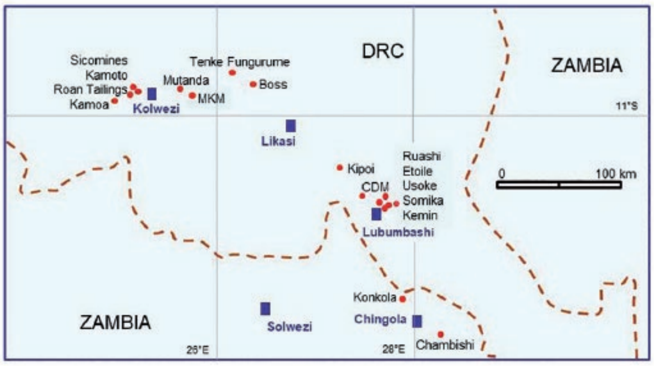
Cobalt processing options explored

The ALTA 2018 Nickel-Cobalt-Copper Sessions in Perth, WA began with the Keynote Address by Dr Kathy Sole (South Africa) entitled 'Flowsheet options for cobalt recovery in African copper-cobalt hydrometallurgy circuits', co-authored by John Parker, Peter Cole and Michael Mooiman.

Along with new electronic and electrical applications, the phasing out of diesel and petrol vehicles is markedly increasing demand for cobalt, nickel, lithium and graphite. For cobalt, supply-chain considerations are important. Presently some 98% of the world's cobalt is a byproduct of the mining of copper or nickel. The price of cobalt has increased by some 450% in the past two years, mainly due to increasing demand for lithium-ion batteries, which are in widespread use in consumer electronics and increasingly required for electric vehicles. There are limited alternatives to cobalt in these batteries at present.



Location of current major cobalt operations and projects in the African Copperbelt

Copperbelt choices

With an official production of 64,000 t in 2017, the Democratic Republic of Congo (DRC) produces more than half of the world's cobalt, which is eight times more than any of its closest competitors, namely Russia, Australia, Canada, Cuba, Philippines and Madagascar. It also holds over one third of known mineral reserves containing cobalt.

African Copperbelt operations have traditionally focused on copper production, but it has now become imperative to also consider cobalt recovery from these ores. All DRC operations carry out leaching under ambient conditions, usually by agitated tank leaching or, less often, by heap leaching. Under these conditions, acid-soluble minerals of both copper and cobalt report to the pregnant leach solution. Most hydrometallurgical flowsheets recover cobalt from the raffinate of the low-grade copper solvent-extraction circuit, although dedicated cobalt leaching, which typically requires reductive conditions, is also considered. Downstream purification processes include sequential precipitation with a variety of reagents, solvent extraction (SX), and ion exchange (IX). Product choices include hydroxide, carbonate, sulphate, and metal cathode.

Copper and cobalt circuits

Copper and cobalt are usually simultaneously dissolved from the oxide ores using acid and SO_2 (added as sodium metabisulphite, SMBS) for reduction of Co(III) minerals. The downstream thickener overflow advances to a high-grade copper SX circuit. The thickener underflow is fed to a counter-current decantation (CCD) train to wash out entrained copper and cobalt values from the leach residue that reports to tailings, while the first-stage CCD overflow reports to a low-grade copper SX circuit. The raffinate from this circuit is treated for cobalt recovery.

The most common cobalt recovery route involves the sequential precipitation of iron, aluminium and manganese using lime at pH 3.5, followed by cobalt precipitation at pH 8.5. Magnesia, despite being far more expensive, is widely used for cobalt precipitation in preference to lime, owing to its preferred product purity and characteristics. A successful demonstration of proposed technologies for recycling MgO and CaO could change the economics of this selection.

Cobalt purification flowsheets based on IX and electrowinning technologies and targeting cobalt metal production are demonstrated to be both economically and technically preferred over the typical $Co(OH)_2$ product, mainly due to logistical challenges and transport costs.

Achieving battery-grade

Most production of battery-grade chemicals presently takes place in China, where the refineries are geared towards treating feed materials such as $Co(OH)_2$ with the current suite and levels of impurities. Unless a very high-purity cobalt product can be cost-effectively and consistently produced, there is no benefit to further upgrading at a mine site. There is also no advantage to producing an intermediate-grade product because the buyer will generally not be willing to pay more to treat such a product through the same refining process as lower-grade materials.

Most of the existing cobalt production facilities in the African Copperbelt (primarily located in the DRC) started out with ambitious project designs to produce a high-value cobalt end product such as electrowon metal. Most later opted for a phased approach, concentrating first on developing copper production capacity and producing a cobalt intermediate product (usually $Co(OH)_2$ produced by MgO precipitation) suitable for sale or stockpiling, with a view to future implementation of plans towards upgraded cobalt products.

Legislation regarding export of concentrates and intermediate products affects flowsheet choice. Another factor is the issue of environmentally acceptable containment of sodium-bearing solutions that are generated in flowsheets employing SX upgrading steps: the tailings return solution can build up to 5-10 g/L Na. These concentrations require lining of tailings disposal dams to prevent seepage into the environment. The alternative of removing sodium by crystallising sodium sulphate is not considered a viable option, due mainly to its limited market in Sub-Saharan Africa.

Many DRC and Zambia operations that possess resources but are not currently producing cobalt are now considering more ambitious flowsheets and higher-purity products. This necessitates the incorporation of multiple SX and/or, preferably, IX steps to achieve the required purity of the electrolyte prior to the final product-recovery step. Chambishi Metals (Zambia) is the only Copperbelt refinery that currently employs both SX and IX process steps. Flowsheet refinements that minimise soluble losses to tailings and filter cakes and that recover soluble cobalt (and copper) from aqueous waste streams will also receive increasing attention in future.

Possibility of overreaching

There is quite clearly a significant technological and philosophical gap between the industries of mining and metal production compared with the production of battery-grade chemicals. It is essential that primary cobalt producers understand the complexity of the value chain and their well-defined role within it, to avoid implementing costly and technically sophisticated flowsheets that may ultimately not be able to deliver the desired benefits in terms of product purity and price.

There is, nevertheless, no doubt that the African Copperbelt will become the incubator of many novel and innovative flowsheets within the next five to ten years, and that cobalt rather than copper will become the main value product of many DRC operations, driving both the mining philosophy and focus of capital expenditure.

This summary article is based upon Dr Kathy Sole's ALTA 2018 Keynote presentation (full document available from the ALTA Free Library (www.altamet.com.au/free-library/) and is published here with the permission of Dr Sole and ALTA Metallurgical Services, organisers of the ALTA Conference Series.