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Science Magazine of IIT Madras

Chemistry

Walking on Water

January 15, 2014 Nithyanand Rao 0 Comments

Arsenic poisoning causes several illnesses from skin diseases to cancer. Six million people are chronically exposed to arsenic-contaminated water in one state alone: West Bengal.

Convinced that nanotechnology holds the key, Prof. T. Pradeep and his students accepted the challenge of developing a sustainable and affordable solution for purification of the contaminated water. The team of young researchers worked relentlessly for several years to develop a suitable nanocomposite material that effectively filters out arsenic. It is also an

environment-friendly material that's not difficult to produce and is cost-effective.

Extensive experiments confirmed the efficacy of the technology in converting arsenic-contaminated water to crystal clear drinking water. And recent field trials conducted in West Bengal showed extremely encouraging results. Now, efforts are on to take this technology to the affected people on a large scale.

Professor Thalappil Pradeep sat bolt upright in his chair and leaned forward, eyes alight and impassioned. He grabbed an imaginary scientist, shook him vigorously, and exclaimed, his voice urgent: "An average Indian could come and ask: 'Have you solved any of my problems?' Take one IIT and ask, what problem did it solve?

He leaned back and said more softly, a sense of quiet satisfaction on his face, "It is one of the motivations for me, to do something.

"Of all the problems that can be solved using basic science, he has picked one which is most urgent: water. The Government of India has, in fact, prioritized the addressal of the water quality problem, particularly that of arsenic contamination of drinking water. This is the case in parts of West Bengal, where water is drawn from deep borewells, chronically exposing an estimated six million people to arsenic toxicity, which causes skin lesions, lung, bladder and skin cancer, and even cognitive deficiencies in children.

The nanoparticle-based water filter developed in Prof. Pradeep's lab requires no electricity to run, is adaptable to local conditions – the variations in the

quality of water and the nature of its contaminants – can be scaled-up from meeting the requirements of a household to that of an entire community, needs little or no maintenance, and is environment-friendly. And affordable. For Prof. Pradeep, that last point is the key: “We defined affordability as 5 paise per litre of clean water delivered at home. Can you give arsenic-free water at 5 paise per litre delivered at home on your kitchen table? That’s what these materials can do.”

The provenance of Prof. Pradeep’s work on water filters goes back more than ten years. While working on nanomaterials, he asked himself what, if anything, these tiny particles could do to solve the problems of everyday life. That was in 2002.

He and his students then developed a nanoparticle-based water filter to remove pesticides, which as Prof. Pradeep points out proudly, “became the first such technology in the world to get commercialized.” The filter consists of silver nanoparticles impregnated on alumina, which upon reacting with the halocarbons in pesticides, breaks them down into metal halides and amorphous carbon. This was licensed to Eureka Forbes in 2004, which started producing water filters incorporating this technology in 2007. “We are getting a very tiny royalty, to the institute,” says Prof. Pradeep.

But that did not satisfy him. After all, there are contaminants other than pesticides – heavy metals like iron and arsenic, and harmful microorganisms – in groundwater.

He holds up a small plastic vial containing a dark powder and continues, “It so happened that we had produced several materials and one of them was

quite good when it comes to handling arsenic. So this is that material."

That material is iron oxyhydroxide in nanoparticle form. "In a composite cage," Prof. Pradeep reminds me. "We have a cage which is made with iron oxyhydroxide, which is now connected with polymers – biopolymers – in this case, chitosan. This whole thing is made in water at room temperature. And that material is one in which you can get arsenic ions to get in. But bigger particles will not. So as a result of that inherent affinity of this oxyhydroxide to arsenic, arsenic is scavenged." All this without the use of electrical power.

For antimicrobial action, aluminium oxyhydroxide nanoparticles are used instead of those of iron oxyhydroxide and the resulting cage is embedded with silver nanoparticles. Aluminium oxyhydroxide sheets of about 20 nanometres – one nanometre is a billionth of a metre – in length and about 5 nanometres in thickness are formed in solution. "That is the inherent nature of this material," explains Prof. Pradeep.

"Now, if you take a stack of these, with polymers connecting them so that there are cages of them getting formed, what we have devised is this composite."Thechitosanensures strong binding of the nanoparticle surface to the matrix. It also addresses one of the key challenges, namely, preventing the nanomaterial surface from being covered by deposits.

The water-filtering unit which Prof. Pradeep's lab has developed, was recently field tested in the districts of Murshidabad and Nadia in West Bengal. The groundwater in some parts of the district contain up to 300 parts per billion (ppb) of arsenic ions, which

can be of two kinds: those that have lost three, or five, of their outer electrons. The World Health Organization guidelines, however, set a safe limit of 10 ppb and the national limit is 50 ppb.

“We installed two of those units and there was a very enthusiastic district collector. Without us knowing about it, he was actually collecting samples and monitoring. He told us some months later that ‘Hey, this is great.’ Of course, we were getting data, but he was excited that arsenic was not even detected. So he was quite happy about it,” says Prof. Pradeep with a smile. The successful trials meant that it has now become a project of the state government. “They are putting up 2,000 units, each unit for 300 people – so it will cover 6 lakh people. That is under the installation process. It will take 18 months to finish.”

Using inputs from these field trials, the design was improved. “And finally you got the AMRIT – Arsenic and Metal Removal through Indian Technology,” says Prof. Pradeep proudly.

The water-filters can be customised to filter out almost any contaminant – lead, iron, or bacteria such as E.coli – just by having another filtering unit containing suitable nanoparticles. The lab has developed a range of nanomaterials which can selectively remove each impurity. Bacteria, for instance, can be destroyed using silver nanoparticles in the size range 10–20 nm because they release trace quantities of silver ions in water, whose concentration (40–50 ppb) although sufficient to destroy microorganisms, is not toxic to humans.

Similarly, manganese dioxide nanoparticles can filter out lead. Thus, an all-inclusive drinking water purifier can be built that functions without electricity. All this

at Rs. 130 per year per family, assuming a daily water consumption of 10 litres.

The antimicrobial unit can filter up to 1,500 litres of water before needing re-activation of the silver nanoparticle surface, for which there are simple methods available: one can heat the matrix, or use diluted lemon juice. This re-activation can be done until the requisite silver ions cannot be released from the matrix any further.

However, Prof. Pradeep cautions: “There is no solution which is a complete solution. The problem of water is so vast, so big, every solution has a role. Moreover, water itself is so diverse. That is, your well water is different from your neighbour’s well water. There is a lot of diversity in this, the chemistry is different. So therefore, there is a need for diverse products.”

Prof. Pradeep acknowledges the support he has received from funding agencies. His lab, the Department of Science and Technology (DST) Unit on Nanoscience, has been designated as a Thematic Unit of Excellence on Water Purification using Nanotechnology under the Nano Mission of the DST. Visitors to the lab are greeted by a serene figurehead of the Buddha. Inside, the routine is to remove one’s footwear and use one of the “lab chappals” kept on a separate, neatly name- labelled footwear stand. The walls give testimony to the success and worldwide acclaim that Prof. Pradeep’s lab has achieved. His friend and mentor during his postdoctoral stint at Purdue University, Prof. Graham Cooks, writes of how Prof. Pradeep “has established a school of molecular materials which is surely without an equal in any other single investigator lab.”

"When I was a student I didn't really know what the excitement of science was. Today, science possesses me. You get engulfed into it, you become so passionate about it," says Prof. Pradeep. That passion has been duly recognized on many occasions.

Among the photos which adorn the walls are those of Prof. Pradeep receiving the B.M. Birla Science Prize from the then-President of India, Dr. APJ Abdul Kalam, and of receiving the Shanti Swarup Bhatnagar award – India's highest science award – from the Prime Minister, Dr. Manmohan Singh. "But recognitions apart, what is more important is to do meaningful science," observes Prof. Pradeep.

The success comes from hard work by Prof. Pradeep and his students. "I've been fortunate to have students who are so passionate about it. This passion is what drives. But nobody can fully understand the effort involved in making a student," he points out.

One of those students is Anshup. A 2005 B.Tech Chemical Engineering graduate from IIT Madras, he has a disarming smile and a firm handshake that puts you at ease immediately. Behind all the charm lies a strong will, and an ability and willingness to work extremely hard at something he is passionate about. A busy man Anshup is, and we meet up on his way home from a long day at work.

"The last six years or so have been very fascinating. The materials we have developed are new, the properties which we have found are very new, and the way these materials have been applied are also new," says Anshup. "We spent a lot of time in developing these materials. We have about 20 Indian and international patents," he says, counting

them off, and beaming with the pride of a man who is reaping the fruits of his toil. “And we are continuing to work on more,” he adds matter-of-factly.

Anshup is one of the co-founders – along with Udhaya Sankar, who holds a Master’s degree in Nanoscience from Madras University, and Amrita Chaudhary, a B.Tech in Chemical Engineering from IIT Madras, the three big movers, as Prof. Pradeep describes them – of InnoNano Research, a company incubated at IIT Madras and established to manufacture the nanomaterials specifically for community projects such as the one in West Bengal. Prof. Satish Kailas of the Indian Institute of Science, Bangalore, has been providing advisory support for this venture.

The state government of West Bengal has committed to setting up 2,000 of the arsenic-filtering units. “We’re doing it in eight phases. Now, phase one is complete and we’re going to phase two. We have prepared ourselves to manufacture close to 40 kilograms of the nanomaterial everyday,” says Anshup excitedly. They have set up a plant for this purpose at Ambattur, just outside Chennai city. “This plant is spread over an area of close to 10,000 square feet. It is pretty huge,” says Anshup. “The plant is functional. Once it’s fully ready, we can manufacture as much as 200 kilograms per day of these nanoparticles.”

And then his voice trails off. “It has taken nearly six years to get to this stage,” Anshup reminds me again. “We’ve gone through all the pains that one can imagine. But it gives you immense satisfaction to be a part of this long journey through which we can serve the people of our country.”

His fellow travellers on this journey, Udhaya Sankar and Amrita, have been with InnoNano as co-founders from the beginning. Talking about Udhaya Sankar, Anshup says, “Whenever we wanted to create new things, it was his eyes which visualized them and his craft which shaped them.” Udhaya Sankar is passionate about what he does. “I have learnt that it is the best way to conquer my fear of failure,” he says.

About Amrita, Anshup says, “Without her unwavering perseverance and commitment to work, InnoNano couldn’t have come this far. In those trying moments, it was her yearning to see a product which kept the work moving.” Amrita finds every day an exciting one, as she learns something new which is not written anywhere. “It gives me immense pleasure when I see our products work in the field, and not just on paper or in the lab,” says Amrita.

The team has bigger plans still. They are in the process of creating another company, which will develop the same technology for the household consumer market as well as for sale to other countries. This is in partnership with a venture capital firm which has constantly supported the water research programme for the past two years.

They also plan to perfect their antimicrobial unit, which, as they verified through laboratory tests, kills the microbes responsible for a range of illnesses such as hepatitis, encephalitis, diarrhoea and gastroenteritis. “All were cleaned,” says Anshup with obvious delight. “All you need is this cartridge. Before you drink the water, just pour it through that cartridge, and leave it for an hour. It’ll be free of all microbes.”

Further, they are perfecting the filtering unit for fluoride-contaminated water, which affects parts of Tamil Nadu. If all these different units are used together, it would, as Anshup points out, “be a standalone, completely Indian product.”

Prof. Pradeep gives me a quick tour of his lab and the state-of-the-art instruments, some of which he has built himself, and then the new DST-funded premises under construction, whose second floor will be the Thematic Unit of Excellence on Water.

He enthusiastically explains the floor plan, no less than 10,000 square feet, with new labs meant for both basic science, and industry-oriented, research.And a conference room.He then effortlessly climbs rusty ladders at the construction site, which look suspiciously unsteady, taking us to the terrace.

Back inside the lab, the forty or so students go about their work, a beehive of activity. Outside the lab, the Buddha smiles contentedly, knowing, perhaps, that the land of his birth is finally awakening from its deep slumber.

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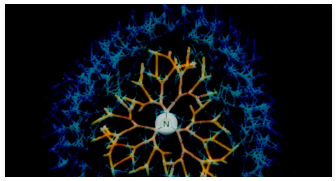

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