Cheaper selenium removal

David Kratochvil explains how innovation in water treatment can generate major savings for the cost of compliance with new selenium regulations

Essential to all life in trace amounts, selenium at higher concentrations has been found to have implications for humans, animals and aquatic life. This rising awareness has led to new selenium regulations being promulgated and enforced by regulatory agencies in the US and Canada, as indicated in Table 1. As a result, the mining industry is in need of innovative and effective methods to reduce the cost of removing selenium from mine-impacted waters.

Selenium is a naturally occurring element that acts as a substitute for sulphur in a variety of minerals present in coal, base metal and precious-metal ore deposits. Consequently, trace concentrations of selenium can be present in waters generated by a wide spectrum of mining, mineral processing and hydrometallurgical operations.

One of the most challenging streams to treat is run-off water that comes into contact with waste rock and/or exposed mineral surfaces in open pits and underground workings in wet and cold climates, where the volume of wastewater is very high (often in the order of tens of thousands of cubic metres per day), the water temperature is low, and the selenium concentration is highly variable, typically in the range of 10-1,000ppb.

Although different selenium species can be present, the large majority of selenium in mine-impacted waters is hexavalent selenium or selenate. Currently, the only systems commercially available to treat high flows of mine water containing selenate include membranes combined with evaporators-crystallisers, and/or biological selenium-reduction systems.

The main disadvantages of these systems are the high capital and operating costs. These can translate into significant water-treatment life-cycle costs that can run hundreds of millions of dollars per wastewater stream. Although

Two views of the BioteQ Selen-IX pilot plant

the industry has applied these systems at several sites in the US and Canada, the large majority of sites where active treatment for selenium removal is needed remains uncommitted, primarily due to the high life-cycle costs.

This has created a gap in the market for innovators who may be able to develop a new treatment system that would help the mining industry achieve compliance with selenium regulations cost-effectively.

SELEN-IX

BioteQ is one company working to bring a cost-effective solution to market within the next 12 to 24 months. BioteQ's new patented selenium-removal process, Selen-IX, is based on selective ion exchange (IX) combined with electrochemical reduction of selenate to selenium metal.

The ion-exchange part of the process allows the treatment of large volumes of cold water, regardless of the feed selenium concentration, down to as low as 1ppb, using commercially available ion-exchange resins placed in a set of columns arranged in a compact module. The ion-exchange process is selective for selenium, leaving other non-toxic constituents such as chloride and sulphate in the water, which reduces treatment costs.

While the majority of columns in the module receive selenium-laden wastewater, several columns are always being regenerated, which ensures that freshly regenerated resin is always available for continuous treatment.

The volume of the spent regenerant brine solution is only a fraction of the volume of water treated. Consequently, this small volume of spent regenerant solution contains selenium at concentrations several orders of magnitude greater than in the feed, e.g. 5,000 to 30,000ppb, and is directed to an electrochemical selenium-reduction step where iron is added to the brine solution and selenium is removed in the form of an iron-selenium solid. The selenium solids are separated from the solution and subsequently dewatered.

With the brine solution free of selenium solids, it is then recycled back to the selenium IX step. Recycling of the ion-exchange regenerant eliminates waste liquid brine that is typically produced by conventional IX systems and reduces the overall operating cost of the treatment process.

The only by-product of the Selen-IX process is a small quantity of stable inorganic iron-selenium solids that passes the US Environmental Protection Agency's Toxicity Characteristic Leaching Procedure (TCLP) tests as non-toxic, and that can potentially be shipped to steel-alloying operations that represent one of the main consumers of selenium metal.

PILOT PLANT

Based on successful laboratory bench-scale testing, BioteQ constructed a mobile Selen-IX pilot plant that allows the company to offer field testing of its new process on waters collected

Table 1: selenium discharge requirements

Jurisdiction & requirement	Discharge Limit (ppb)
Canada – Aquatic Life WQG	1-2
Canada – Drinking Water	10
US EPA – Aquatic Life WQG	5
US EPA – Drinking Water	50

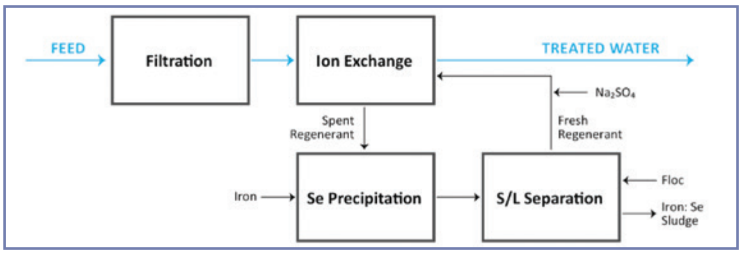

Fig 1: schematic of the Selen-IX process

directly at customer sites. The pilot plant can operate under any weather condition, on a continuous basis, and is fully automated for ease of operation.

In the latter part of 2013, BioteQ deployed the Selen-IX mobile pilot plant to test selenium removal from mine-impacted surface water for a Canadian mining company. With anticipated regulatory changes to permissible selenium discharge levels, the pilot trial was undertaken to test the effectiveness of Selen-IX to remove selenium to a requisite limit of < 20ppb and a desired elective limit of < 5ppb. Feed water composition for the pilot is summarised in Table 2.

Figure 2 shows the selenium concentration in 24-hour composite samples of the plant feed and discharge during the 24/7 continuous operation of the pilot. The data points represent consecutive days of operation and demonstrate that the pilot plant was able to produce treated effluent that met the requisite limit of < 20ppb. Once plant operations were optimised after a few days, the desired elective limit of < 5ppb was also met.

The pace at which Selen-IX has moved from bench scale to pilot scale along with the positive results from pilot testing obtained to date indicate that the technology will be commercially ready in the next 12 to 24 months

More importantly, the results of pilot testing indicate that Selen-IX can, depending on feed flow and composition, deliver significant savings of 30-80% in the lifecycle cost of selenium removal in comparison with other commercially ready technologies.

These savings will come from minimising solids handling and disposal, reducing plant footprint and replacing large site-erected tanks and structures with a pre-fabricated modular system, and no requirement to pre-heat the cold feed water to ensure proper operation of the system.

Selen-IX also eliminates the need to polish and remove residual phosphate and biological oxygen demand that results from biological treatment methods. In addition, it minimises the pre-treatment requirements of membrane systems, which are susceptible to a host of constituents commonly found in mine waters, including finely suspended solids and chemical constituents such as aluminium, iron, silica, manganese, alkaline earth metals and sulphate.

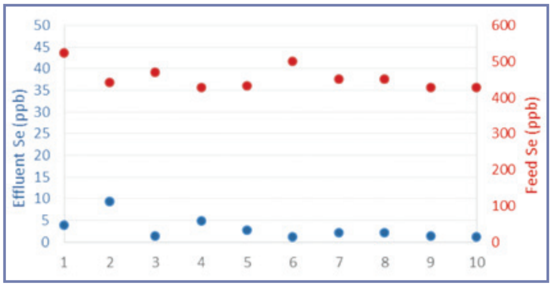

Fig 2: pilot feed and discharge during pilot operation

Table 2: pilot feed composition

Constituent	Feed
Selenium	457ppb
Chloride	27ppm
Nitrate	57ppm
Sulphate	2,050ppm
Alkalinity	436ppm
Total dissolved solids	2,983ppm

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