AMRIT

Arsenic and Metal Removal by Indian Technology

AMRIT community water purification unit installed in an affected area of West Bengal (in association with Government of West Bengal)

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AMRIT – a research-borne product of IITM

IIT Madras has laid strong emphasis on applying state-of-the-art homegrown technologies for addressing pressing challenges faced by the people of our country. Provision of clean drinking water to each and every citizen in a reliable and affordable manner is one such noble cause. Our faculty and students have worked hard for over 10 years to address this problem scientifically.

AMRIT is a reflection of our efforts starting from basic research to find new routes for affordable and robust solutions, translating them to viable technologies, and finally realizing their potential as well-tested products.

AMRIT water purification unit is a cost-effective and simple solution for providing clean drinking water to people, especially in areas where the water table is contaminated by arsenic and iron.

We thank the Department of Science and Technology, Government of India for its continuous support to undertake this research at IITM.

Prof. Bhaskar Ramamurthi
Director
Indian Institute of Technology Madras

Executive Summary

Presence of arsenic and iron in drinking water affects water quality significantly. Damage to human health due to the presence of arsenic in water is well-known.

Amongst the various methods practiced for arsenic removal, adsorption on activated alumina or iron hydroxide is most popular. However, these adsorbents suffer from several disadvantages: requirement of large adsorbent quantities leading to higher cost, larger treatment plants and consequent sludge. Maintenance of such plants is also very difficult for local communities.

With the advent of nanotechnology, it is possible to address contaminants such as arsenic at affordable cost. A product, aptly titled, AMRIT (Arsenic and Metal Removal by Indian Technology) is presented in this brochure. AMRIT uses a composition based on iron oxyhydroxide to remove arsenic from water.

A design variant of AMRIT is the only solution globally which removes iron without requiring any maintenance and generates zero sludge

Advantages of AMRIT

AFFORDABLE
arsenic removal at less than 2 paise/litre

ADAPTABLE
capacity from 100-9,000 litres/day

EASY MAINTAINABILITY
surface rubbing by brush, preferably every week

EASY INTEGRATION
with other solutions

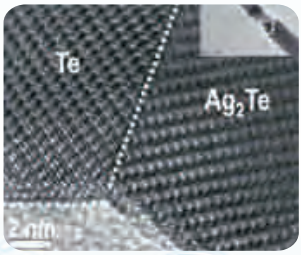
A brief about nanotechnology

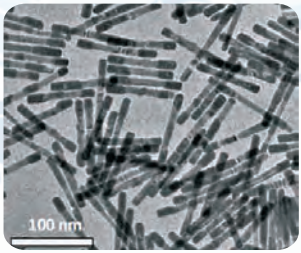
Nanotechnology is concerned with the modification of materials at a scale, 100,000 times smaller than the human hair. Materials modified by nanotechnology usually appear similar to commonly seen objects. However, such materials possess new and unusual properties which can be used for human welfare, such as water purification.

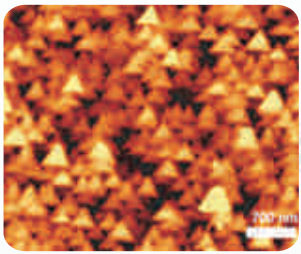
Nanotechnology is omnipresent in Nature; we are learning skills to modify materials at nanoscale.

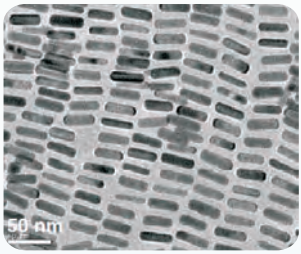
(i) plants transform sunlight into chemical energy through a nanoscale assembly of chlorophyll.

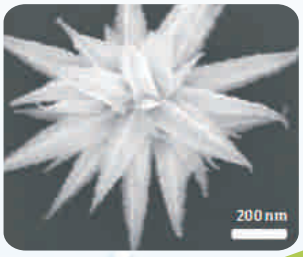
(ii) human brain transfers information to various body parts through a nanoscale assembly of neurons.







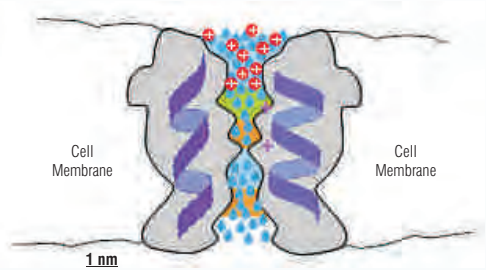




Diverse nanoscale materials made in the laboratory

An example of nanoscale material made by Nature

Channel for movement of ion-containing water



Human kidney purifies water through nanoscale protein channels called aquaporin.

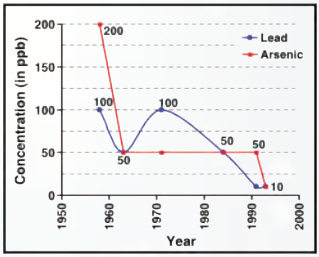
Adapted from:
http://en.wikipedia.org/wiki/Aquaporin

A brief about nanotechnology for clean water

WHO limit for allowed arsenic concentration has decreased significantly as understanding of its health effects improved

200 ppb (year 1960)
10 ppb (year 2000)

*Several installations in USA follow arsenic concentration below 2 ppb.



Changes in maximum allowable concentration for lead and arsenic in drinking water, based on WHO advisory

Old technologies are increasingly becoming outdated

1. For fluoride and arsenic removal: Nanomaterials perform 25 times better over activated alumina.

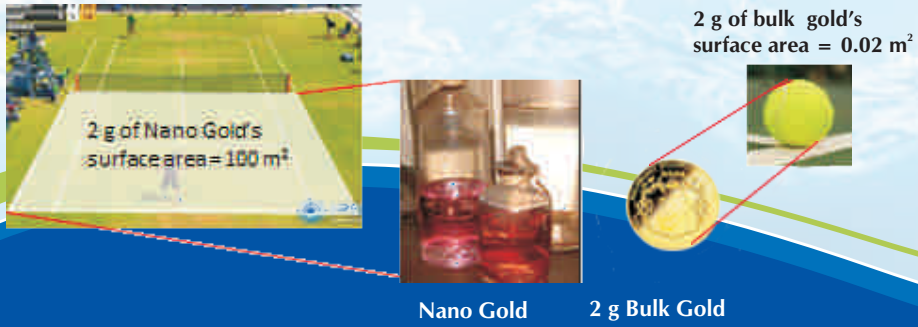
2. For arsenic removal: Nanomaterials performs 10 times better over commercial ferric hydroxide.

Nanomaterials offer green and affordable alternatives to old technologies

- Very high adsorption capacity.
- Reduced capital cost (> 25-50% cheaper).
- Affordable running cost (any contaminant at less than 2 paisa per liter, in field).
- Reduced sludge after adsorbent is saturated (10-25 times lower quantity).
- Green method and net water positive product: Uses just 10 units of power for production of 1 kg material and purifies over 40-100 L water for every 1 L water used for production.

Difference of nanomaterial over bulk material – An example (surface area of material in nano vs. bulk)

Nanoscale materials offer several unique properties vis-a-vis its bulk form, e.g., surface area of material in nano form is several times higher than the bulk form.



About our work on clean water

The world's first nanochemistry based drinking water purification product came out from our laboratory

A plant to make supported nanomaterials for water purification; with capacity of 4.5 tons per month, 2007.
Technology protected in India, USA & Europe. Product is marketed by Eureka Forbes Ltd.

RSC | Advancing the Chemical Sciences
Chemistry World

Pesticide filter debuts in India

20 April 2007

Killugudi Jayaraman/Bangalore, India

A domestic water filter that uses metal nanoparticles to remove dissolved pesticide residues is about to enter the Indian market. Its developers at the Indian Institute of Technology (IIT) in Chennai (formerly Madras) believe it is the first product of its kind in the world to be commercialised.

Mumbai-based Eureka Forbes Limited, a company that sells water purification systems, is collaborating with IIT and has tested the device in the field for over six months. Jayachandra Reddy, a technical consultant to the company, expects the first 1000 units to be sold door-to-door from late May.

'Our pesticide filter is an offshoot of basic research on the chemistry of nanoparticles,' Thalappil Pradeep who led the team at IIT Chennai told *Chemistry World*. He and his student Sreekumaran Nair discovered in 2003 that halocarbons such as carbon tetrachloride (CCl_4) completely break down into metal halides and amorphous carbon upon reaction with gold and silver nanoparticles[1].

Pradeep said this prompted them to extend their study to include organochlorine and organophosphorous pesticides, whose presence in water is posing a health risk in rural India. In research funded by the Department of Science and Technology in New Delhi, his team found[2,3] that gold and silver nanoparticles loaded on alumina were indeed able to completely remove endosulfan, malathion and chlorpyrifos - three pesticides that have been found at elevated levels in Indian water supplies.


The pesticide-zapping filter © Thalappil Pradeep

Use and recycle

The mechanism of removal is 'adsorption followed by catalytic destruction', Pradeep explained. 'The chemistry occurs in a wide concentration range of environmental significance.' He added that tests proved silver particles from the filter are not released into the water. The IIT study found that gold particles perform better in the case of endosulfan. However, for cost reasons, the commercialised filters use only silver particles, which range in size from 60 to 80 nanometres at a concentration (on their alumina support) of 33 parts per million.

'Based on consumption patterns of a typical Indian household, the filter is designed to have enough nanomaterials to provide 6000 litres of pesticide-free water for one year,' Pradeep said. 'After that, the company will recycle the filters to recover the silver.'

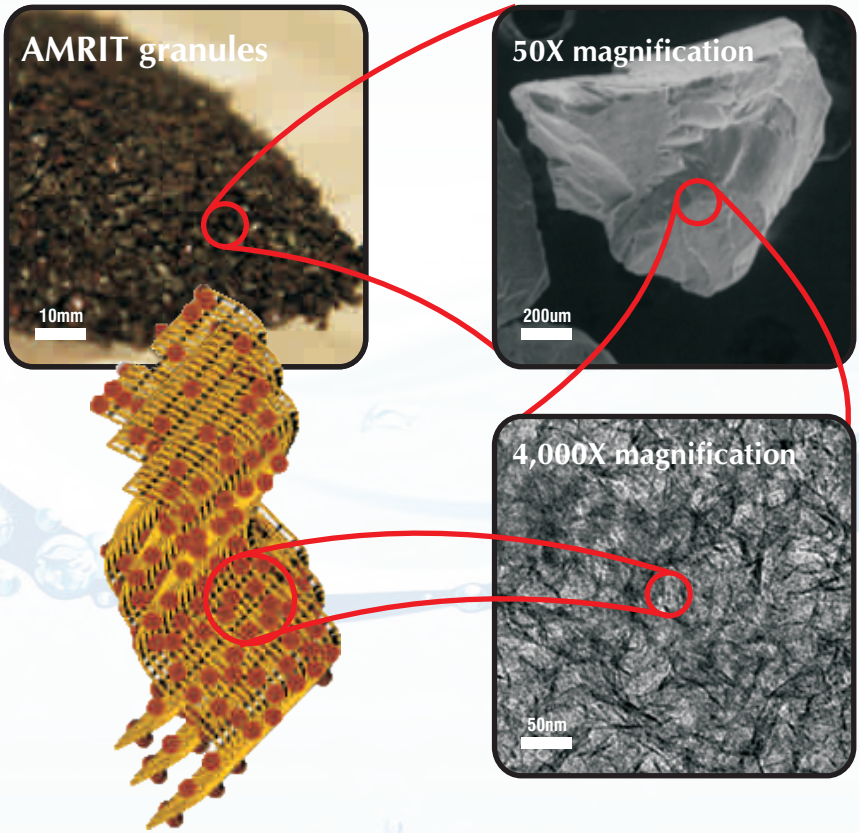
Use of nanoparticles for environmental remediation is an emerging area of research worldwide. Nanoscale iron powders had been shown to degrade other pesticides, including DDT and lindane[4], 'and there are reports about the use of nanomaterials for removing arsenic, heavy metals and fluorides,' said Pradeep. 'But ours is the first product to hit the market,' he said.

World first

Murali Sastry, chief scientist of TATA Chemicals Innovation Centre in Pune - India's first nanotechnology research centre in the private sector - agrees. 'What Pradeep has done is definitely novel,' Sastry told *Chemistry World*. 'I am not aware of any similar product in the market.'

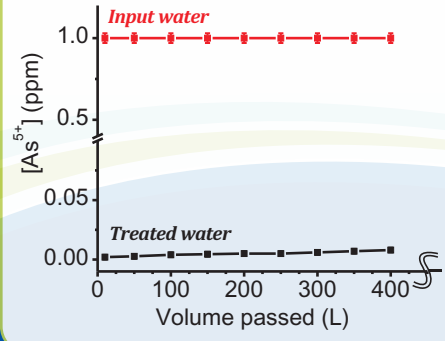
Eureka already markets a water purifier that combines a sedimentation chamber with activated carbon filters and UV irradiation, and costs around Rs8500 (£100). Reddy estimated that adding the [illegible]-litre-long nanosilver cartridge (see image) to remove pesticides will increase the price by [illegible] silver recycling (in an environmentally-friendly manner, stressed Pradeep) should help

A brief about material and its performance

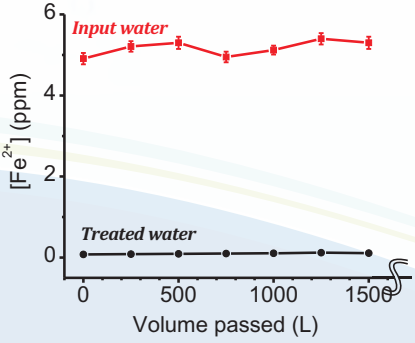


Seeing the material in detail – to a normal eye, material appears similar to bulk material. When one zooms to finer detail, nanoscale features are visible.

Performance of the arsenic cartridge



Performance of the iron cartridge



About our work on arsenic removal

The presence of arsenic in various ionic and molecular forms in the aquatic environment is a major concern of the world due to their severe toxicity towards human beings. A number of technologies have been tried in the field and each of them has associated challenges (cost, complexity, efficiency and sludge). Adsorption has earned attention as one of the most widely used methods for decontamination of arsenic.

We looked at adsorption from the context of developing a material surface for the highest arsenic uptake, so that associated challenges are reduced significantly. This was studied from the context of improving adsorption affinity, surface modification and covalent binding of the contaminant. Without any exception, we develop procedures which make manufacturing processes similar to that practiced by Nature (by the use of abundant ingredients, water based synthesis and processes at room temperature).


AMRIT cartridge – a green solution for clean water

AMRIT composition is composed of nanoscale iron oxyhydroxide, prepared with a particle size less than 3 nm. Choice of iron based compounds is based on the fact that they are commonly found in water. Engineering such compounds based on nanotechnology enables them to pick large quantity of arsenic. Particle size below a critical limit increases the number of surface atoms substantially leading to higher surface energy. An important aspect is to ensure that such nanoparticles are strongly anchored onto solid surfaces so as to make sure that they don't leach into water, thereby preventing secondary contamination. Simultaneously, the adsorbed arsenic doesn't get released from the composition, thereby ensuring that spent material can be disposed locally.

What it means in terms of performance and affordability? AMRIT composition can handle up to an input load of 5 ppm of arsenic (equally well for both forms of arsenic, As^{3+} and As^{5+}) and bring the output below the detection limit (<1 ppb). Composition is at least 5-6 times more efficient than any other adsorbent available currently. Since the contact time required for removal is fairly low (less than 1 min), the composition is used in the size of 0.2 mm, thereby offering negligible pressure drop. This helps from several aspects: treatment cost reduces, filtration unit becomes smaller, filtration unit can be operated with minimum pressure, easily maintainable by local community and reduced sludge quantity.

Implementation

A glimpse of products for arsenic and fluoride removal, implemented in West Bengal and Andhra Pradesh, respectively.

About our other technologies for field implementation

Building on the strong belief that effective solutions existing for other common problems of water purification should be integrated for a comprehensive solution, we have developed advanced materials for effective removal of a number of contaminants found in drinking water. Other well-known solutions may also be integrated (such as porous terafil cartridges developed by CSIR for turbidity and iron removal).

Another important aspect of our research is that we have established a national facility for research on clean drinking water. This facility is supported by the Department of Science and Technology, Government of India. This facility also supports monitoring of contaminants in drinking water periodically. We ensure that solutions are monitored, well-maintained and notified in advance for changes.

We propose to implement such solutions across the affected areas of the country.

Composition for arsenic removal

Composition for heavy metal removal

Composition for fluoride removal

Composition for microorganism removal

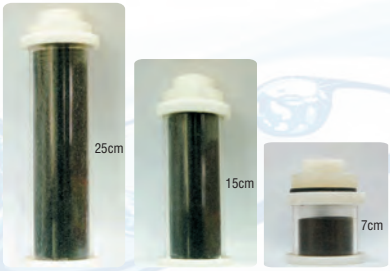
AMRIT community water purification unit installed in an affected area of West Bengal (in association with Government of West Bengal)

Product specification

Product name	AMRIT - Arsenic and Metal Removal by Indian Technology
Product description	An affordable domestic and community scale water purification unit for iron and arsenic removal
Technical details	Iron and turbidity removal by physical filtration. Arsenic removal by adsorption
Product elements	One input water storage tank, one output water storage tank kept on a stand along with purification cartridges
Material of construction	Food grade polypropylene for plastic components. Food grade ingredient for adsorbents
Mode of operation	Manual pouring of water, self water flow in output tank
Working pressure	Gravity-fed water pressure, no electricity required
Feed water quality	Turbidity: up to 200 NTU Iron: up to 15 ppm Arsenic: up to 5 ppm Allowed TDS: up to 2000 ppm
Output water quality	Turbidity: 1 NTU (WHO norm, BIS norm: 5 NTU) Iron : <0.3 ppm (WHO and BIS norms) Arsenic: <0.010 ppm (WHO norm, BIS norm: <0.05 ppm)
Rate of water filtration	50-100 mL/min (Domestic model), 100-500 L/h (Community model). Details for online model can also be provided on request
Replacement frequency	Yearly for arsenic removal media, 3-5 years for turbidity/iron removal media
Expected life of unit	15 years
Adaptability	Very easy integration with existing water purification technologies and products

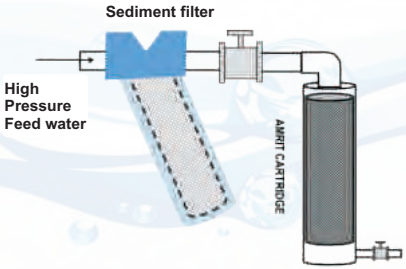
Products

AMRIT CARTRIDGE



AMRIT cartridge can also be easily integrated with existing water purification units at any scale

ONLINE UNIT



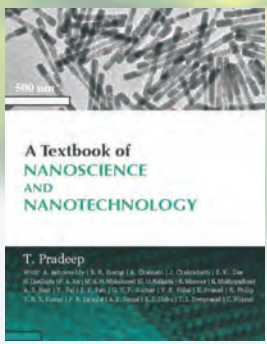
A solution for sludge-free and maintenance free iron and arsenic removal from water

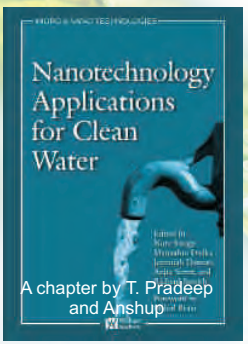
AMRIT water purification unit can be easily integrated with other technologies for the remediation of microbial and chemical contaminants.

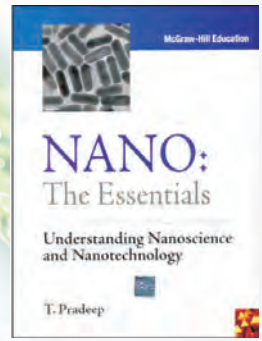
DOMESTIC UNIT

COMMUNITY UNIT

Suggested further reading





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Special Feature

Noble metal nanoparticles for water purification: A critical review

T. Pradeep *, Anshup

Our water research group

Our arsenic research team

T. PRADEEP

Pradeep earned his Ph.D from Indian Institute of Science in 1991 and had post doctoral training at Lawrence Berkeley laboratory, University of California, Berkeley and Purdue University, West Lafayette. He held visiting positions at many leading universities and institutes in Asia and Europe. His research interests are in molecular and nanoscale materials and he develops instrumentation for those studies. He has authored 270 scientific papers in journals and is an inventor in 45 patents or patent applications. He is involved in the development of affordable technologies for drinking water purification. One of his technologies has been commercialized.

He is a recipient of several awards including the prestigious Shanti Swaroop Bhatnagar Prize, BM Birla Science Prize and National Award for Nanoscience and Nanotechnology. He is a Fellow of the Indian Academy of Sciences.

ANSHUP

Anshup holds a B. Tech. degree in chemical engineering from IIT Madras. He has over 7.5 years of professional experience. His research interest is in experimental investigations of surfaces from the context of water purification. He derives motivation from Nature to look at the solutions for water purification. He has contributed to several aspects of water purification in past 5.5 years, including research ideas, material synthesis, performance trials, product design, production and commercialization. He is a co-inventor in 18 patent applications on the subject of water purification.

M.UDHAYA SANKAR

Udhaya Sankar holds M.Sc. and M.Tech. degrees in chemistry and nanotechnology, respectively from Madras University, Chennai. He has over 3.5 years of professional experience. While having contributed to several research ideas, he is the brain behind our product development activities. He has filed 16 patent applications on the subject of water purification.

AMRITA CHAUDHARY

Amrita Chaudhary holds a B.Tech. degree in chemical engineering from IIT Madras, Chennai. She has over 4.5 years of professional experience. She focuses on the development of materials, their performance evaluation and industrial production. She has filed 16 patent applications on the subject of water purification.

A.ANIL KUMAR

Anil Kumar holds a M.Sc. degree in chemistry from Pondicherry University. He has over 1.5 years of professional experience. He focuses on the synthesis of novel materials for water purification. He has filed 2 patent applications.

From basic research to products


Basic research


Inductively coupled plasma-mass spectrometer

Advanced characterization


Pilot production


State-of-the-art affordable water purifier

We create technologies for our people

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