Arsenic Removal: Fixing Drinking Water for Millions

Lehigh University

It certainly seemed like a good idea in the 1970s to improve the health of millions of people in India and Bangladesh by replacing their reliance on polluted river waters with access to small-tube wells. By drawing clean water from underground aquifers UNICEF, World Bank and Indian and Bangladeshi officials hoped to reduce the diarrhea, dysentery, cholera and hepatitis that were constants of life in the Gangetic Delta. And it worked – Bangladesh saw its infant mortality rate, one of the highest in the world, cut in half.

But by the 1990s, it was clear there was an unwelcome trade-off: A fifth of the eight million wells in place by then were contaminated by arsenic. Today, says the World Health Organization, tens of millions of people in Bangladesh and the eastern Indian state of West Bengal are being poisoned by drinking water laden with toxic levels of arsenic.

"We're used to thinking of contaminated water as a man-made problem but arsenic is a natural contaminant of groundwater found throughout the Earth's crust, including in the United States," says Arup K. SenGupta, PhD, a Lehigh University professor whose career has focused on removing trace contaminants from water. "In some places arsenic levels are quite high, and it's become a very serious public health problem."

Compared to the World Health Organization's acceptable standard of 10 parts per billion (ppb) of arsenic to water, 46 percent of Bangladeshi wells are above that level and 27 percent are above 50 ppb. It is, a WHO scientist said in 2000, "the largest mass poisoning of a population in history."

"A similar crisis has since emerged in Cambodia, Laos and Vietnam," notes Tom Meischeid, Interim Director of Lehigh University's Office of Technology Transfer. "It's a case in which research in a university setting can be translated into potential relief for entire populations."

SenGupta, P.C. Rossin Professor of Civil and Environmental Engineering and of Chemical Engineering at Lehigh, has found a novel way to impregnate tiny polymeric beads, known as anion exchange resins, with ferric hydroxide nanoparticles to create a safe, effective mechanism for separating arsenic from the water in wells and public water supplies. The technique is the basis of LayneRTTM, an advanced filtering medium manufactured by Northborough, MA-based SolmeteX®, Inc.

Chronic, Long-term Effects

Unlike its "Arsenic and Old Lace" image, arsenic poisoning doesn't automatically lead to one's keeling over and expiring on the spot. Individuals' responses to it can vary – some people do have acute reactions that include nausea, heart failure and death within a few hours and some can tolerate large doses without ill effect. For most, arsenic poisoning is a matter of chronic, long-term, possibly fatal diseases – including skin, lung, bladder and kidney cancers. Studies have linked arsenic to cardiovascular disease and Type II diabetes. Hyperkeratosis – blotchy thickenings and changes in pigmentation of the skin – are common. It's an ingestion issue. Arsenic-laden water is safe to use for bathing and laundry.

"Arsenic is found in drinking water in more than 70 countries, from Argentina to Taiwan, but its presence varies from region to region and even from well to well," SenGupta says. "It's a severe regional problem in eastern India, Bangladesh and southeast Asia."

In the United States, arsenic levels are not as toxic as in other regions but a 2006 Environmental Protection Agency tightening of acceptable levels from 50 ppb to 10 ppb has meant that many areas are now considered to have excessive levels. That's estimated to be the case for more than a third of wells in Arizona and California.

The Iron Factor

SenGupta's involvement in arsenic removal began in the 1990s, when he started collaborating with staff at the Bengal Engineering College in India on developing a sustainable well-based system to filter out the poison. Placed in some 150 villages, the manually operated pumps used granular activated alumina to generate arsenic-reduced water.

The devices yield arsenic levels of less than 20 ppb. For their work, SenGupta and his associates were awarded the 2005 Mondialogo Sustainable Engineering Award by Daimler-Chrysler and UNESCO, the 2007 Grainger Silver Prize Award by the National Academy of Engineering and the 2008 Dhirubhai Ambani Award from the Institution of Chemical Engineers in the United Kingdom.

In his laboratory at Lehigh, SenGupta focused on other filtering substances. He saw iron oxide nanoparticles as an excellent medium for arsenic separation – but one that clumps and clogs the filter column when water is run through it. He thought it should be possible to disperse ferric oxide through a substrate base to achieve a stable structure.

The Massachusetts-based SolmeteX, Inc., had been focused on remediation of arsenic in industrial wastes when the EPA announced plans in 2001 to lower the acceptable levels for drinking water in the United States as of 2006, notes SolmeteX CEO Owen Boyd. The company began looking – with little success – for a technology that would do that when, in 2003, Boyd and his team came across accounts of SenGupta's work.

"We talked to him on the phone," he says. "We drove down to Lehigh that afternoon. And we signed an agreement not long afterwards."

SenGupta worked with doctoral candidate Luis Cumbral at Lehigh for several years before they found a way to place a hybrid ion exchanger ("HAIX") in columns of tiny polymeric ion-exchange beads that could be irreversibly impregnated with hydrated iron oxide nanoparticles.

The LayneRT™ Factor

In 2007, SenGupta and Cumbral received a U.S. patent for their invention, a HAIX dubbed ArsenXnp and produced by SolmeteX. After SolmeteX was acquired by Layne Christensen Company some 18 months later, the technology was further modified and commercialized as LayneRTTM,, a substance offering enhanced performance economically and safely.

"The beauty of Arup's approach," Boyd says, "is that by embedding iron oxide into a polymeric structure, he's created a very durable product that lasts a long time and generates very little waste. They're both positively charged and should repel each other. He figured out how to get a positively charged iron oxide solution onto a positively charge polymer."

Certified by the EPA in early 2009, LayneRT offers a capability for reducing arsenic levels to the U.S. and WHO standards of 10 ppb. By mid-2009, it had been installed in 30 to 40 systems throughout the United States, the largest a 1,500 gallons/minute application in Arizona serving about 4,000 homes.

"We're working with companies in India to try to get products made in that country for use there," Boyd says. "It's not feasible to simply install and maintain these systems from here. It's essential that the materials and services be available locally."

The newest hot spot in the arsenic crisis is Cambodia, Laos and Vietnam, notes Yatin Karpe, Ph.D., Associate Director in Lehigh's Office of Technology Transfer. Working with the Technology Office, in early 2009 SenGupta received a grant from the National Collegiate Inventors and Innovators Alliance to install sustainable arsenic removal systems in Cambodia.

“He’s collaborating with the Institute of Technology of Cambodia to develop arsenic-selective adsorbents, emphasizing indigenous materials available locally,” Karpe says.

SenGupta notes that he and his team spent more than a year developing two grams of HAIX material in the early 2000s, then refined and upscaled the process. Today, there are more than one million pounds in use or available. He believes that the HAIX technology has the potential for applications to separate other heavy metals. He also notes that other companies have started manufacturing similar materials.

“That’s not necessarily good for business,” he says, “but it’s good to see that science is following up on this.”