Since 1959

# Affordable Clean Water Using Advanced Materials

**Thalappil Pradeep**
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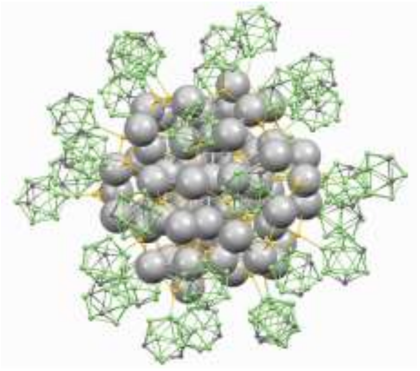
https://pradeepresearch.org

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

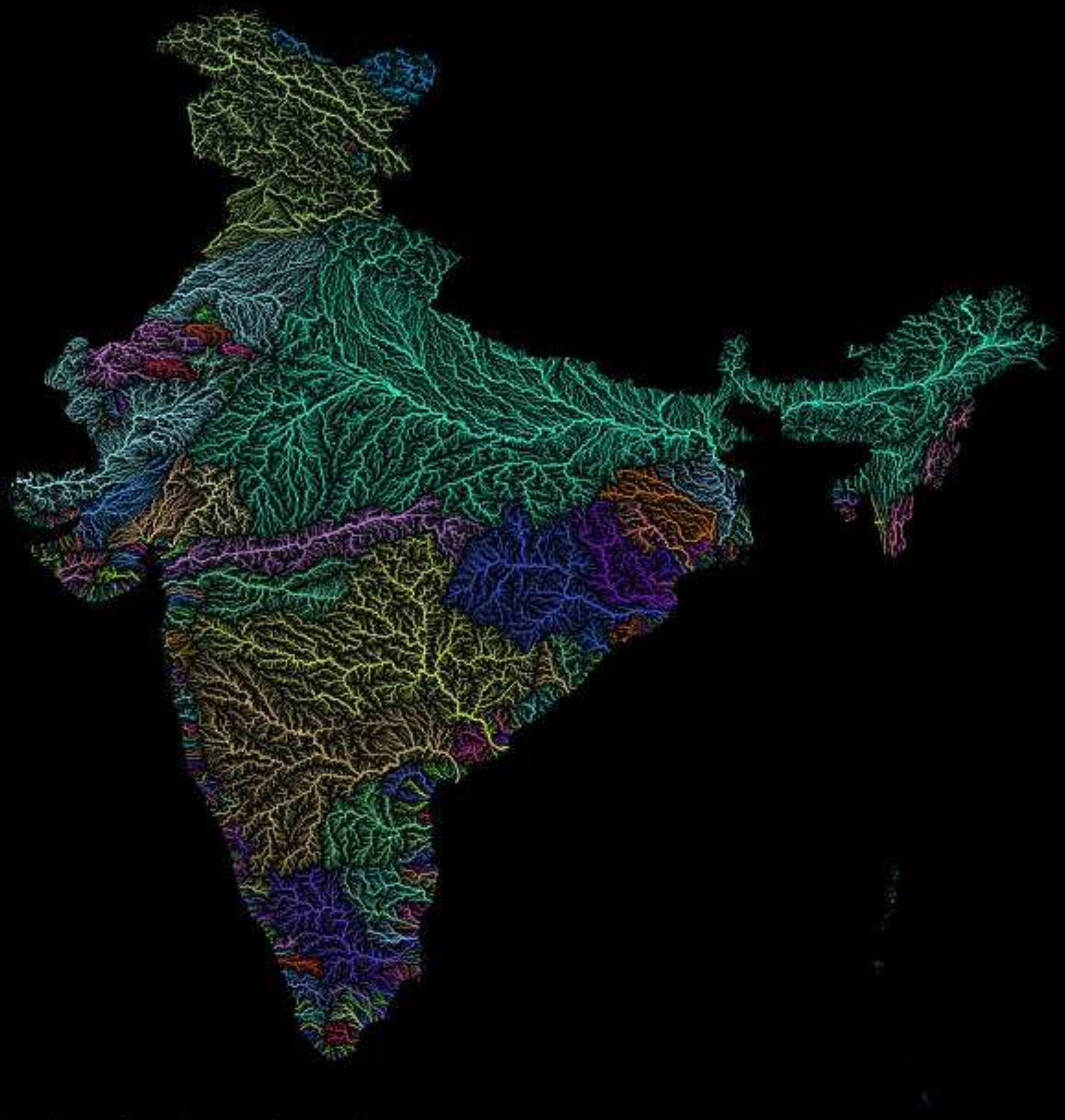


Professor-in-charge

International Centre for Clean Water

Associate Editor
ACS Sustainable Resource Management

IUPAC 2025, 50th World Chemistry Congress July 14-19, 2025




From S. Vishwanath

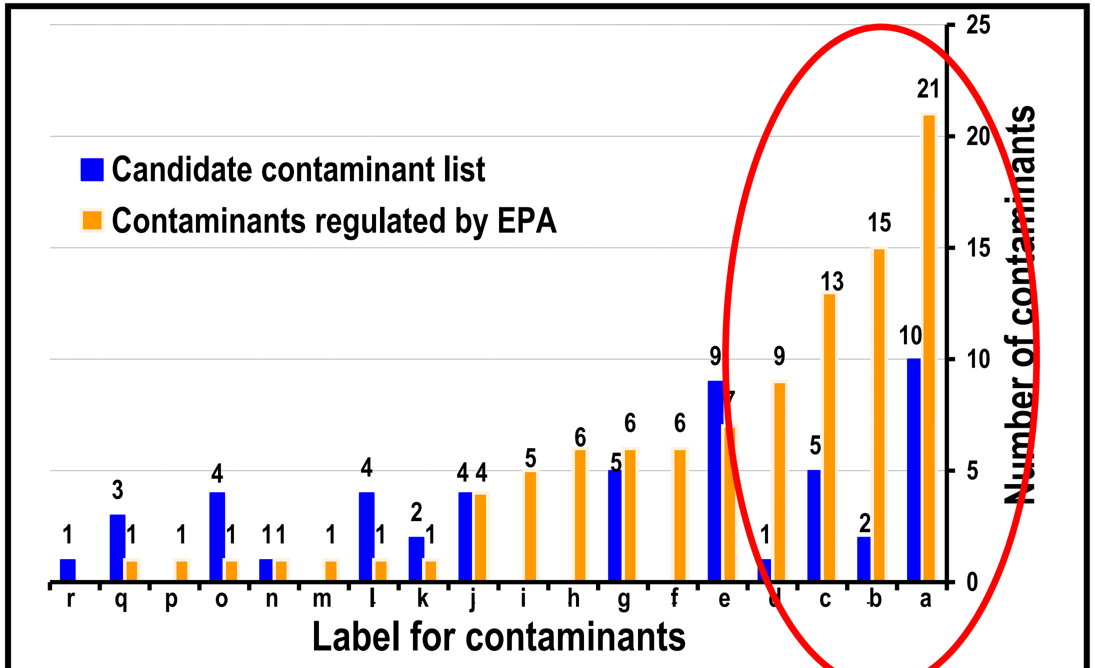
# Water purification, history

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 | *Silent Spring* 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<br>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) |

T. Pradeep and Anshup, *Thin Solid Films*, 2009

# Future of water purification: An enigma with some pointers




(a): Halogenated organic (b): Metal (c): Organochlorine pesticide (d): Inorganic salt (e): Biological contaminant (f): Nuclear (g): Benzo derivative (h): Carbamate pesticide (i): Pesticides (others) (j): Unclassified (k): Triazine derivative pesticide (l): Organophosphorus pesticide (m): Organobromine pesticide (n): Non-metal (o): Nitrophenol derivative, (p): Dioxin, (q): Benzo and halogenated organic (r): Organometallics

Category-wise distribution of contaminants regulated by USEPA and future contaminants

Noble metal nanoparticles for water purification: A critical review, T. Pradeep and Anshup, Invited critical review, Thin Solid Films, 517 (2009) 6441-6478 (DOI: 10.1016/j.tsf.2009.03.195).

# World's first nanochemistry-based water purifier

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 (CCl4) 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 ...

water supplies.

Use and recycle

**Chemistry world**

First ever nanotechnology product for clean water



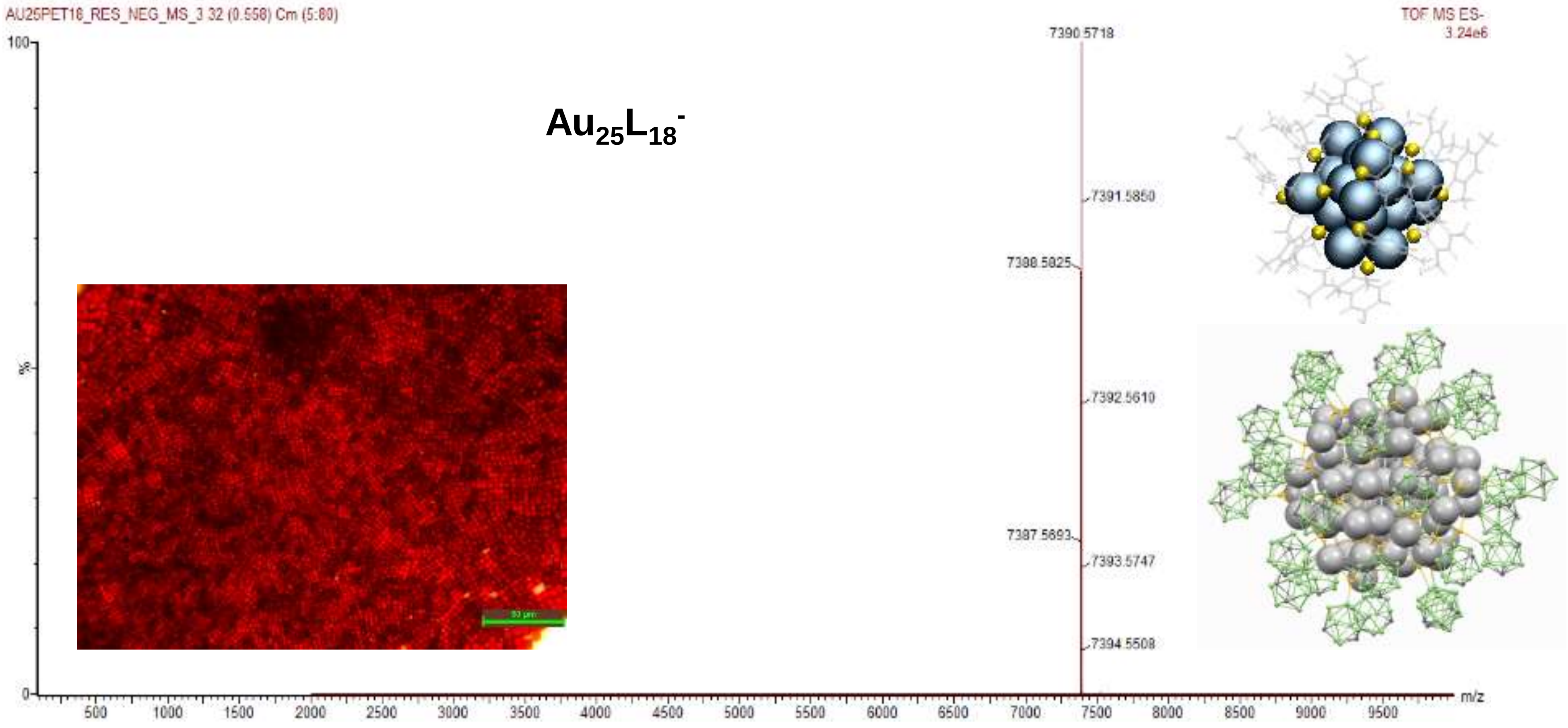
**A plant to make supported nanomaterials for water purification; with capacity of 4.5 tons per month, 2007**

1. Patents: A method of preparing purified water from water containing pesticides, **Indian patent 200767**
2. Extraction of malatheon and chlorpiryhphos from drinking water by nanoparticles , **US 7,968,493** A method for decontaminating water containing pesticides, **EP 17,15,947**

Product is marketed now by a Eureka Forbes Ltd.

Several new technologies are now available

# Nanomaterials are now atomically precise

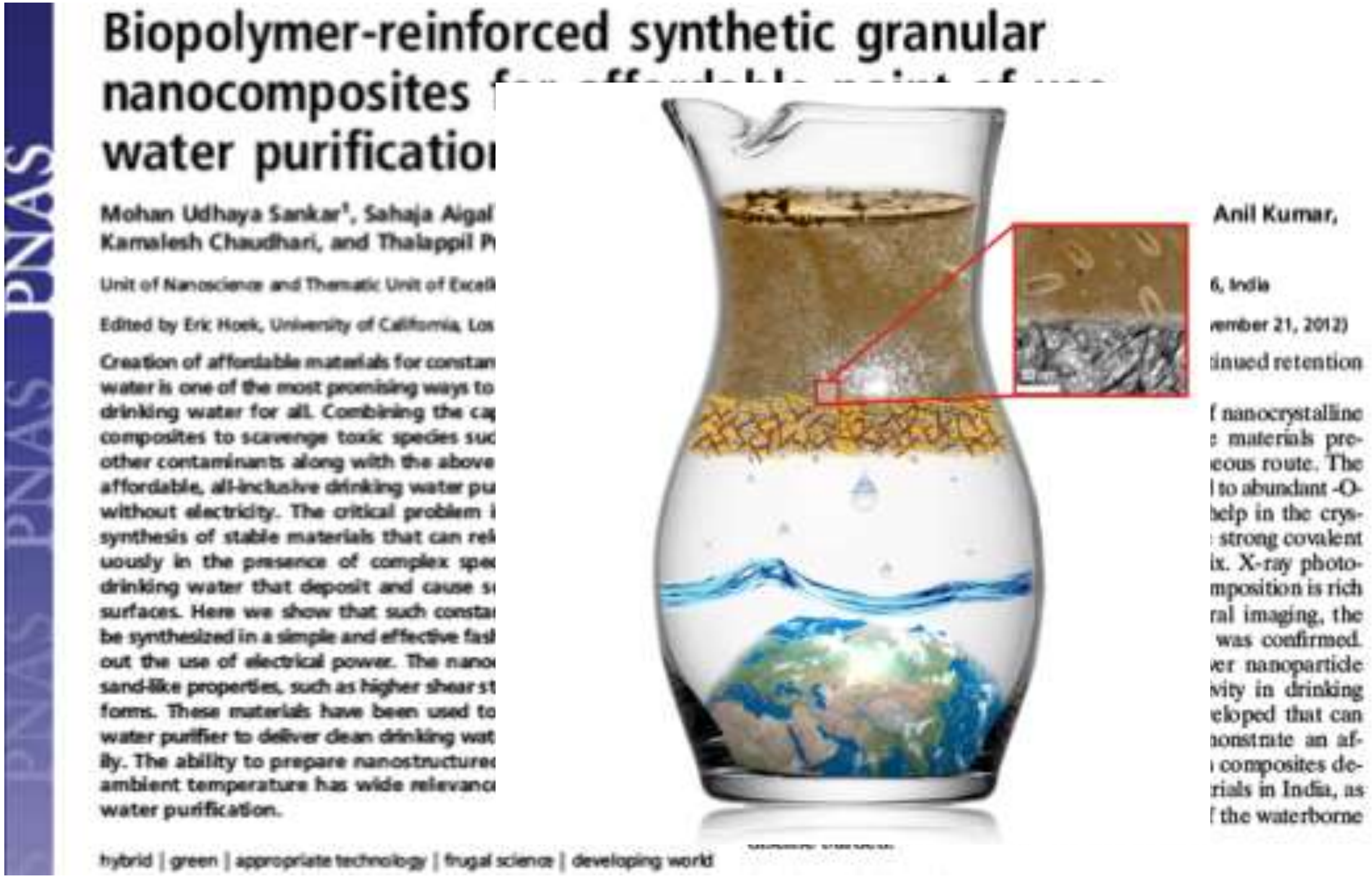



T. Pradeep et. al. *Acc. Chem. Res.* 2018; 2019.

# Clean water for everyone

ACS Sustainable Chemistry & Engineering Editorial, December 2016

# Water positive materials



PNAS PNAS PNAS PNAS

Biopolymer-reinforced synthetic granular nanocomposites f
water purificatio

Mohan Udhaya Sankar[1], Sahaja Aigal Anil Kumar,
Kamalesh Chaudhari, and Thalappil P

Unit of Nanoscience and Thematic Unit of Excell 6, India

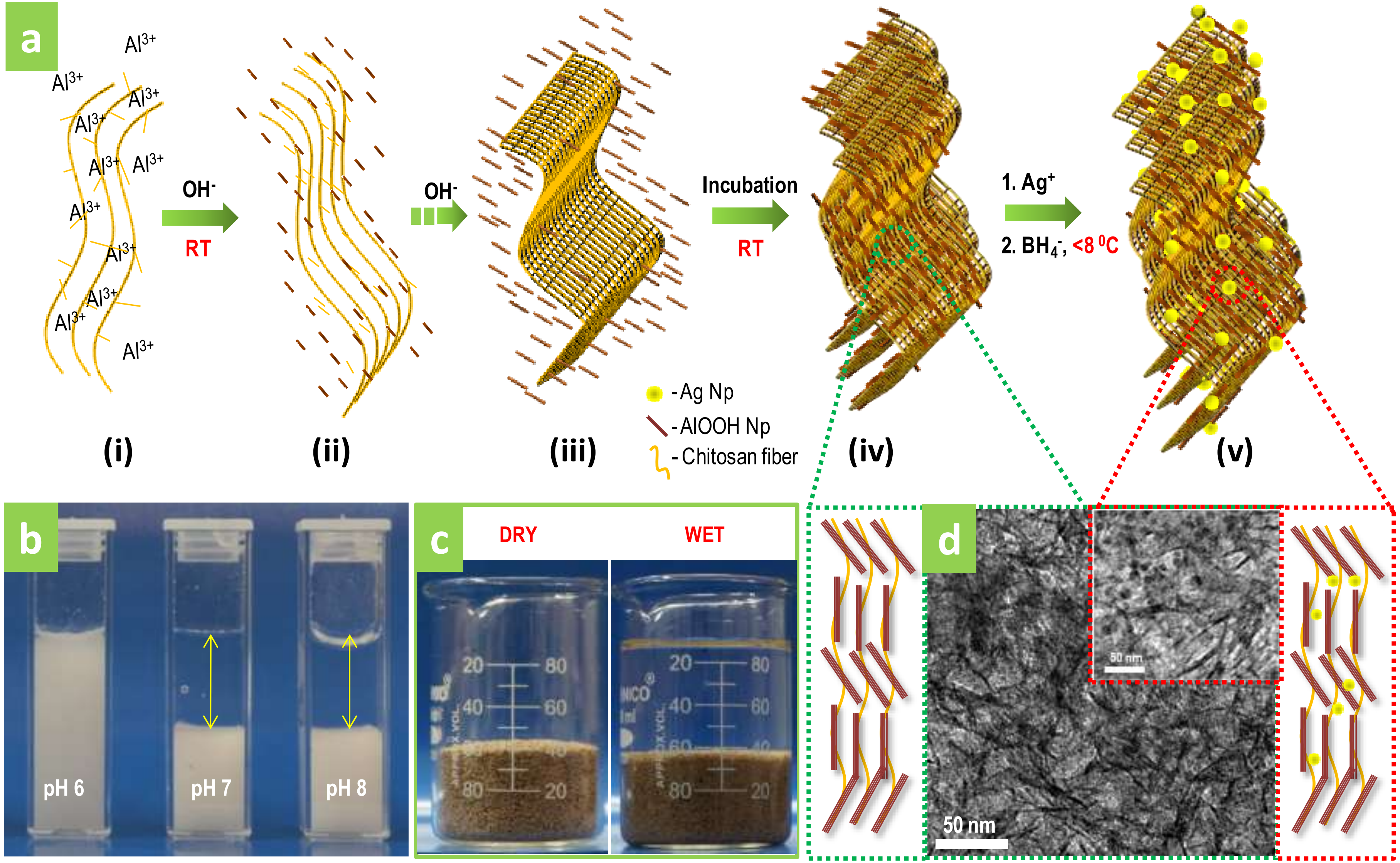
Edited by Eric Hoek, University of California, Los vember 21, 2012)

Creation of affordable materials for constan
water is one of the most promising ways to
drinking water for all. Combining the ca
composites to scavenge toxic species su
other contaminants along with the above
affordable, all-inclusive drinking water pu
without electricity. The critical problem i
synthesis of stable materials that can rel
uously in the presence of complex spe
drinking water that deposit and cause s
surfaces. Here we show that such consta
be synthesized in a simple and effective fas
out the use of electrical power. The nano
sand-like properties, such as higher shear st
forms. These materials have been used to
water purifier to deliver clean drinking wat
ily. The ability to prepare nanostructure
ambient temperature has wide relevanc
water purification.

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

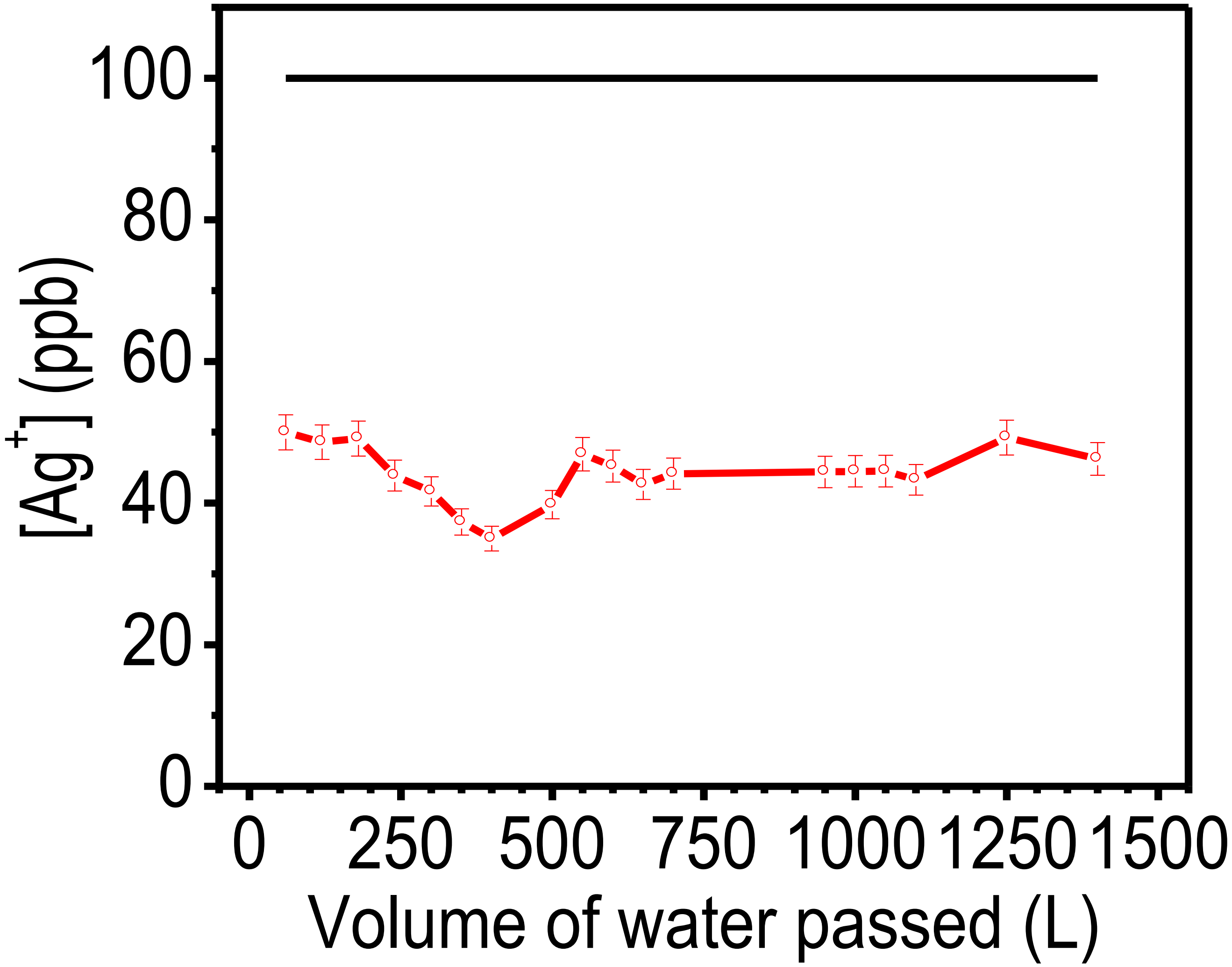
M. Udhaya Sankar, et. al. *Proc. Natl. Acad. Sci.,* 110 (2013) 8459-8464.

# How to make?

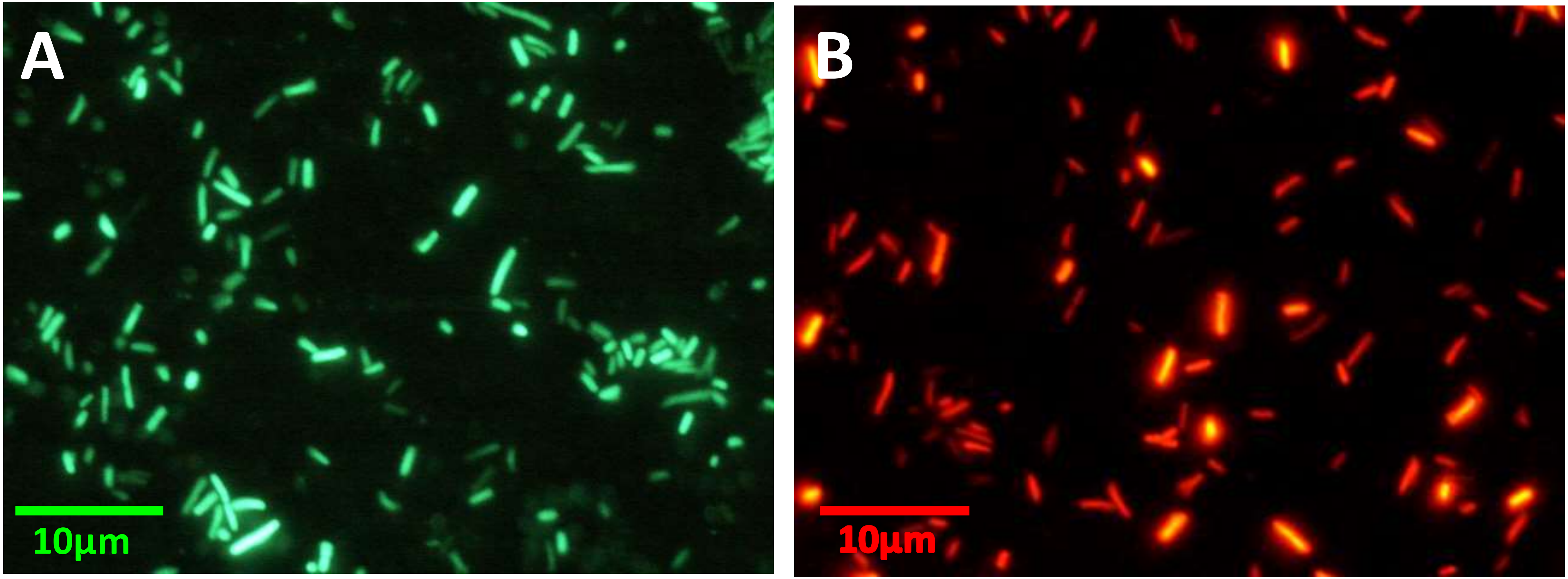


a
Al3+
OH-
RT
OH-
Incubation
RT
1. Ag+
2. BH4-, <8 0C
-Ag Np
-AlOOH Np
-Chitosan fiber
(i)
(ii)
(iii)
(iv)
(v)
b
pH 6
pH 7
pH 8
c
DRY
WET
d
50 nm
50 nm

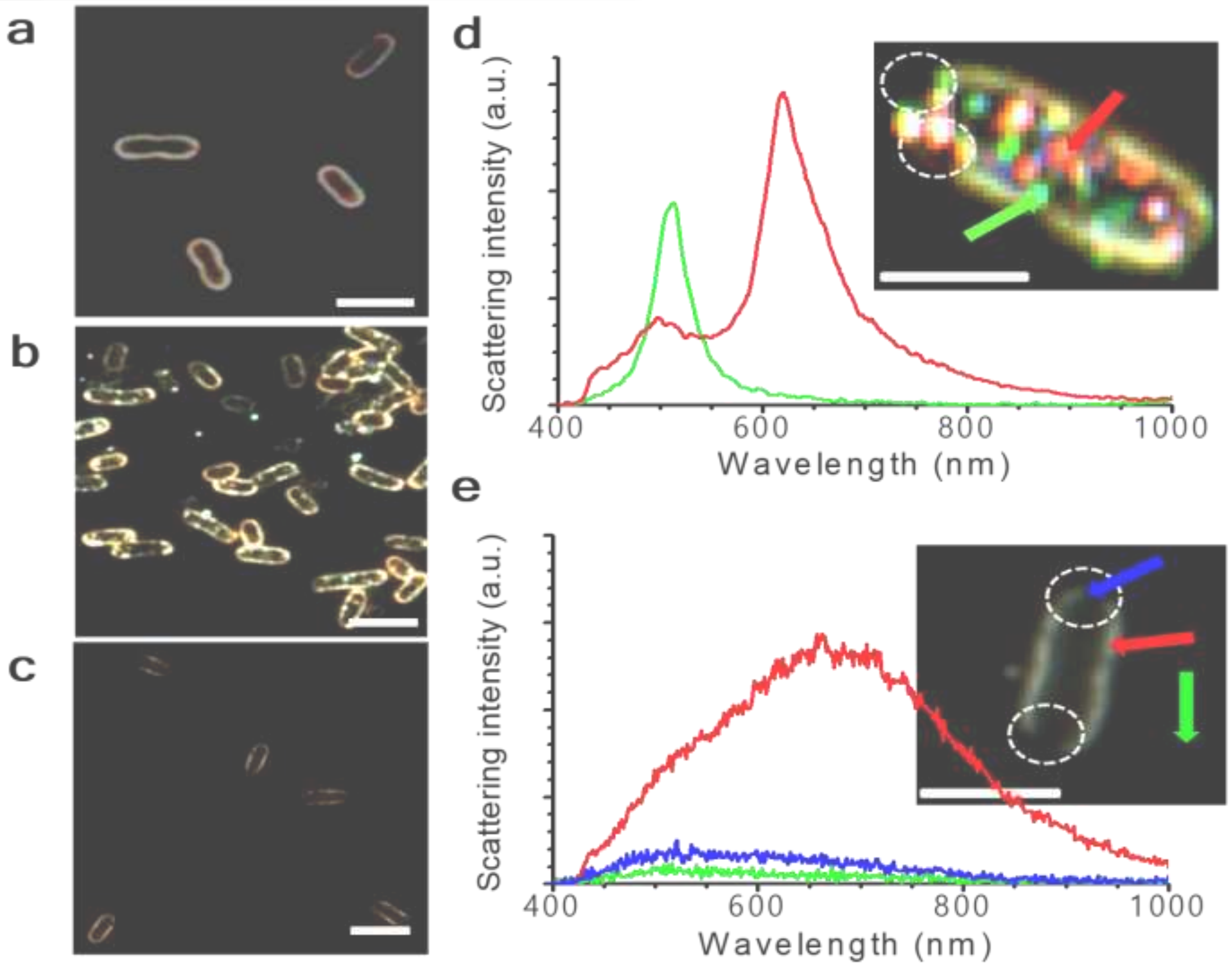
# What is special?



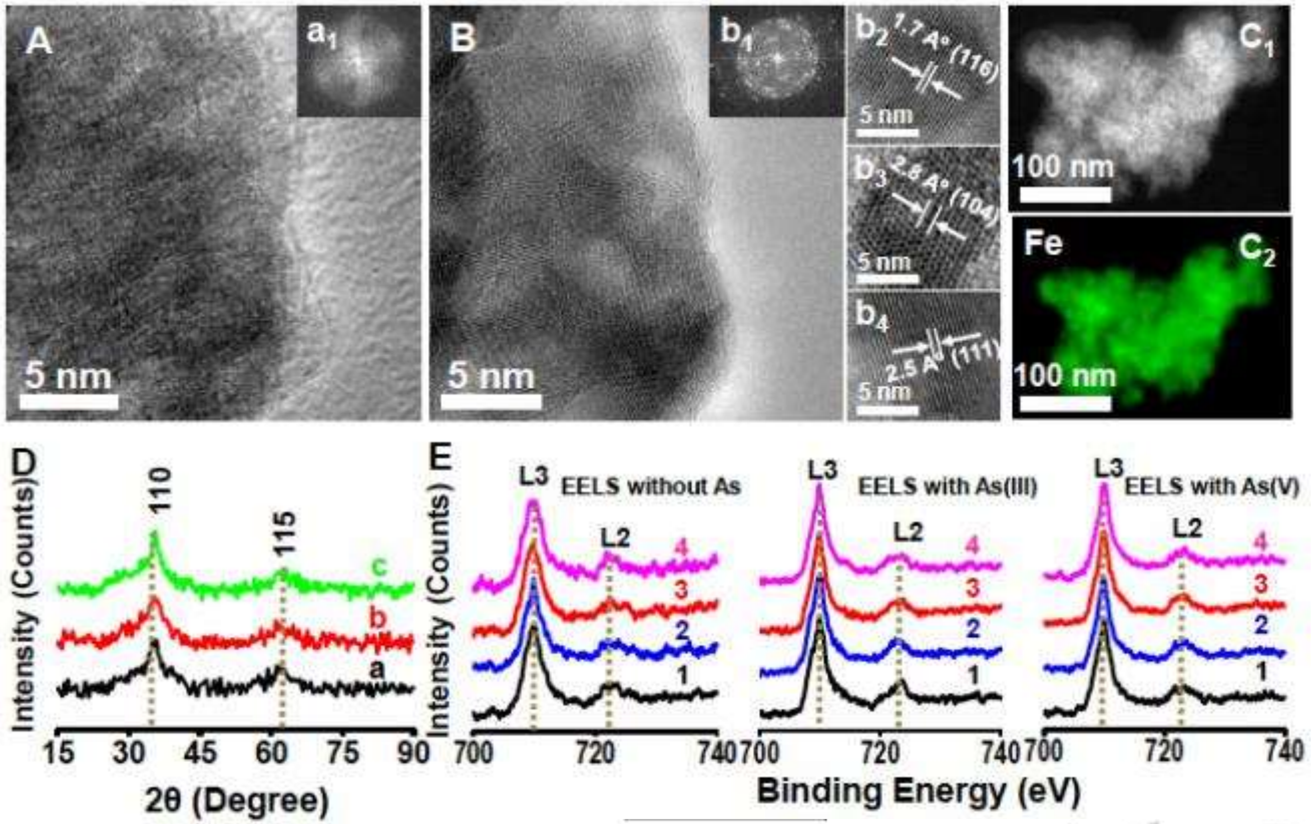
# Live/dead staining experiments



# No nanotoxicity



# Variety of materials





Author Proofs

ADVANCED MATERIALS

www.advmat.de

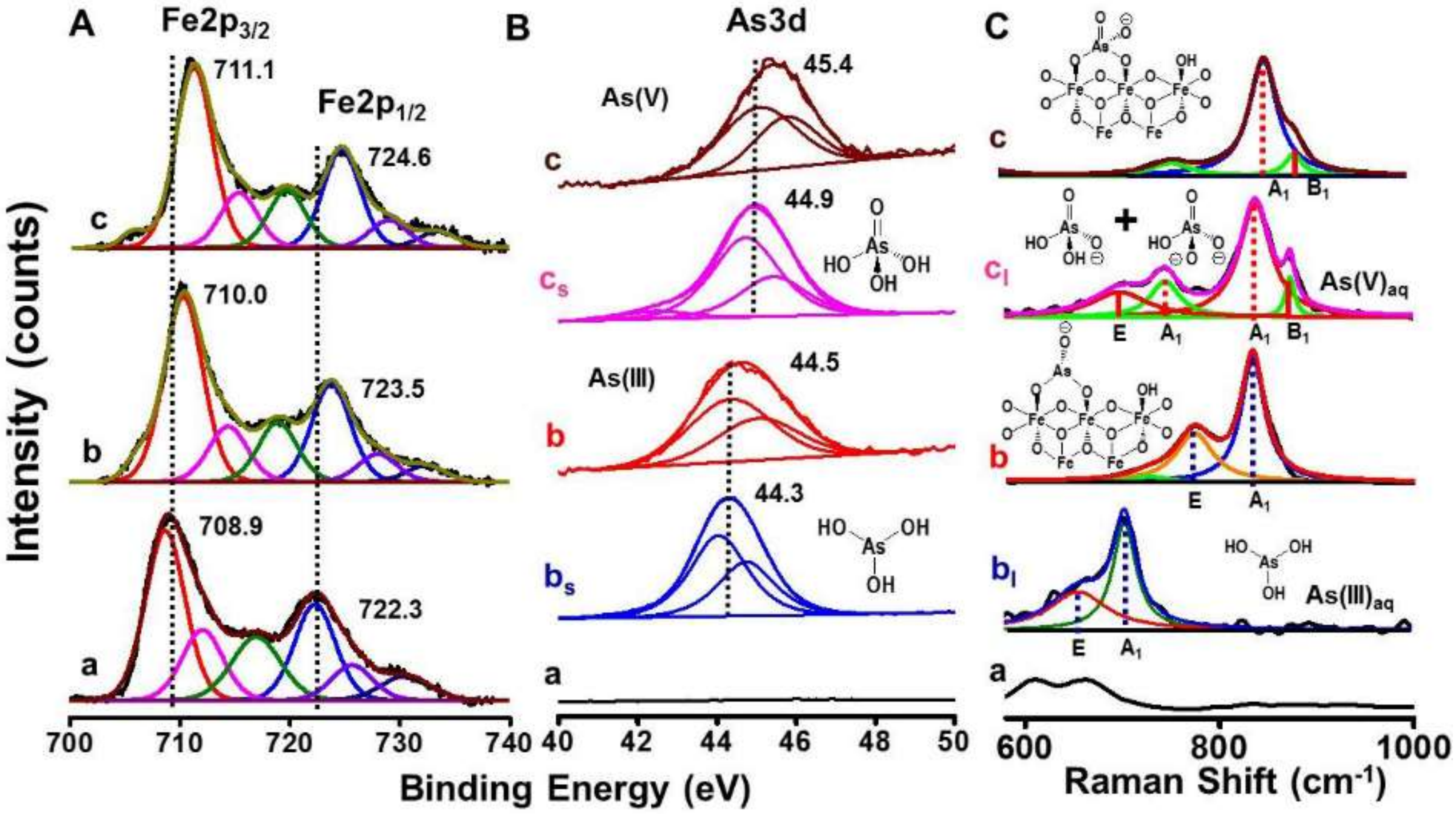
Communication

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

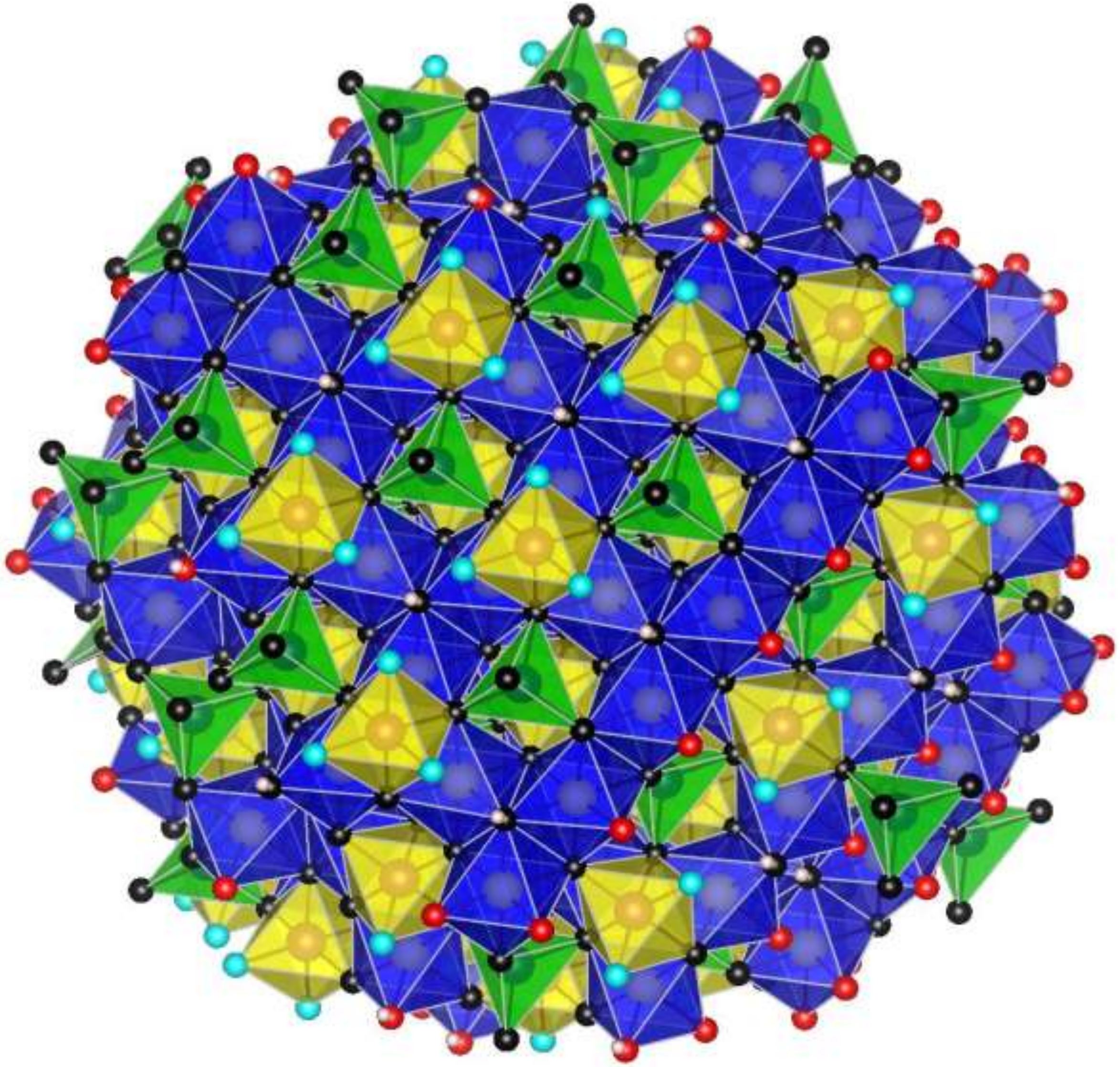
By Avula Anil Kumar, Anirban Som, Paolo Longo, Chennu Sudhakar, Radha Gobinda Bhuin, Soujit Sen Gupta, Anshup, Mohan Udhaya Sankar, Amrita Chaudhary, Ramesh Kumar, and T. Pradeep*

A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

# Mechanism – molecular tools

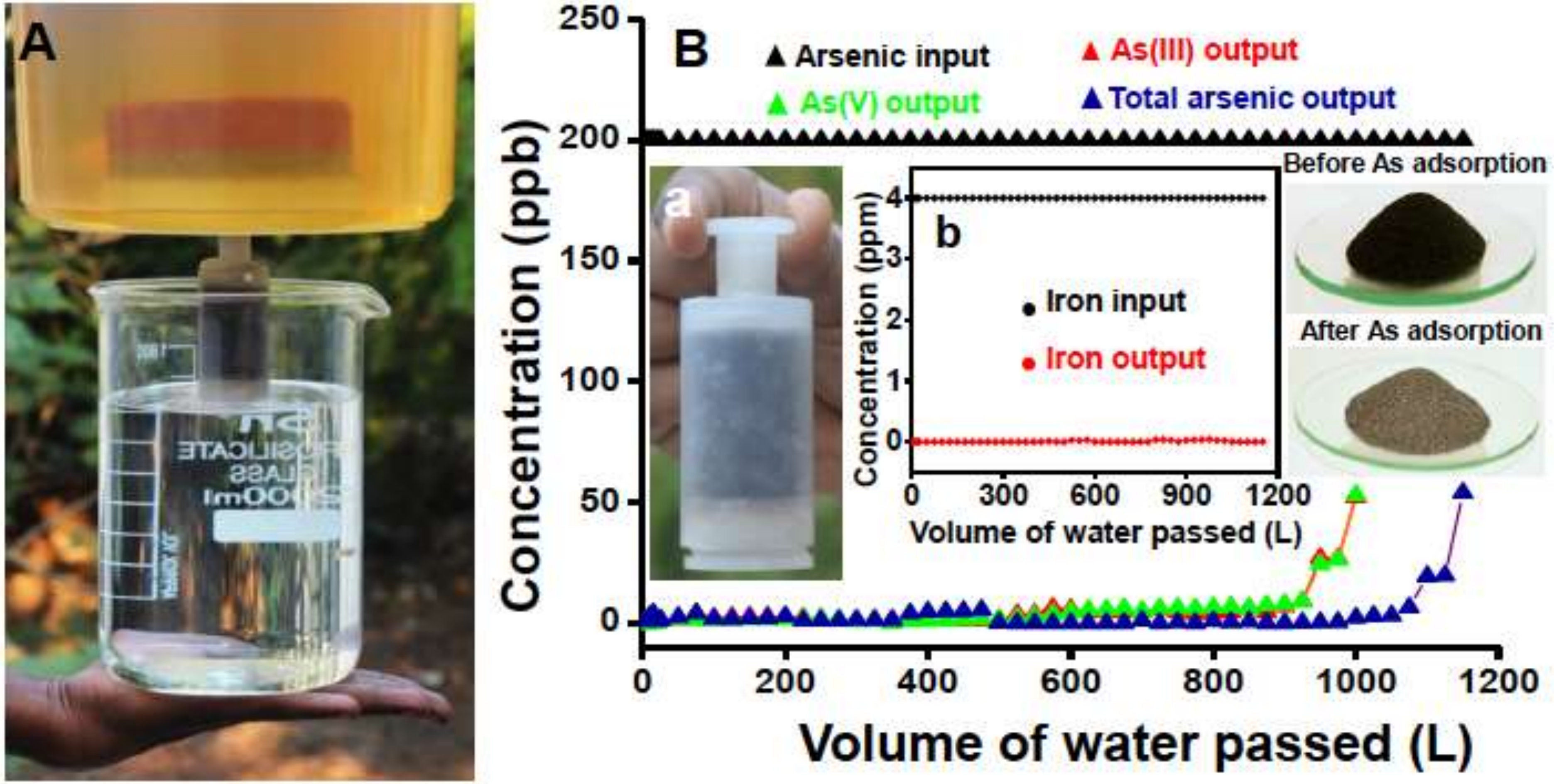


# Modeling surfaces



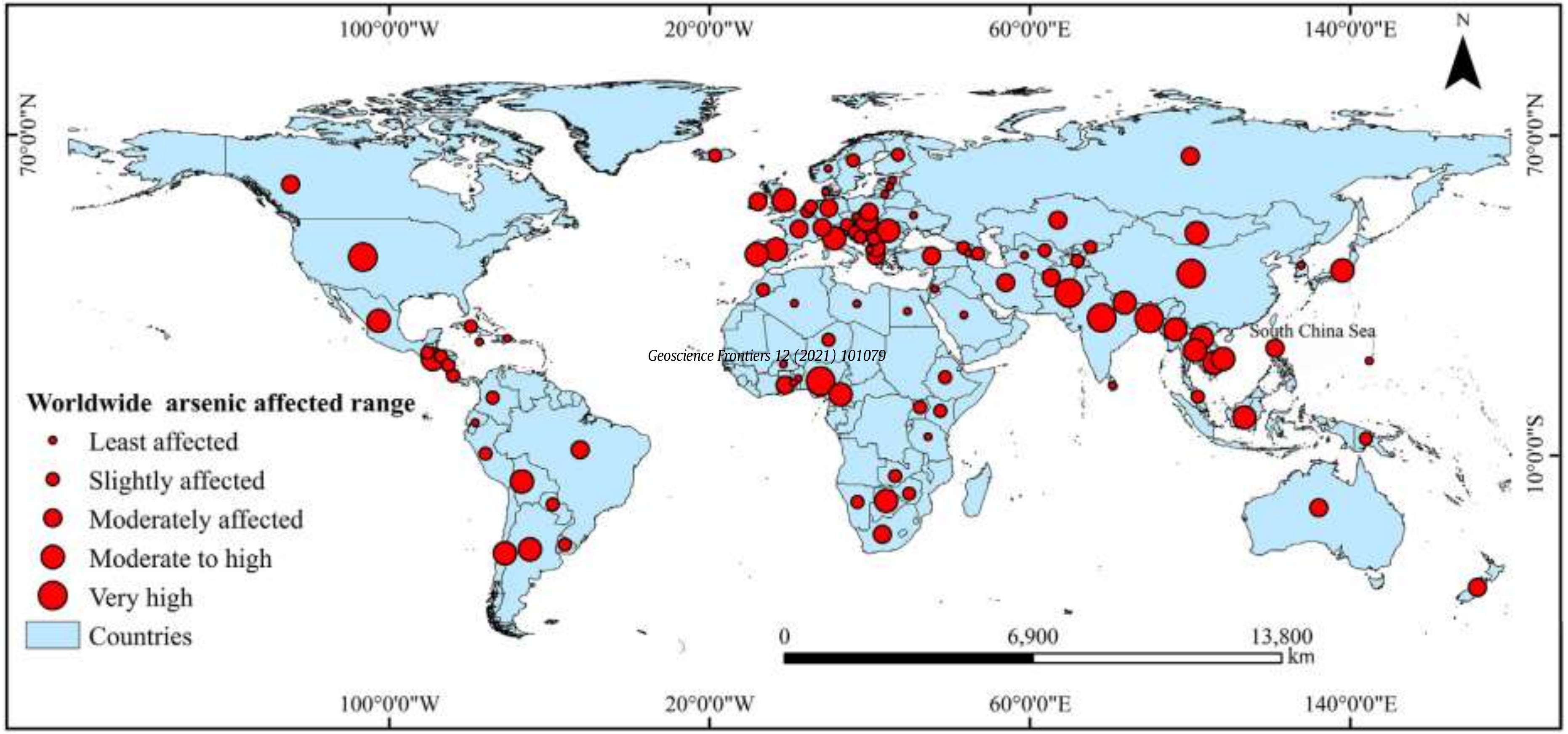
Chennu Sudhakar, et al. *ACS Sustainable Chemistry & Engineering*, 6 (2018) 9990-10000.

# Lab studies




A. Anil Kumar, et. al. *Adv. Mater.*, 29 (2016) 1604260.

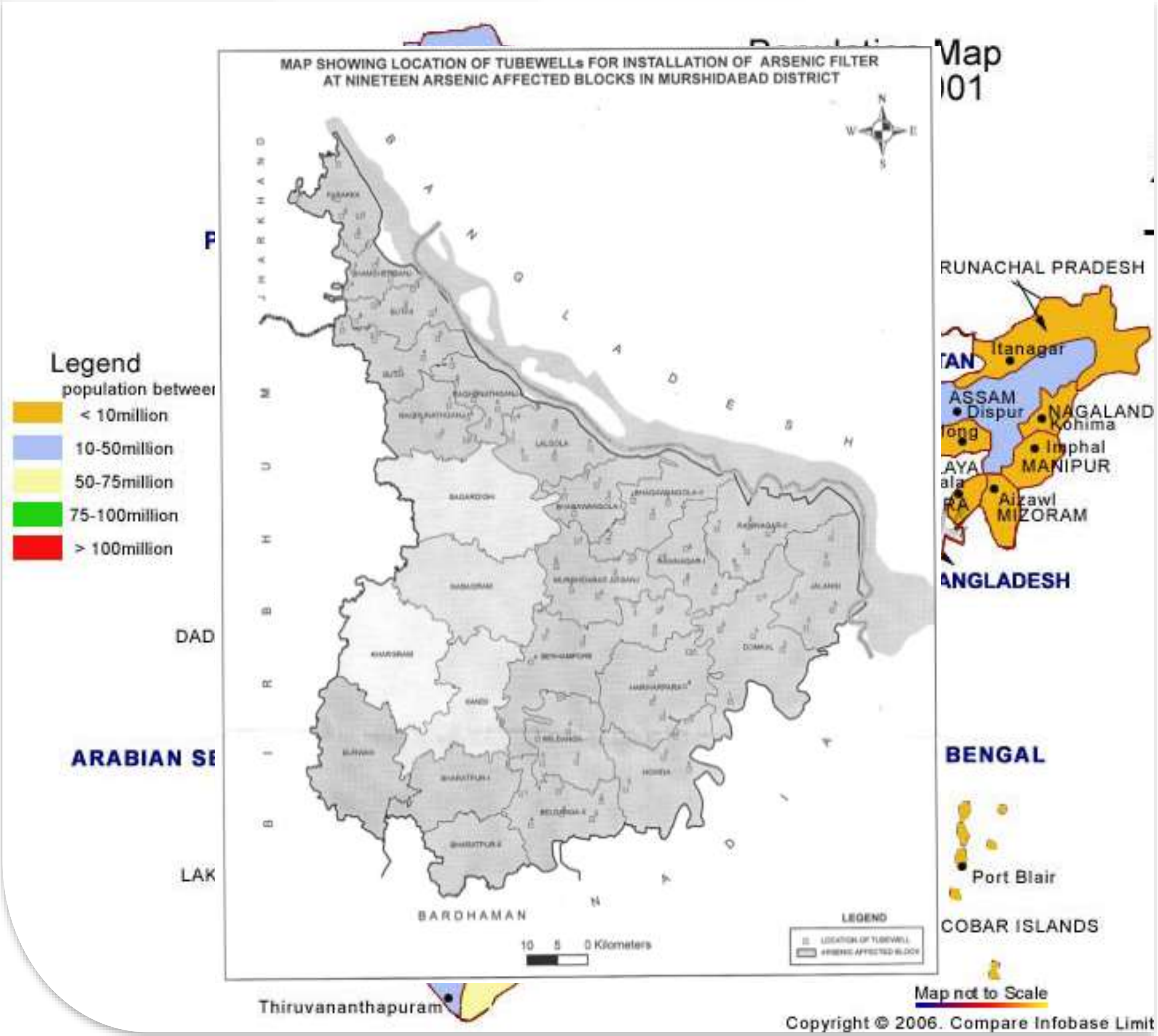
# Arsenic poisoning across the world




E. Shaji, M. Santosh, K. V. Sarath, Pranav Prakash, V. Deepch and B. V. Divya, Geoscience Frontiers, 12 (2021) 101079.

# Initial pilot studies

# Larger pilot studies



# Changing the dynamics in the field


- Existing unit for iron and arsenic removal – 20 $m^3/h$
- Uses activated alumina and iron oxide (old generation of adsorbents)


- Existing unit for iron and arsenic removal – 18 $m^3/h$
- Uses iron oxyhydroxide (new generation of adsorbents)
- Input arsenic concentration: 168 ppb
- Output arsenic concentration: 2 ppb

# Now they are across the country

# 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**

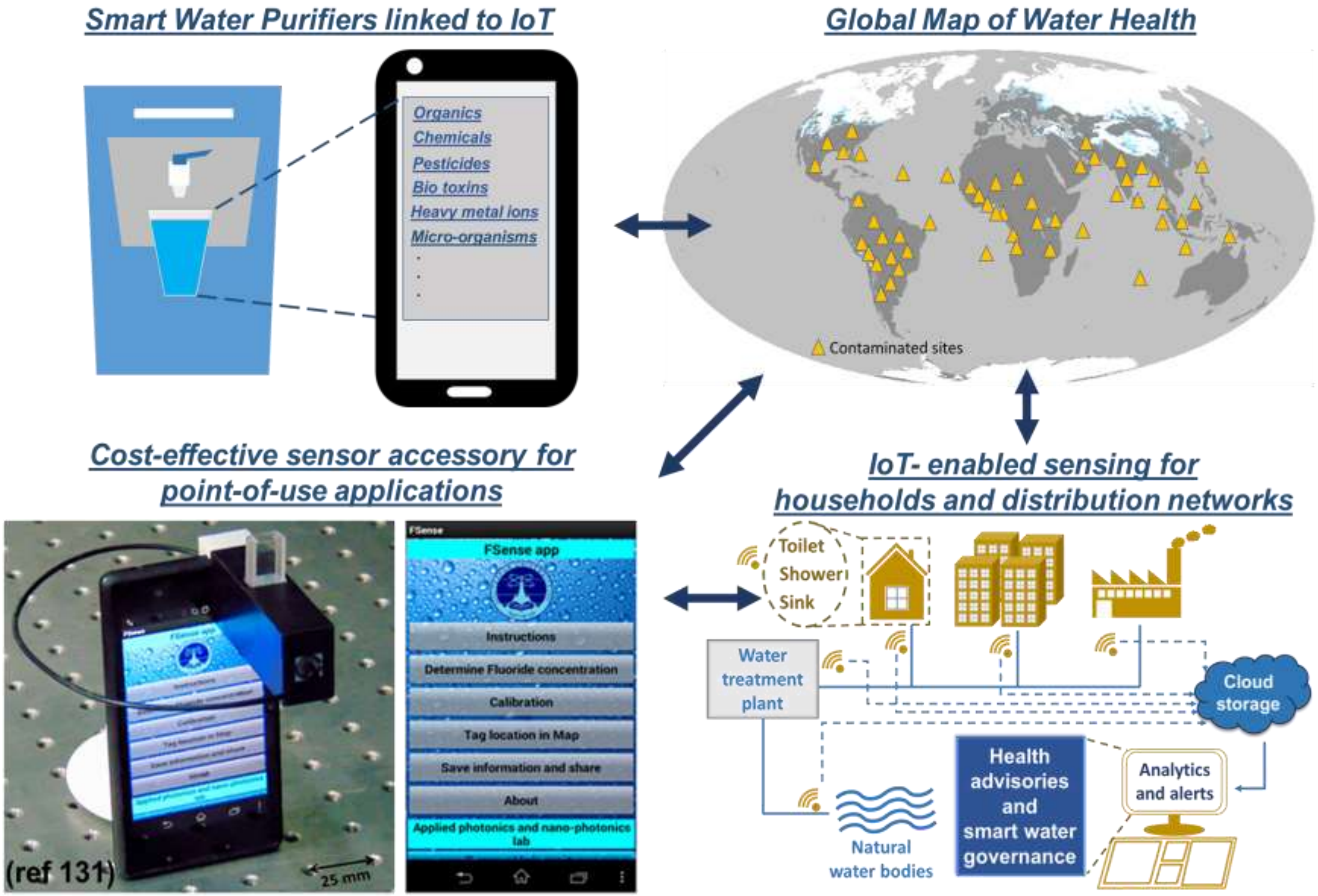
# Clean water at 2.1 paise per litre!

| 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 litr of water | 2.1 Paise per ltr | 0.025 cents |
| 9 | Cost of replacement of media | **1.36** | Rs. per head per day =Media replacement cost per year/365/Design population |
| | | **40.80** | per head per month for 70 LPCD water |

# Waste management

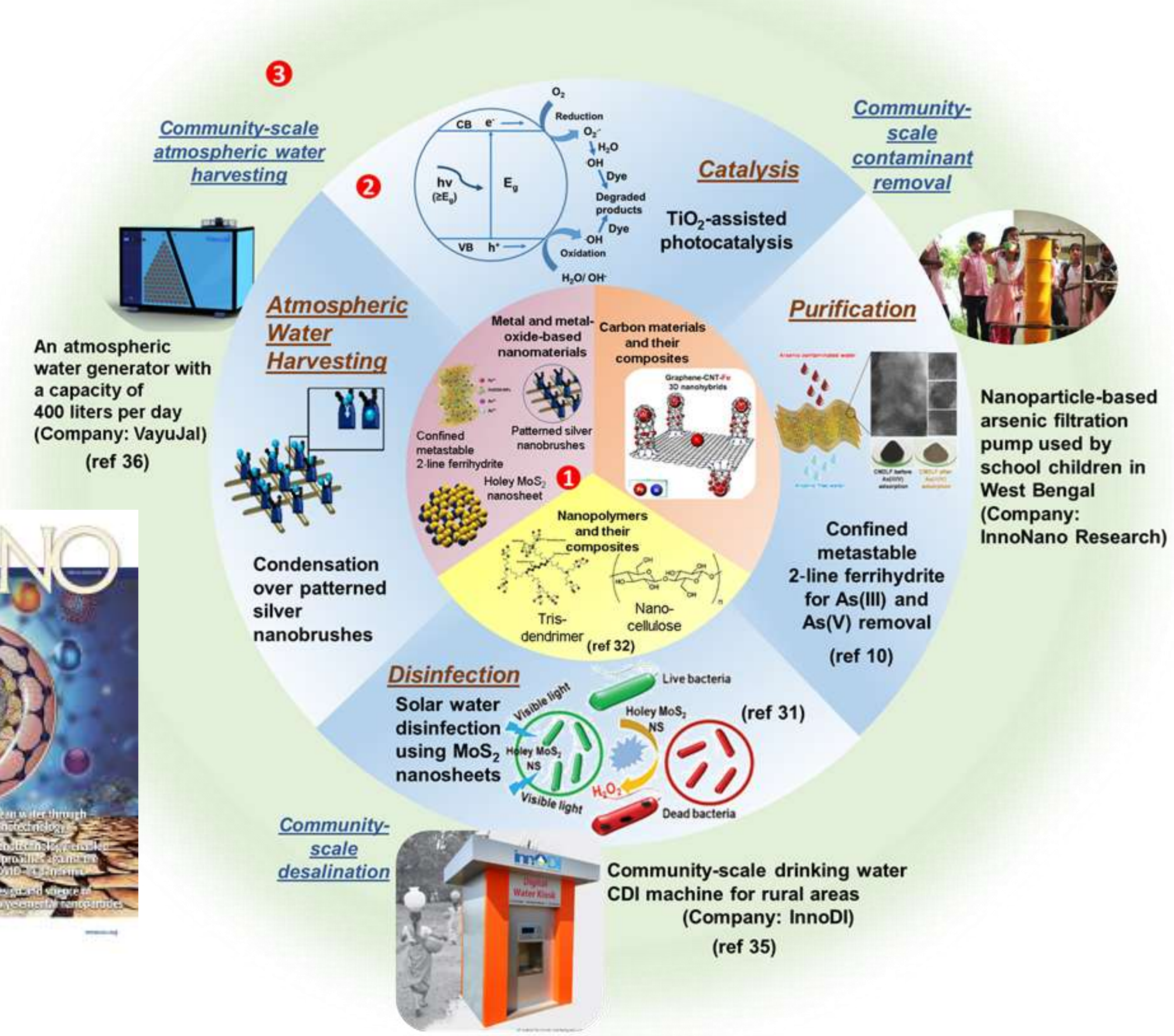
- Adsorbents conform to toxicity characteristic leaching procedure
- Elemental waste goes back to local environment
- Safe disposal of arsenic (or any other) laden waste
- Additional protection could be considered, if necessary
- Exploring viable uses

# Smart water purifiers and big data




Ankit Nagar and T. Pradeep 14(2020). *ACS Nano*, 6420-6435

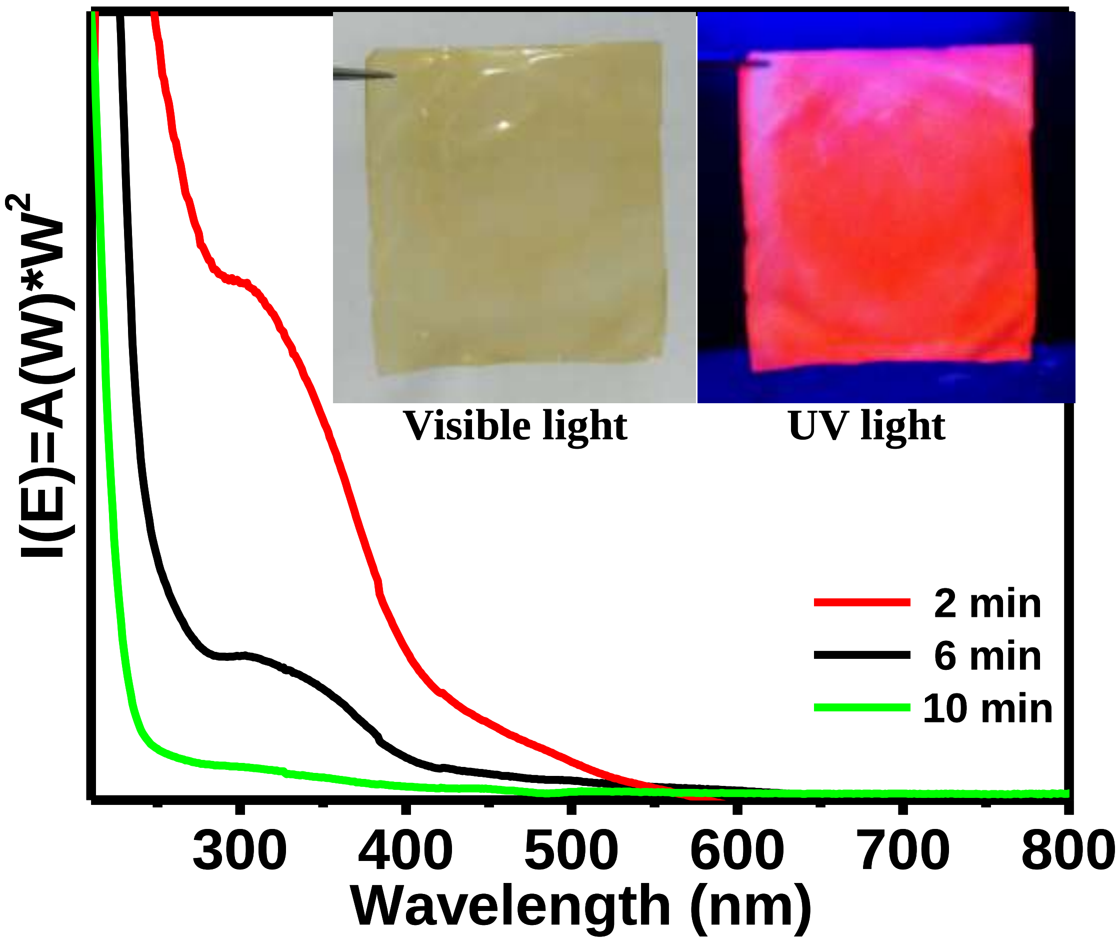
# Evolution of materials to products





Ankit Nagar and T. Pradeep, *ACS Nano* 14 (2020) 6420-6435.

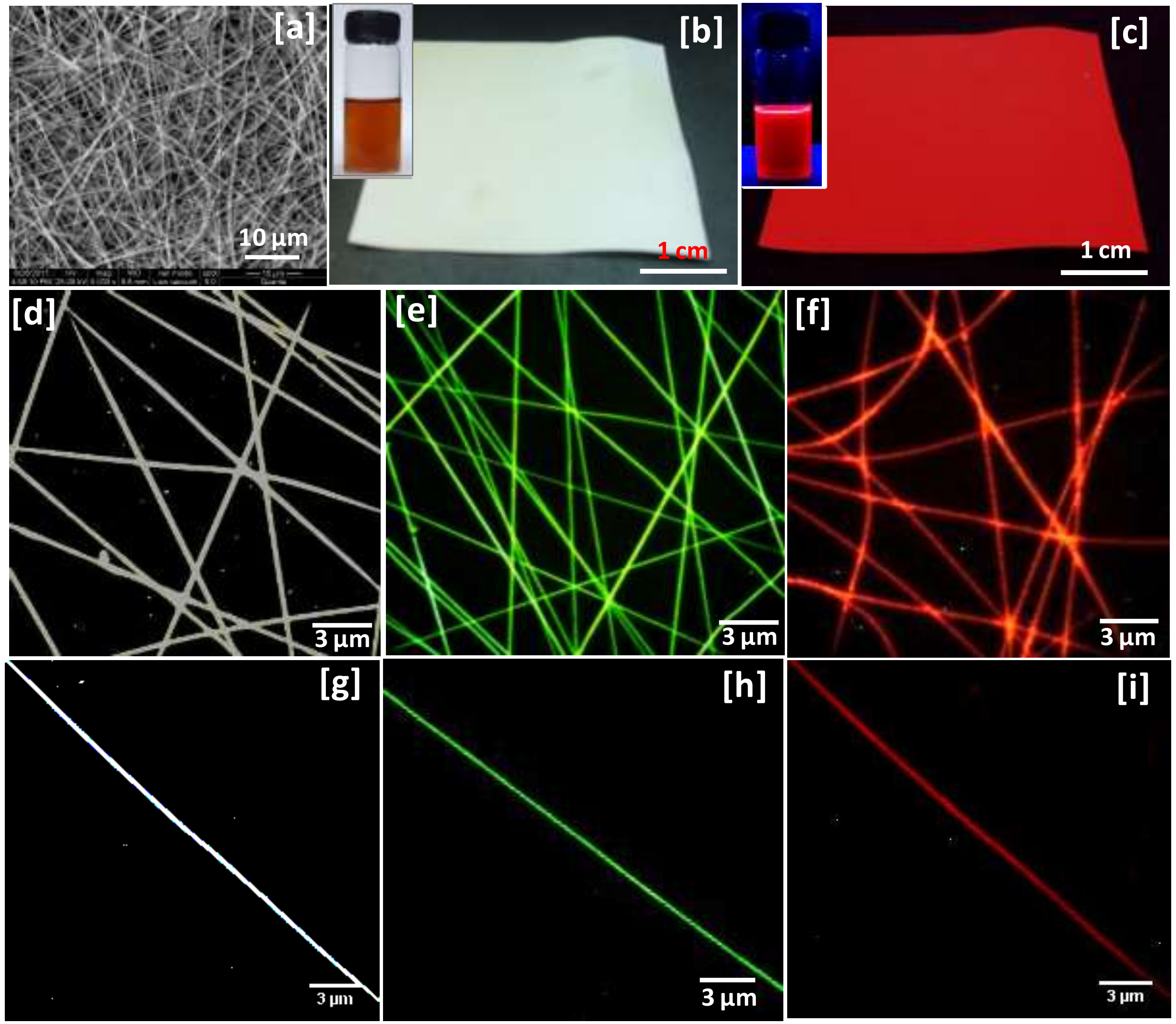
# Cluster-based metal ion sensing




Decrease in the absorption of $Au_{15}$ as a biofilm is dipped into the cluster solution. Inset: Free standing quantum cluster loaded film in visible light and UV light.

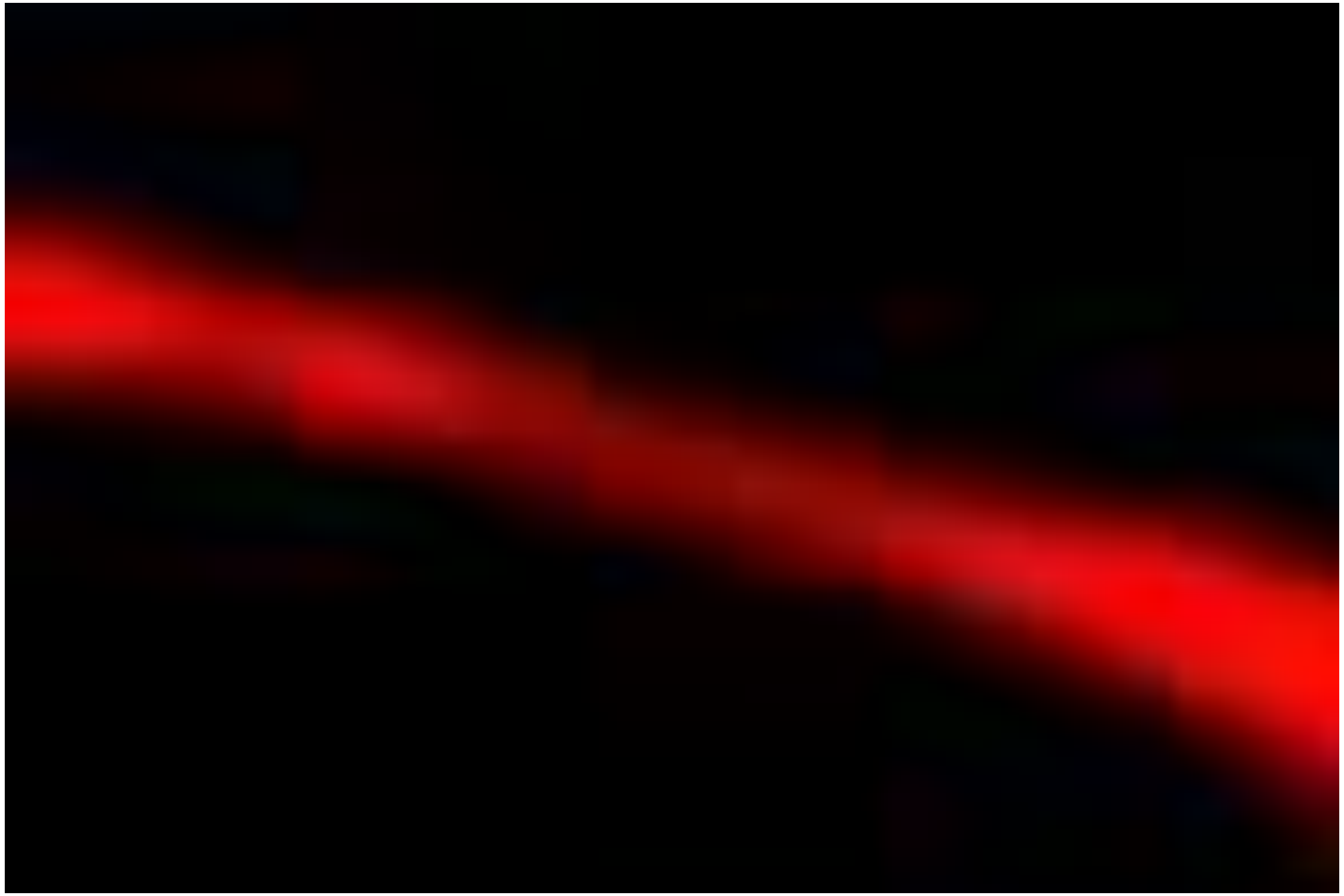
Anu George et al. *ACS Applied Materials & Interfaces*, 2012

# Approaching detection limits of tens of $Hg^{2+}$

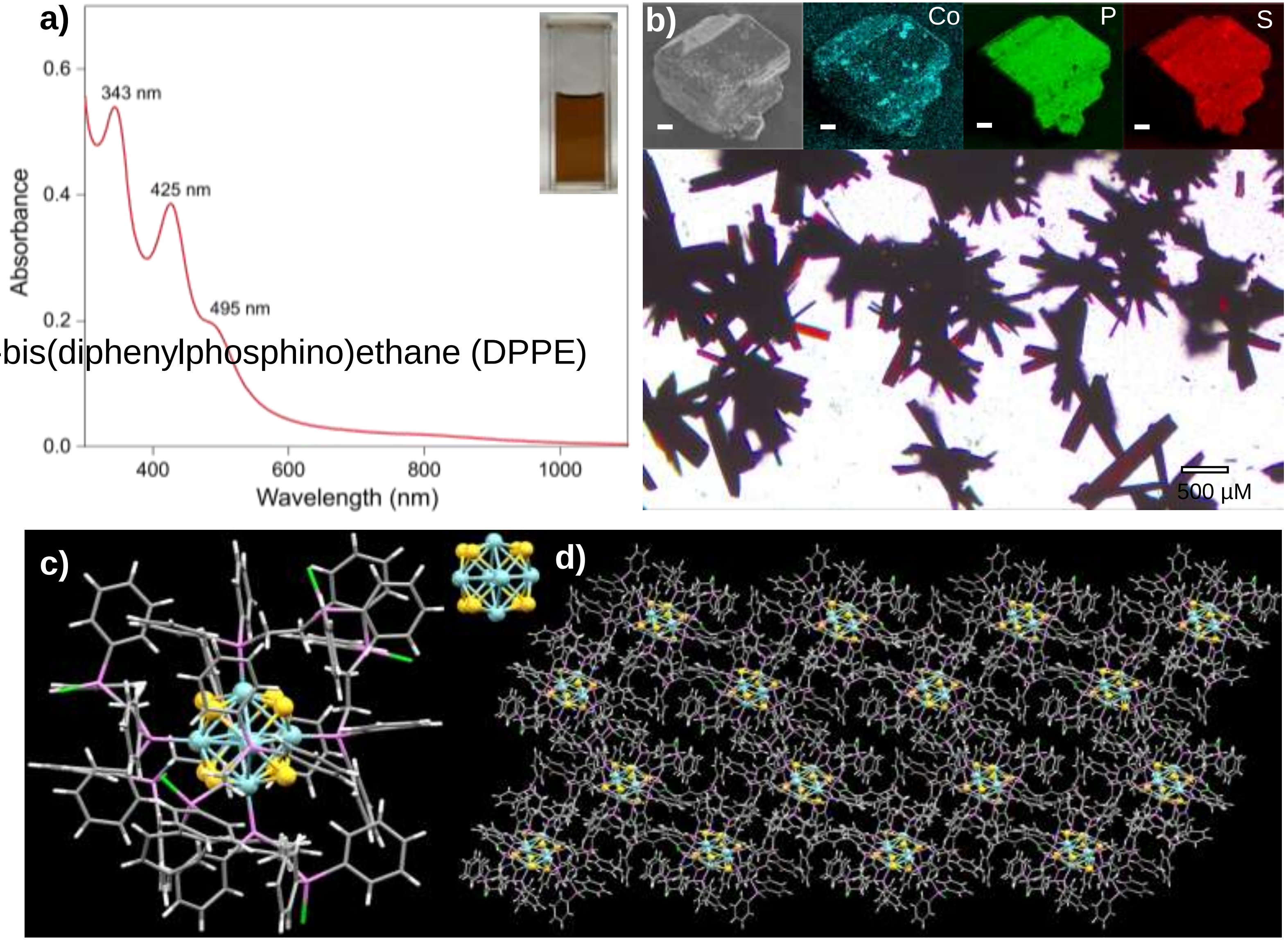



Atanu Ghosh et al. Anal. Chem. 2014.

# Mercury quenching experiment using nanofiber

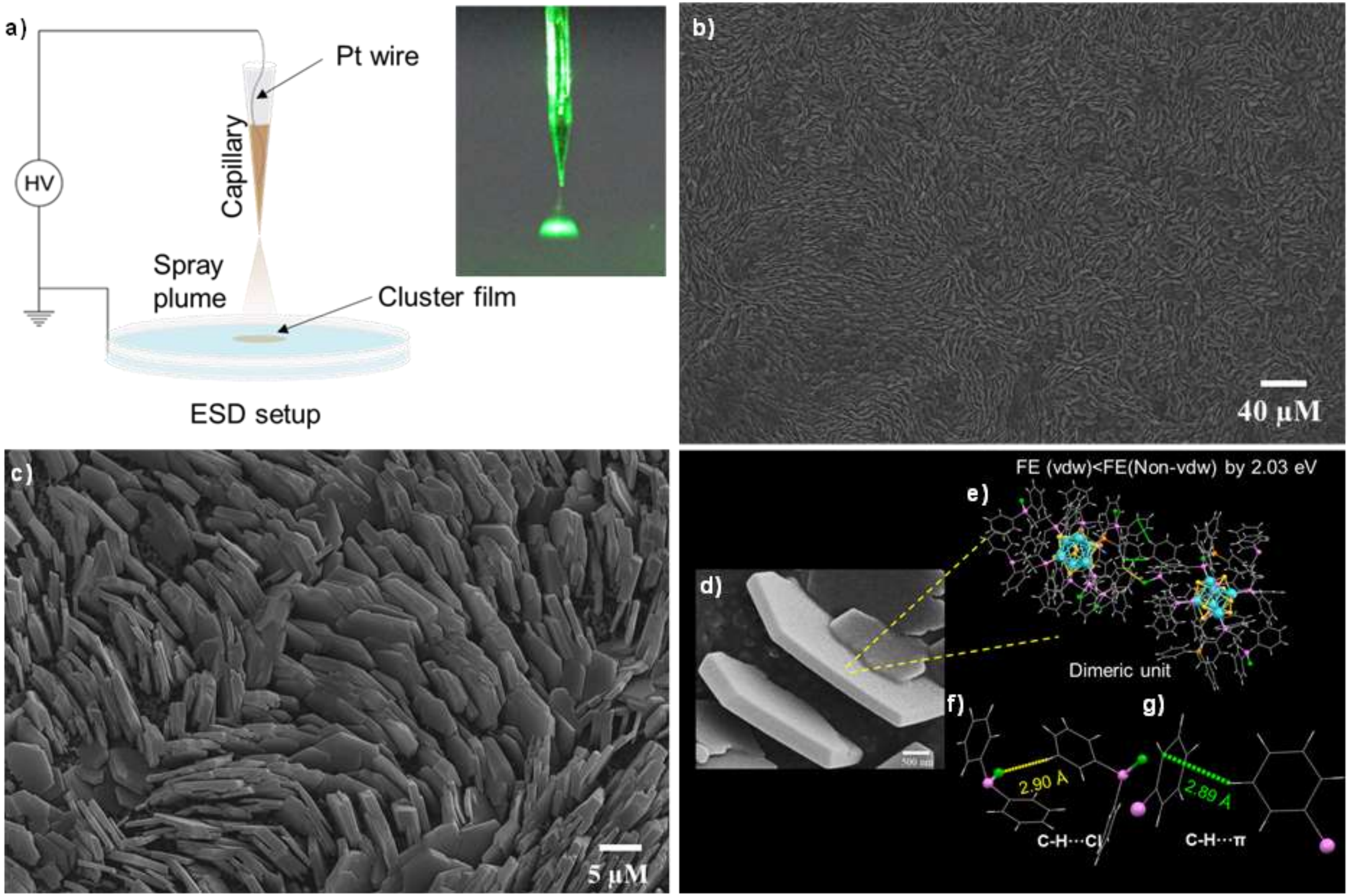


# New electrodes - Aligned nanoplates of $Co_6S_8$

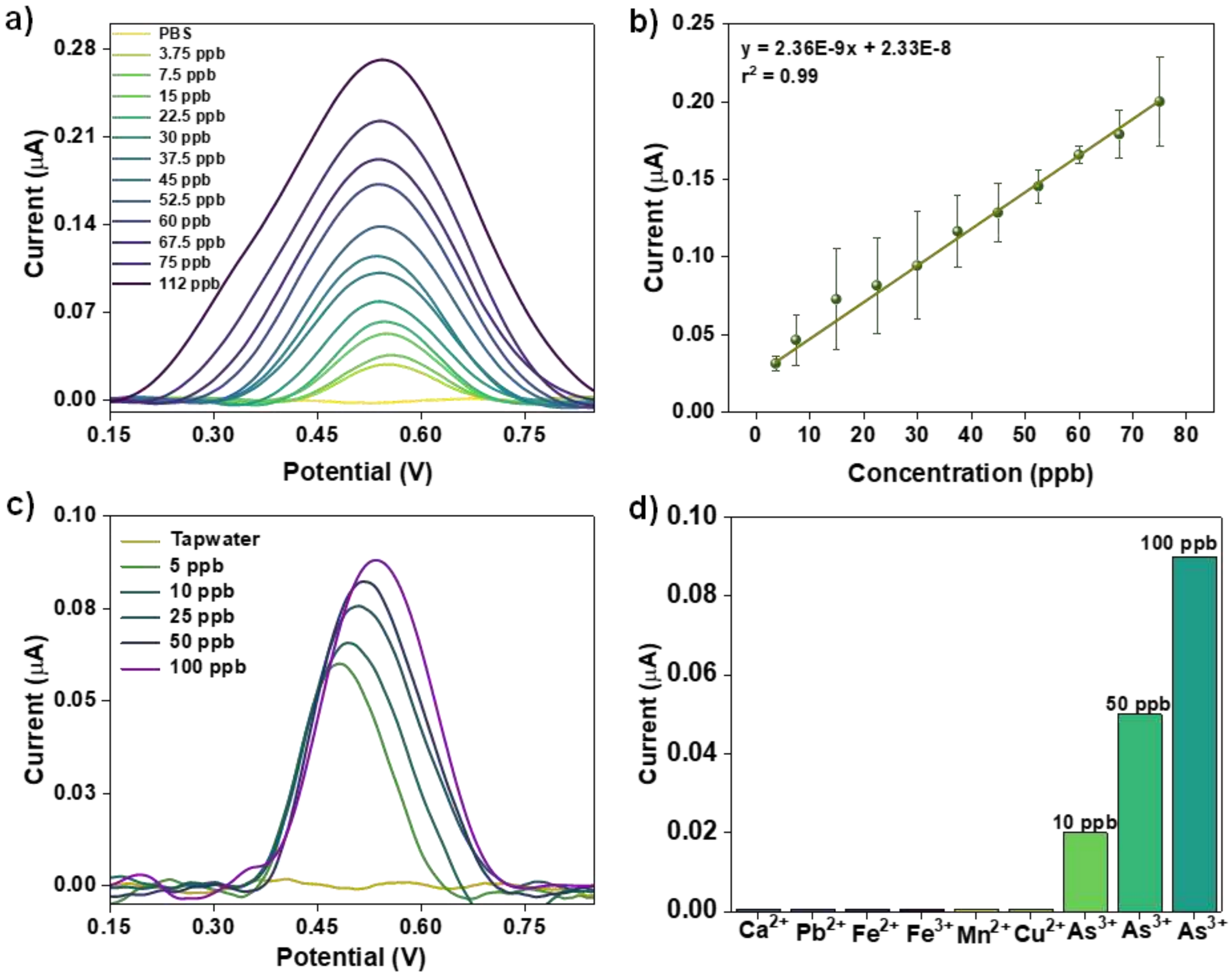



1,2-bis(diphenylphosphino)ethane (DPPE)

# Electrospray deposition

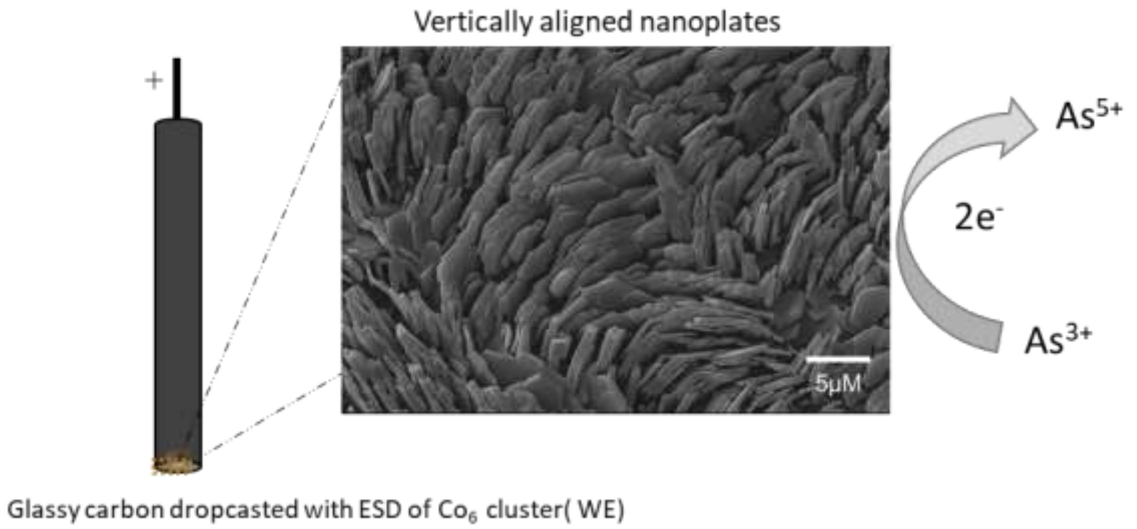


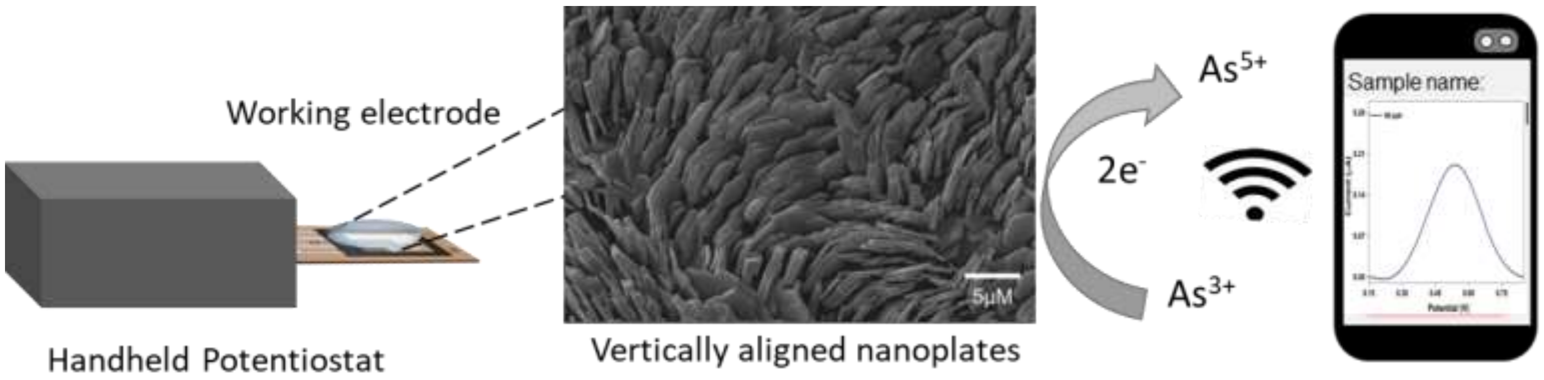
# Sensing



a)
PBS
3.75 ppb
7.5 ppb
15 ppb
22.5 ppb
30 ppb
37.5 ppb
45 ppb
52.5 ppb
60 ppb
67.5 ppb
75 ppb
112 ppb
Current (μA)
Potential (V)
b)
y = 2.36E-9x + 2.33E-8
r² = 0.99
Current (μA)
Concentration (ppb)
c)
Tapwater
5 ppb
10 ppb
25 ppb
50 ppb
100 ppb
Current (μA)
Potential (V)
d)
100 ppb
50 ppb
10 ppb
Current (μA)
Ca2+ Pb2+ Fe2+ Fe3+ Mn2+ Cu2+ As3+ As3+ As3+

# Working electrode




Anagha Jose et al. *ACS Materials Lett.*, 5 (2023) 893–899.

# Water that Heals

A TRAVELOGUE

a SURESH MENON film

# Conclusions

Affordable clean water with advanced materials is possible.
Such technologies are implemented at scale.
More work is needed to address all the relevant contaminants at scale.
Advanced materials can also lead to affordable sensors.

Affordable, inclusive, sustainable and contextual excellence

The AMRIT Team, 2013


International Centre for Clean Water

# People’s Water Data

**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, Tanmayaa Nayak, Sonali Seth…

**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:**

**PhD Theses:** Bindhu Varughese, M. R. Resmi, M. Venkataramanan, N. Sandhyarani, R. Selvan, A. Sreekumaran Nair, M. J. Rosemary, Renjis T. Tom, C. Subramaniam, Jobin Cyriac, V. R. Rajeev Kumar, D. M. David Jeba Singh, Akshaya Kumar Samal, E. S. Shibu, M. A. Habeeb Muhammed, P. R. Sajanlal, T. S. Sreeprasad, J. Purushothaman, T. Udayabhaskararao, M. S. Bootharaju, Soumabha Bag, Robin John, Kamalesh Chaudhari, Ammu Mathew, Indranath Chakraborty, Radha Gobinda Bhuin, Ananya Baksi, Amitava Srimony, Anirban Som, Rabin Rajan Methikkalam, K. R. Krishnadas, Soujit Sengupta, Depanjan Sarkar, Atanu Ghosh, Rahul Narayanan, Avijit Baidya, Shridevi Bhat, Papri Chakraborty, Swathy Jakka Ravindran, C. K. Manju, Abhijit Nag, S. Vidhya, Jyoti Sarita Mohanty, Debasmita Ghosh, Jyotirmoy Ghosh, Md. Bodiuzzaman, Biswajit Mondal, Tripti Ahuja, Esma Khatun, Krishnan Swaminathan, K. S. Sugi, Amrita Chakraborty, Sudhakar Chennu, Sritama Mukherjee, Madhuri Jash, Sandeep Bose, Md. Rabiul Islam, Pallab Basuri, Mohd Azhardin Ganayee, Tanvi Gupte, Ankit Nagar, Srikrishnarka Pillalamarri, Arijit Jana, Paulami Bose, Gaurav Viswakarma, Vishal Kumar, Jayoti Roy, A. Anil Kumar, Jenifer Shantha Kumar

**MS Theses:** Ananthu Mahedranath, Ramesh Kumar Soni

>25 Post-doctoral fellows, >130 masters students and visitors

# Indian Institute of Technology Madras

Bhaskar Ramamurthi/V. Kamakoti

Associate Editor
ACS Sustainable Resource Management

Pradeep Research Group

Thematic Unit of Excellence