gold mining companies evaluate new technologies, there is no question that interest in SART will grow."

BioteQ has resumed water treatment operations at its joint venture plant in Bisbee, Arizona, USA. Bioreactor activity has been restored and water treatment has resumed. The Bisbee plant treats water emanating from a low-grade stockpile containing dissolved

copper and recovers copper as part of the treatment process. The plant is expected to recover some 325,000 lb of copper over the balance of 2011. BioteQ and its joint venture partner, Freeport-McMoRan Corp, share equally in the treatment process and associated costs.

Alexander Mining is undertaking AmmLeach® testwork for Tiger Resources on ore from its Kipoi copper/cobalt project in the DRC. In addition, Alexander is completing detailed pilot plant design engineering for the project and expected to have preliminary designs completed by the end of July. Tiger began producing at its flagship Kipoi project in April 2011. The Stage 1 plan of the Kipoi project is for annual production of 35,000 t of copper. The Kipoi Central high grade zone includes a mineral resource estimate of 7,400 t of contained cobalt, of which the Kipoi Central Stage 1 Pit contains 590,000 t ore at 0.75% Co for about 4,500 t of contained cobalt. Tiger has indicated it would like a pilot cobalt plant to be operational early in 2012.

Martin Rosser, Alexander Mining CEO, said that: "Alexander is delighted to be working with Tiger Resources to unlock the potential of its asset with a second pilot plant opportunity for the Company in the DRC. We continue to pursue other exciting base metals opportunities and advanced discussions are underway in Australia and Latin America."

MetaLeach® is a wholly owned subsidiary of Alexander Mining that was formed to enable the commercialisation of its proprietary hydrometallurgical mineral processing technologies. These technologies, the company says, "have the potential to revolutionise the extraction processes for many base metals deposits by reducing costs, and hence enhancing operating margins, at the mine



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*Injection well for ISCR*

site." MetaLeach owns the intellectual property to two ambient temperature, ambient pressure, hydrometallurgical technologies, namely AmmLeach (patents pending) and HyperLeach® (patents pending). These technologies are environmentally friendly, cost effective processes for the extraction of base metals from amenable ore deposits and concentrates allowing the production of high value products at the mine site (i.e. metal powder or sheets). These technologies were created as a result of the company's work at its Leon copper project in Argentina and subsequent research and development undertaken by the company and its consultant Dr. Nicholas Welham.

**Reagent news**

Cytec Industries has developed a new series of reagents (ACORGA® NR Series) for operations with concerns over nitration. These new reagents can be formulated at varying strengths to maximise copper transfer (based on the PLS copper and acid) while maintaining chemical stability under nitrating conditions. Historically plants with high nitrate in their PLS solutions (20 – 40 g/litre) or concerns over nitration risk, have elected to use ketoxime (due to its high hydrolytic stability). The use of ketoxime has the disadvantages of reduced copper transfer, copper: iron selectivity, and low copper recovery when the PLS copper grade is high or the pH is low. Often the ketoxime is too weak of a formulation for efficient SX operation.

The new formulations are modified oxime extractants, which demonstrate higher stability than ketoxime extractants under nitrating conditions. These formulations maintain the chemical and physical performance characteristics of the traditional ACORGA products, while allowing customisation of the formulation for the specific feed conditions to maximise metallurgical performance.

Cytec has also developed a new range of formulations with enhanced stability to

oxidation. The company says "the ACORGA OR series of extractants provide excellent

chemical stability under high oxidation-reduction potential (ORP) while maintaining the desired physical and metallurgical characteristics.

"Prior to the development of the ACORGA OR series of reagents – there has been no copper SX formulation designed to protect against oxidative degradation. To prevent oxidation of the organic phase due to high ORP values, the Fe<sup>2+</sup>/Mn ratio in the electrolyte and ORP should be monitored and controlled. During plant upset conditions, steps should be

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Official opening of El Teniente's Pilar Norte. *Minera.Andina.com* reported in April that Codelco could see a dramatic drop in its production by more than 50%, from 1.7 Mtpy of fine copper to some 800,000 tpy in 2020. For this reason, a strategic plan to ensure Codelco remains "the biggest copper producer in the world, and the company that contributes most to Chile's economy" was approved in May 2010. Diego Hernandez, Executive Chairman of the corporation told the CRU's 10th World Copper. CODELCO is undertaking a portfolio of huge projects, which seek to maintain and increase the present production levels in the mid and long term. This includes an investment of some \$34 billion from now to 2022, and involves transforming the Chuquicamata open-pit to a huge underground block cave mine; deepening El Teniente mine; transforming Andina to an open-pit operation, as well as increasing its mineral resource base.

El Teniente mine will move to a new level 300 m deeper using a mining method similar to the present one; however, the mineral will be hauled to the plant through a system of conveyor belts and not by the current rail system. Andina mine will see a new expansion phase, which not only will transform it into an open-pit mine, but to one that has the largest Codelco producers, overtaking Chuquicamata. The plan will also consider the \$2.3 billion Ministro Hales mine project, which is already approved by the Board and by all the pertinent Government authorities. This project will be converted to a new large-scale mining division.

Hernandez also indicated that the long term objective is to maintain or increase the resource base, adding that Codelco owns around 10% of the world's copper reserves, while Chile has 30% of the total reserve. Codelco's copper resources stand at 17.772 Mt of ore @ 0.7% Cu that will last the next 70 years at the current production rate.

The most relevant recent exploration results achieved were in the Andina District, where Codelco found mineralisation in a newly interesting sector called Cerro Negro, with results that suggest very attractive potential. Also two new areas of mineralisation have been identified at El Teniente.

Hernández also highlighted that in the international arena, "we have entered into joint ventures in the Carajas mining district in Brazil, which covers five groups of mining properties that we are already exploring." And also work is ongoing in Ecuador.

taken to quickly bring the electrolyte ORP back under control.

"The use of Cytec's oxidation resistant formulations will provide an extra level of security to address temporary permanganate issues or other conditions resulting in oxidation (short term or ongoing).

Using its proprietary Flotation Matrix 100 process for mineral flotation, Cytec has developed a number of new reagents that are delivering measurable improvements over existing technology. One such reagent is

AERO® MX-5128 promoter, an AERO XD-5002 promoter formulation that was evaluated in a copper/molybdenum operation in the European region. AERO MX-5128 promoter was tested in conjunction with OREPREP® F-549 frother to improve the copper and molybdenum metallurgy over the current reagent suite of Potassium Isobutyl Xanthate (KBX), diesel oil and OPSB frother.

Cytec concludes that "the increase in copper recovery of about 2% and in molybdenum of 3.7% is statistically significant with 90% confidence."

## In situ leaching

ISL or in-situ copper recovery (ISCR) has been used extensively around the world for decades, and its advantages include lower capital and operating costs, no ore moved or tailings created, minimal visual disturbance, fewer permits versus other mining methods, and an ability to produce copper cathodes on site.

Pretty obviously, the orebody must be permeable with respect to the leaching fluid in order to apply ISCR. Typically, ores contained in permeable sedimentary formations such as sandstones or highly fractured rocks are suitable candidates. Furthermore, the ores should be sandwiched between relatively impermeable layers (aquicludes), in order to channel the leaching agent through the ore and avoid leakage. Furthermore, the following conditions should be met:

- Favourable dissolution kinetics of the valuable minerals
- Low buffer capacity with respect to pH and Eh, especially a low carbonate content since carbonates are notorious acid-consumers
- Confined medium, to avoid leakage and to guide the leaching fluid through the ore
- Permeable orebody, with an optimum accessibility of the grains.

"A perfect combination of all these conditions is rarely met," according to Jan van der Lee<sup>1</sup>. "Each leaching installation has its specific configuration, mineralogy, geology and hydrogeological environment."

Curis Resources, associated with HDI (Hunter Dickinson Inc), aims to become a global leader in ISCR production and production technologies. In 2010, it acquired a 100% interest in the Florence copper project - an advanced-stage ISCR project in central Arizona, midway between Phoenix and Tucson near the community of Florence. Extensive geological, engineering and pilot ISCR test work undertaken by previous owners indicate that the Florence project has the potential to be a near-term, low-cost copper producer. Road, rail, power and water infrastructure is all located in close proximity to the property, which also features on-site administration offices and certain facilities for ISCR production. Curis believes there are a number of opportunities to enhance operational performance and production efficiencies at Florence. A feasibility study is currently underway, with production targeted for 2012.

The feasibility study on final design, engineering, capital and operating costs for the Florence project is being undertaken by M3 Engineering. M3 will be working with other contractors to complete trade-off studies, complete engineering designs, and to establish



detailed capital and operating costs required to develop and operate the project over the anticipated 19-year operating life. Brown and Caldwell will undertake a review of the overall copper extraction plan and Knight Piesold Consulting Engineers will complete project geotechnical, water treatment and water impoundment designs.

Following the successful completion of project permitting and approvals that is anticipated in the fourth quarter of this year, it is the intention to immediately begin development of a 12-14 month production test at the project site. Work has begun on sourcing a suitable pilot scale SX/EW plant and preparing detailed engineering plans and cost estimates for this phase of the project.

ISCR offers a number of benefits over traditional mining practices, including minimal disturbance to the surface and aesthetics of the land, lower operating and capital costs, and a broader range of post closure land use opportunities.

An ISCR operation consists of a series of injection, recovery and monitoring wells penetrating a soluble oxide copper deposit. A weak acid solution, similar in pH to household vinegar or lemon juice, is pumped through perforations in the injection wells and into the copper mineralisation. The solution passes through cracks in the ore and dissolves the copper into the solution. This copper-rich solution is then pumped to surface through recovery wells where it is recaptured for processing.

Typically a ring of four recovery wells surrounds each injection well, creating an inward hydraulic gradient of fluids that allows recapture of the copper bearing solution. Further, there are monitoring wells that ensure this inward gradient is maintained at all times to protect surrounding groundwater quality. Copper bearing solution is then sent to an SX/EW plant to produce 99.999% pure copper cathode sheets.

The Florence deposit has an estimated Measured plus Indicated mineral resource of oxide material in bedrock of 389.6 Mt grading 0.331% Cu, and an additional 84.2 Mt of Inferred resource grading 0.267 % Cu. The PEA completed by SRK noted base case economic analysis results indicate an after-tax NPV of \$359.8 million at a 7.5% discount rate with an IRR of 30%. Payback will be early in production Year 4 in a projected 19-year mine-life. The economics are based on a base case of \$2.50/lb long-term copper price and a design production rate of 76.5 Mlb/y of copper. Direct operating costs are estimated at \$0.680/lb; total operating costs including property taxes are \$0.704/lb. Total capital costs

are estimated at \$682.1 million, consisting of initial capital costs of \$237.8 million, and ongoing sustaining capital over the life of operations of \$444.3 million.

River sand, silt, and gravel buried the entire deposit to a depth of some 115 m. During this period of erosion and deposition, calcareous silty mud and clay layers were deposited in shallow basins that extended over the region. This clay layer, which occurs 18 to 30 m above the top of bedrock, is 6 to 12 m thick and acts as an aquitard, preventing groundwater in aquifers above and below the layer from mixing, which is important for ISCR.

BHP Billiton's ISCR pilot test work in the 1990s included shuttered wells with flow meters/controllers, pressure transducers and other wellhead equipment, fibre-optic communications to the control trailer, a high-density polyethylene (HPDE) lined solution pond that has remained in use with water and sediment contained within it, and a tank farm to store water, sulphuric acid, raffinate, and caustic soda.

That work indicated 85% of the acid soluble copper (ASCu) resource would be extracted over a five-year period, and 90% recovery would occur over six-year period; this is equivalent to 47 to 51% of the total copper (TCu) resources. SRK reviewed the available

metallurgical column and field test work, site characteristics, and previous modelling, and incorporated the metallurgical recovery factors into the current production plan. It reported "ISCR is estimated to allow recovery of approximately 49% of the total contained copper identified as mineral resources over a six-year recovery period. The estimates of total copper recovery and the rate of copper recovery will be confirmed and refined when a field test is initiated and completed by Curis."

BHP's assumptions were based on average characteristics of the deposit (chrysocolla/other copper silicates; oxide zone thickness of 122 m; ratio of ASCu:TCu was 67%), metallurgical test results from BHP Column Test 2 (representative material with an average grade of 0.38 %TCu), and operational cell distance of 30 m.

SRK has developed a conceptual ISCR wellfield production plan and schedule for life-of-operations development, and prepared an estimate of associated development and production costs. A basis of design for well construction has been developed to satisfy environmental and production objectives. Pumping rates for the recovery wells are assumed to be 3% greater than those in injection wells to maintain inward hydraulic gradient and comply with permit conditions. The development schedule incorporates pre-



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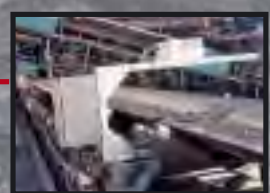
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development, development, reclamation, and well closure activities. The wellfield arrangement assumes a staggered line drive pattern of repeating 'five-spot' cells with a distance of 30 m from recovery well to recovery well and a distance of 21.6 m from each injection well to the nearest recovery well.

The planned facilities are the ISCR wellfield, a SX/EW plant, tank farm, raffinate pond, water impoundments, and infrastructure. The wellfield occupies an 87 ha site and will expand in size as wellfield resource blocks are brought on line and will contract in size when reclamation begins after copper recovery declines to non-economic level. Some 150 to 260 new wells will be drilled per year. Reclamation will begin in month 73 and continue until the groundwater chemistry meets the requirements of the UIC and the Aquifer Protection permits for the site.

Raffinate will be pumped from the raffinate pond to the wellfield distribution tanks. The distribution tank will have an 113,560-litre capacity with a high level alarm and level indicator. The tanks will be fitted with control valves to prevent overflow of solution. They will be located inside a spill control area and any incidental spills will be captured in a lined spill sump. Spillage will be collected in the sump and pumped back into the circuit. The raffinate will be pumped from the distribution tank to the individual injection wells.

The PLS from the recovery wells will be pumped to the in-situ wellfield advance tank and then into the PLS feed pond. The PLS feed pond will be double-lined with an inter-liner leak detection system that meets the Arizona Best Available Demonstrated Technology Control Guidance (2004). A pump back system will allow leakage to be returned to the PLS pond or transferred to the raffinate pond. The PLS will be advanced by pumps into a SX train. Each of the two trains will consist of two extraction settlers and mixer sets and one stripper mixer set. Each settler will be fitted with dual mixer boxes. The PLS will enter one extractor and then the solution will be advanced to the second extraction stage. The copper-depleted solution, now raffinate, will be pumped back to the raffinate pond.

## New horizons

Mintek, South Africa's national mineral research organisation, offers expertise in minerals technologies. From the service requests being lodged at its laboratories, an impression can be gained of the level of activity in the exploration and development of new minerals projects, especially on the southern African sub-continent. Currently the scope of copper projects under investigation in the region include greenfield exploration, expansion at existing operations and re-treatment of tailings, including projects in Angola, Madagascar, Mozambique and Tanzania that have historically not been viewed as copper producing countries.

The southern African region is experiencing a high level of exploration activity, where a recent survey by the Mineral Economics and Strategies Unit (MESU) of Mintek identified more than 30 copper prospects at various stages of exploration, feasibility study or early

development. Many of those include consideration of a form of acid leaching or heap leaching with on-site cathode production as part of the process flowsheet.

In southern Africa many of the new prospects are relatively remotely located, and the delivered cost of acid and other reagents makes on-site processing both an economic and a logistical challenge. Another challenge that needs to be addressed in the copper-producing region of southern Africa is the electrical power generation required to sustain the potential growth in the mining sector.

Mintek provides a complete range of metallurgical test work and process design services as well as certain plant and equipment to the industry. Furthermore Mintek maintains a portfolio of research projects on topics that can benefit the minerals industry, such as improved methods of extraction, water utilisation, process control, reagent recycle, gangue chemistry and others.

The need is felt universally for maximising beneficiation to metal either by leaching and SX-EW or by smelting of concentrates to blister copper or refined metal. "For the foreseeable future," according to Mintek, "it can be expected that the oxide portions of the orebodies will be leached whereas the sulphide portions will be smelted, either locally or abroad. Hydrometallurgical copper sulphide leaching can generally not outperform the economics of smelting of concentrates, unless the concentrates contain a level of deleterious impurities that result in high smelting penalties being incurred."

The Southern African Institute of Mining and Metallurgy is hosting a few conferences during 2011 that are relevant to the regional copper industry, particularly the Base Metals Conference in July and the Percolation Leaching Conference in November. Interested readers can visit the web page at <http://www.saimm.co.za>, and follow the links from the icons.

The world's copper projects from prefeasibility, through feasibility to development decisions, first production and expansions are tracked by International Mining Project News – published every two weeks. Contact [emma@im-mining.com](mailto:emma@im-mining.com) for subscription details and a trial copy. **IM**

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