



Since 1959

Affordable clean water using advanced materials

T. Pradeep

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<https://pradeepresearch.org>

Co-founder

InnoNano Research Pvt. Ltd.

InnoDI Water Technologies Pvt. Ltd.

VayuJAL Technologies Pvt. Ltd.

Aqueasy Innovations Pvt. Ltd.

Hydromaterials Pvt. Ltd.

EyeNetAqua Solutions Pvt. Ltd.

DeepSpectrum Innovations Pvt. Ltd.



Associate Editor

ACS
Sustainable
Chemistry & Engineering

Professor-in-charge



International Centre for Clean Water

Dr. Indu Ramakrishnan and
colleagues at Filtrex Technologies,
Marmon Water, Inc.



Residential Filtration Innovation Summit 2023, Bangalore



“Pale blue dot” Voyager 1 Feb. 14, 1990

Water is the most important inheritance of our planet

Water is at the centre of action



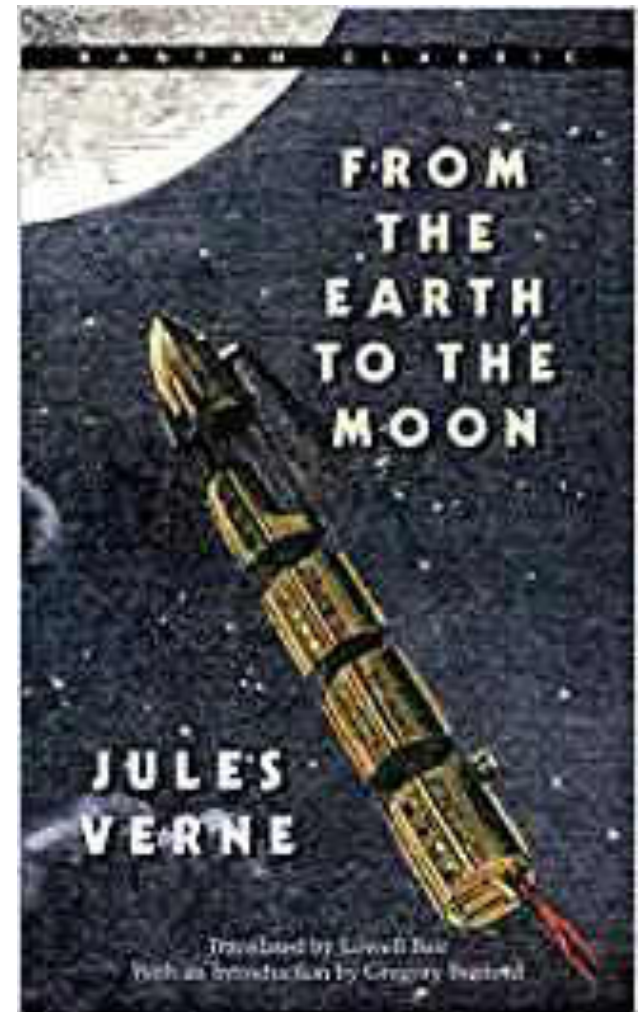
There is water in everything we do.



From S. Vishwanath

© Robert Szucs/Grasshopper Geography

Our dreams become reality with materials



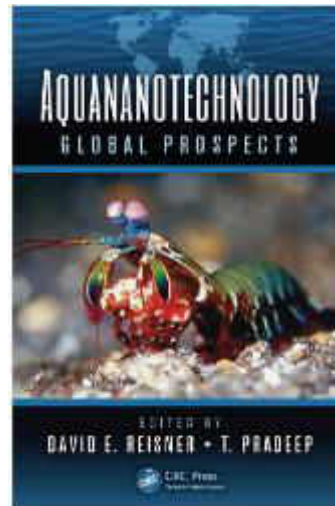
Water purification, history

Important milestones in the history of water purification (1800–2007) from the perspective of noble metal nanoparticles in water treatment (compiled from multiple sources on the World Wide Web).

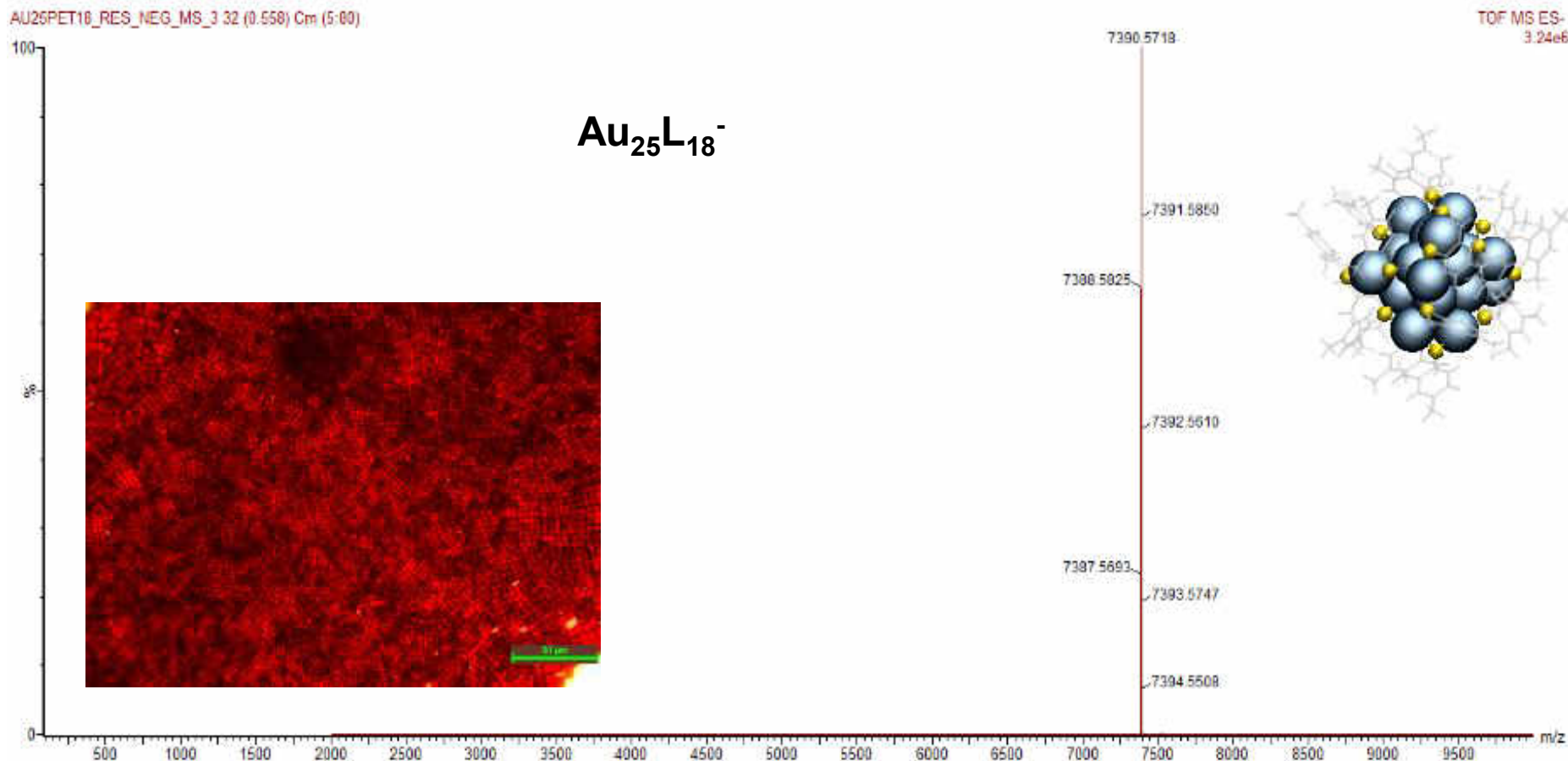
Year	Milestone
1804	Setup of world's first city-wide municipal water treatment plant (Scotland, sand-filter technology)
1810	Discovery of chlorine as a disinfectant (H. Davy)
1852	Formulation of Metropolis Water Act (England)
1879	Formulation of Germ Theory (L. Pasteur)
1902	Use of chlorine as a disinfectant in drinking water supply (calcium hypochlorite, Belgium)
1906	Use of ozone as a disinfectant (France)
1908	Use of chlorine as a disinfectant in municipal supply, New Jersey
1914	Federal regulation of drinking water quality (USPHS)
1916	Use of UV treatment in municipal supplies
1935	Discovery of synthetic ion exchange resin (B. A. Adams, E. L. Holmes)
1948	Nobel Prize to Paul Hermann Muller (insecticidal properties of DDT)
1959	Discovery of synthetic reverse osmosis membrane (S. Yuster, S. Loeb, S. Sourirajan)
1962	<i>Silent Spring</i> published, first report on harmful effects of DDT (R. Carson)
1965	World's first commercial RO plant launched
1974	Reports on carcinogenic by-products of disinfection with chlorine Formulation of Safe Drinking Water Act (USEPA)
1975	Development of carbon block for drinking water purification
1994	Report on use of zerovalent iron for degradation of halogenated organics (R. W. Gillham, S. F. O'Hannesin)
1997	Report on use of zerovalent iron nanoparticles for degradation of halogenated organics (C-B. Wang, W.-X. Zhang)
1998	Drinking Water Directive applied in EU
2000	Adoption of Millennium Declaration during the UN Millennium Summit (UN Millennium Development Goals)
2003	Report on use of noble metal nanoparticles for the degradation of pesticides (A.S. Nair, R. T. Tom, T. Pradeep)
2004	Stockholm Convention, banning the use of persistent organic pollutants
2007	Launch of noble metal nanoparticle-based domestic water purifier (T. Pradeep, A. S. Nair, Eureka Forbes Limited)

Affordable clean water is a problem of advanced materials

New adsorbents
New sensors
New catalysts
Novel phenomena
New devices



Nanomaterials are now atomically precise



T. Pradeep et. al. *Acc. Chem. Res.* 2018; 2019.

Clean water for everyone



ACS Sustainable Chemistry & Engineering Editorial,
December 2016

Water positive materials

Biopolymer-reinforced synthetic granular nanocomposites for affordable point-of-use water purification

Mohan Udhaya Sankar¹, Sahaja Aigal¹, Shihabudheen M. Malyekkal¹, Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamallesh Chaudhari, and Thalappil Pradeep²

Unit of Nanoscience and Thematic Unit of Excellence

Edited by Eric Hoek, University of California, Los Angeles

Creation of affordable materials for constant access to clean drinking water is one of the most pressing ways to provide drinking water for all. Combining the capabilities of nanocomposites to scavenge toxic species such as heavy metals and other contaminants along with the above capabilities, we have created an affordable, all-inclusive drinking water purifier without electricity. The critical problem in the synthesis of stable materials that can reliably function in the presence of complex species in drinking water that deposit and cause scale on surfaces. Here we show that such constant-flow materials can be synthesized in a simple and effective fashion without the use of electrical power. The nanocomposite sand-like properties, such as higher shear strength, form. These materials have been used to develop a water purifier to deliver clean drinking water locally. The ability to prepare nanostructured composites at ambient temperature has wide relevance for water purification.



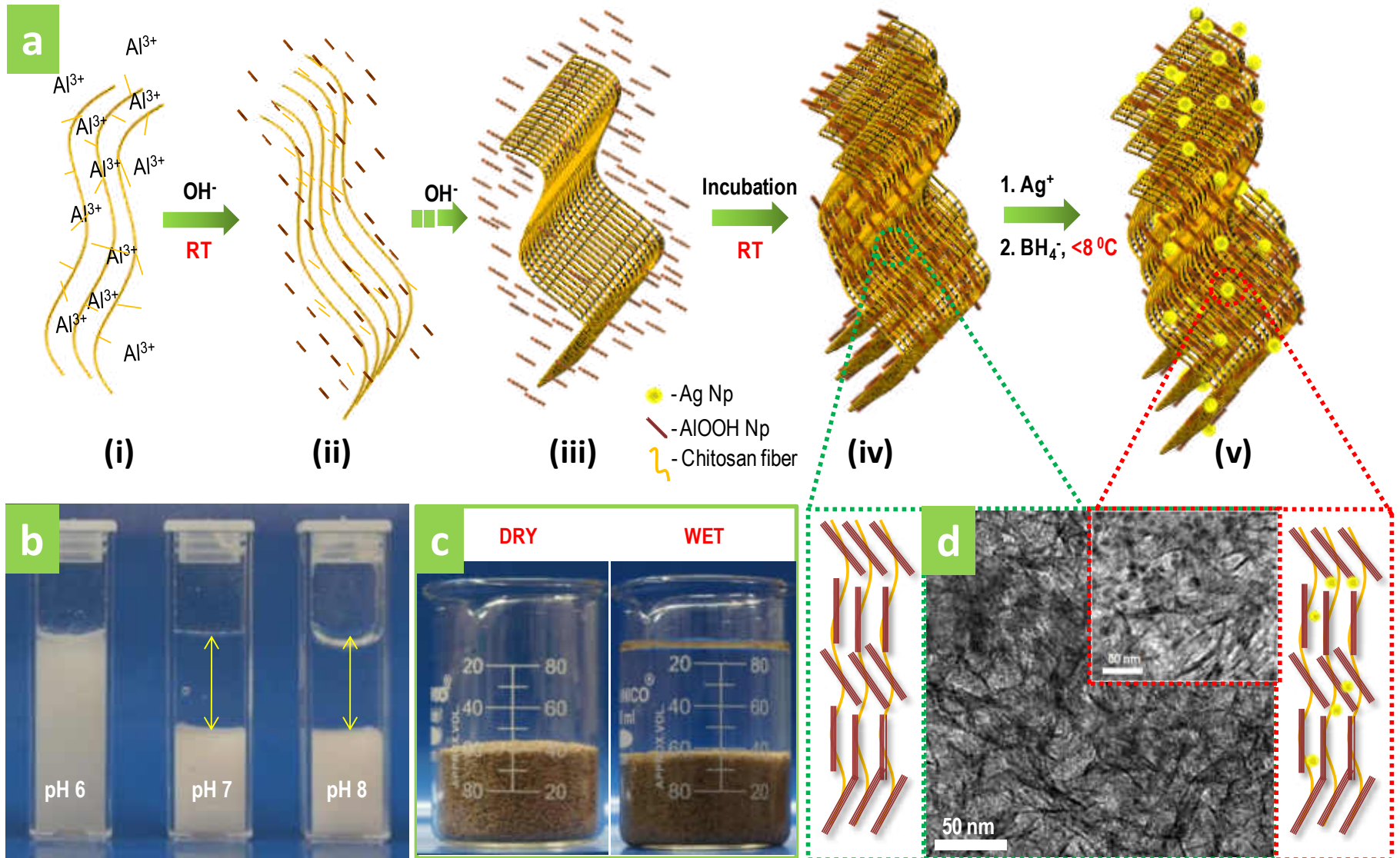
Chennai 600 036, India

Received for review November 21, 2012

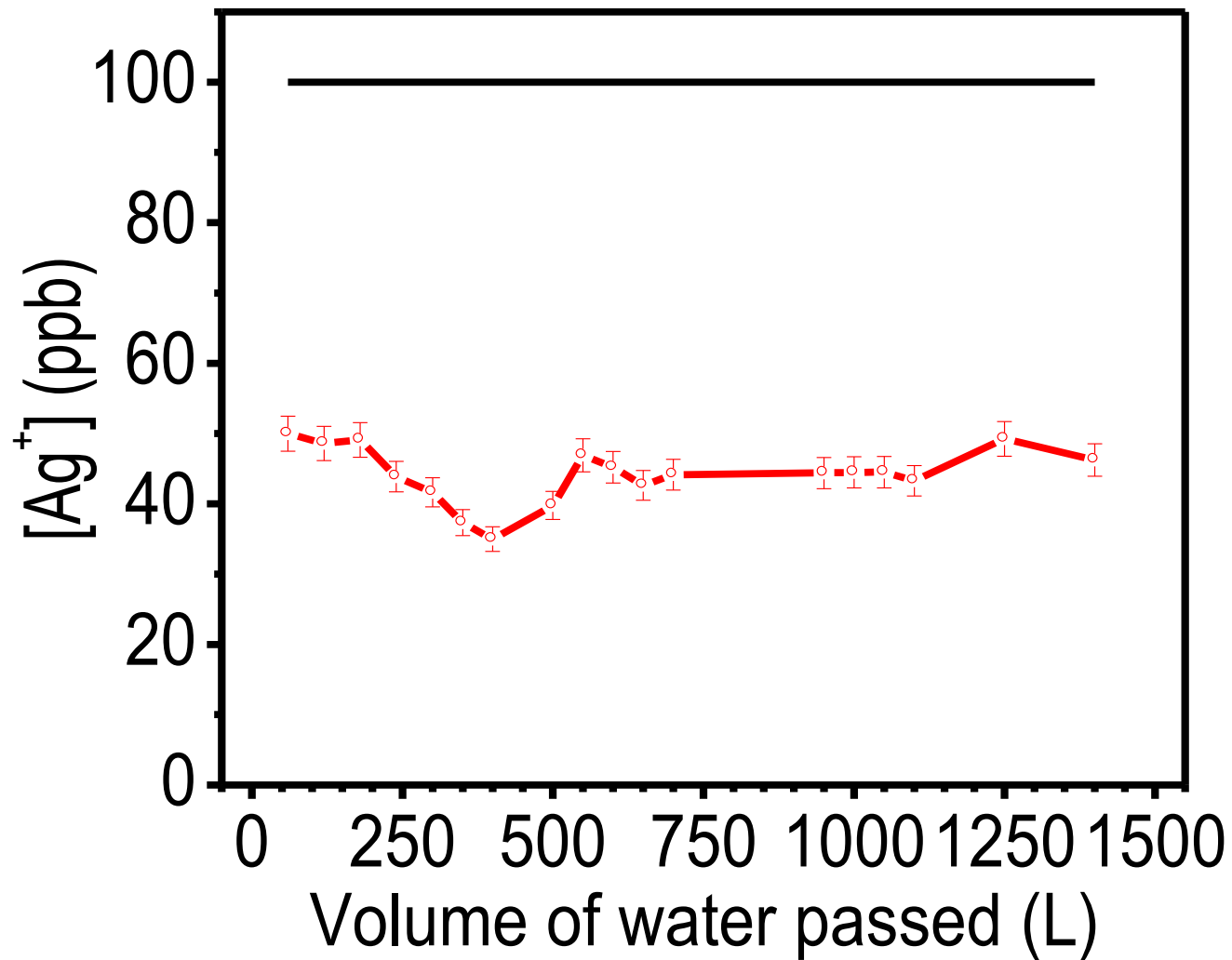
...le; and (c) continued retention of the material is difficult. A unique family of nanocrystalline granular composite materials prepared through an aqueous route. The retention is attributed to abundant -OH groups, which help in the crystallization and also ensure strong covalent bonding to the matrix. X-ray photoelectron spectroscopy confirms that the composition is rich in silver. Using hyperspectral imaging, the silver in the water was confirmed. The silver nanoparticles activate the silver nanoparticle antimicrobial activity in drinking water. We demonstrate an affordable water purifier based on such composites undergoing field trials in India, as well as eradication of the waterborne

hybrid | green | appropriate technology | frugal science | developing world

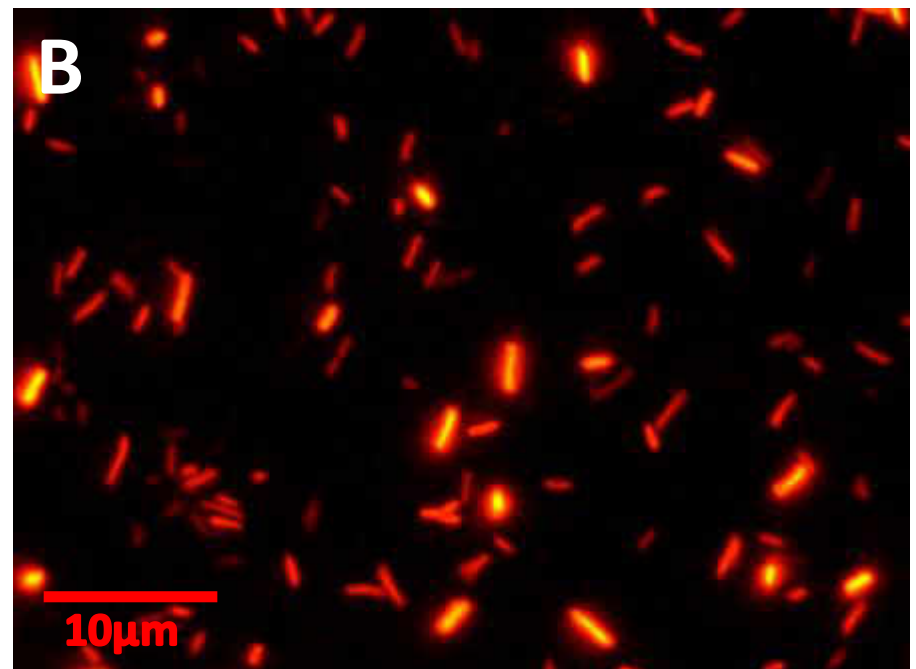
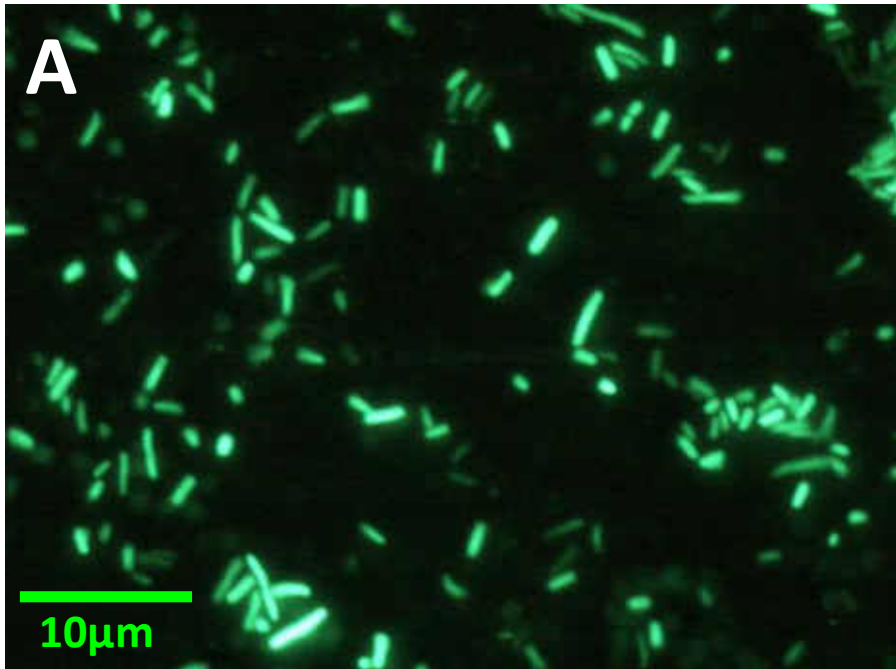
How to make?



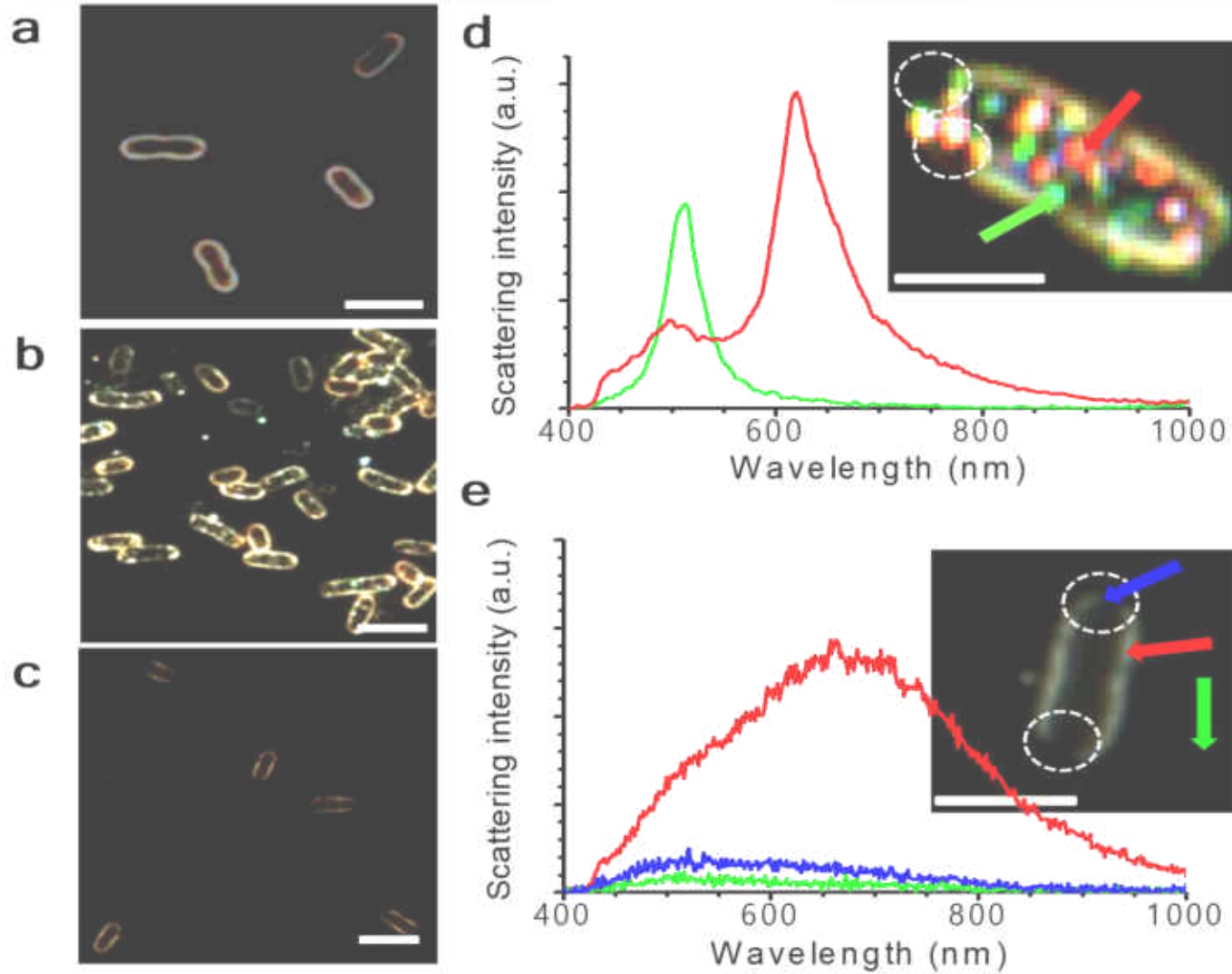
What is special?



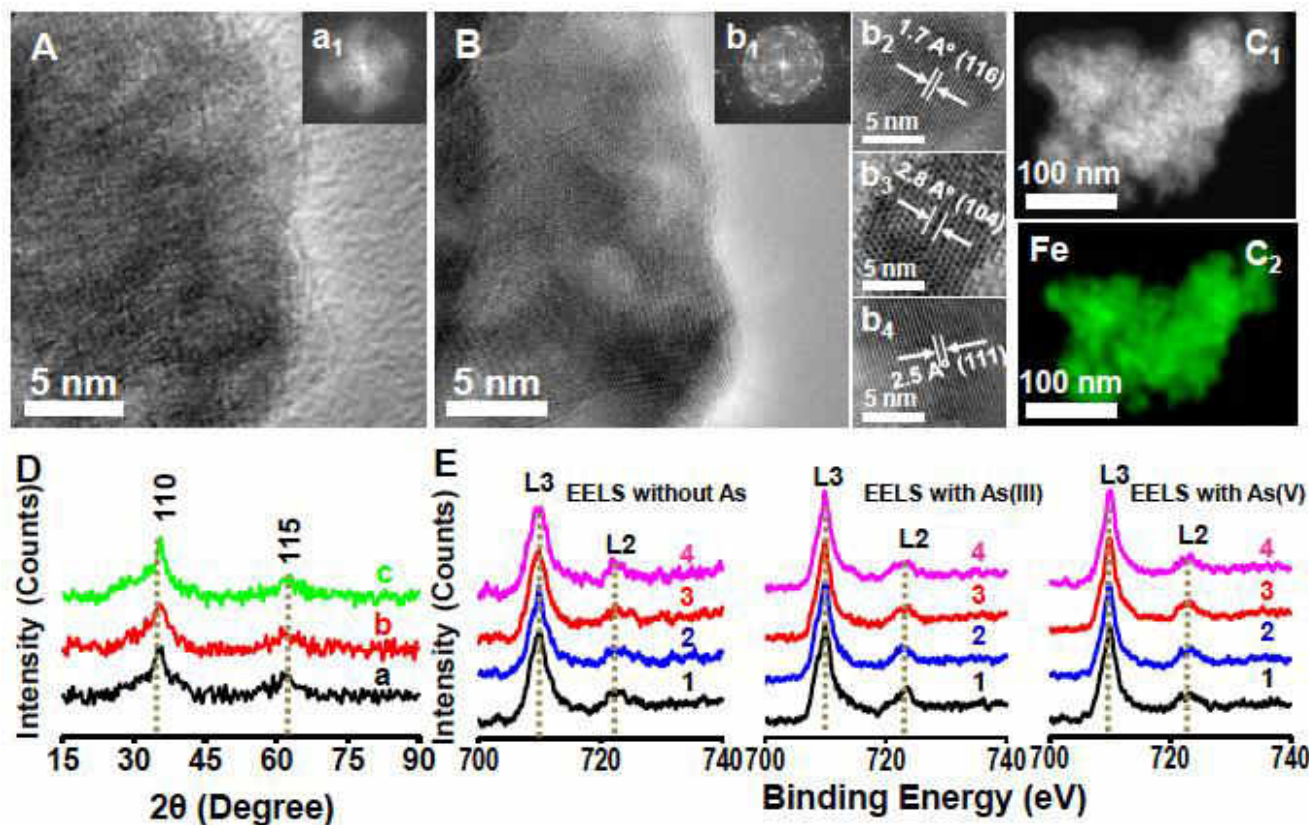
Live/dead staining experiments



No nanotoxicity



Variety of materials



www.advmat.de

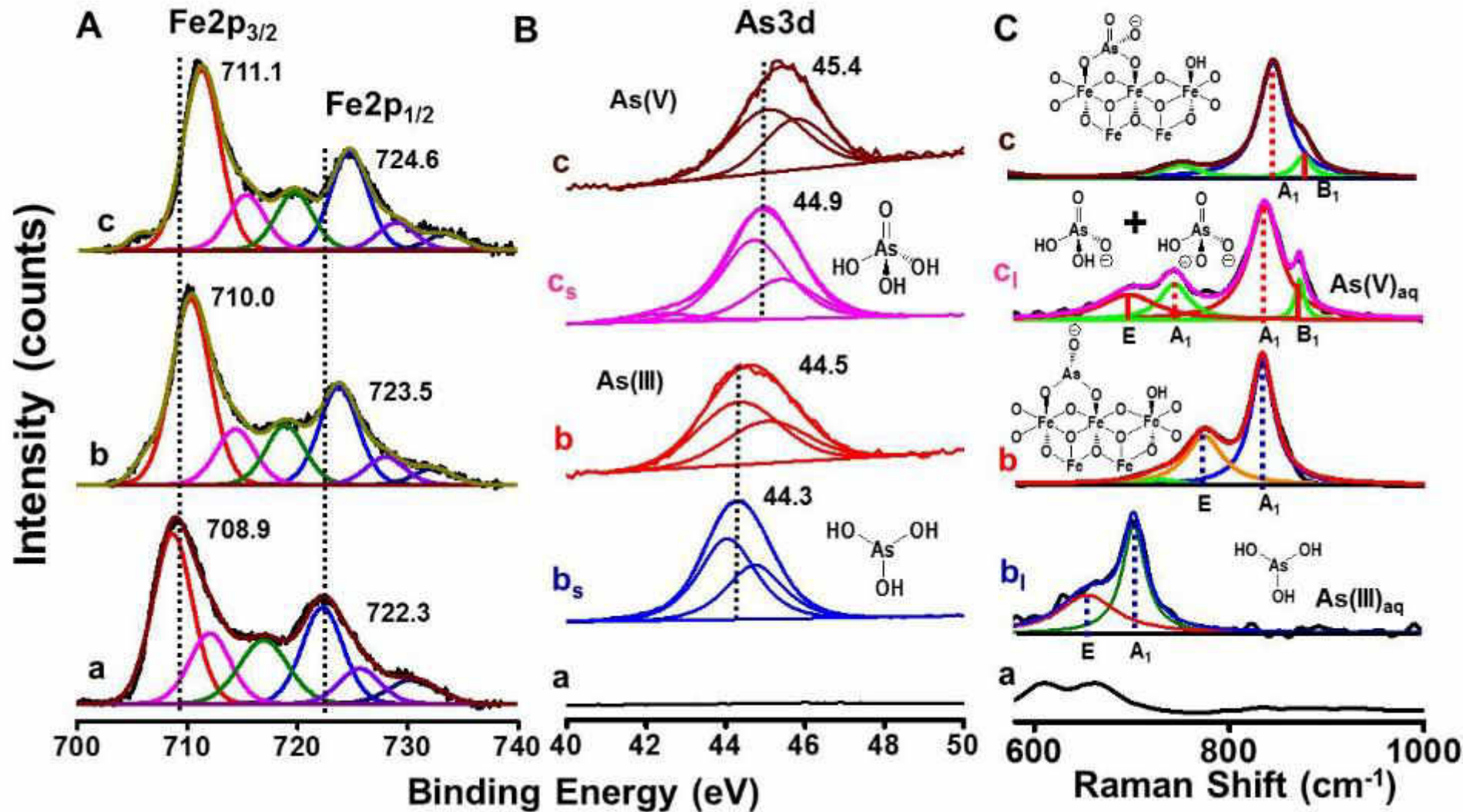
Author P ADVANCED MATERIALS

Confined Metastable 2-Line Ferrihydrite for Affordable Point-of-Use Arsenic Free Drinking Water

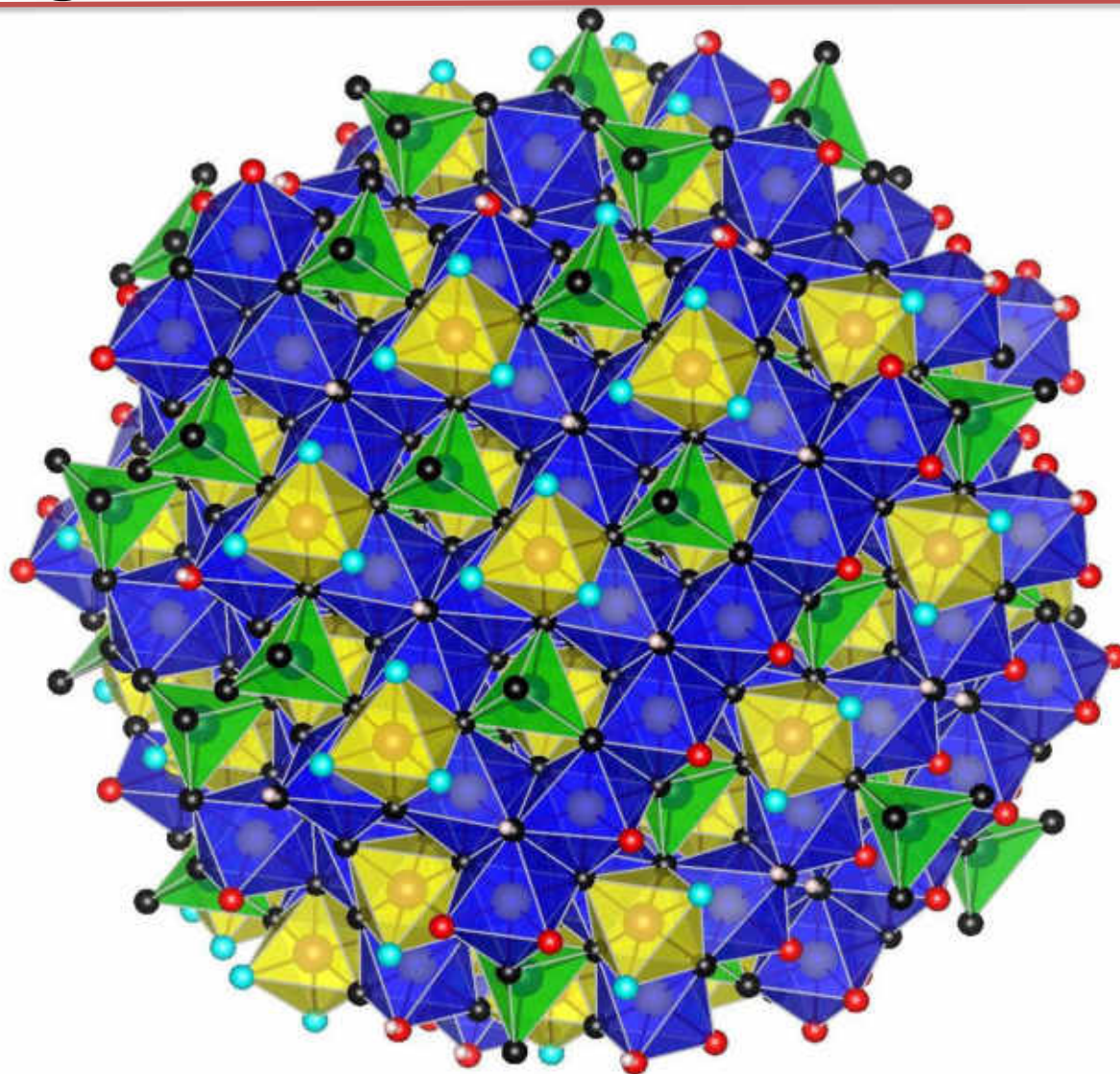
By Avula Anil Kumar, Anirban Som, Paolo Longo, Chennu Sudhakar, Radha Gobinda Bhui, Soujit Sen Gupta, Anshup, Mohan Udhaya Sankar, Amrita Chaudhary, Ramesh Kumar, and T. Pradeep*

Communication

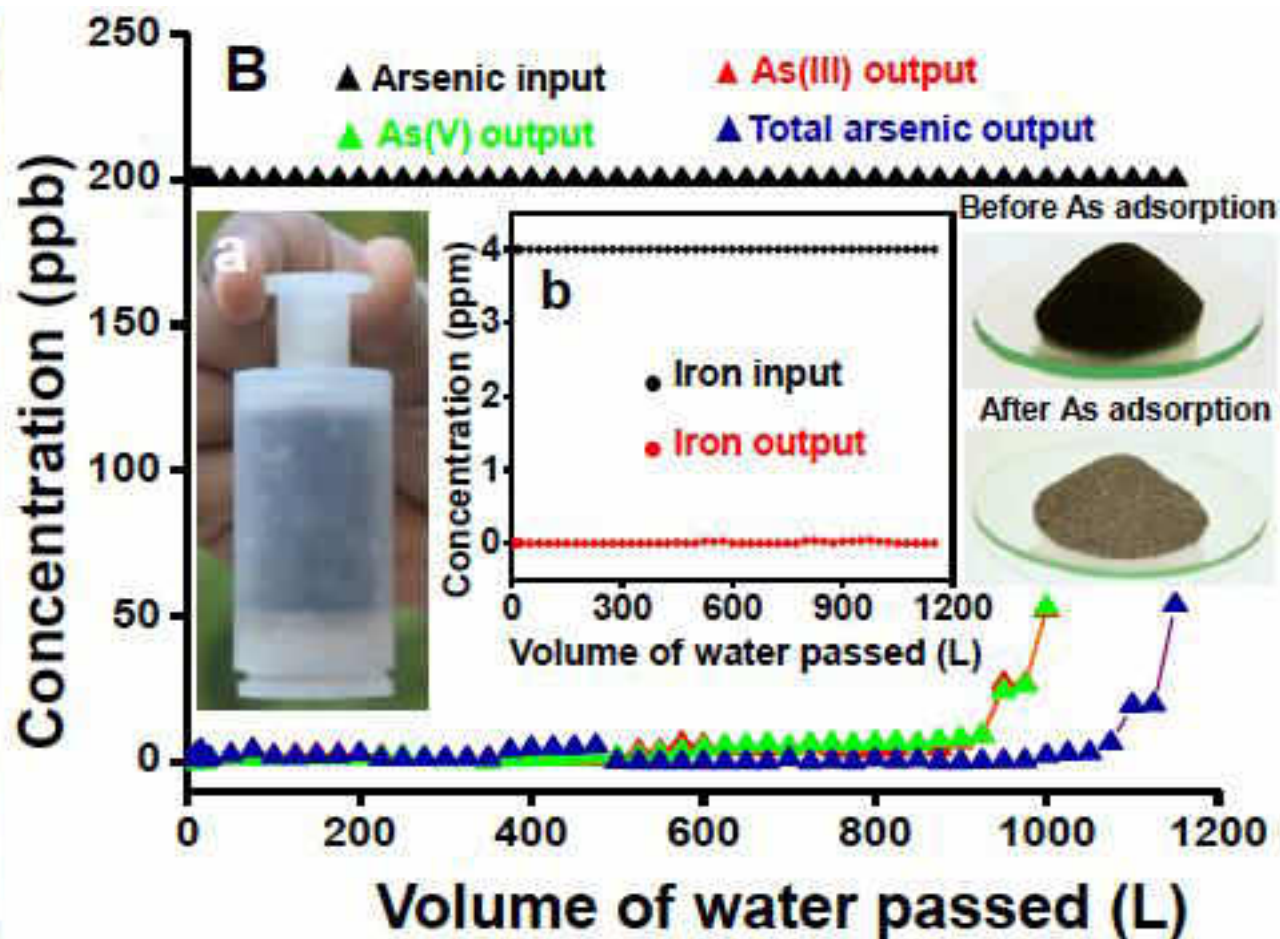
Mechanism



Modeling surfaces



Lab studies

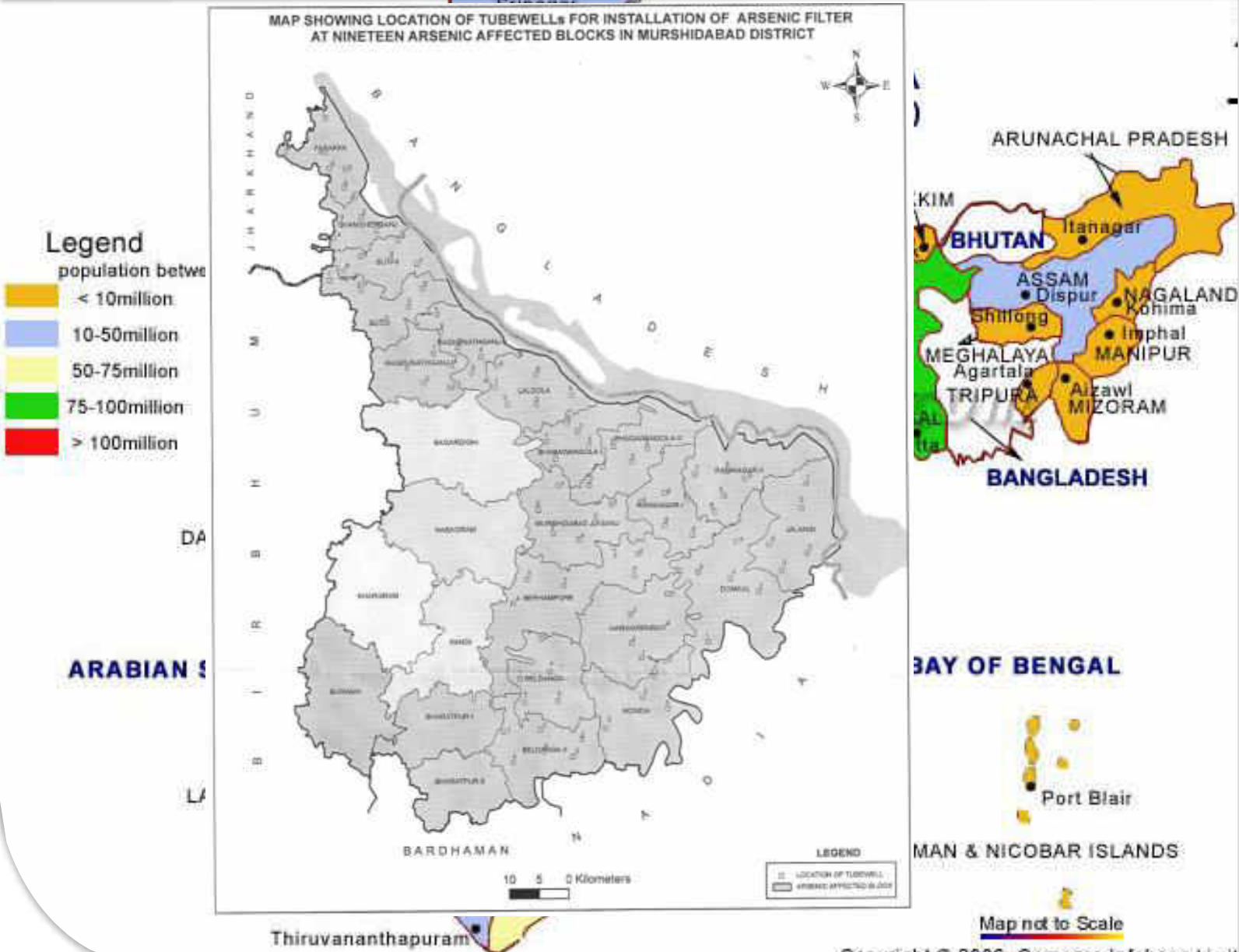


Initial pilot studies



Larger pilot studies

Population Map Of India-2001



Changing the dynamics in the field

A photograph of an existing water treatment plant. It features two large, dark blue cylindrical tanks mounted on a metal frame. The plant is situated outdoors on a dirt and grass area, with trees in the background. A sign is visible in the background.

Existing plant in 40 cents

- Existing unit for iron and arsenic removal – 20 m³/h
- Uses activated alumina and iron oxide (old generation of adsorbents)

A photograph of a new water treatment plant. It features three tall, blue cylindrical tanks connected by a complex network of white pipes and valves. The plant is enclosed in a metal fence.

New plant in 3 cents

- Existing unit for iron and arsenic removal – 18 m³/h
- Uses iron oxyhydroxide (new generation of adsorbents)
- Input arsenic concentration: 168 ppb
- Output arsenic concentration: 2 ppb

Completed 3 years maintenance (stipulated: 2 years)
for 330 bamboo unit project in Nadia, WB



Minimum uptime: 91%, Maximum: 98%
Only 4/330 have reported arsenic above 10 ppb
Benefiting over 100,000 children and villagers

Glimpse of Installed units (330 nos)

Implementation - From 25 KLD to 1 MLD



Large water supply schemes
Capacity: above 1 MLD

5 schemes in use across India



Retrofitted Water Purification Plant
Capacity: 0.1-1 MLD

Over 180 units in use across India

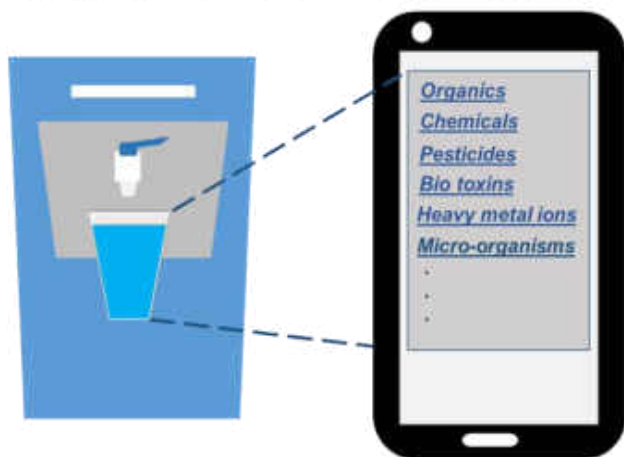
Cleanwater at 2.1 paise per litre!

Calculation for the Tariff to be collected for treated water (Revision if Required)

	Design population	1,071	Plant capacity/70 LPCD
Sr.No	Item/Description	Cost / Quantity	Remarks
1	Cost of Replacement of Iron removal media	56400	After minimum two years if Iron concentration is more than 5 ppm. But iron concentration is more than 5 ppm at only two to three places. Therefore media may work for 3 years also.
2	Cost of Replacement of Arsenic removal media	978660	After minimum two years if Arsenic concentration is more than 100 ppb. But arsenic concentration is more than 100 ppb at only two to three places. Therefore media may work for 3 years also.
3	Cost of replacement of Activated Carbon	28560	
4	Total cost of Replacement of media	1063620	After minimum two years.
5	Total cost of Replacement of media for one year	531810	
6	Plant capacity	75000	ltr per day
7	Design population	1,071	Plant capacity/70 LPCD
8	Cost per liter of water	2.1 Paise per ltr	0.025 cents
		1.36	Rs. per head per day
9	Cost of replacement of media	40.80	=Media replacement cost per year/365/Design population
			per head per month for 70 LPCD water

Smart water purifiers and big data

Smart Water Purifiers linked to IoT



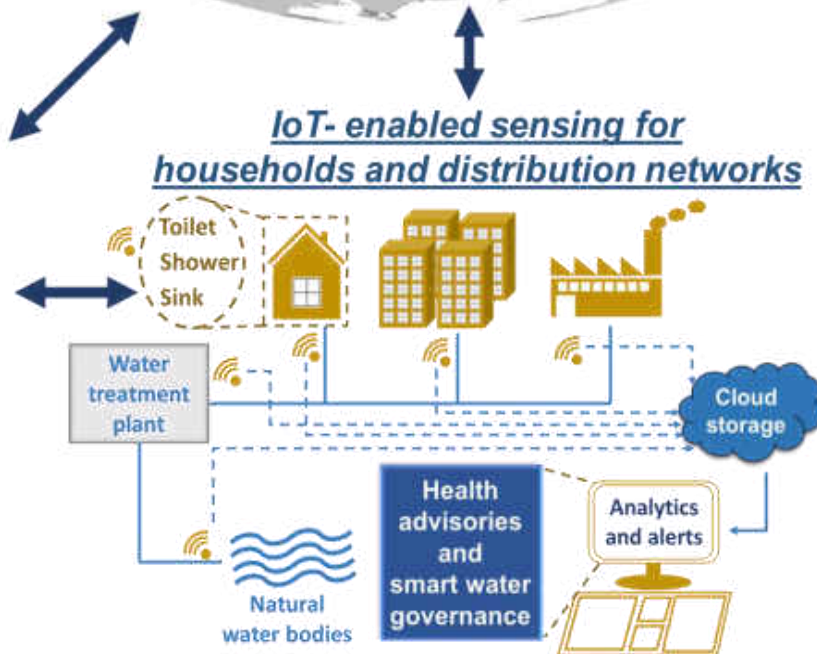
Cost-effective sensor accessory for point-of-use applications



Global Map of Water Health



IoT-enabled sensing for households and distribution networks



Waste management

Adsorbents conform to toxicity characteristic leaching procedure

Elemental waste goes back to local environment

Safe disposal of arsenic (or any other) laden waste

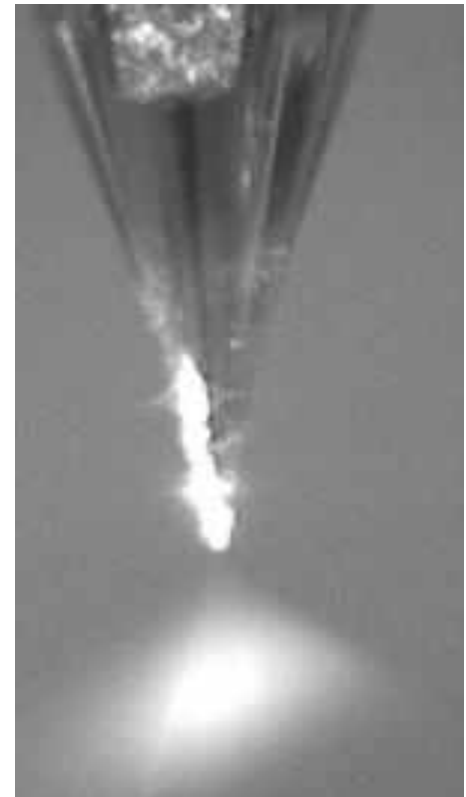
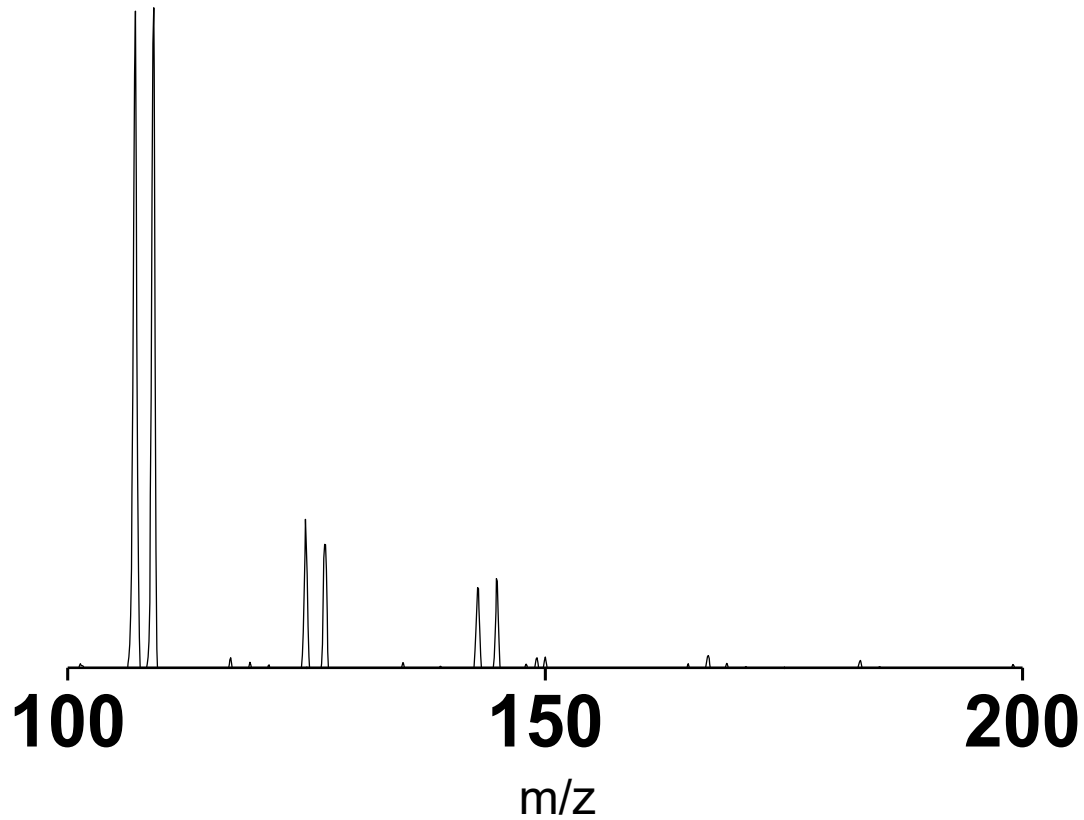
Additional protection could be considered, if necessary

Exploring viable uses

Across the country



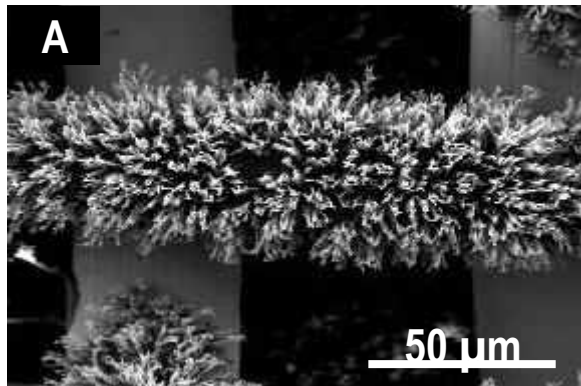
Atmospheric water harvesting



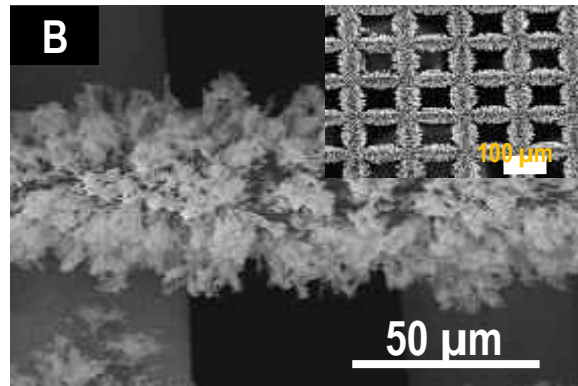
New harvesters

A black and white photograph showing a dense, textured, fibrous material, possibly a new type of harvester or a natural material. The material is composed of many fine, overlapping fibers that create a complex, almost crystalline structure. It is set against a dark, blurred background, which makes the light-colored fibers stand out. The overall appearance is that of a highly detailed, organic or synthetic material.

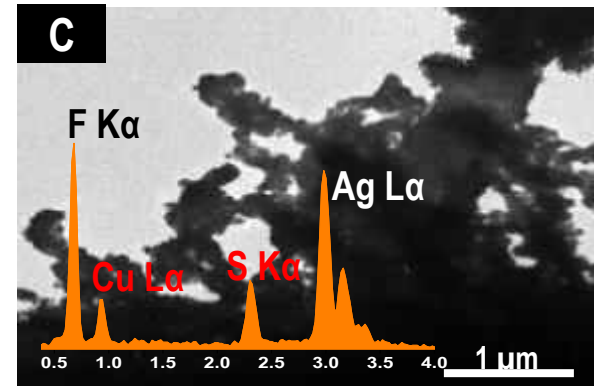
Depanjan Sarkar, et. al. *Advanced Materials*, 28 (11), 2016.



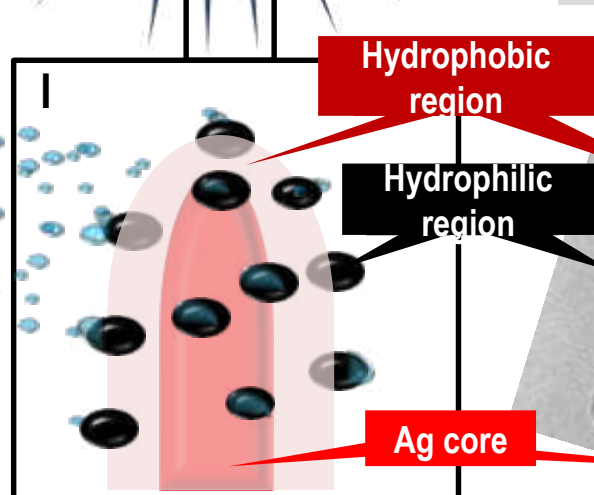
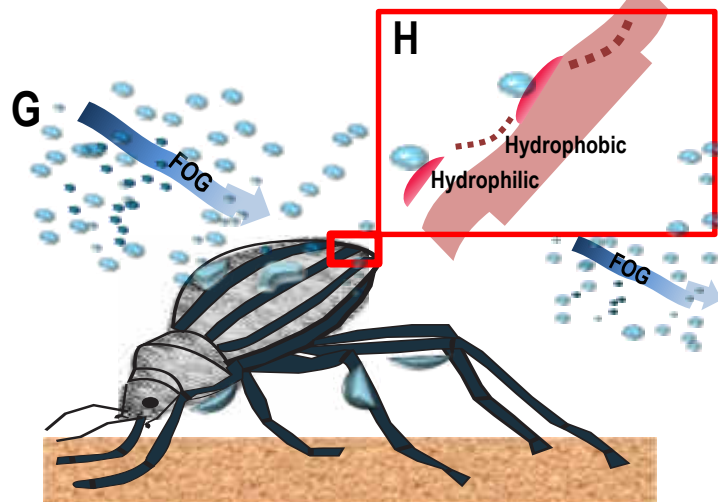
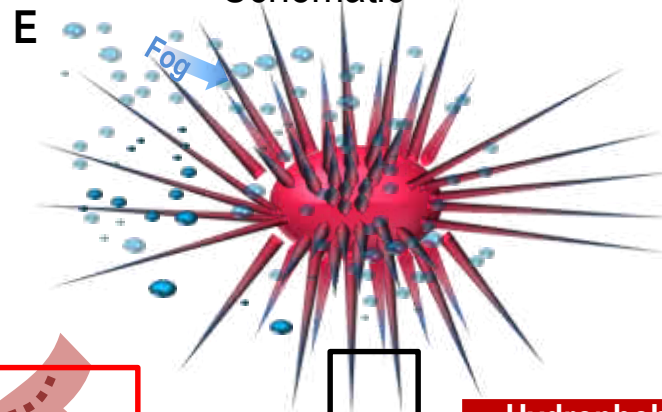
Nature



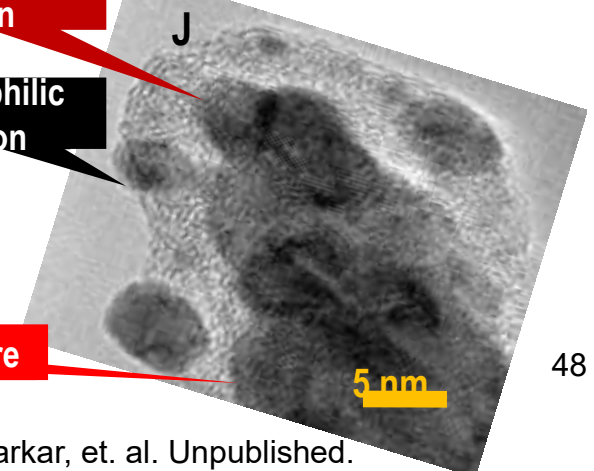
Schematic

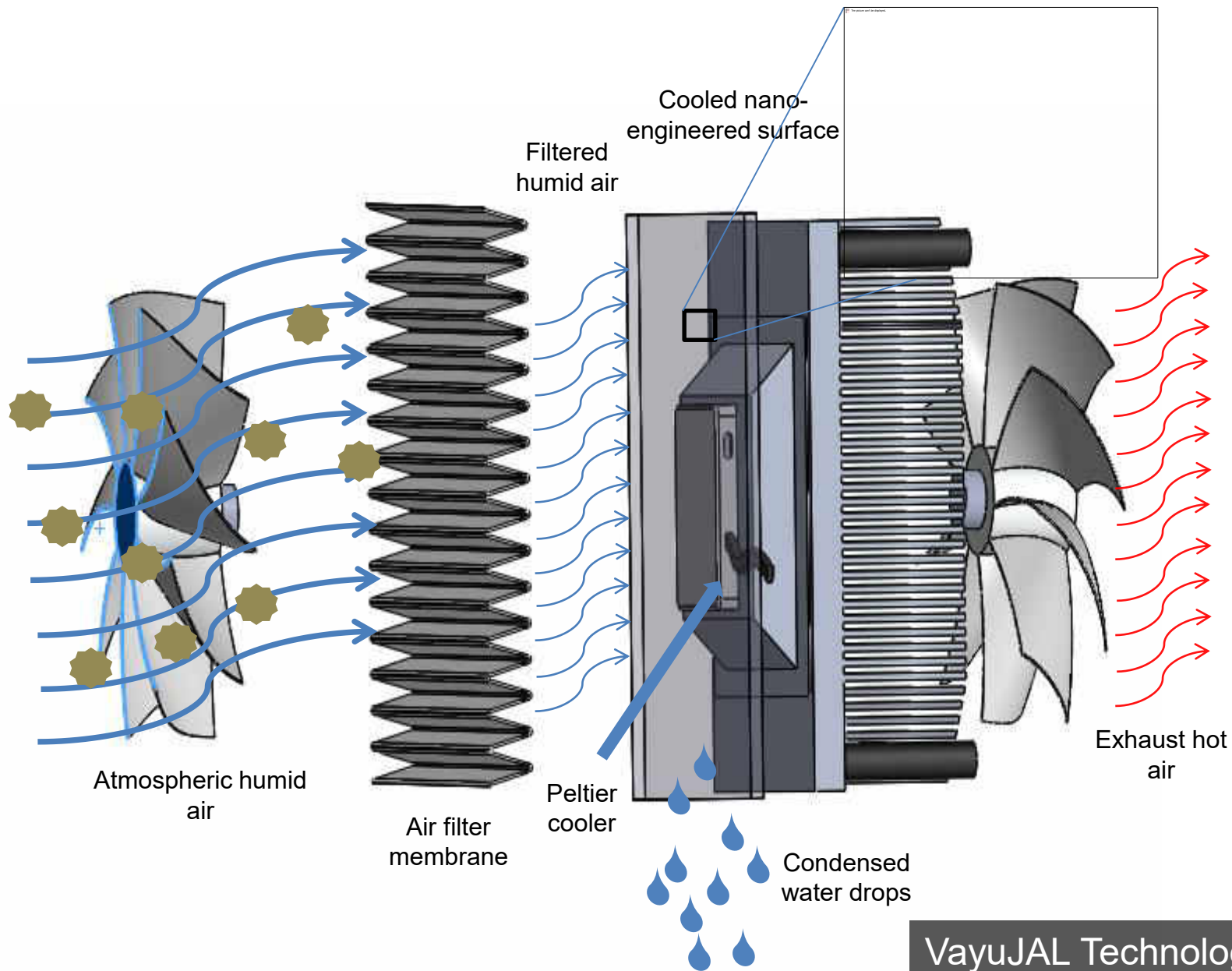


Our material



Combination of cactus and Namib desert beetle effect





VayuJAL Technologies Pvt. Ltd.

Ramesh Kumar Soni and Ankit Nagar

Products in the field



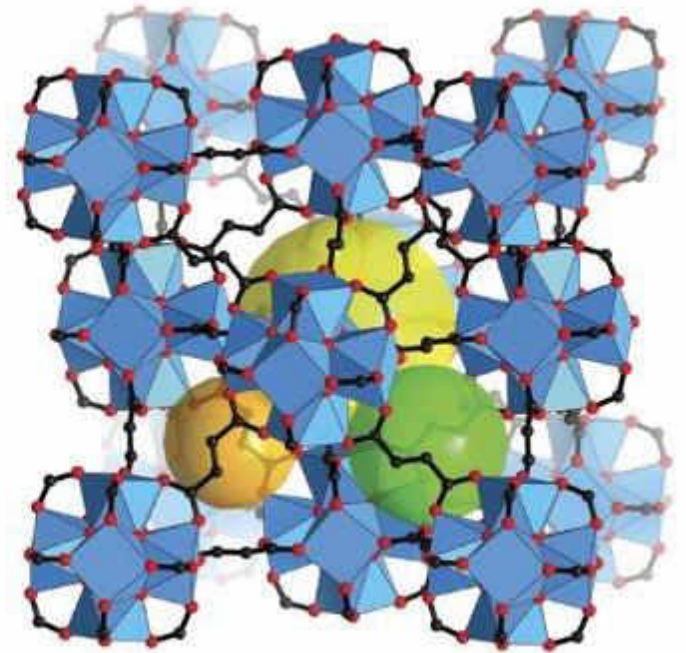
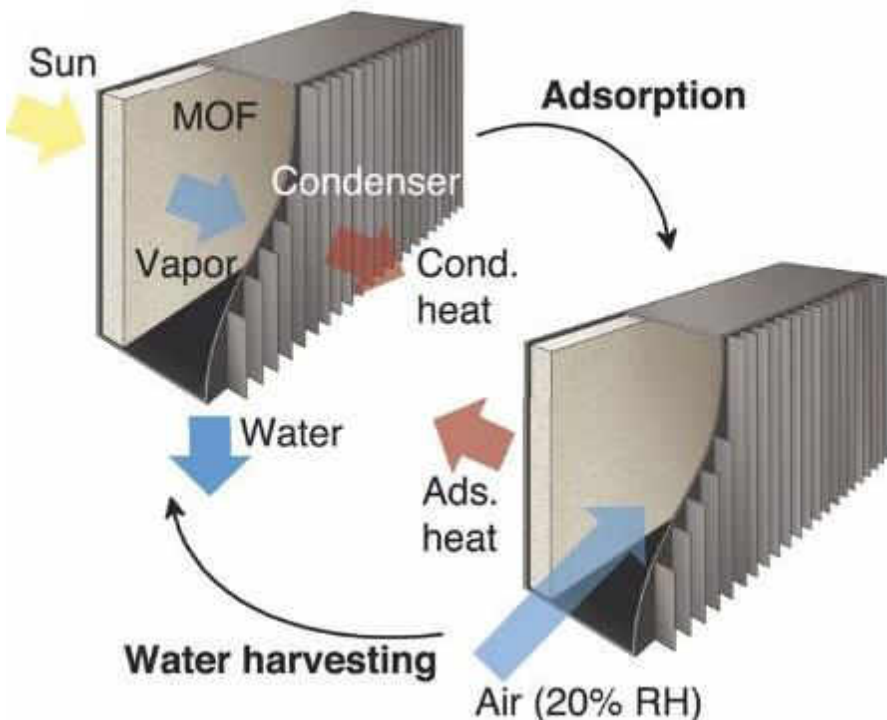
(LPD: Litres per day)



July 2023

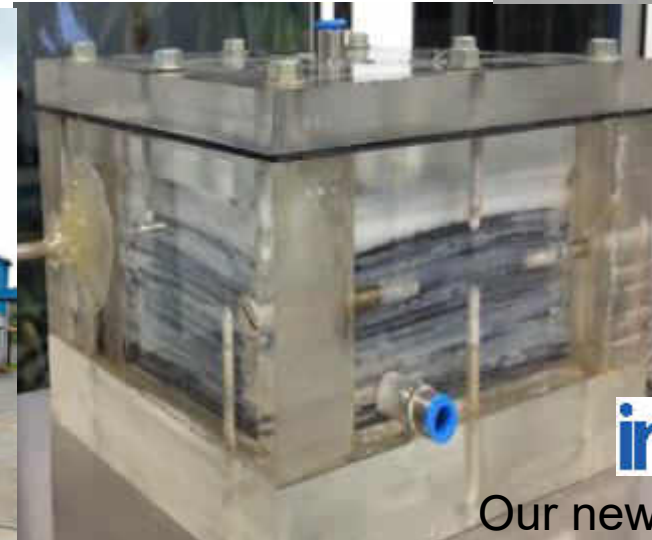
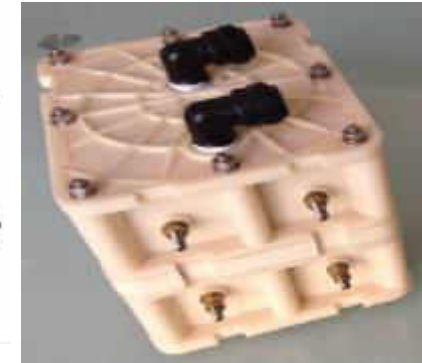
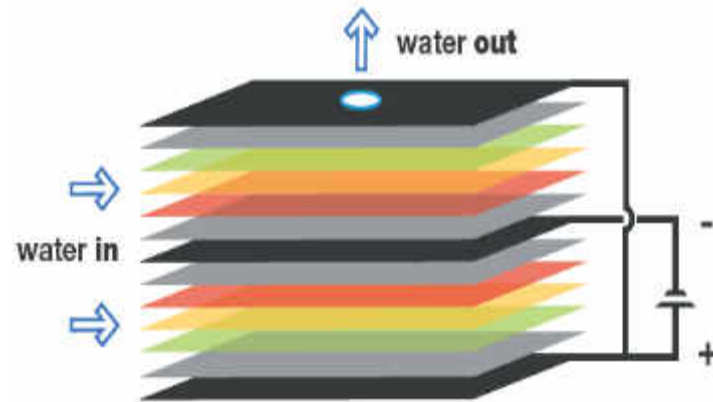
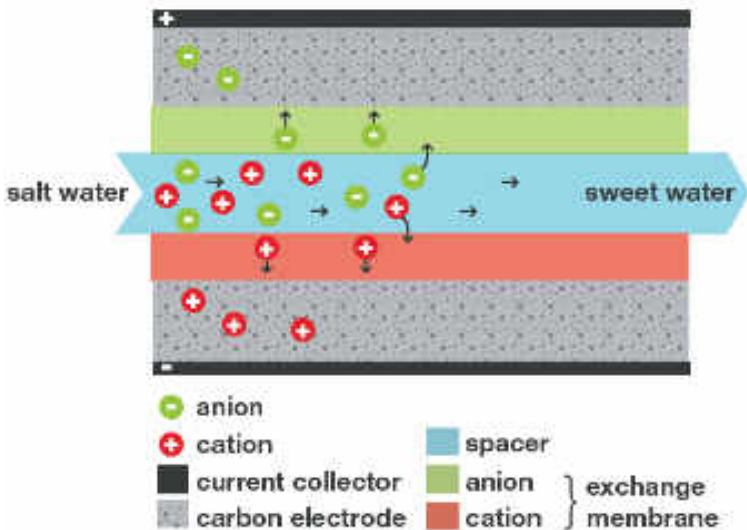
Sustainable atmospheric water harvesting

Solar- heat-enabled atmospheric water capture at a relative humidity as low as 20%



Porous metal-organic framework (MOF-801, $\text{Zr}_6\text{O}_4(\text{OH})_4(\text{fumarate})_6$)

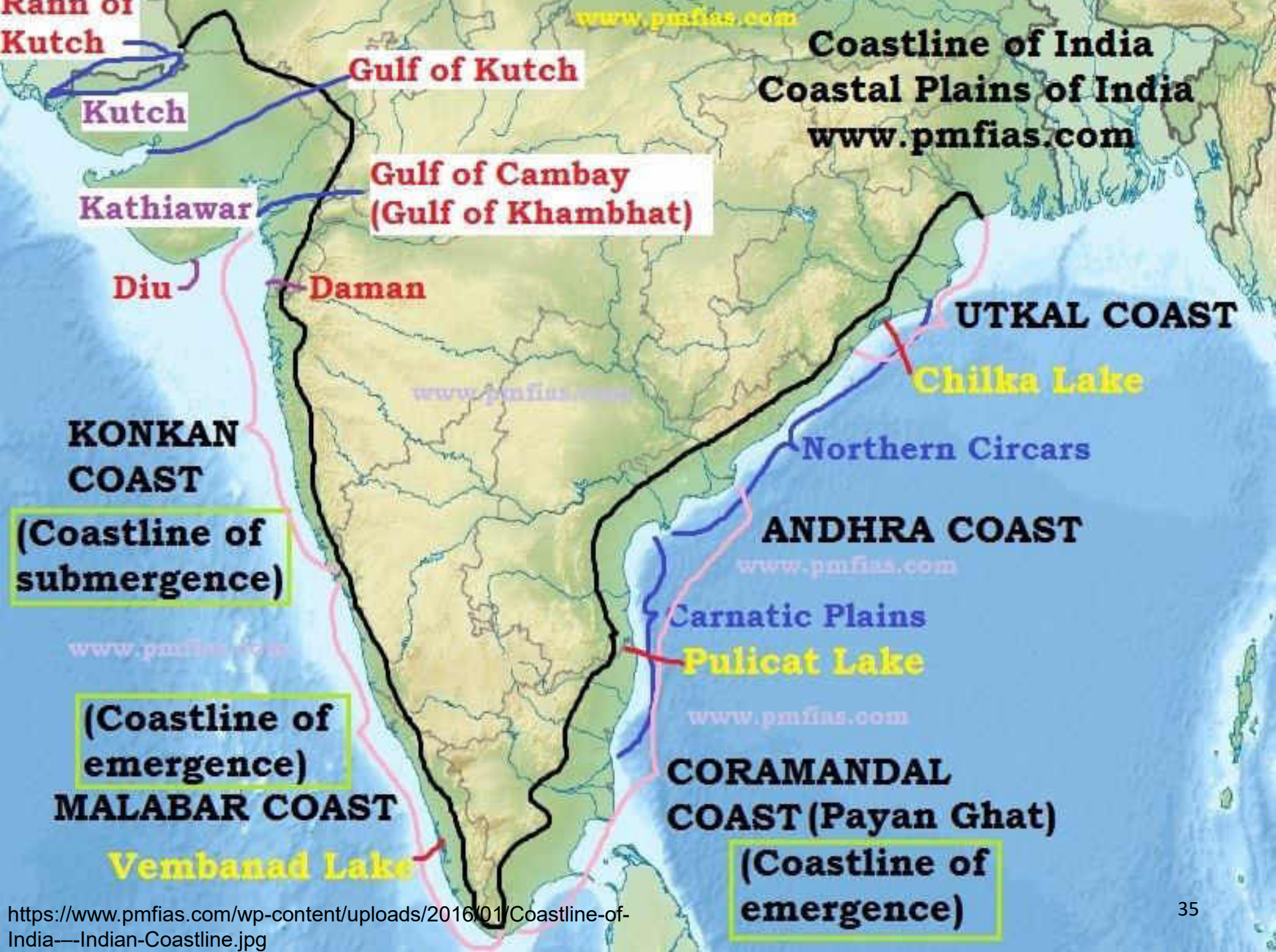
Capacitive Desalination (CDI)



imODI

Our new company

Soujit Sengupta, Rabiul Islam and others



Kutch

Gulf of Kutch

Gulf of Cambay (Gulf of Khambhat)

Kathiawar

Diu

Daman

KONKAN COAST
(Coastline of submergence)

MALABAR COAST
(Coastline of emergence)

Vembanad Lake

UTKAL COAST

Chilka Lake

Northern Circars

ANDHRA COAST

Carnatic Plains

Pulicat Lake

CORAMANDAL COAST (Payan Ghat)
(Coastline of emergence)

Coastline of India

Coastal Plains of India

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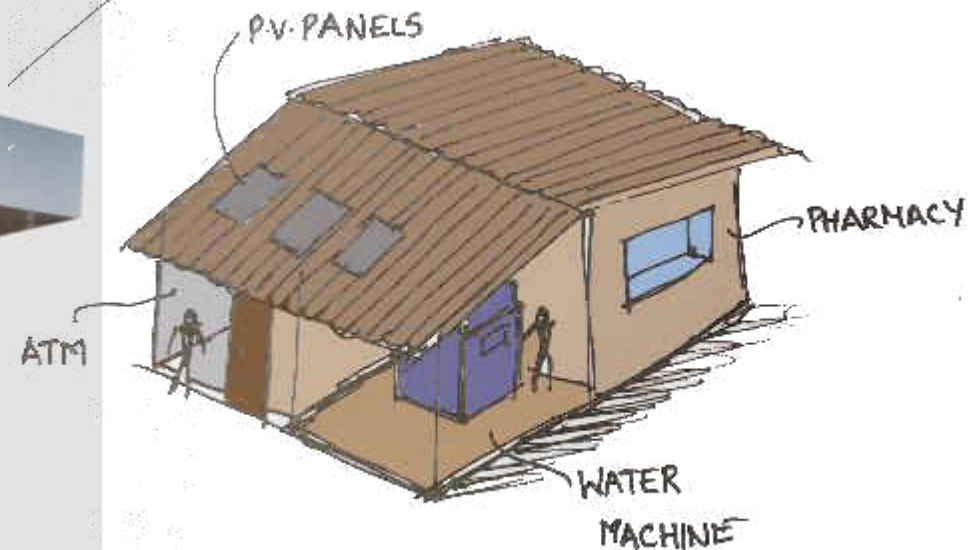
www.pmfias.com

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DIGITAL WATER KIOSK

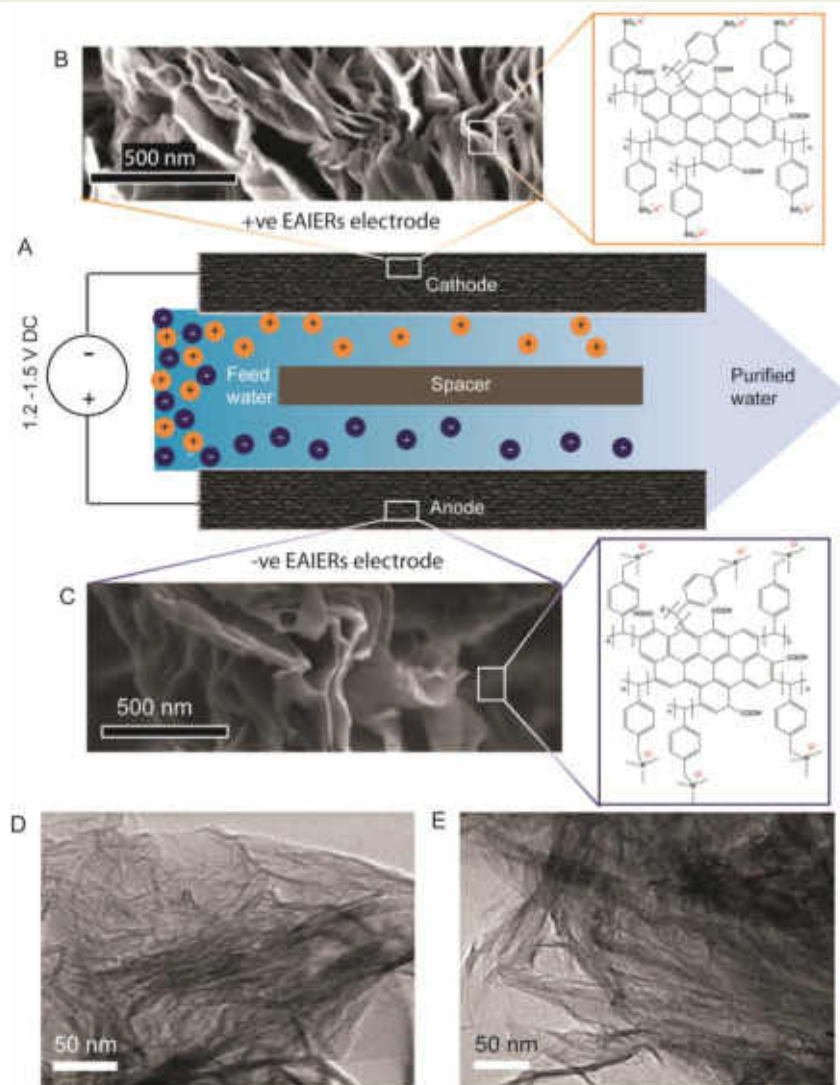
for community drinking using CDI Technology



Products under implementation

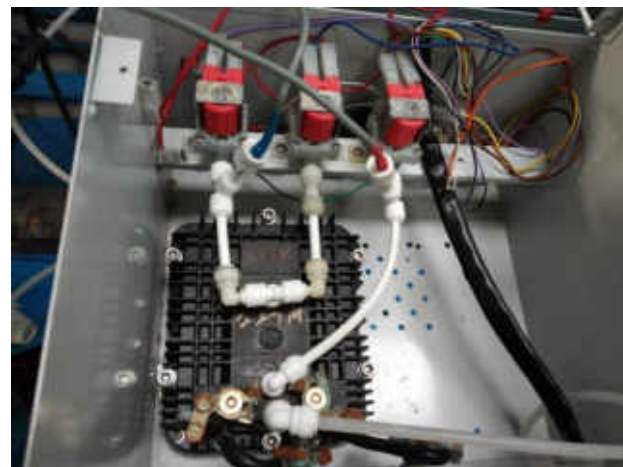
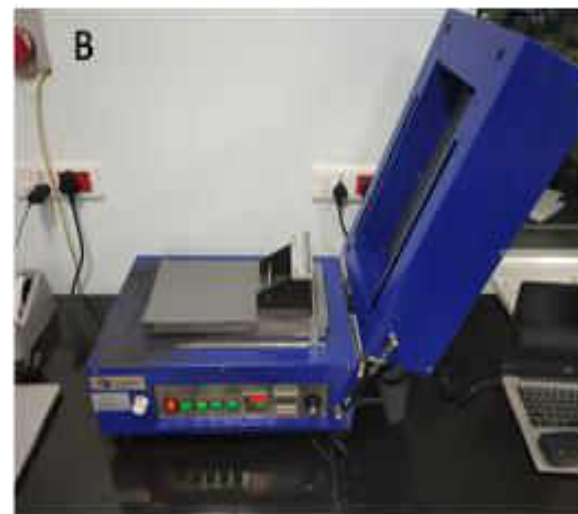
Vijay Sampath and Tullio Servida

A Covalently Integrated Reduced Graphene Oxide -Ion Exchange Resin Electrode for Efficient CDI

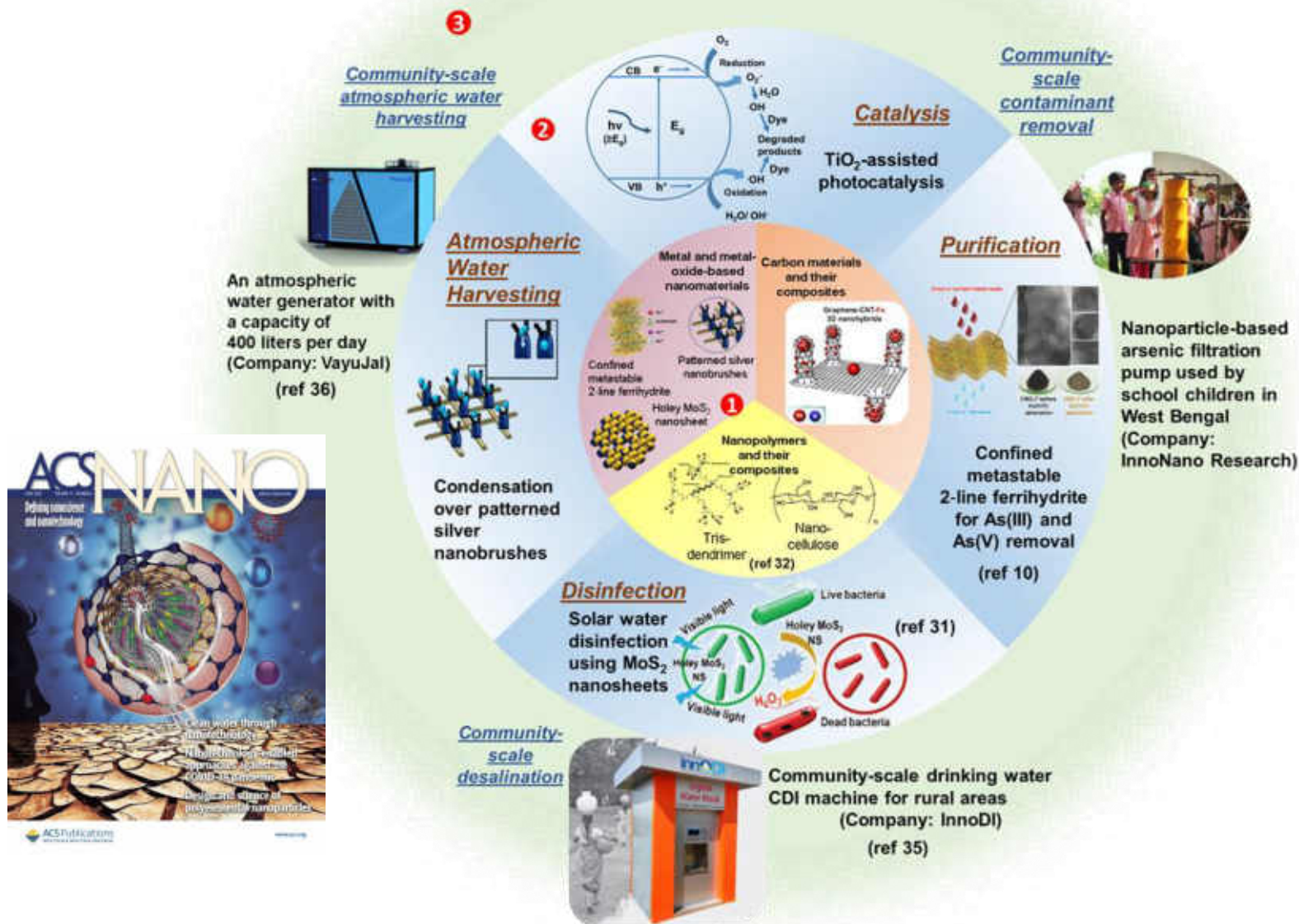


Rabiul et al., *Adv. Mater. Interfaces* **2021**, 8, 2001998

Various stages of electrode preparation



Evolution of materials to products



Sensors and new opportunities



Analog/Grating
Equipment
\$ 5~6 Billion (2017)
a few **100k units** (2017)



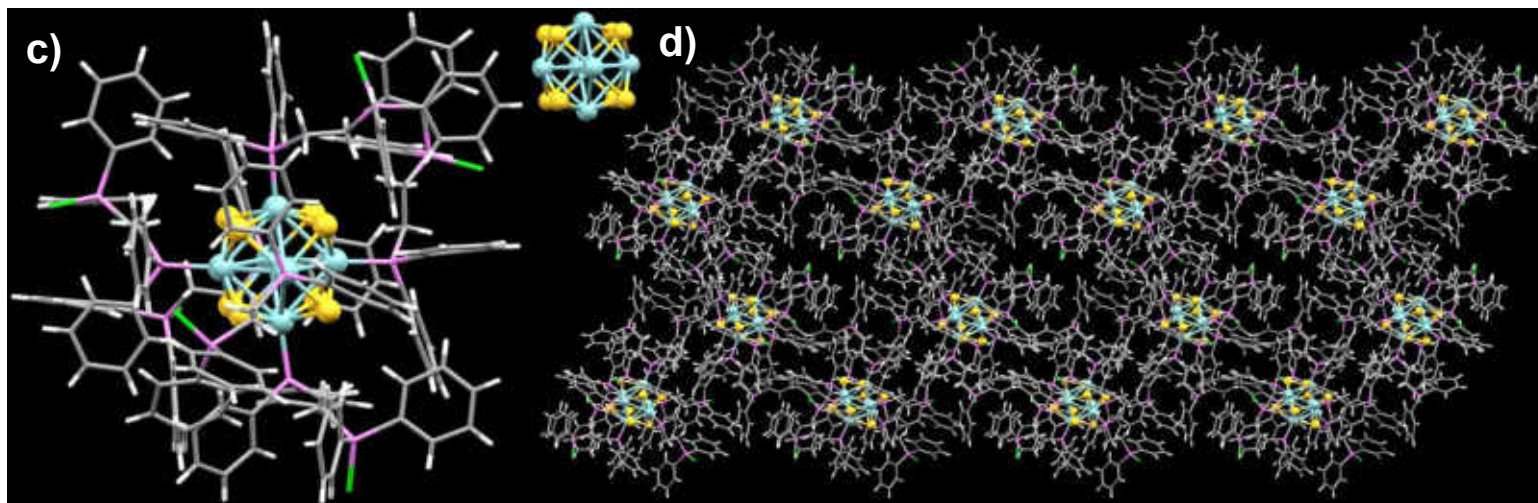
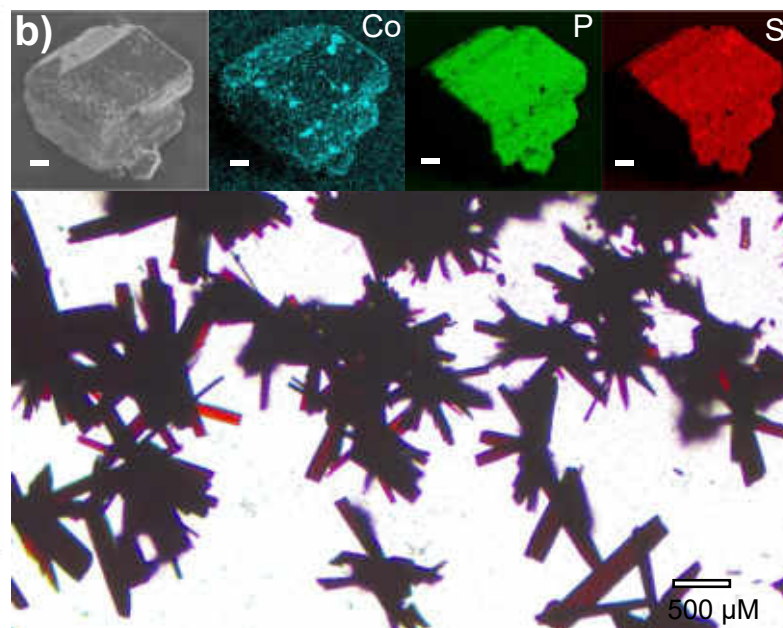
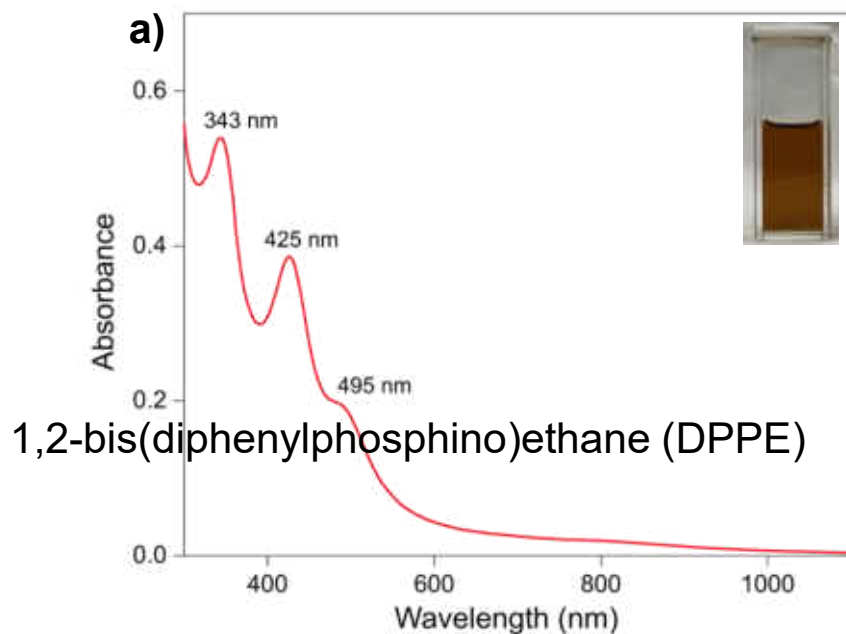
**Ultra compact Low Cost
Spectral Sensor Module**
~ **Billions units** (? 2027)



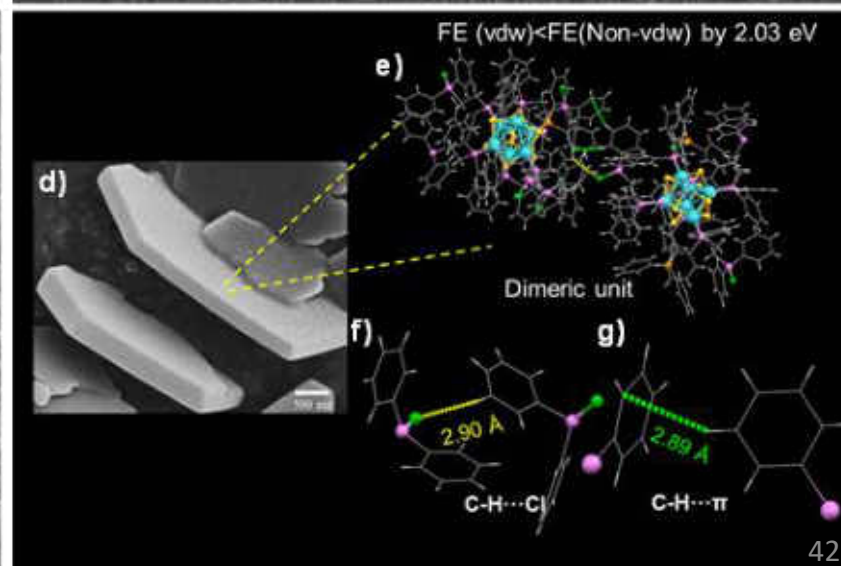
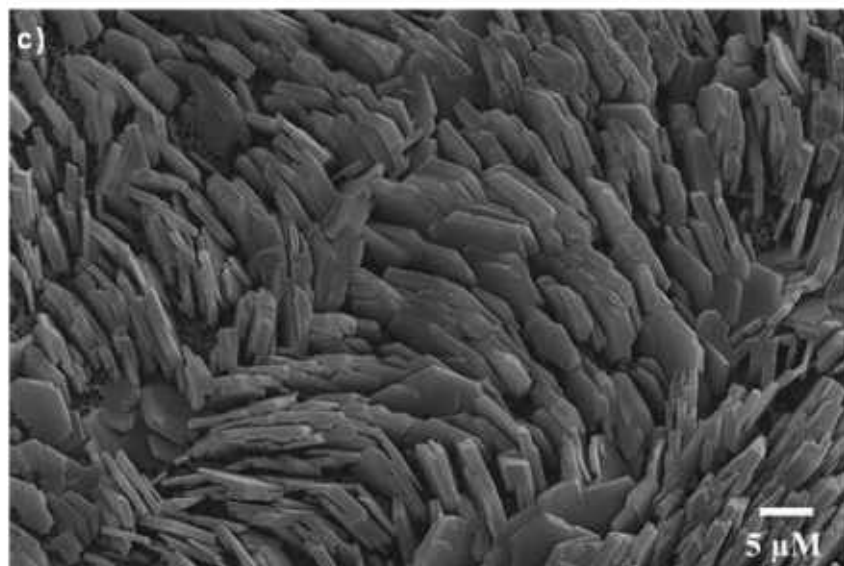
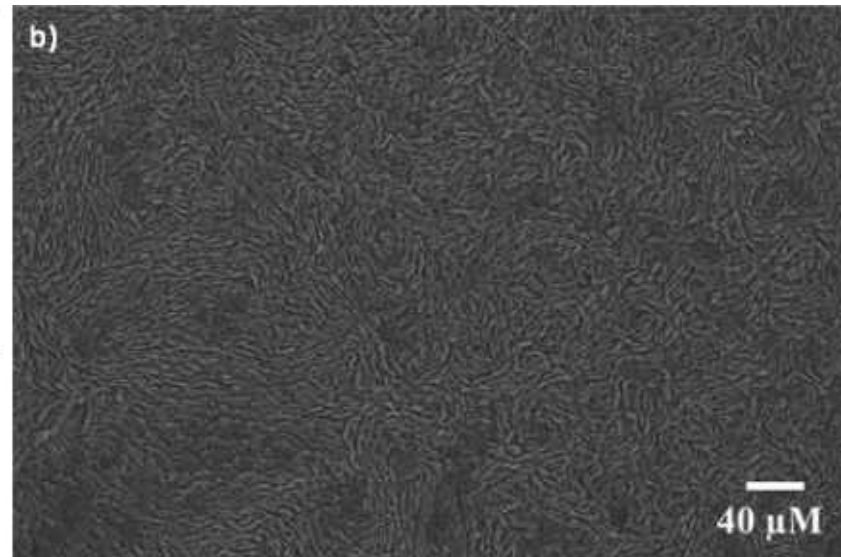
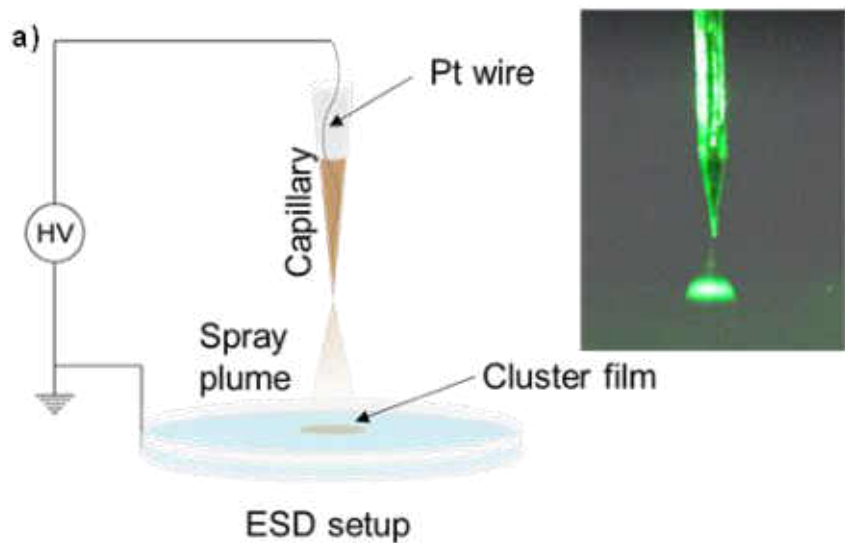
Water quality measurement – In the pipeline

nano λ

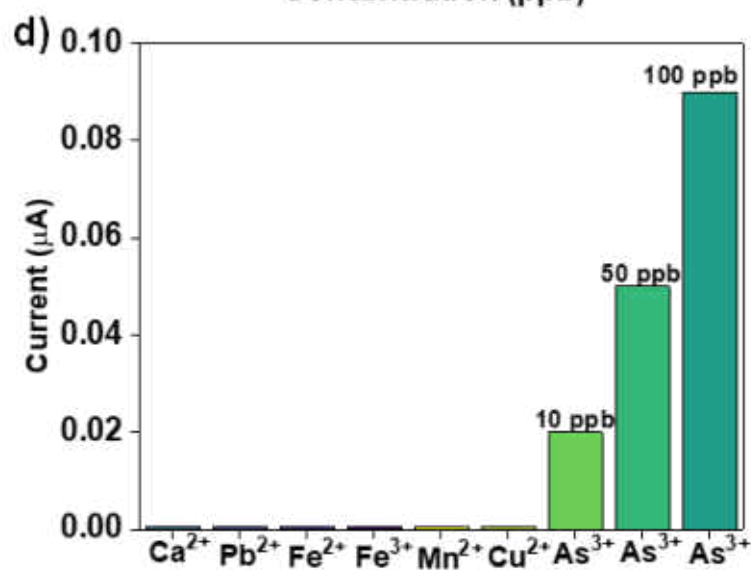
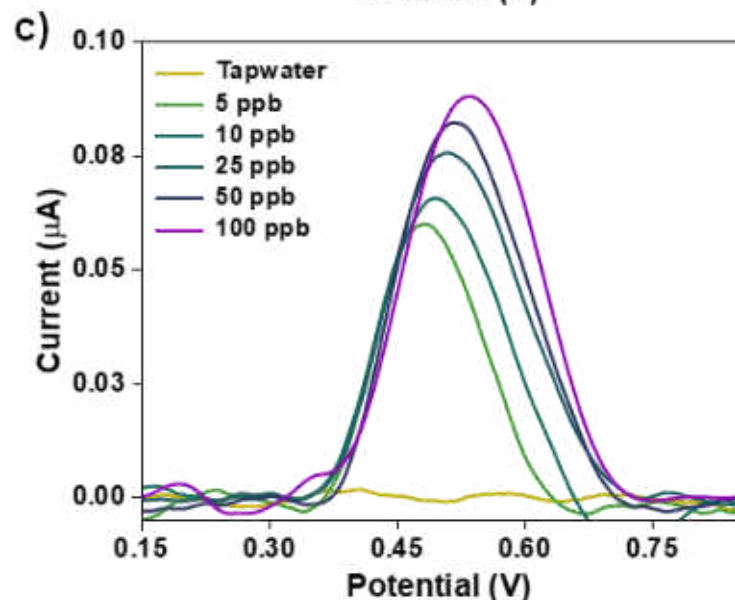
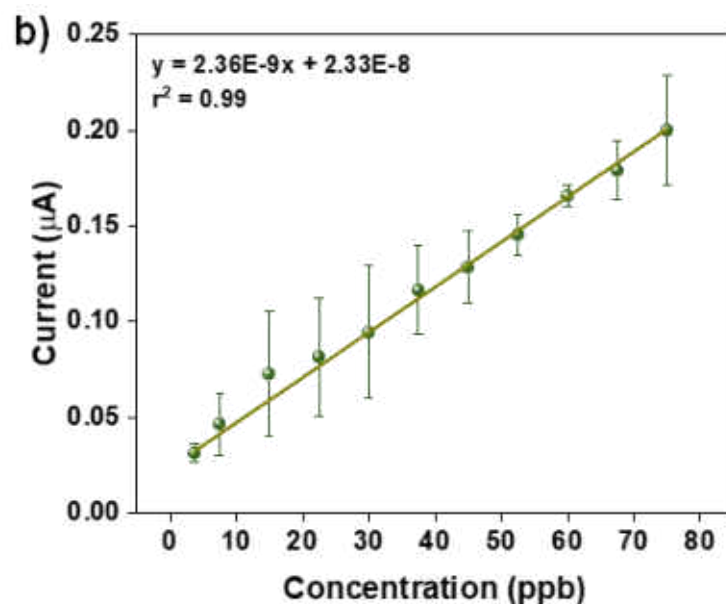
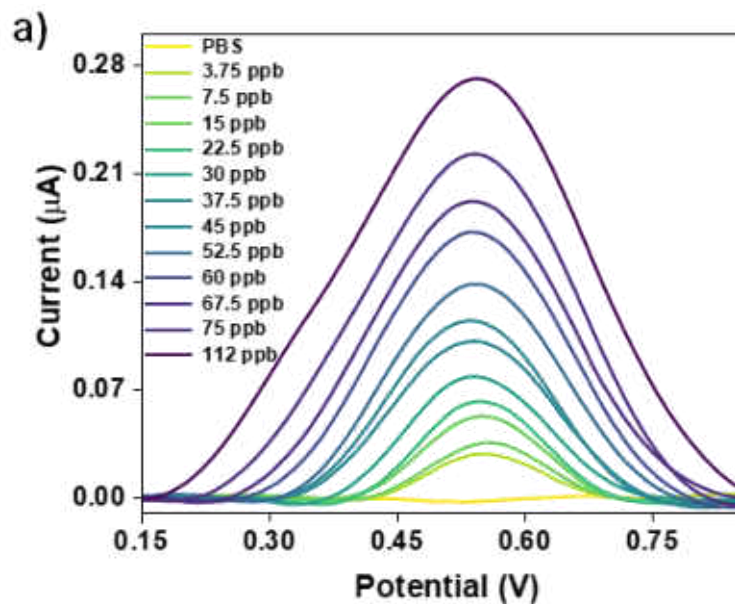
New electrodes - Aligned nanoplates of Co_6S_8



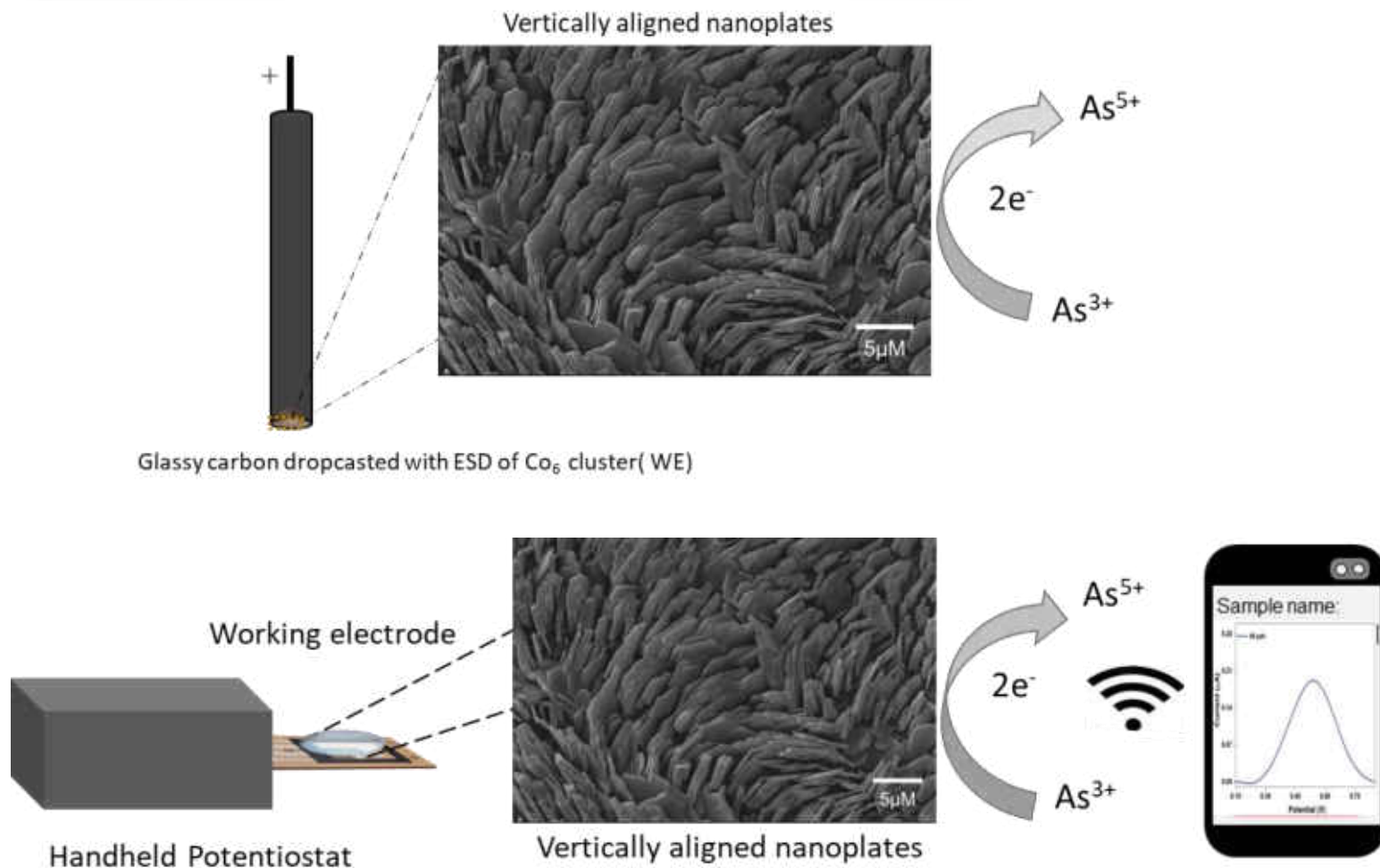
Electrospray deposition



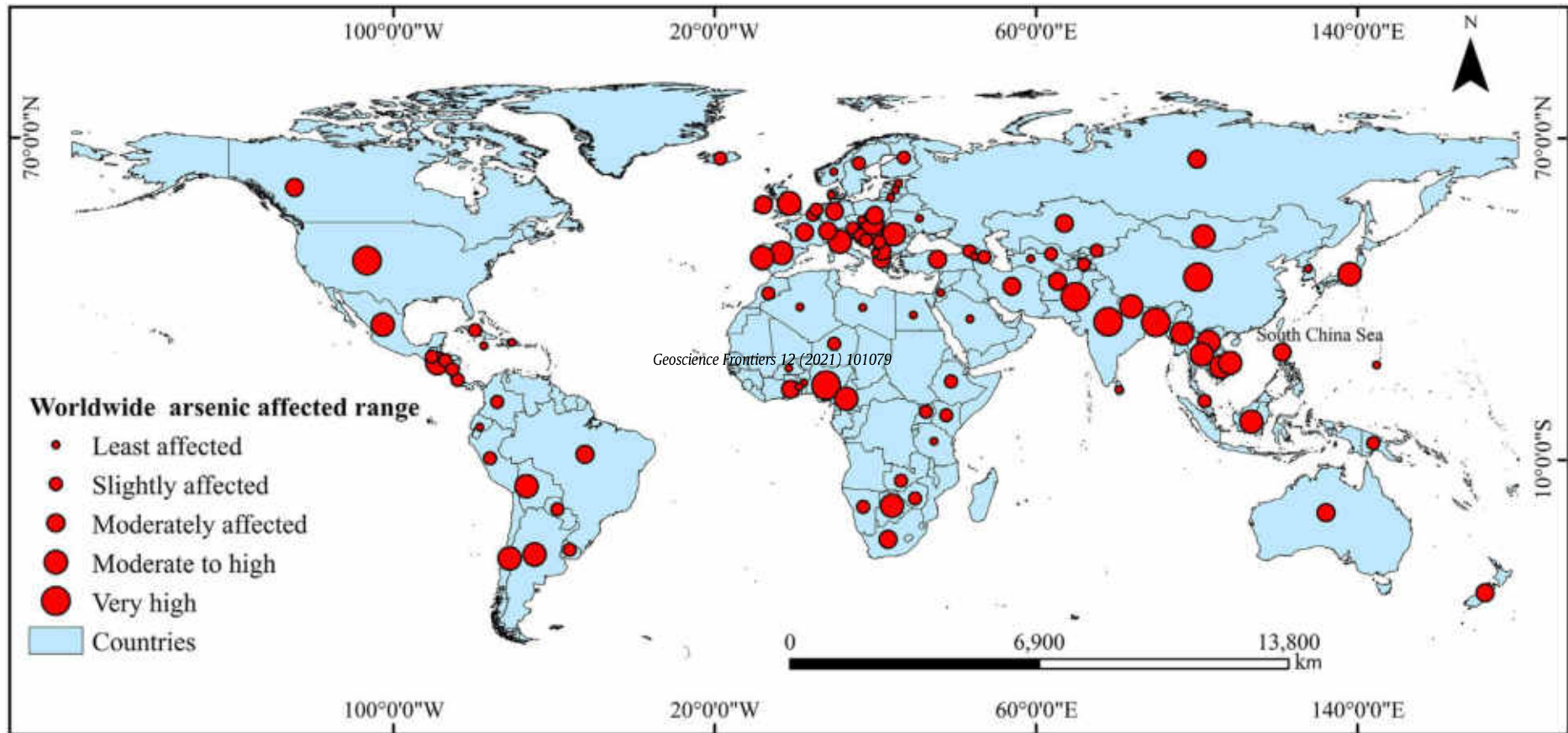
Sensing

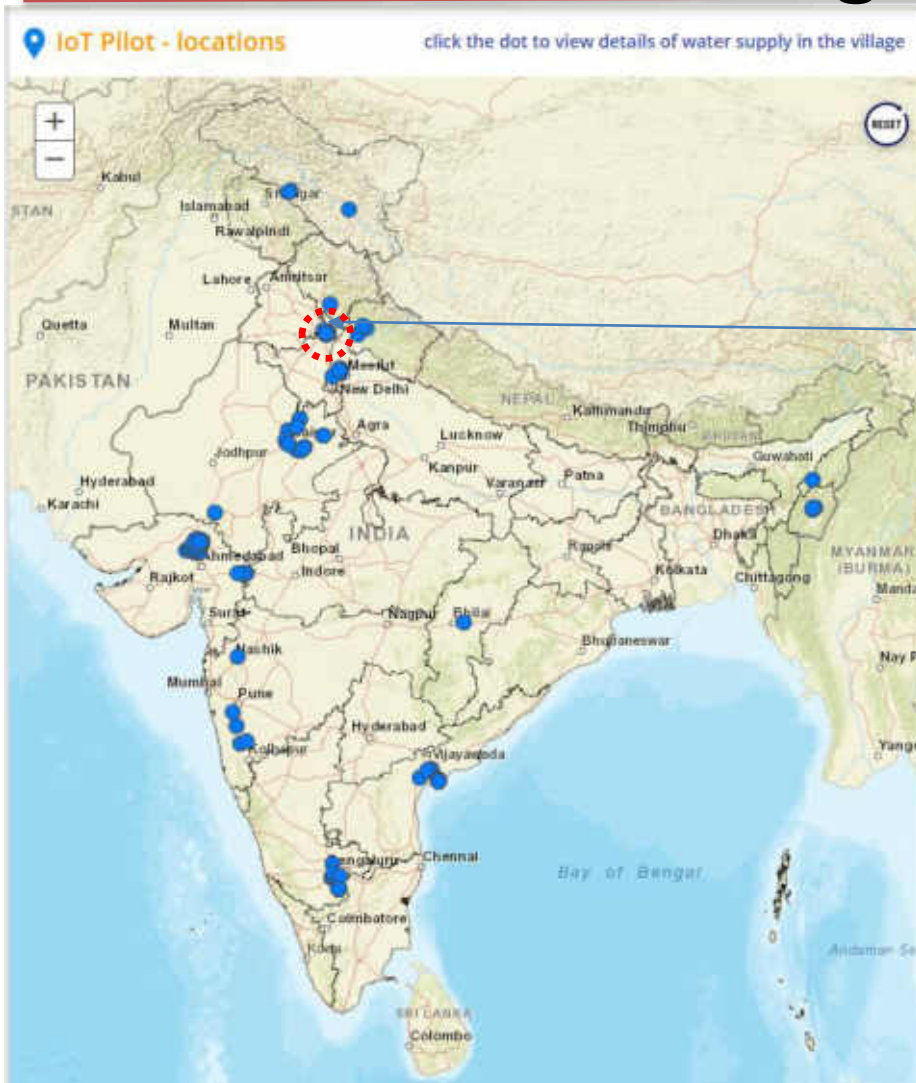


Working electrode



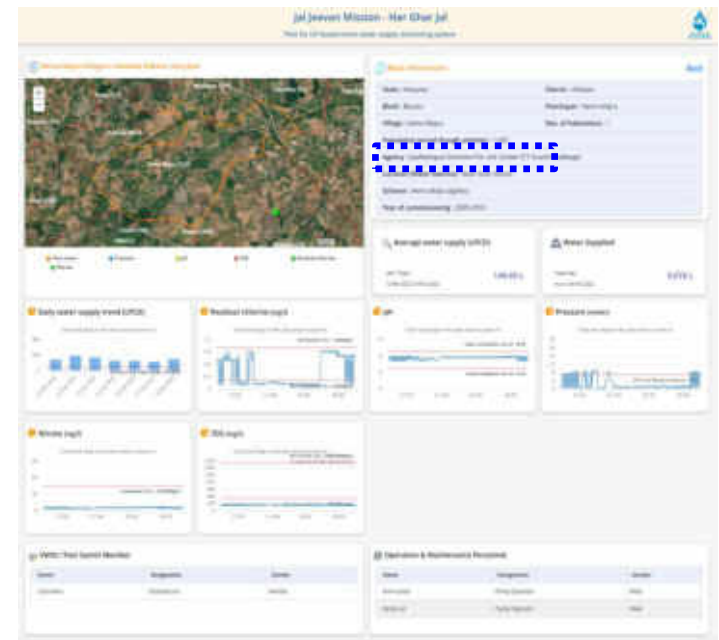
Arsenic poisoning across the world





IITM/IISc

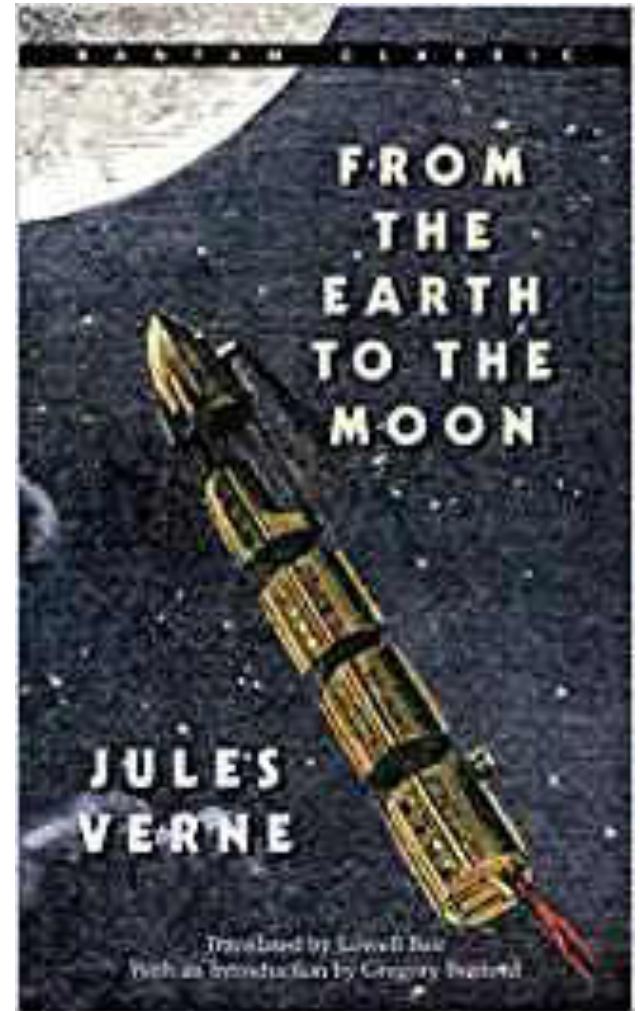
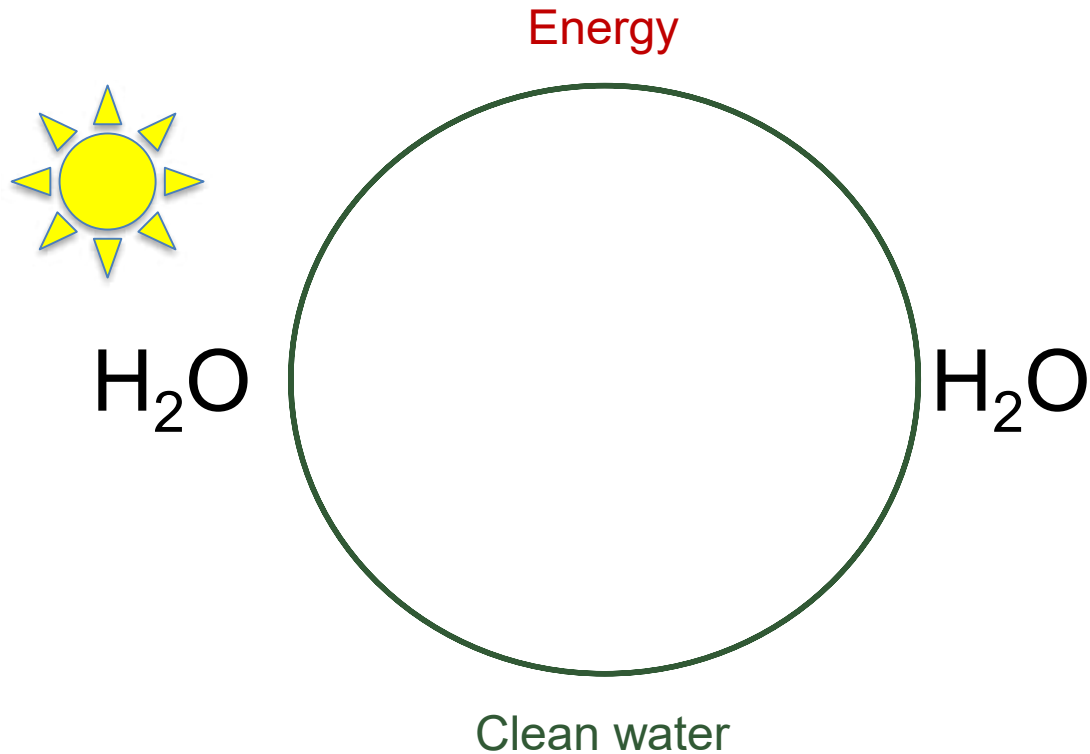
Installations made by four companies



A wide-angle photograph of a large, green lawn under a blue sky with scattered clouds. In the background, there is a tall, metal water tower on the right, a playground with various equipment in the center, and some trees and buildings on the left. A black oval is drawn over the lower-left portion of the lawn.

Policy

Our dreams become reality with materials



Affordable, inclusive, sustainable and contextual excellence



International Centre for Clean Water



IIT Madras Research Park



The AMRIT Team, 2013

Water team at IIT: A. Sreekumaran Nair, Anshup, M. Udhaya Sankar, Amrita Chaudhary, Renjis T. Tom, T. S. Sreeprasad, Udayabhaskararao Thumu, M. S. Bootharaju, K. R. Krishnadas, Kalamesh Chaudhari, Soujit Sengupta, Depanjan Sarkar, Avijit Baidya, Swathy Jakka Ravindran, Abhijit Nag, S. Vidhya, Biswajit Mondal, Krishnan Swaminathan, Azhardin Gnayee, Sudhakar Chennu, A. Suganya, Rabiul Islam, Sritama Mukherjee, Tanvi Gupte, Jenifer Shantha Kumar, A. Anil Kumar, Ankit Nagar, Ramesh Kumar Soni, Tanmayaa Nayak, Sonali Seth, Shihabudheen M. Maliyekkal, G. Velmurugan, Wakeel Ahmed Dar, Ganapati Natarajan, N. Pugazhenthiran, A. Leelavathi, Sahaja Aigal, S.Gayathri, Bibhuti Bhusan Rath, Ananthu Mahendranath, Harsh Dave, Erik Mobegi, Egor Moses, Hemanta R. Naik, Sourav Kanti Jana,...

Avula Anil Kumar, Chennu Sudhakar, Sritama Mukherjee, Anshup, and Mohan Udhaya Sankar

Funding: Department of Science and Technology, Government of India

Start-ups and partners:

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Thank you all

