The KNeW process: a profitable way of recovering salinated wastewater

Trailblazer Technologies' John Bewsey is pioneering cost effective and potentially profitable ways of processing neutralised acid mine drainage (AMD) water, industrial wastewater and even underground 'brakwater'. In this article, he describes his KNeW (Potassium Nitrate ex Waste) process, which relies on scalable ion exchange CSTR batteries with some value adding regeneration and post regeneration twists to transform dissolved contaminants into valuable fertilisers and industrial salts.

Acid mine drainage (AMD) is an expensive problem and one that remains largely unresolved. Treatment begins when acidic minewater is filtered to remove coarse particles and then neutralised with lime, which precipitates the dangerous heavy metals and neutralises the acidity. But the acid/base neutralisation reaction leaves the 'treated' solution contaminated with an excess of dissolved salts.

Of these, the worst and most difficult to deal with is sodium in the cation form (Na^+). 63% of South Africa's fresh water is used for irrigation in agriculture and sodium contaminated water causes more devastation to our soils than all other dissolved substances put together.

Sodium ions attach themselves to clay particles in soil and are not readily removed. Once attached, the sodium ion hydrates and causes the clay to swell making the soil impervious to water and air. Without water and oxygen penetrating the soil, agricultural yields drop quickly and drastically, a far more serious long-term AMD associated problem than any other.

South Africa's water scarcity affects food production far more than it does the potable water shortages in urban areas, yet many of the widely publicised AMD successes tend to focus on potable water quality, which is far too expensive for agriculture to consider using.

To put this argument into perspective, the daily off-take of the Rand Water Board is 5 000 Mℓ/day while all of the AMD arising across from mining activity is estimated to be about 350 Mℓ/day. To be putting a large and expensive effort into partially or completely cleaning AMD for drinking water purposes seems to be misguided, but it must usually be promoted as a revenue source to justify the viability of a particular process. It is far more important that AMD be brought to a quality suitable for agriculture and returned to our water courses for irrigation purposes than to be trying to supplement the lesser requirements of the city user.

Of utmost importance is that any process used to clarify AMD, as well as being able to remove the toxic heavy metals and, where applicable, residual radio-activity, is also able to substantially remove the sodium salts from any water being returned into our natural freshwater reservoirs.

The key focus of the KNeW process is, therefore, not only to desalinate wastewaters derived from AMD and other industrial wastewater effluents, but to go on to remove and separate the dissolved salts into those that are valuable and the sodium salts, which are not.

For treatment using the KNeW process, a twin line of stirred tank reactors (CSTRs) operate continuously, with the effluent water flowing from tank to tank. In the foreground is a ring of PLC controlled vessels for regenerating the resins: dilute nitric acid to regenerate the cation resin; and methanol for the anion resin.

Counter-current ion-exchange

The KNeW process is a wastewater treatment process that uses ion exchange resins to remove dissolved cations – such as sodium (Na^+), calcium (Ca^{+2}) and magnesium (Mg^{+2}) – and anions – including chloride ($C\ell^-$), sulphate (SO_4^{-2}) and carbonate (CO_3^{-2}). All dissolved ions can be removed from the effluent water leaving demineralised water to any required quality.

Ion exchange processes are usually operated in column batch style, which is limited to solutions containing up to a maximum of 3 000 mg/ℓ of dissolved solids due to the large amount of rinse water used to regenerate the columns. In addition, there is a flow rate limit due to the high pressure drop and the process is impossible to make genuinely continuous. This makes these systems unsuitable for continuous high volume water treatment.

For treatment using the KNeW process, a twin line of stirred tank reactors (CSTRs) operate continuously, with the effluent water flowing from tank to tank, while the resins are pumped in the opposite direction. Both volume flow and the rate of demineralisation can be varied by either increasing or decreasing the size or number of tanks in each side of the battery.

After passing through the catex and anex ion exchange resins, the water is demineralised, leaving the respective resins loaded with the dissolved cations and anions. The water is then treated and suitable for use, while the resins must then be regenerated before they can be used again.

Volume flow and the rate of demineralisation can be varied by either increasing or decreasing the size or number of ion exchange tanks in each side of the battery.

After precipitating out the multi charged cations, the residual sodium nitrate solution is mixed with an equimolal amount of potassium chloride and then evaporated. This causes the least soluble salt – sodium chloride – to crystallise out, leaving only the high-value potassium nitrate in the 'waste' cation regeneration solution.

The KNeW process

Dilute nitric acid is used to regenerate the cation resin, while an ammonia solution regenerates the anion. The nitrate-based regeneration solution is then treated with sodium carbonate, which causes all the multicharged cations (Ca^{+2} and Mg^{+2} for example) to precipitate. These are filtered out for use in agriculture as a soil ameliorant.

The residual sodium nitrate solution, which remains in solution, is mixed with an equimolal amount of potassium chloride and then evaporated, causing the least soluble salt – sodium chloride – to crystallise out. This is then separated from the cation regeneration solution to produce a pure and dry product for the animal feed industry.

The residual liquor is cooled to produce a pure crystalline potassium nitrate, which is separated and dried for use in horticulture as a primary fertilizer. Another option is to use vegetable ash, which has a very high potassium carbonate content as a raw material to precipitate out the multicharged elements giving an even more economic route to the formation of potassium nitrate.

The anion regenerant solution is treated with methanol to precipitate ammonium sulphate. This is then dried and supplied to agriculture as another fertiliser. The residual liquor is treated with sodium hydroxide to recover the ammonia content for reuse and the remaining sodium chloride is recovered by evaporation and added to that derived from the cation regeneration part of the process.

From an economic perspective, the sale of the high-value potassium nitrate pays for the purchase of all the raw materials and the costs of operating the process, while leaving a reasonable profit. If the water produced can be sold – and this is not often the case – then additional profits can be realised.

In comparison, reverse osmosis requires considerably more power and is expensive to operate and, unless it can be simply pumped back out to sea, it does not offer solutions for the concentrated brine problem for inland installations. The KNeW process can successfully remove all dissolved salts and convert them into beneficial raw materials for agriculture and industry while delivering suitable and affordable water for agricultural irrigation.

All of the costs of the operation can be covered, very little power is needed and much needed jobs in the chemicals processing industry can be created. ❑

Key advantages of KNeW

- Zero net operating costs and the process usually shows a profit.
- Products from the regeneration are high-end fertilisers and feed-grade sodium chloride.
- Low electrical usage.
- Ease of operation – most of the plant is PLC operated.
- Minimal maintenance costs.
- Very little waste for disposal.
- Competitive capital cost.
- Ability to treat effluent with high inorganic contamination levels.
- Plants can cater for high treatment rates of over 100 Mℓ/day.
- Start-up and shut-down procedures are simple and PLC operated.