NANOTECH ON TAP

Indian technology offers **CLEAN WATER** at low cost

GROUNDWATER in the Indian state of West Bengal naturally contains arsenic, causing ailments including skin diseases and cancer. Thanks to nanotechnology, thousands of people there have gained access to arsenic-free water since 2013, with the installation of treatment tanks using porous granules developed by a team at the Indian Institute of Technology (IIT), Madras, led by chemistry professor Thalappil Pradeep. The technology has received government support for field-testing as an option for low-cost, point-of-use water treatment.

COURTESY OF THALAPPIL PRADEEP

INVENTORS The InnoNano team in front of a water treatment tank that uses the materials they developed. From left, Anshup, holding a cartridge of ferric oxyhydroxide-chitosan nanocomposite; Chaudhary; Anil Kumar; Pradeep; and Sankar.

The granules are nanocomposites made from ferric oxyhydroxide and a biopolymer, chitosan. Iron oxides remove arsenic ions from water by adsorption. The team boosted their metal oxyhydroxide's activity by reducing the particle size to nanoscale, thereby increasing the surface-to-volume ratio, and anchoring the material within a network of chitosan. With this structure, which resembles sand and is made at room temperature, embedded particles don't leach into water, and the captured arsenic stays put. What goes on "in the atomic scale is not completely understood," Pradeep says, but that has not stopped the material's real-world use.

At the Ambattur industrial estate, in a suburb of the Indian city of Chennai, a facility makes about 36 kg of the ferric oxyhydroxide-chitosan nanocomposite per day. Production at the plant—run by InnoNano Research, a start-up founded by the IIT Madras team—is enabling field trials in West Bengal.

With funding from the state government, about 100 community water purifiers using the nanocomposites, typically in 600-L tanks, have been installed in the district of Murshidabad, says an InnoNano cofounder known only as Anshup.

Each one, he estimates, serves 50–100 families and lasts one to two years. In the lab, the composite reduces a 1-ppm arsenic load to less than 10 ppb, the limit set by the World Health Organization (WHO). In field trials, natural arsenic loads of up to 330 ppb, the highest found in the field according to the team, drop to less than 10 ppb.

Globally, 137 million people are exposed to arsenic levels greater than the WHO limit. And some 780 million people do not have clean drinking water, according to the Centers for Disease Control & Prevention (CDC). "Every 20 seconds, a child dies from a water-related disease, especially in the developing world," says Emmanuel I. Unuabonah, a researcher from Redeemer's University in Nigeria who also develops water treatment materials.

TO REMOVE MICROBES, the Ambattur plant produces smaller quantities of another material developed by the team, an aluminum oxyhydroxide-chitosan composite (*Proc. Natl. Acad. Sci. USA* 2013, DOI: 10.1073/pnas.1220222110). When impregnated with silver nanoparticles, the material kills microbes by gradually releasing Ag^+, a microbicide. Team member Udhaya Sankar estimates that 120 g of the composite could continuously provide 10 L of microbe-free drinking water daily for a year.

In the lab, microbial loads of 10^5 colony-forming units (100 times the amount in natural drinking water) drop to zero. Lab studies also show that together, the Fe and Al composites remove both arsenic and microbes; limited field trials corroborate the lab results, says team member Amrita Chaudhary.

The composites can be made to remove other contaminants, such as lead or mercury, and assembled for specific needs. The antimicrobial material is housed at the roof of a vessel fed with untreated water from the top. The vessel volume can vary from a few liters for a household to hundreds of liters for a small community. A multilayer block of composites for specific contaminants sits behind the water tap.

InnoNano's materials join many water purification techniques, including ultraviolet radiation, chlorine treatment, and various filtration methods. "You need a basket of technologies," Pradeep says, to address the diverse needs around the world.

A powder called the P&G Purifier of Water, developed by CDC and Procter & Gamble, is perhaps the best-known water purification technology for use in impoverished or disaster-stricken areas. The product, which contains ferric sulfate and calcium hypochlorite, costs 3.5 cents per sachet. One sachet treats 10 L of water in about 30 minutes, removing metals, including arsenic, and killing microbes. For a family using 10 L of drinking water per day, treatment would cost $12.80 per year, a month's earnings for many West Bengalis. InnoNano's filters would deliver the same amount of drinking water for $2.00–$3.00 per year, Chaudhary says.

The nanocomposites stand a good chance of being used on a large scale, Redeemer's Unuabonah says. However, more evidence of their robustness is needed, and the arsenic-scavenging material needs to be tested on higher levels of contamination.

The technology is already popular in Murshidabad. The system works well, says Rajeev Kumar, a former Murshidabad district magistrate, and because community units—such as schools or offices—are responsible for operating the tanks, people have a sense of ownership. In a documentary prepared for IIT Madras, residents ask for installations in their villages. The district has ordered at least 100 more purifiers.

For its part, InnoNano wants not only to provide a purification solution, but also to maintain the installations. "Originally, we were thinking of keeping our role to materials manufacturing," Pradeep says, "but that alone is not enough."—VIRAT MARKANDEYA, *special to C&EN*