Ion exchange pre-treatment and recovery solutions for mines

Vincent Ridgard, process engineer at Multotec Process Equipment, talks to MechChem Africa about treating effluent from mines, which often makes use of reverse osmosis (RO) technology. Ridgard argues that pre-treatment using fit-for-purpose ion exchange (IX) plants to remove divalent and trivalent ions in mine wastewater can significantly improve efficiencies and reduce the costs of water treatment.

Treating effluent on mines often makes use of reverse osmosis (RO) technology, but low recoveries can raise costs substantially. “Osmosis is an naturally occurring phenomenon, where the molecules of a solvent such as water tend to move spontaneously towards a solution with a higher concentration of dissolved solids; in the direction that tends to equalise the concentration of the two sides,” Ridgard explains.

Natural osmosis only works in one direction, moving water in a solution, for example, from areas of high concentration to areas of lower concentration. “However, when purifying water, we want the water to move in the opposite direction, leaving contaminants behind and enabling only purer water to pass through,” this process, called reverse osmosis (RO), can be achieved by applying pressure greater than the osmotic pressure of water at a semi-permeable membrane, he continues. “With enough pressure, dissolved contaminants can be removed. Water can be created by forcing it across a membrane that rejects salts and other contaminants while allowing only pure water through.”

But, says Ridgard, RO was initially designed to remove monovalent common salt, that is sodium chloride ions (Na+Cl−) from mine water. While softened water remains successful and widely applied, the waste-water on mines also includes divalents, such as calcium, barium, magnesium, carbonate and sulphate ions (Ca2+, Ba2+, Mg2+, CO32−, and SO42−), and trivalents, such as iron, manganese and phosphate (Fe3+, Mn3+, and PO43−), which can cause scaling of the membranes in RO systems, he notes. “This means that when a standalone RO plant is utilised to treat these waters, it has to be operated at lower recoveries to enhance the lifespan of the membranes.”

RO membranes, he explains, reject contaminants based on their size and charge, preventing contaminants with high molecular weights and multiple ionic charge from passing through. Sodium ions (Na+), for example, can exchange with the charged groups on the membrane while Ca2+ and Mg2+ ions are retained by the membrane as well as Ca2+ ions, which have two charges. Also, monovalent ions are more easily dissolved (ionised) in water than divalent ions, which makes them less likely to precipitate. “In water treatment practices it can be said that all salts of sodium, chloride and sulphate are relatively soluble, and those of calcium, barium, carbonate and sulphate are much less soluble when paired. Therefore, the most commonly observed scaling substances on RO system membranes are CaCO3, CaSO4 and BaSO4. In seawater, due to the high concentration of sodium chloride, pairings of these divalent principals is less of a problem, but when treating mine effluent, scaling results in large volumes of highly concentrated brine streams, which are either recirculated within the system or require very expensive extraction and treatment systems.

To address these challenges, Multotec offers niche ion exchange technologies that are well suited to removing divalent and trivalent ions in mine wastewater before passing the water through the RO plant where the monovalents can be more effectively removed. “In an ion exchange system we are designed to suit the specific effluent being treated, scale-causing divalent and trivalent ions can be almost completely removed prior to RO treatment, with the potential to increase overall water recovery to more than 95%,” Ridgard reveals.

**CIF® DESAL®** and HIROX® technologies

Through a close partnership with Clean TeQ Water in Australia, Multotec offers mines across Africa several variations of continuous counter-current ion exchange technologies. “These all use resins to selectively extract the larger cations and anions from the mine effluents,” he continues.

While these scientific principles are well accepted, there has previously not been a suitable technology to truly unlock the significant potential of resin chemistry. Clean TeQ’s ‘moving bed’ solution – supplied to the African market by Multotec – is therefore a game-changer,” says Ridgard.

Describing the basic principle of removing a divalent cation such as Ca2+ or Mg2+, he says cation exchange resin beads introduced into the top of an adsorption column move counter-current to the flow of the feed solution being pumped from the base and flowing to the top of the column. The divalent cations load onto the resin, displacing the H+ ions that are part of the resin beads’ chemical functional group. Different resins with varying chemical functional groups are used to maximise selective contaminant removal and to suit the contaminants available on site.

The resin loaded with Ca2+ cations exits the adsorption column at the bottom and is moved across to a desorption column via a pneumatic lift. For cation removal, sulphuric acid (H2SO4) is added, which reacts with the resin to form CaSO4 (gypsum), while regenerating the resin by placing H+ ions back onto the beads. After filtering out the insoluble gypsum, the resin is washed and then recirculated back to the adsorption column.

Ridgard notes some key differences this approach has compared to the more widespread fixed bed (batch) ion exchange (IX) technology, where a solution is pumped through a static resin bed until the resin is fully loaded/exhausted:

- **The counter-current resin-to-solution flow** in a similar manner to a sand filter whilst chemically filtering out selected pollutants.
- **CIP**, a single stage solution that can be used for a range of treatment applications including acid and mine drainage remediation and membrane pretreatment (desalting). It can also be used for dealkalinisation and the removal of target ions for the recovery of valuable metals such as copper or zinc, for example.
- **DESA®**, which is a two stage CIP solution for the removal of cations and anions. A cationic resin is used in the first stage to remove the larger cations such as calcium and magnesium, while the second stage uses anionic resin to also remove trace metals, formatting loads of total dissolved solids (TDS) that can often mean additional process units are needed, since the resin is exhausted sooner. This provides both operational robustness and future proofing against composition changes.

- **CIP columns operate at atmospheric pressure, enabling low pumping costs. Contrast this with IX systems, which operate as pressure vessels and can suffer pressure drop that increases power costs.**

- **CIP’s tolerance to precipitated solids and its counter-current resin-to-solution flow enables close to 100% bioclimatic reagent usage, and intensive regent recycling, which lowers operational costs. In batch IX systems regents are often dosed by more than 150% of the chemical stoichiometry required, due to the less efficient ion exchange chemistry that occurs in a fixed resin bed.** Similarly, the spent solution cannot be recycled after use since precipitates commonly form.

Ridgard describes three different systems that use continuous counter-current ion exchange solutions from Multotec:

- **CIP**, a single stage solution that can be used for a range of treatment applications including acid and mine drainage remediation and membrane pretreatment (desalting). It can also be used for dealkalinisation and the removal of target ions for the recovery of valuable metals such as copper or zinc, for example.

Further analyses have been done to establish the effect of flowrate and feed concentration on the process, economic feasibility, effluent concentration streams of anything above 100 mg/l of salt give payback periods of less than a year at flowrates greater than 150 m³/h, while if the effluent flow is limited to 100 m³/h, copper concentrations of 160 mg/l can still realise a one year payback. The most impressive results have been achieved for zinc mining recoveries using studies for a zinc mine, where, following zinc extraction, the water is passed through a DESAL® system to produce reusable treated water, and the waste brine passes through a high-density sludge process to enable easily disposable waste solids to be extracted.

“While the most exciting success story is our DESAL® plant for an antimony roaster in the Middle East, which has achieved 99.6% of the calcium ions and 99.4% of sulphate ions prior to the water stream being passed through the reverse osmosis plant – and we are hoping to achieve further success at this plant in the near future,” concludes Ridgard.

www.multotec.com