Battelle Develops VEP to Remediate Acid Rock Drainage

A breakthroguh process collects ARD, purifies the water, removes the pyrites and recycles the extractant at minimum expense in a rather small footprint

By Steve Fiscor, Editor-in-Chief

A test facility in Pennsylvania treats ARD at a rate of 30 gpm.

The engineering and science firm Battelle has developed a breakthrough technology to efficiently remove sulphate ions and metal cations from acid rock drainage (ARD). This technology is based on a novel adaptation of liquid-to-liquid extraction, cool kinetic efficiencies and some inherent chemical engineering principles. This is the first cost-effective method to purify ARD from metals and sulphate without generating a waste stream. It produces purified water and recyclable products, such as potassium sulphate and iron sulphate, which has other uses, such as fertilizer. Other remediation technologies exist, but all of them create a waste stream that has to be land-filled. Battelle's innovation could potentially save thousands of miles of waterways from discharge from abandoned mines and help other mines in regions where scarce water resources are tainted naturally.

In 15 months, the Battelle team converted a concept into a practical demonstration plant, located at an ARD site near St. Michaels, Pennsylvania, USA. The project was funded by Battelle, Winner Global and the Pennsylvania Department of Environmental Protection. This first stage demo of this technology involved treating and processing the acid mine water at 30 gallons per minute (gpm) over six weeks. "Fast kinetics" enabled a small equipment footprint. Using automation and inexpensive consumables, the plant successfully treated the ARD at a relatively low cost (including energy consumption). Upon analyzing the field results, the plan is to now scale up the demonstration plant to 500 gpm–eventually scaling up to 5,000 gpm.

The Value Extraction Process (VEP) offers mining companies numerous positive environmental and economic advantages. The purified water can be subsequently treated to make it potable. There are minimal pollutants released as the extraction process economically recycles the metals and minerals. This treatment process can be adapted to extract other types of metals and minerals, such as selenium, arsenic, aluminum, iron, cobalt and nickel.

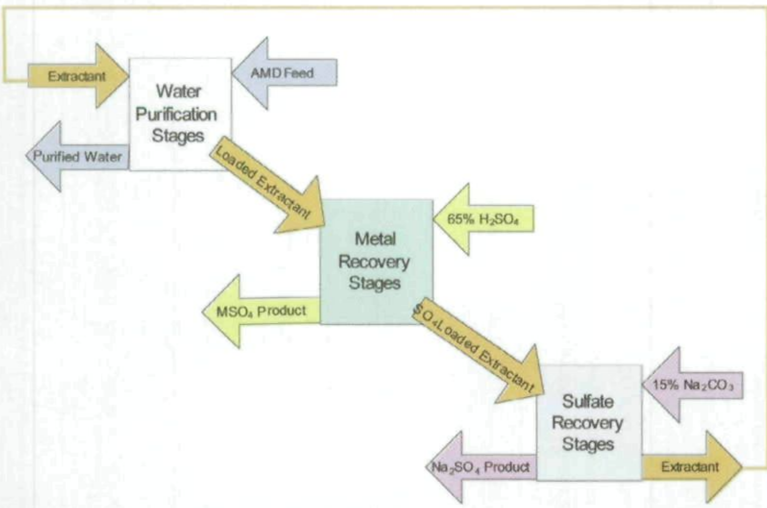
In Pennsylvania, there are 4,600 miles of waterways impaired with ARD. Battelle's VEP is poised to offer states with abandoned mines and active mining companies an effective, affordable treatment of ARD discharges that will not produce a residual sludge. This system can potentially restore miles of polluted streams and rivers, thereby rejuvenating currently impaired environments and economies.

They Said It Couldn't Be Done; Battelle Did Not Listen

Winner Global approached Battelle and asked if they thought their chemical engineering team could develop a method to address ARD. In particular, the objectives were to have a technology that could not only remove iron, but also sulphates, and not generate a secondary waste stream. "Lime treatment [gypsum], for example, generates piles of waste and they wanted to avoid that," said Mike von Fahnestock, program manager, chemical, environmental, material operations department for

Fast kinetics keeps the footprint small.

AMD F-LLX™ Process Block Flow Diagram



The VEP has three phases: extraction, metals recovery and sulphate recovery.

Battelle. "They also wanted the process to be scalable, cost effective and technologically feasible."

Battelle submitted a proposal with a few concepts and ideas. The Commonwealth of Pennsylvania provided matching funds to do the work. "We were able to leverage some existing liquid-to-liquid extraction technologies," von Fahnestock said. "Battelle had designed some technology for the Air Force to remove chromium from industrial waste water from a shaft plating processes and thought they could adapt that process to ARD and remove sulphate. This was non-obvious because the solvent extraction industry specifically said that sulphate could not be removed cost effectively with scalability using solvent extraction. We overcame that hurdle with some innovative chemistry."

The proposed concept incorporated four phases. The scientists started with some batch tests and equilibrium studies. Then they moved the research to a bench-scale test that continuously operated with actual ARD from several different locations. "We gained some very good results," von Fahnestock said. "From that design, we adapted the solvent extraction technology into a 30-gpm pilot system and took it to St. Michaels. It operated for three months. We demonstrated excellent sulphate removal, iron removal and scalability.

"We took the VEP from an idea to test tubes in a 200 ml/min lab bench pilot to a 30-gpm pilot where we range tested from 10 gpm to 30 gpm," von Fahnestock said. "[The VEP] had different flow rates, excellent repeatable sulphate removal, good iron removal. We met secondary drinking water standards for sulphate removal. We found we could maintain the desired pH." As far as economics, the researchers found that the VEP process could be cost competitive with other techniques for removing sulphates, such as bio treatment, reverse osmosis and lime treatment, especially considering the secondary waste stream.

"We have demonstrated the process successfully and we are working out a license agreement with Winner Global to take this technology forward commercially," von Fahnestock said. "The next target is to go for a 500 gpm plant and we believe we could easily scale it up to 5,000 gpm."

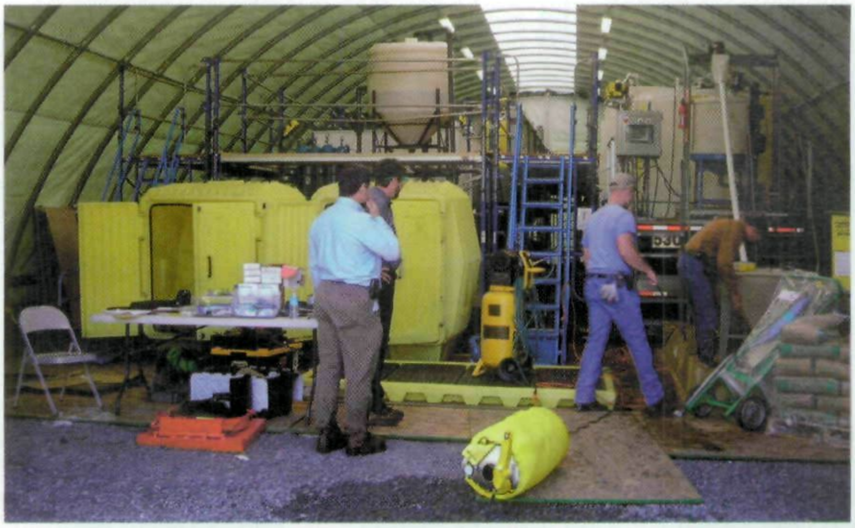
How the VEP Process Works

To avoid generating a waste stream, the contaminants are removed in four extraction stages and the process regenerates the extractant. The extractant is expensive and inorganic, so discharging it is not an option. The loaded contaminants (metals, sulphates, etc.) are stripped in these four stages. In the metals recovery stage, the metals make contact with sulphuric acid to generate a product. In the case of iron, the product would be ferrous or ferric sulphate.

The VEP has three phases: extraction, metals recovery and sulphate recovery. "From a chemical engineering standpoint, during solvent extraction processes, you reach a certain equilibrium state and that's all you get," von Fahnestock said. "By running a few tests, we were able to calculate how many extraction boxes were needed to accomplish the level of sulphate removal desired. If we started with 2,000, and we wanted it to be less than 250, we calculated that we need four extraction sections or boxes. Each box is a mixer that mixes the inorganic extractant with the water, and a second part to the box, a weir, serves as a separator."

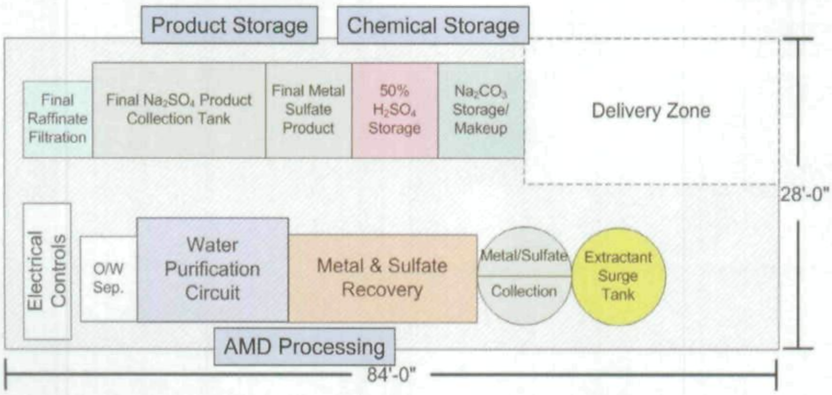
Fast Kinetics Enable a Small Foot Print?

"The traditional solvent extraction literature says that you can not economically pull sulphate out of the stream," von



Product storage occupies one side and processing takes place on the other side.

Equipment Layout



A schematic (plan view) shows how the stations are arranged.

Fahnestock said. "That's because the kinetics–or the rate at which the sulphate would be removed from the water pulled into the extractant and subsequently recovered–would be too slow. We adapted the chemistry and process design to overcome that. With a contact time of 60 to 90 seconds, we can remove the iron and sulphate and whatever else is in there. If the residence time was one to two hours, the plant would have to 60 to 120 times larger in size. When that would be scaled up the capital costs and land costs would be enormously cost prohibitive."

By purifying all of the water first and discharging it, the process does not have to carry that water through to the back end of the plant. "We only need to add enough chemicals to stoichiometrically remove the contaminants that are loaded on the extractant. So we don't have to acidify or build-up the pH on all of the water," said von Fahnestock. "As much as 98% of the water has been discharged before anything is added. All the process is dealing with is extractant and some minor water that caries through the process. The extractant can be recharged and recycled. The extractant is designed to make a very clean split with the water so that extractant is not entrained. That can be polished off with a filter."

Similar to oil and water, the process allows chemistry to follow its natural course. The mixture wants to split apart and it overflows the weir. "After five to seven minutes of residence time, the inorganic, which is lighter than water, overflows a weir in one direction," von Fahnestock said. "That process has to be repeated four times for the extractors before the mixture moves through a couple of metal strippers, and four sulphate recovery strippers." At the St. Michaels demonstration plant, the process used two trailers. One had the extractors and strippers and the other had the chemical feed tanks and product storage tanks.

The net result was that the VEP was able to produce purified water to less than 250 mg sulphate. It removed the iron and it can remove aluminum if necessary. "In the recovery stage, we recover the iron as iron sulphate as a concentrated liquid," von Fahnestock said. "It can be used as a water conditioner or it can be dried and used as a fertilizer. It has value. The process yields potassium or sodium sulphate depending on which process is used. Potassium carbonate would generate potassium sulphate."

The product is useful, but by no means would not it cover the costs of the process. "No, it's not a money making process by itself, but it avoids waste disposal costs and it offsets operating costs through product recovery," von Fahnestock said. "The purified water itself would have value. Because it's low in sulphate, it will not corrode or scale equipment. Or it could be fed to a municipal plant or it could be used to restore a water shed with pure water rather than polluted water."

Costs are estimated at $6 per 1,000 gallons for total life cycle cost. "We performed an economic assessment and it's around $6 and we have done enough testing that we think that's a pretty good number," von Fahnestock said. "It's not $20 and it's not $2. Lime is about $1.50. Reverse osmosis can be as much as $30.

"Solvent extraction is certainly nothing new to mining, so why not leverage what's already out there," von Fahnestock said. "This is just a different way of doing solvent extraction."

The stakeholders are obviously excited about VEP's potential and its future commercial scale up. "It's not a silver bullet," von Fahnestock said. "We think it's a perfect technology for heavily contaminated sites with high sulphate problems and lots of iron. The passive systems can handle the easy stuff and this process can clean up the difficult sites. At St. Michaels, that point source was responsible for one-third of the pollution in the Conemaugh River. If you could eliminate that with one system, it would have a magnifying benefit downstream."

Metal and sulphate strippers need only 60 to 90 seconds of contact.