Research Brief 205: Ramping Up Mixed Metals Removal

NIEHS National Institute of Environmental Health Sciences

Release Date: 01/04/2012

A novel system developed by researchers at the Brown University NIEHS Superfund Research Program has been shown to effectively remove low concentrations of copper, nickel and cadmium simultaneously from a liquid solution, returning the contaminated water to federally accepted standards of cleanliness. By combining two methods, the system, developed by Joseph M. Calo, Ph.D., P.E., produces very large volume reductions of metals from the original contaminated water without producing toxic sludge as a byproduct. The end products are decontaminated water and solid particles with the accumulated metal, which can then either be safely disposed of, or recovered for other uses.

The automated system is scalable as well, said Calo, Professor of Engineering (Research) at Brown, so it has commercial potential, especially in the environmental remediation and metal recovery fields.

According to Calo, eliminating trace metals from water is really hard to do given the cost, inefficiency, and time needed. "It's like trying to put the genie back into the bottle," he said. So he and colleagues created a system that combines two commonly used techniques—chemical precipitation and electrowinning—to take advantage of their good points and minimize their drawbacks.

Precipitation uses a chemical that reacts with the metals and converts them into solids that can be filtered out. But these solids constitute a toxic sludge, and there is not a good way to deal with it. Landfills generally won't take it, and letting it sit in settling ponds is toxic and environmentally unsound. "Nobody wants it, because it's a huge liability," Calo said. Then there's electrowinning, during which an anode and a cathode are submerged in the metals solution. When a current is applied, the metals are reduced and deposited on the cathode. The major drawback of electrowinning is that it uses too much current when used with solutions of metals at low concentrations.

Calo and colleagues combined the two methods to create a cyclic system that does not export precipitate sludges. In their Cyclic Electrowinning/Precipitation (CEP) system, the electrowinning step uses a spouted particulate electrode, which minimizes some of the disadvantages of other electrode systems, allowing operation at higher current densities and current efficiencies. The system also uses multiple precipitation cycles to increase the metal ion concentrations in the solution sufficiently such that electrowinning can then be used to reduce the metal ions to solid particles at good current efficiencies. Precipitation is then used as a finishing step to reduce metal concentrations in the final effluent water. During the precipitation/redissolution cycles, metal precipitates are formed and redissolved, but no toxic sludge ever leaves the system.

The team has demonstrated the novel CEP system's performance in removing mixtures of copper, nickel and cadmium from aqueous solutions to low concentrations, and has begun to refine the parameters for optimal removal of each of these metals. "This approach produces very large volume reductions from the original contaminated water by electrochemical reduction of the ions to zero-valent metal on the surfaces of the cathodic particles," the authors state. "For an initial 10 ppm ion concentration of the metals considered, the volume reduction is on the order of 10^6."

This strategy is not anticipated to be a panacea for remediation of all heavy metals, but it is expected to be applicable to a wider range than those tested in the current study (copper, nickel, and cadmium). In addition, the work increases understanding of the behavior of heavy metals in complex contaminated aqueous mixtures. Heavy metals are persistent environmental toxicants, and all of the heavy metal species are included in the 2007 CERCLA Priority List of Hazardous Substances. Thus, the novel CEP system represents a major advance.

To learn more about this research…

Contact:
Joseph M. Calo, Ph.D., P.E.
Brown University
Chemical & Biochemical Engineering Program
Division of Engineering
Barus & Holley Building
182 Hope St.
Providence, RI 02912
401-863-1421
JMCalo@brown.edu

Or refer to:

Pengpeng Grimshaw, Joseph M. Calo, George Hradil. 2011. Cyclic electrowinning/precipitation (CEP) system for the removal of heavy metal mixtures from aqueous solutions. Chemical Engineering Journal. 175. 103–109.
doi:10.1016/j.cej.2011.09.062

By Angela Spivey, Contractor to NIEHS

NIH... Turning Discovery Into Health