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Research & Impact: My Story

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

Thalappil Pradeep
Institute Professor, IIT Madras
pradeep@iitm.ac.in
<https://pradeepresearch.org>

Professor-in-charge



International Centre for Clean Water





Lost in the countryside

Image from Wikipedia

Books and roots

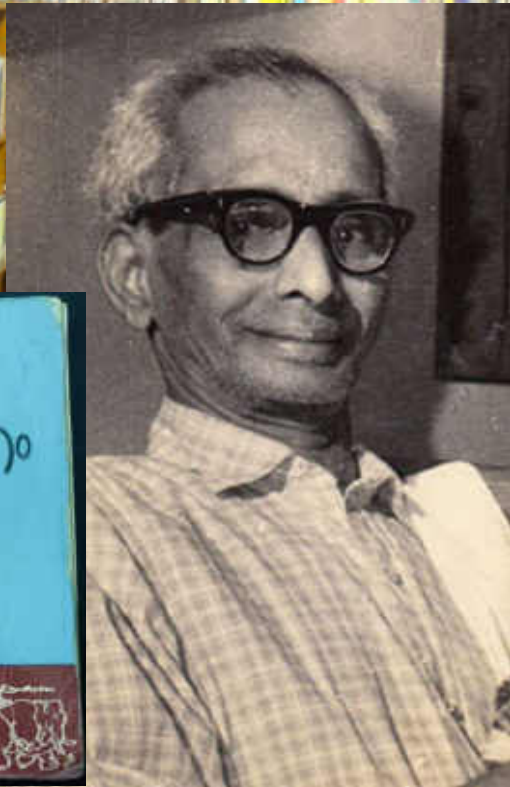


Image from Wikipedia



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

Water is the most important inheritance of our planet



From S. Vishwanath

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World's first nanochemistry-based water purifier

RSC | Advancing the
Chemical Sciences
Chemistry World

Pesticide filter debuts in India

20 April 2007

Kilipati 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. Jayachandrab Reddy, a technical consultant to the company, expects the first 1000 units to be available to-door from late May.

Our pesticide filter is an offshoot of basic research on the chemistry of nanoparticles. The IIT Chennai team led by the team at IIT Chennai led Chemistry World. He and his student Sreenivasan have discovered in 2003 that nanoparticles such as carbon nanotubes (CNTs) completely break down into metal ions and amorphous carbon upon reaction with gold and silver nanoparticles.

Pradeep said this prompted them to extend their study to include organochlorine and organophosphorus 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 that gold and silver nanoparticles loaded on alumina were more able to completely remove endosulfan, malathion and chlorpyrifos - three pesticides that have been found in drinking water supplies.

Use and recycle

The filter

Pradeep

Pradeep

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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 malathion and chlorpyrifos 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

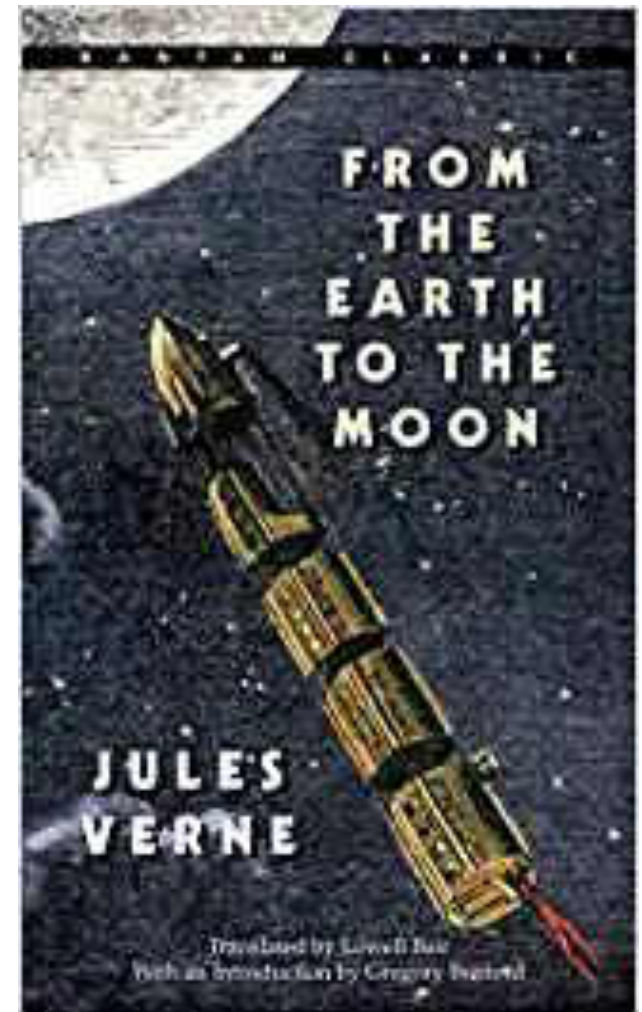


Water is at the centre of action



There is water in everything we do.

Our dreams
become reality
with materials





Atomic number: 6
Symbol: C
Name: Carbon
Ground-state Configuration: $1s^2 2s^2 2p^2$
Ground-state level: $2p$
Standard Atomic Weight: 12.011
Ionization Energy (eV): 11.2605

¹ Based upon ^{12}C . Reported values from CIAAW, 2015.
² Reported values from NIST, 2015.

Atomic weight exceptions:

(¹) Mass number of longest lived isotope reported.

² The IUPAC conventional atomic weight is reported.

For more information including the standard IUPAC atomic weight expressed as an interval, visit ciaww.org/atomic-weights.htm.

Water is incomplete without this table

Source:
Intechopen

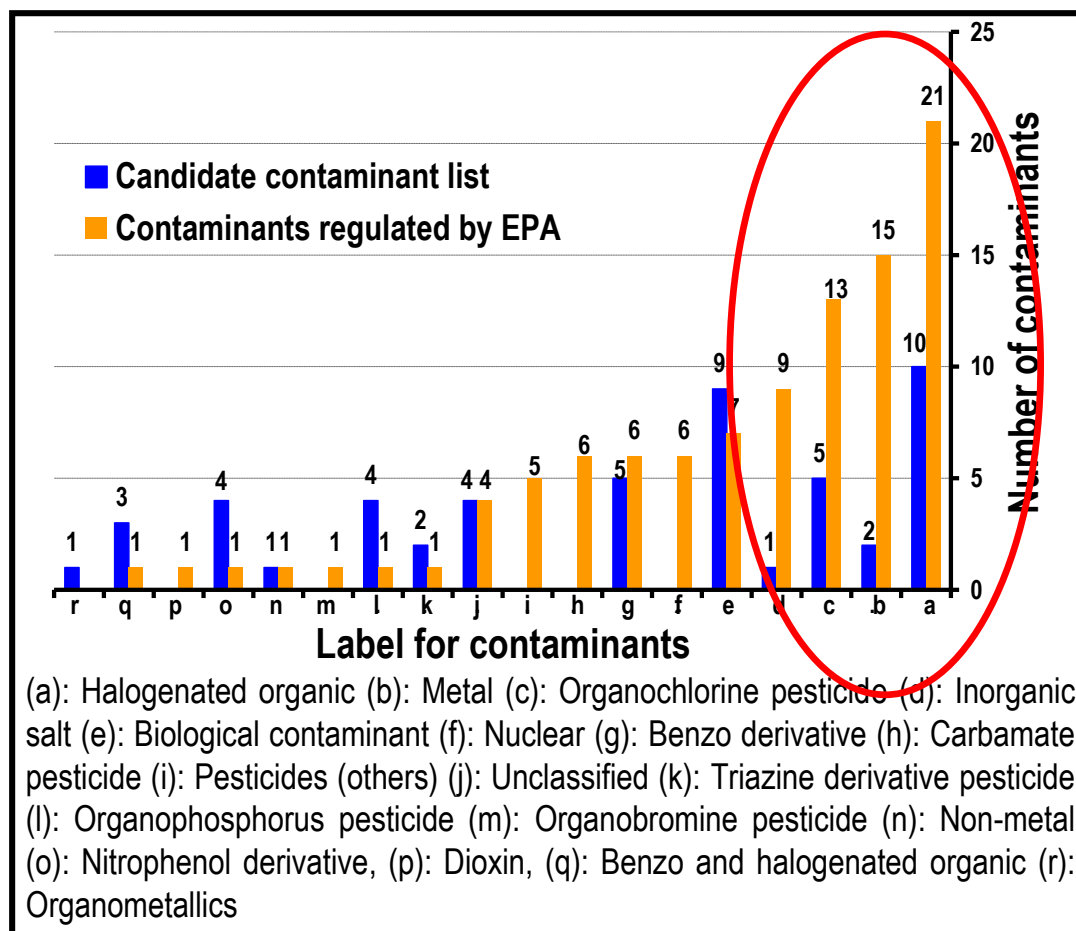
1 H Hydrogen 1.008 1s 13.6184																		2 He Helium 4.00302 1s ² 23.5174																		3 B Boron 10.81 1s ² 2s ² 2p ¹ 8.2983																		4 C Carbon 12.011 1s ² 2s ² 2p ² 11.3803																		5 N Nitrogen 14.007 1s ² 2s ² 2p ³ 14.5341																		6 O Oxygen 15.999 1s ² 2s ² 2p ⁴ 13.8131																		7 F Fluorine 18.9984032 1s ² 2s ² 2p ⁵ 17.4221																		8 Ne Neon 20.1797 1s ² 2s ² 2p ⁶ 21.5645																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
11 Na Sodium 22.98976928 [Ne] 3s ¹ 5.1391																		12 Mg Magnesium 24.304 [Ne] 3s ² 7.38462																		13 Al Aluminum 26.9815386 [Ne] 3s ² 3p ¹ 5.9893																		14 Si Silicon 28.0855 [Ne] 3s ² 3p ² 8.4517																		15 P Phosphorus 30.973762 [Ne] 3s ² 3p ³ 10.4867																		16 S Sulfur 32.06 [Ne] 3s ² 3p ⁴ 10.0001																		17 Cl Chlorine 35.453 [Ne] 3s ² 3p ⁵ 13.9816																		18 Ar Argon 39.948 [Ne] 3s ² 3p ⁶ 15.7596																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
19 K Potassium 39.0983 [Ar] 4s ¹ 4.3407																		20 Ca Calcium 40.078 [Ar] 4s ² 6.1132																		21 Sc Scandium 44.955912 [Ar] 3d ¹ 4s ² 6.345																		22 Ti Titanium 47.88 [Ar] 3d ² 4s ² 6.345																		23 V Vanadium 50.9415 [Ar] 3d ³ 4s ² 6.345																		24 Cr Chromium 51.9961 [Ar] 3d ⁵ 4s ¹ 7.7694																		25 Mn Manganese 54.938044 [Ar] 3d ⁵ 4s ² 7.4334																		26 Fe Iron 55.845 [Ar] 3d ⁶ 4s ² 7.646																		27 Co Cobalt 58.933194 [Ar] 3d ⁷ 4s ² 7.7322																		28 Ni Nickel 58.6934 [Ar] 3d ⁸ 4s ² 7.6398																		29 Cu Copper 63.546 [Ar] 3d ¹⁰ 4s ¹ 7.727																		30 Zn Zinc 65.38 [Ar] 3d ¹⁰ 4s ² 7.932																		31 Ga Gallium 69.723 [Ar] 3d ¹⁰ 4s ² 4p ¹ 5.7884																		32 Ge Germanium 72.630 [Ar] 3d ¹⁰ 4s ² 4p ² 5.7884																		33 As Arsenic 74.9216 [Ar] 3d ¹⁰ 4s ² 4p ³ 5.7884																		34 Se Selenium 78.96 [Ar] 3d ¹⁰ 4s ² 4p ⁴ 5.7884																		35 Br Bromine 79.904 [Ar] 3d ¹⁰ 4s ² 4p ⁵ 10.8376																		36 Kr Krypton 83.798 [Ar] 3d ¹⁰ 4s ² 4p ⁶ 14.9996																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
37 Rb Rubidium 85.4678 [Kr] 5s ¹ 4.1771																		38 Sr Strontium 87.62 [Kr] 5s ² 5.6849																		39 Y Yttrium 88.90584 [Kr] 4d ¹ 5s ² 6.345																		40 Zr Zirconium 91.224 [Kr] 4d ² 5s ² 6.345																		41 Nb Niobium 92.90638 [Kr] 4d ⁴ 5s ¹ 6.7589																		42 Mo Molybdenum 95.94 [Kr] 4d ⁵ 5s ¹ 7.3924																		43 Tc Technetium 98 [Kr] 4d ⁵ 5s ² 7.5194																		44 Ru Ruthenium 101.07 [Kr] 4d ⁷ 5s ¹ 7.3924																		45 Rh Rhodium 102.90550 [Kr] 4d ⁸ 5s ¹ 7.4334																		46 Pd Palladium 106.42 [Kr] 4d ¹⁰ 8.3389																		47 Ag Silver 107.8682 [Kr] 4d ¹⁰ 5s ¹ 7.5762																		48 Cd Cadmium 112.414 [Kr] 4d ¹⁰ 5s ² 8.9948																		49 In Indium 114.818 [Kr] 4d ¹⁰ 5s ² 5p ¹ 5.7884																		50 Sn Tin 118.710 [Kr] 4d ¹⁰ 5s ² 5p ² 7.3439																		51 Sb Antimony 121.757 [Kr] 4d ¹⁰ 5s ² 5p ³ 8.6584																		52 Te Tellurium 127.60 [Kr] 4d ¹⁰ 5s ² 5p ⁴ 9.0067																		53 I Iodine 126.90447 [Kr] 4d ¹⁰ 5s ² 5p ⁵ 10.4513																		54 Xe Xenon 131.29 [Kr] 4d ¹⁰ 5s ² 5p ⁶ 12.1298																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
55 Cs Cesium 132.90545196 [Xe] 6s ¹ 3.8933																		56 Ba Barium 137.327 [Xe] 6s ² 5.2117																		57 La Lanthanum 138.90547 [Xe] 5d ¹ 6s ² 5.5789																		58 Ce Cerium 140.12 [Xe] 4f ¹ 6s ² 5.5789																		59 Pr Praseodymium 140.90766 [Xe] 4f ³ 6s ² 5.478																		60 Nd Neodymium 144.242 [Xe] 4f ⁴ 6s ² 5.5238																		61 Pm Promethium 144.9127 [Xe] 4f ⁵ 6s ² 5.5238																		62 Sm Samarium 150.36 [Xe] 4f ⁶ 6s ² 6.437																		63 Eu Europium 151.964 [Xe] 4f ⁷ 6s ² 6.437																		64 Gd Gadolinium 157.25 [Xe] 4f ⁷ 6s ² 6.437																		65 Tb Terbium 158.92535 [Xe] 4f ⁹ 6s ² 6.437																		66 Dy Dysprosium 162.5003 [Xe] 4f ¹⁰ 6s ² 6.437																		67 Ho Holmium 164.93032 [Xe] 4f ¹¹ 6s ² 6.437																		68 Er Erbium 167.259 [Xe] 4f ¹² 6s ² 6.437																		69 Tm Thulium 168.93422 [Xe] 4f ¹³ 6s ² 6.437																		70 Yb Ytterbium 173.054 [Xe] 4f ¹⁴ 6s ² 6.437																		71 Lu Lutetium 174.967 [Xe] 4f ¹⁴ 6s ² 6.437																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
87 Fr Francium 223 [Rn] 7s ¹ 4.0717																		88 Ra Radium 226 [Rn] 7s ² 5.7164																		89 Ac Actinium 227 [Rn] 6d ¹ 7s ² 5.8942																		90 Th Thorium 232.0377 [Rn] 6d ² 7s ² 6.1067																		91 Pa Protactinium 231.03688 [Rn] 5f ² 6d ¹ 7s ² 5.89																		92 U Uranium 238.02891 [Rn] 5f ³ 6d ¹ 7s ² 6.1941																		93 Np Neptunium 237 [Rn] 5f ⁴ 6d ¹ 7s ² 6.2655																		94 Pu Plutonium 244 [Rn] 5f ⁶ 7s ² 6.4194																		95 Am Americium 243 [Rn] 5f ⁷ 7s ² 6.4194																		96 Cm Curium 247 [Rn] 5f ⁸ 7s ² 6.4194																		97 Bk Berkelium 247 [Rn] 5f ⁹ 7s ² 6.4194																		98 Cf Californium 251 [Rn] 5f ¹⁰ 7s ² 6.2817																		99 Es Einsteinium 252 [Rn] 5f ¹¹ 7s ² 6.4194																		100 Fm Fermium 257 [Rn] 5f ¹² 7s ² 6.4194																		101 Md Mendelevium 258 [Rn] 5f ¹³ 7s ² 6.4194																		102 No Nobelium 259 [Rn] 5f ¹⁴ 7s ² 6.4194																		103 Lr Lawrencium 261 [Rn] 5f ¹⁴ 7s ² 7p ¹ 6.4194																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															
104 Rf Rutherfordium 261 [Rn] 5f ¹⁴ 6d ² 7s ² 6.4194																		105 Db Dubnium 262 [Rn] 5f ¹⁴ 6d ³ 7s ² 6.4194																		106 Sg Seaborgium 266 [Rn] 5f ¹⁴ 6d ⁴ 7s ² 7.4																		107 Bh Bohrium 264 [Rn] 5f ¹⁴ 6d ⁵ 7s ² 7.4																		108 Hs Hassium 277 [Rn] 5f ¹⁴ 6d ⁶ 7s ² 7.4																		109 Mt Meitnerium 268 [Rn] 5f ¹⁴ 6d ⁷ 7s ² 7.4																		110 Ds Darmstadtium 271 [Rn] 5f ¹⁴ 6d ⁸ 7s ² 7.4																		111 Rg Roentgenium 281 [Rn] 5f ¹⁴ 6d ⁹ 7s ² 7.4																		112 Cn Copernicium 285 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7.4																		113 Nh Nihonium 284 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ¹ 7.4																		114 Fl Flerovium 289 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ² 7.4																		115 Mc Moscovium 288 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ³ 7.4																		116 Lv Livermorium 293 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁴ 7.4																		117 Ts Tennessine 294 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁵ 7.4																		118 Og Oganesson 294 [Rn] 5f ¹⁴ 6d ¹⁰ 7s ² 7p ⁶ 7.4																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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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)

Future of water purification: An enigma with some pointers



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).

Affordable clean water is a problem of advanced materials

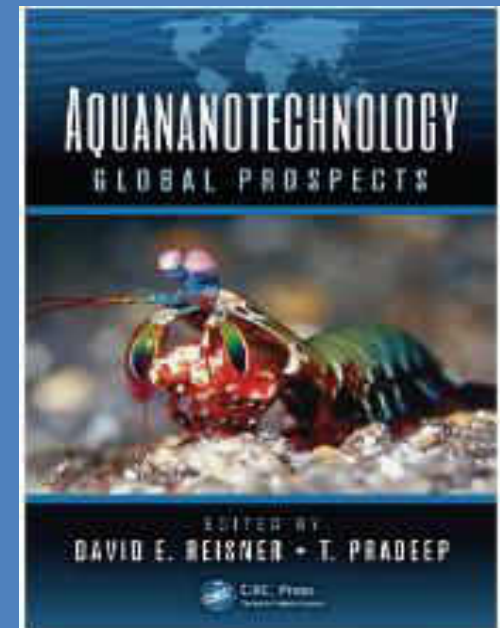
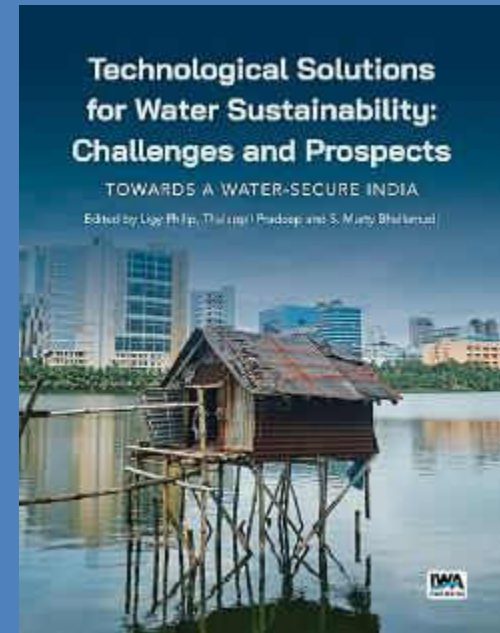
New adsorbents

New sensors

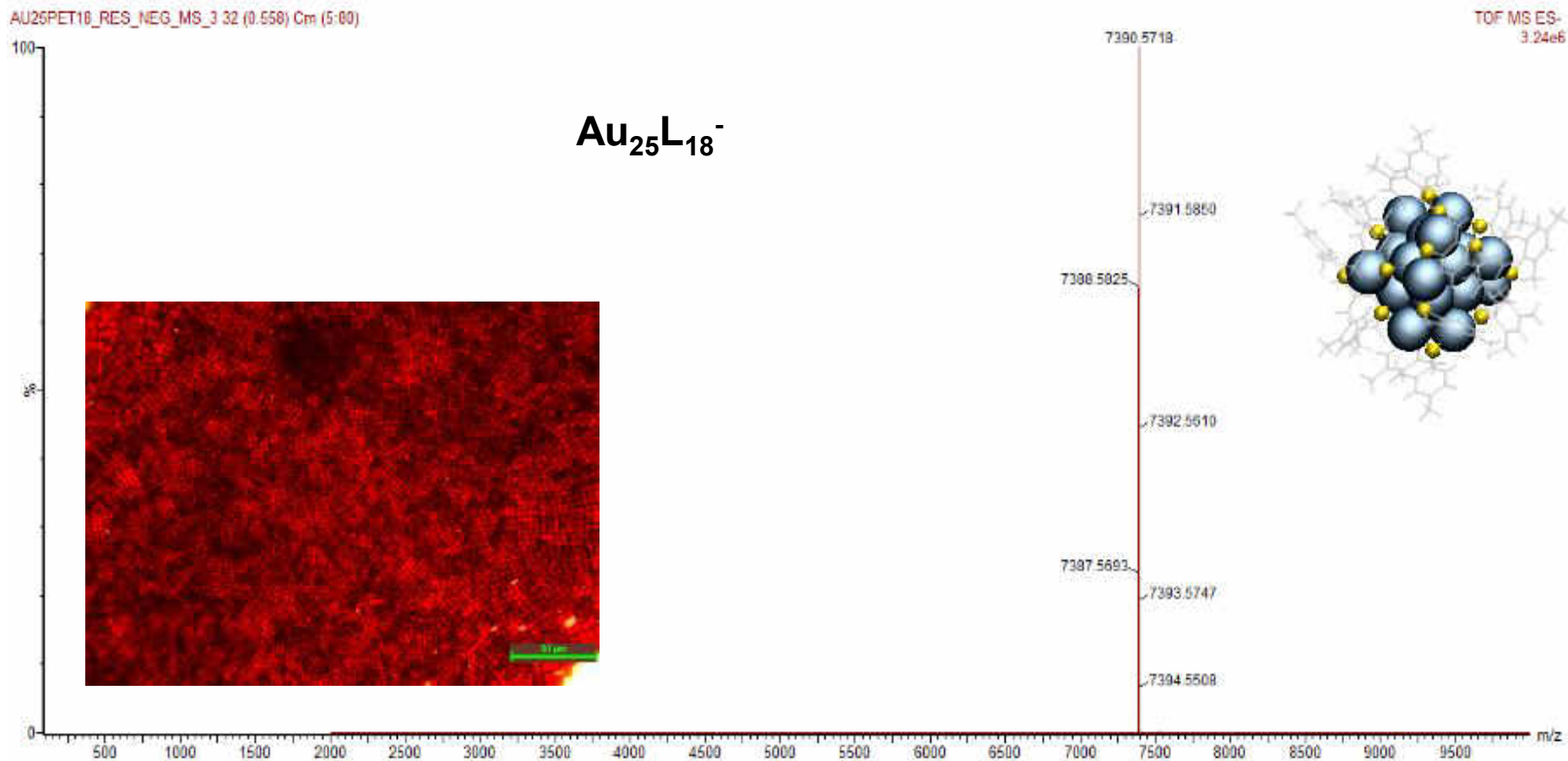
New catalysts

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 promising 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 of biopolymers to provide 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 access to clean drinking water 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.



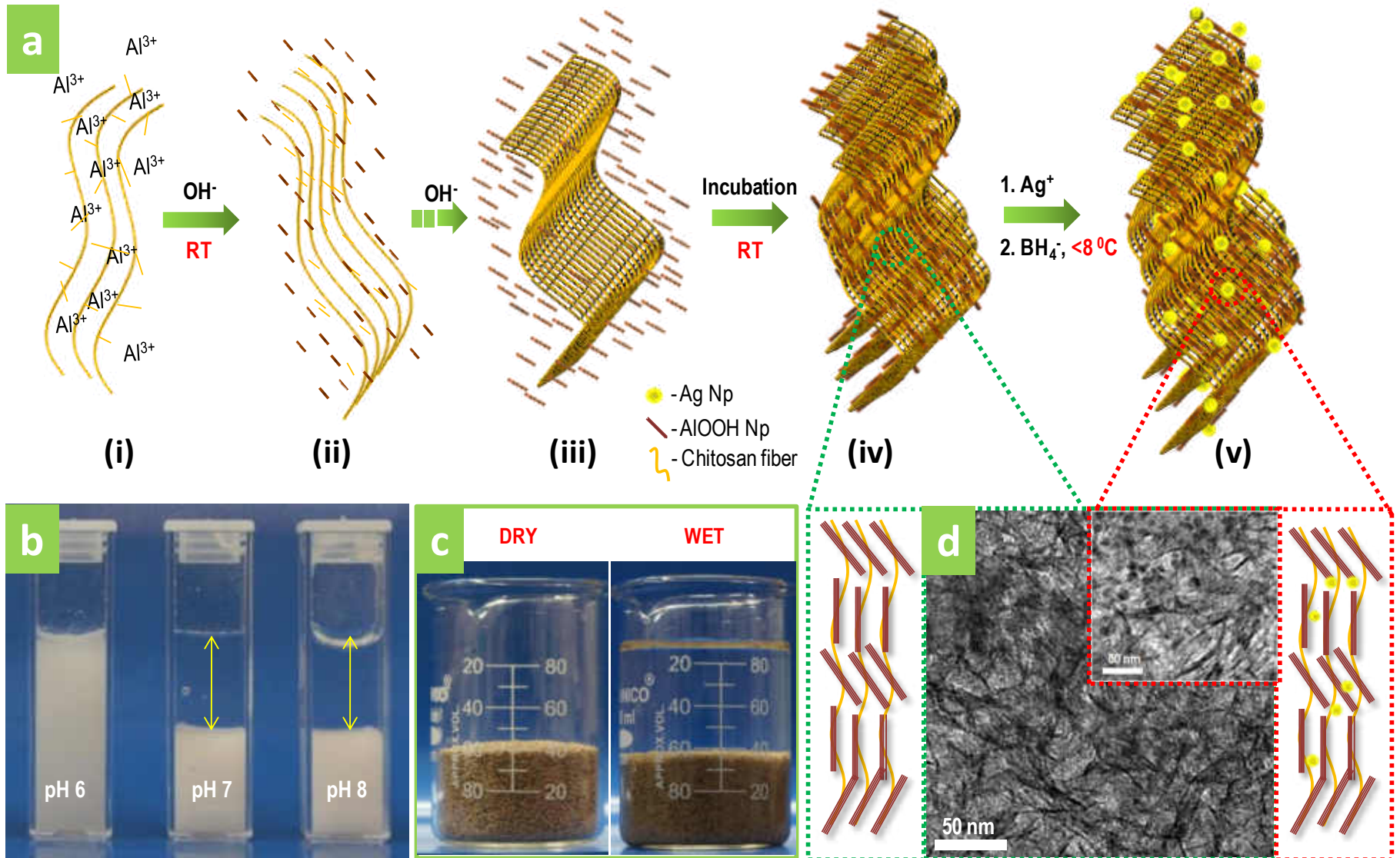
1, Chennai 600 036, India

Received for review November 21, 2012

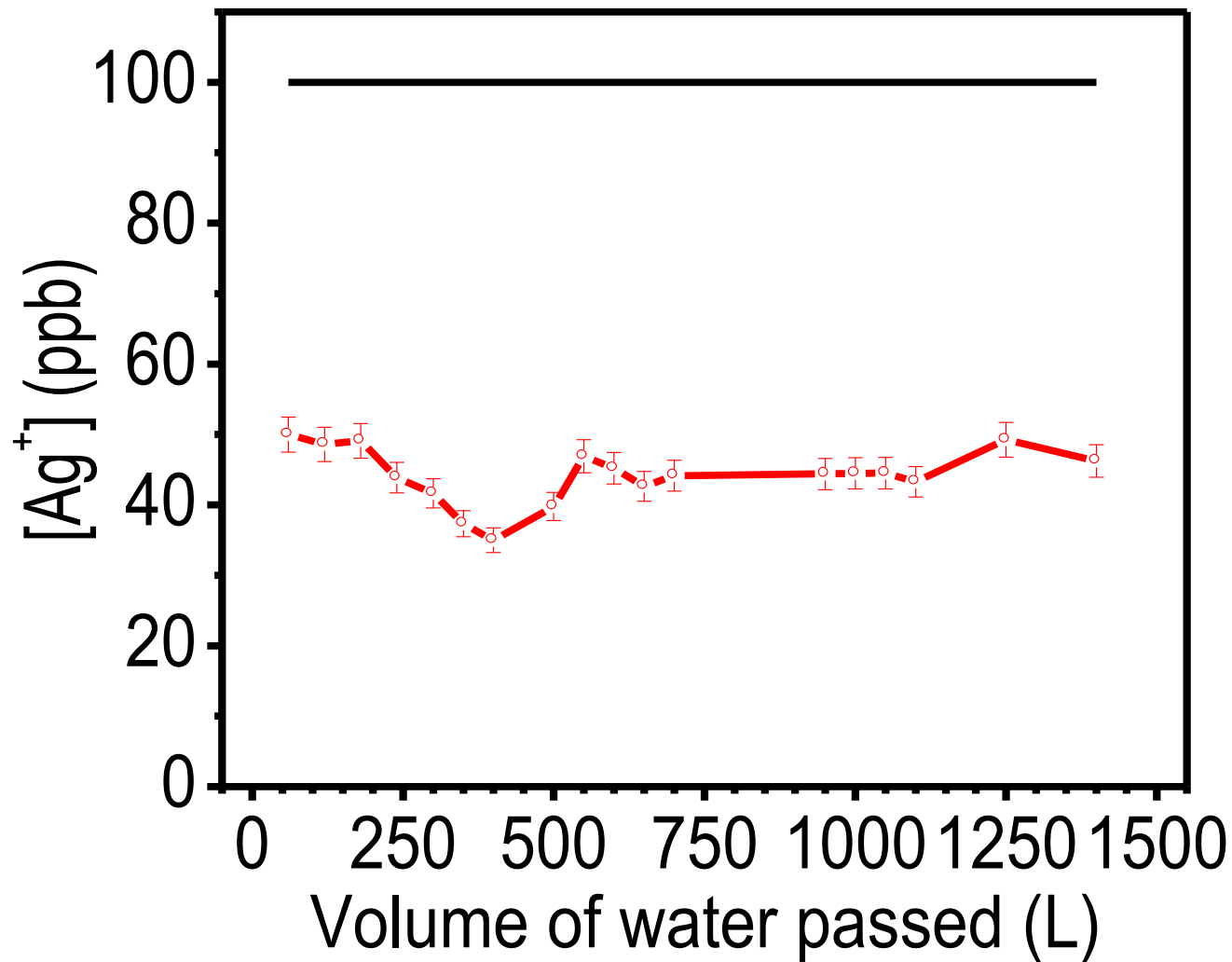
able; and (c) continued retention of the material is difficult. A unique family of nanocrystalline granular composite materials prepared through an aqueous route. The retention is attributed to abundant α -chitosan, which help in the crystallization and also ensure strong covalent bonding to the matrix. 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 that can purify water. We demonstrate an affordable water purifier that can purify water. We demonstrate an affordable water purifier that can purify water.

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

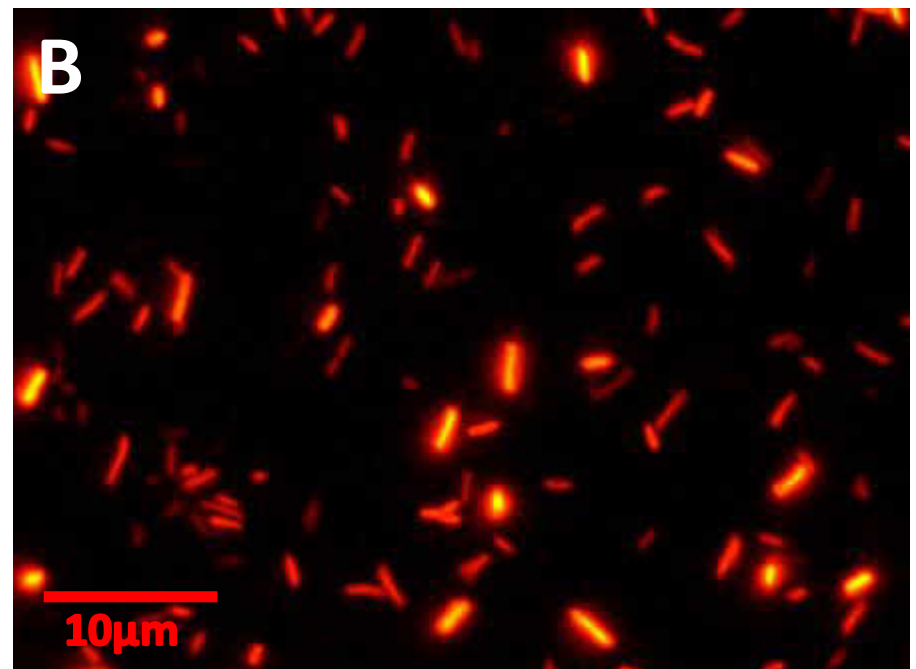
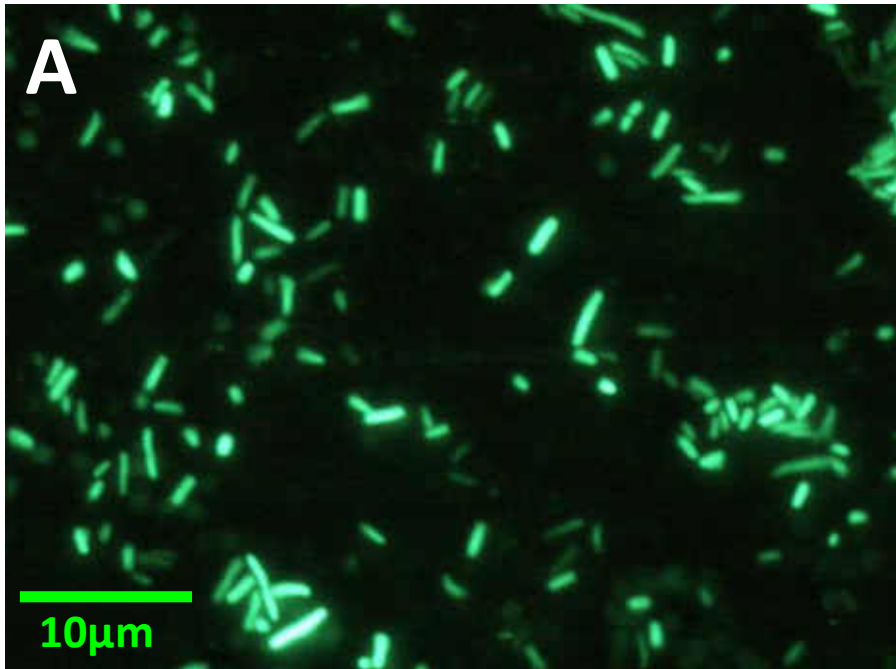
How to make?



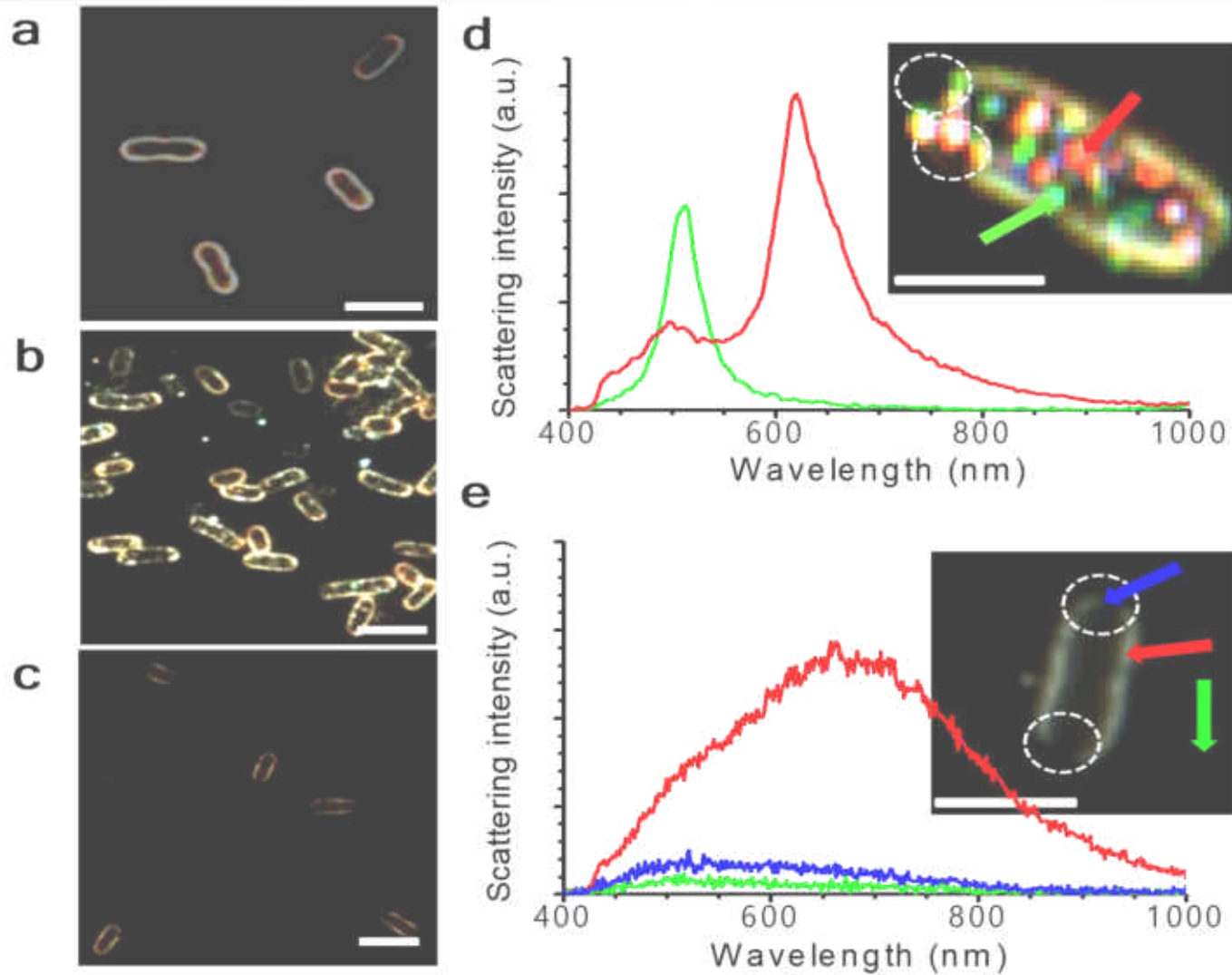
What is special?



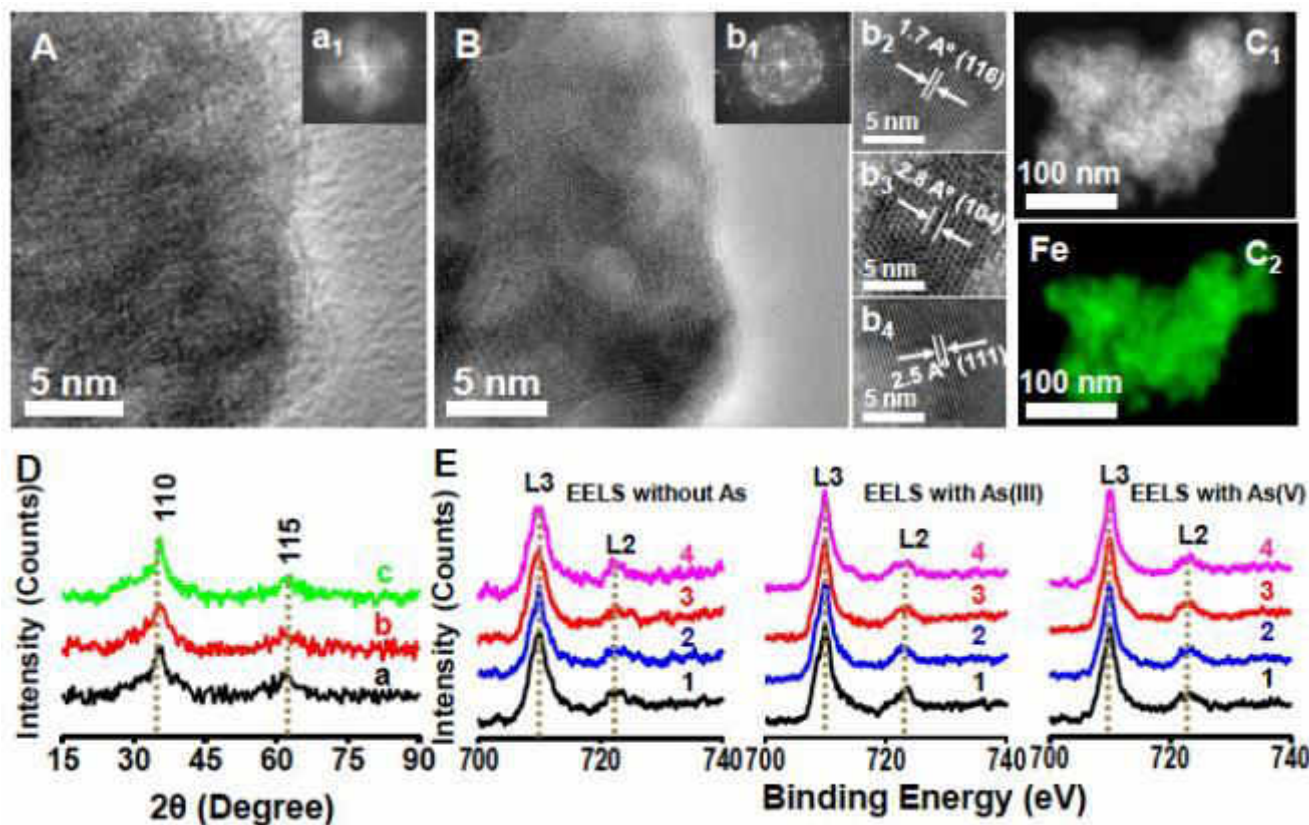
Live/dead staining experiments



No nanotoxicity



Variety of materials



www.advmat.de

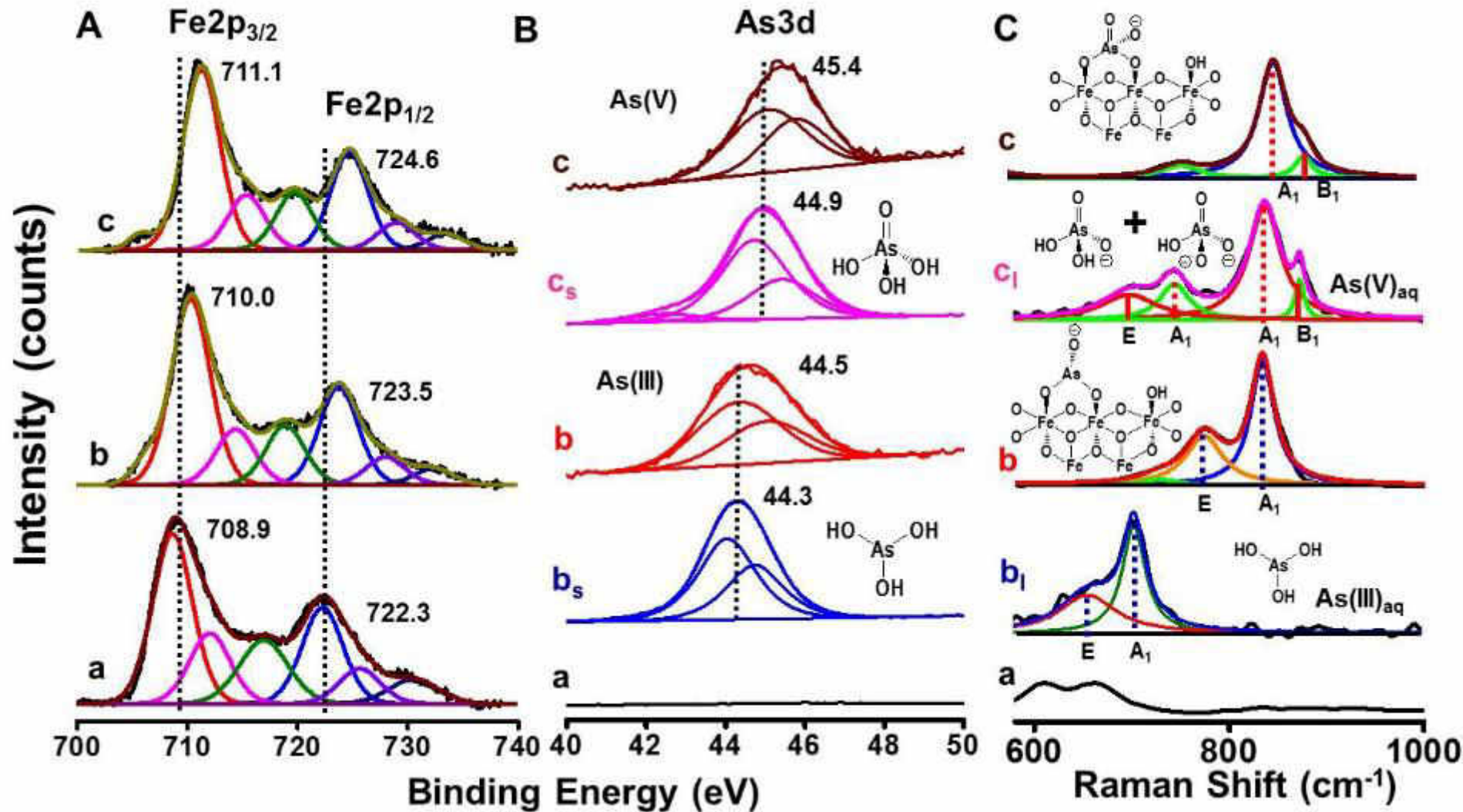
Author P **ADVANCED MATERIALS**

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

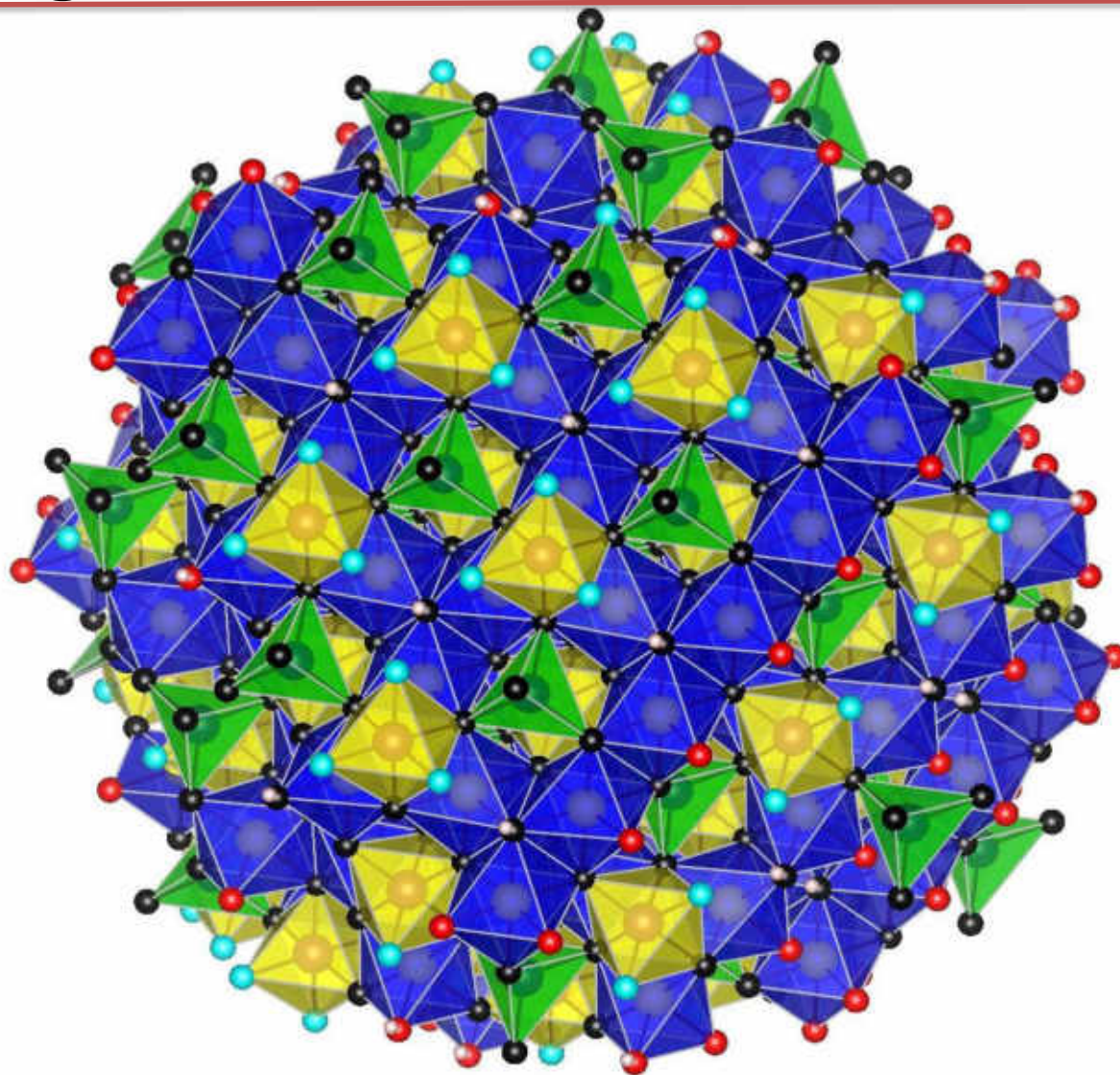
By Avula Anil Kumar, Anirban Som, Paolo Longo, Chennu Sudhakar, Radha Gobinda Bhui, Soujit Sen Gupta, Anshup, Mohan Udhaya Sankar, Amrita Chaudhary, Ramesh Kumar, and T. Pradeep*

Communication

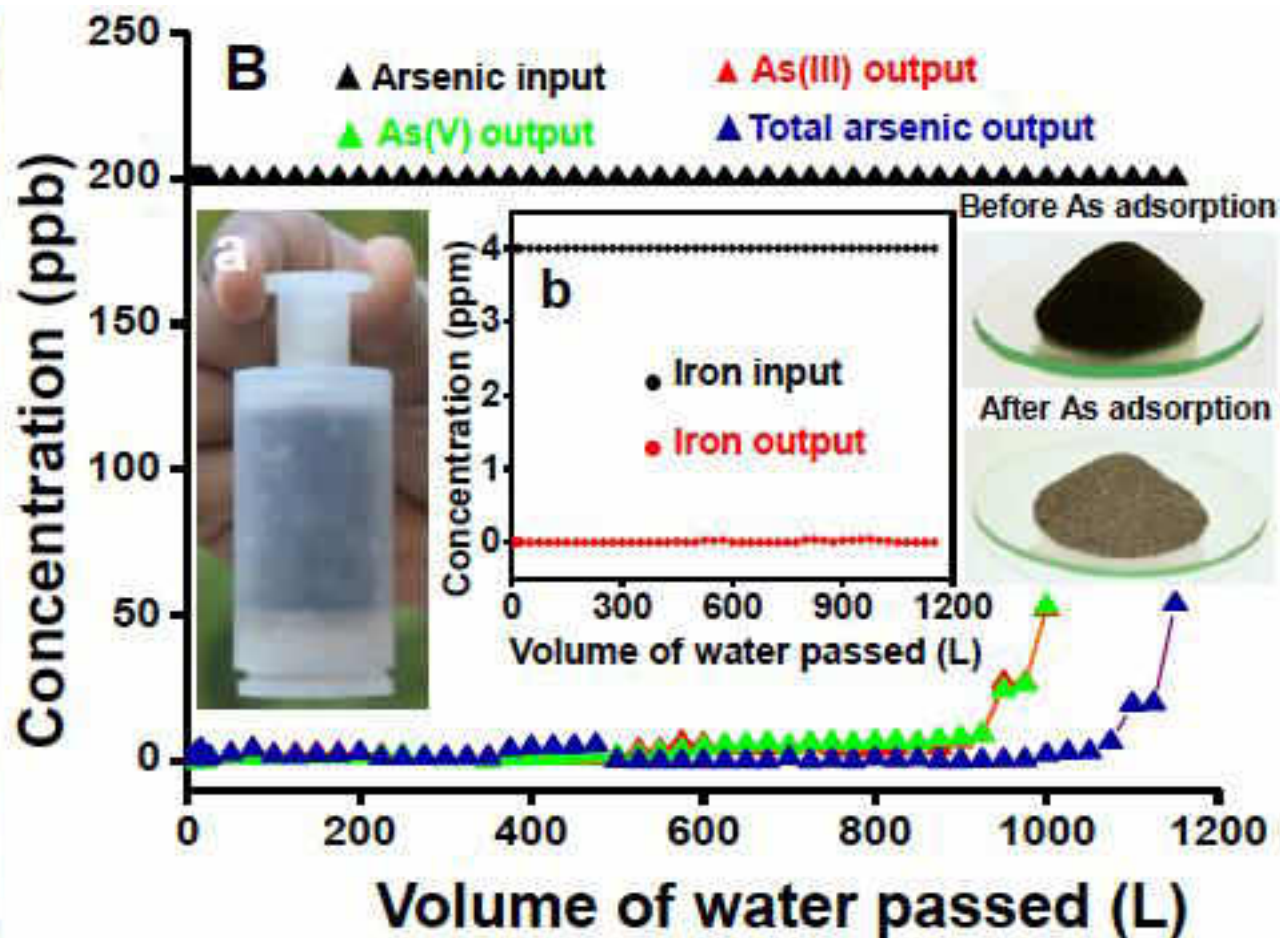
Mechanism



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

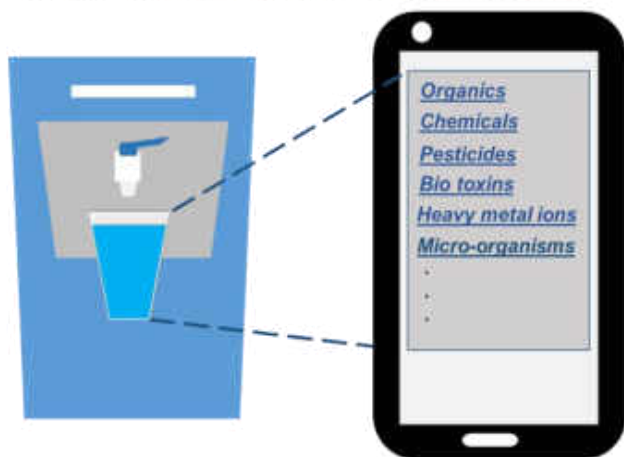
Over 180 units in use across India

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
9	Cost of replacement of media	1.36	Rs. per head per day =Media replacement cost per year/365/Design population
		<u>40.80</u>	per head per month for 70 LPCD water

Smart water purifiers and big data

Smart Water Purifiers linked to IoT



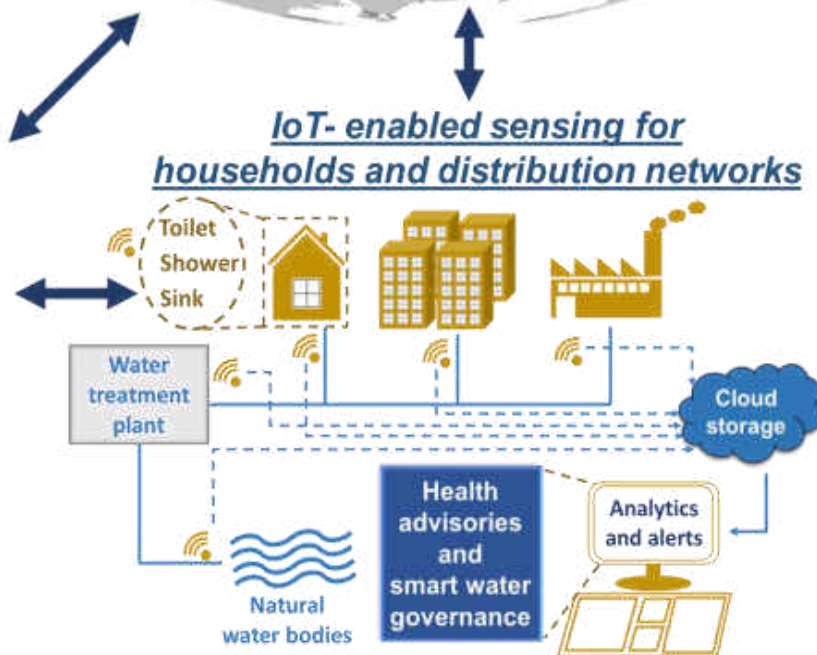
Cost-effective sensor accessory for point-of-use applications



Global Map of Water Health



IoT-enabled sensing for households and distribution networks



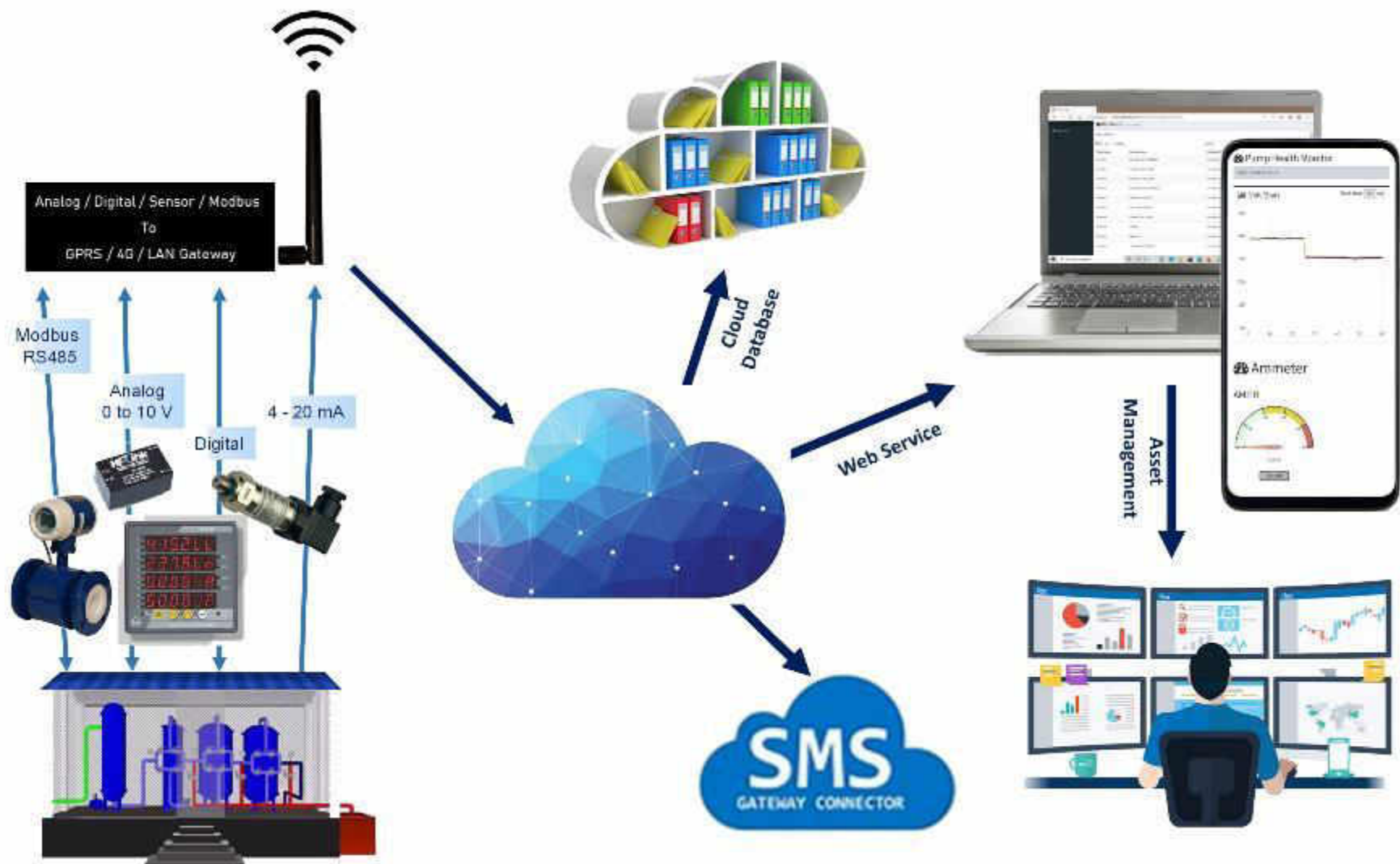
Waste management

- 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



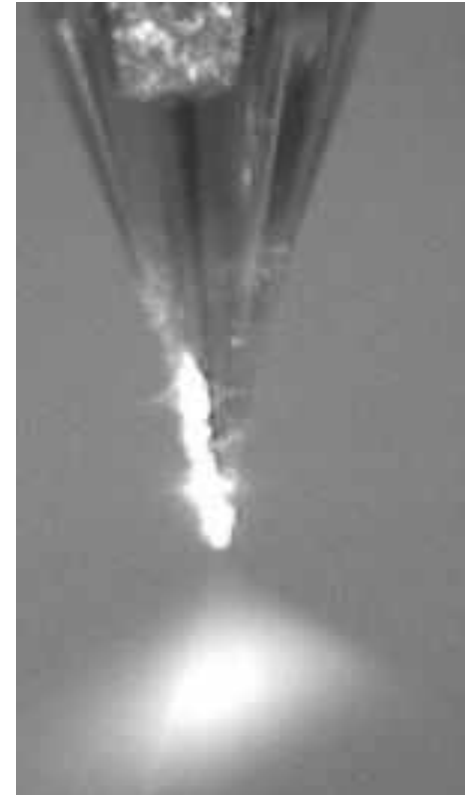
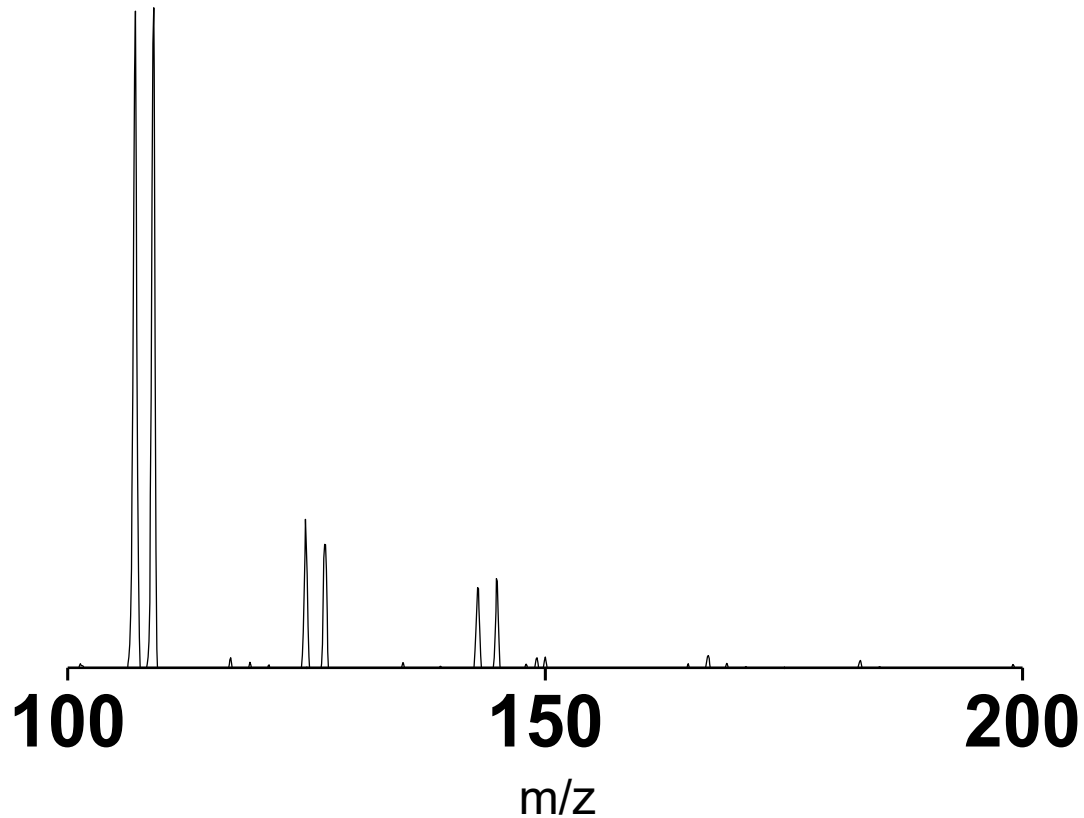
Components of IoT architecture implemented by DWSS, GoP



Typical IoT architecture comprises various sensors and meters, communication gateway, Cloud Server, SMS gateway, Webservices and mobile phone application for operator



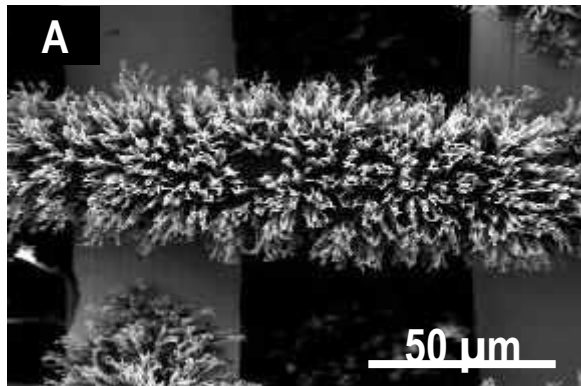
Atmospheric water harvesting



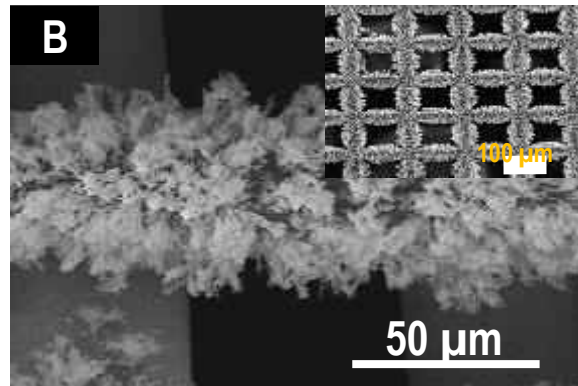
New harvesters

A black and white photograph showing a dense, textured, fibrous material, possibly a new type of harvester or a biological structure. The material is composed of many fine, overlapping fibers that create a complex, almost crystalline appearance. It is set against a dark, blurred background, which makes the light-colored fibers stand out. The overall shape is somewhat irregular but generally horizontal across the frame.

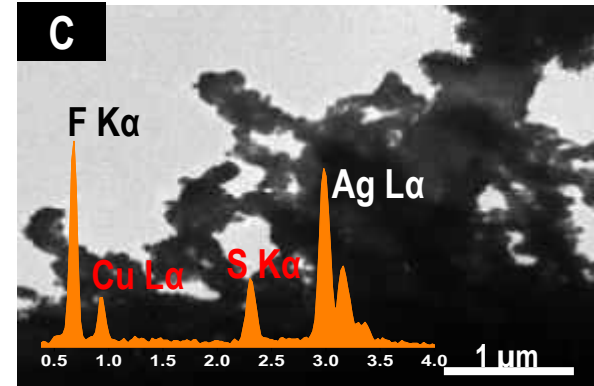
Depanjan Sarkar, et. al. *Advanced Materials*, 28 (11), 2016.



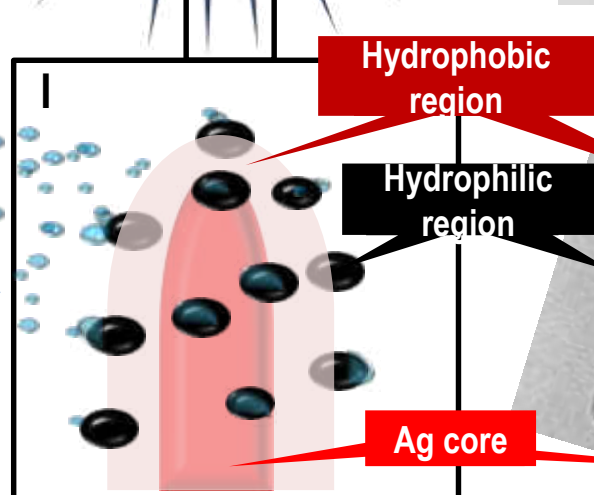
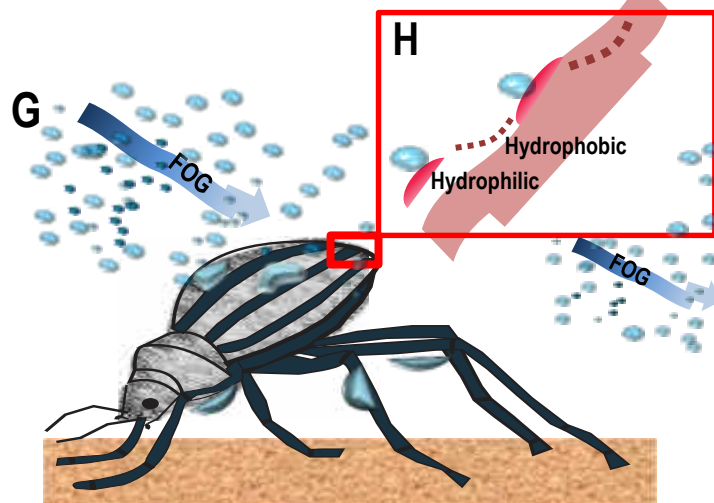
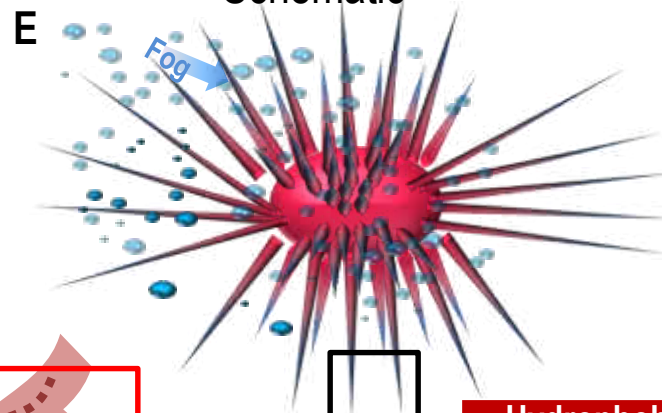
Nature



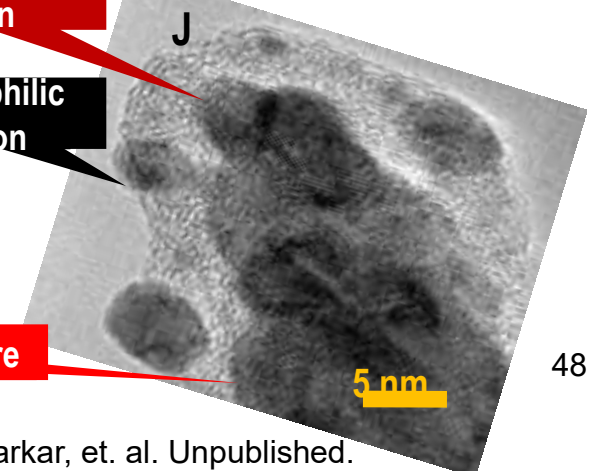
Schematic

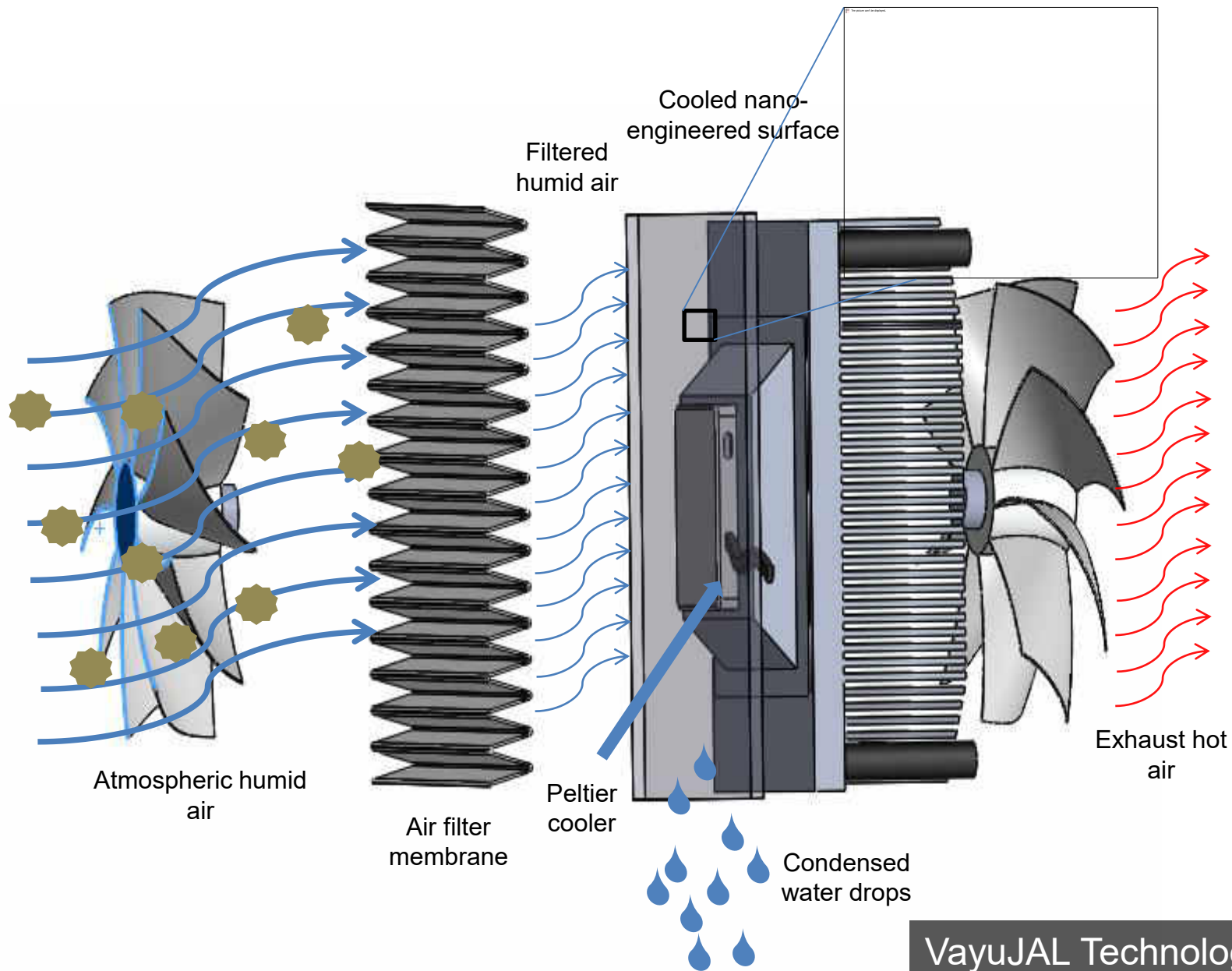


Our material



Combination of cactus and Namib desert beetle effect





VayuJAL Technologies Pvt. Ltd.
Ramesh Kumar Soni and Ankit Nagar

Products in the field

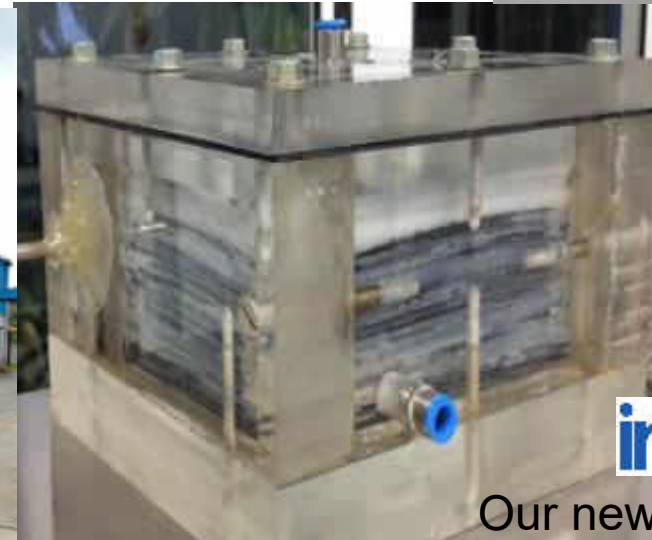
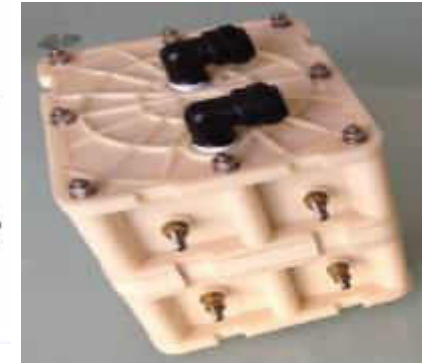
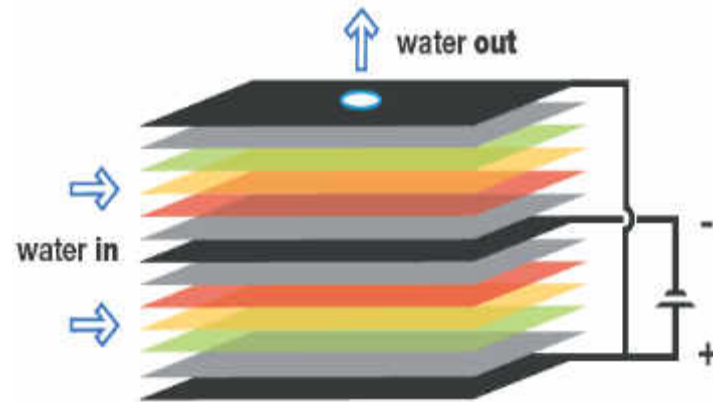
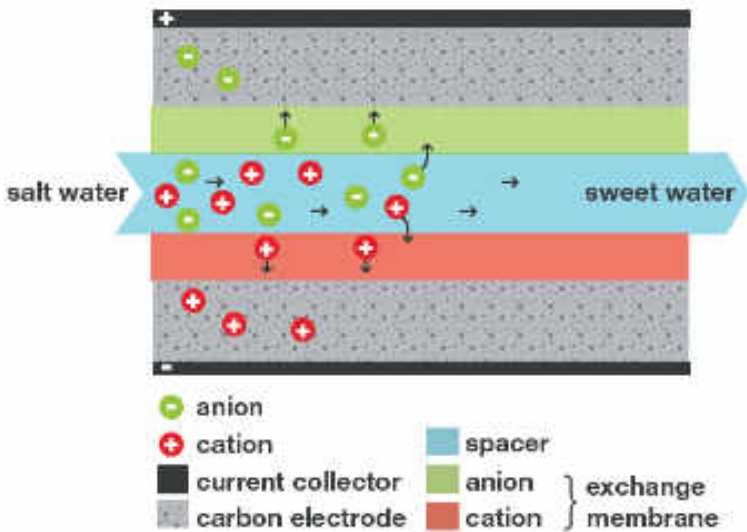


(LPD: Litres per day)



July 2023

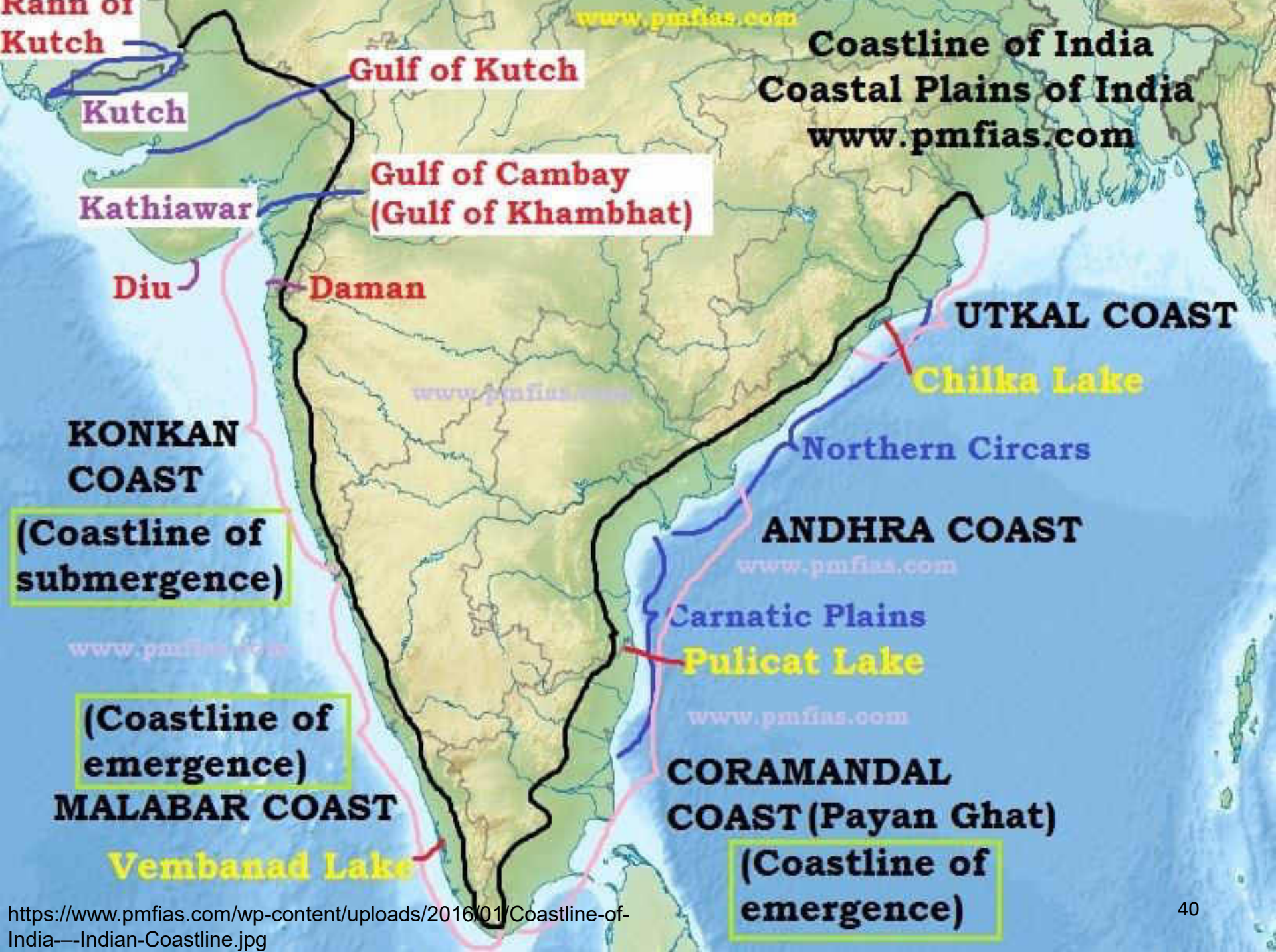
Capacitive Desalination (CDI)



imODI

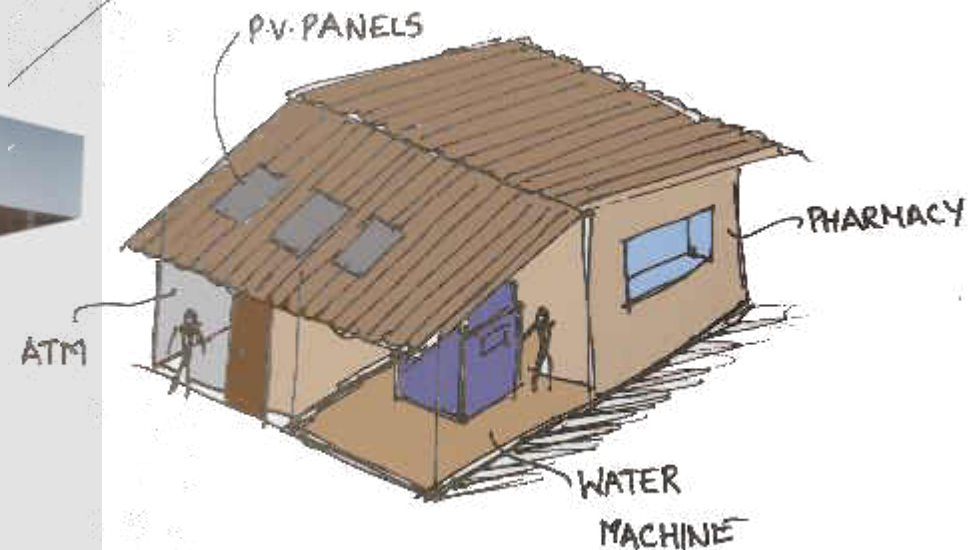
Our new company

Soujit Sengupta, Rabiul Islam and others



DIGITAL WATER KIOSK

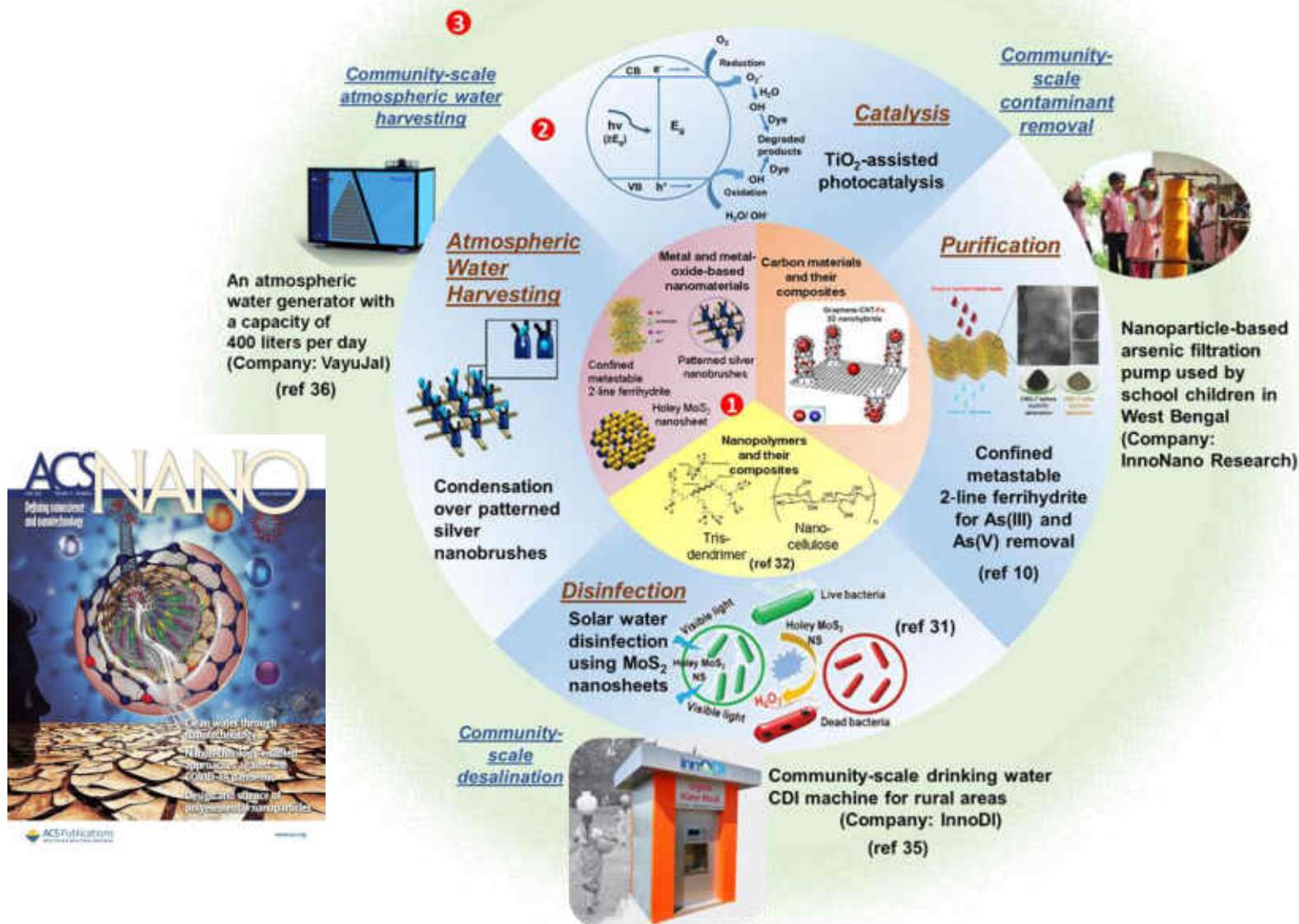
for community drinking using CDI Technology



Products under implementation

Vijay Sampath and Tullio Servida

Evolution of materials to products



Sensors and new opportunities



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



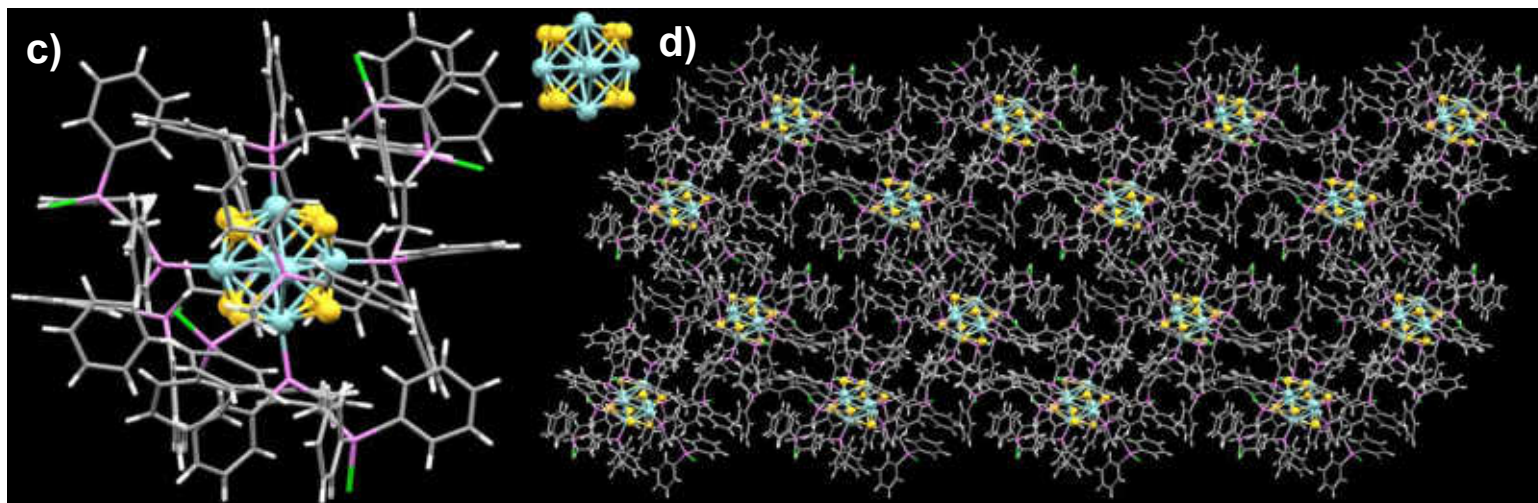
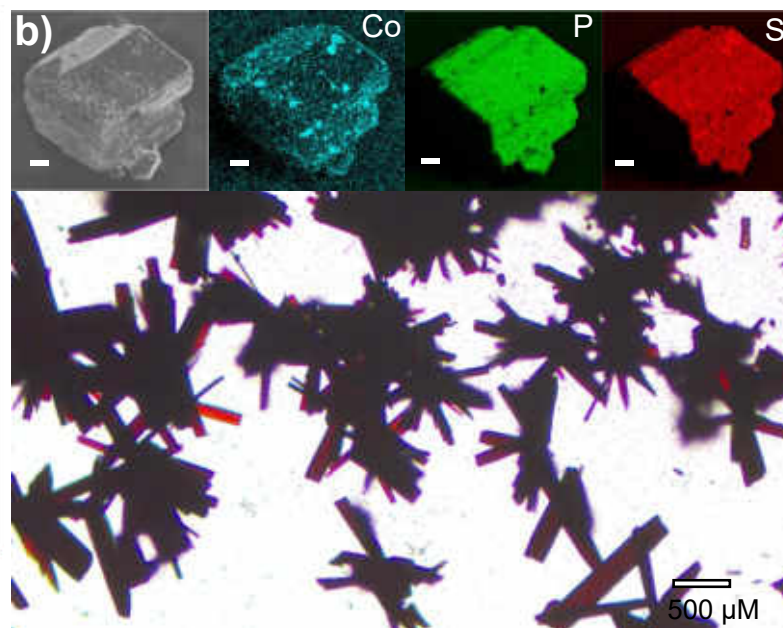
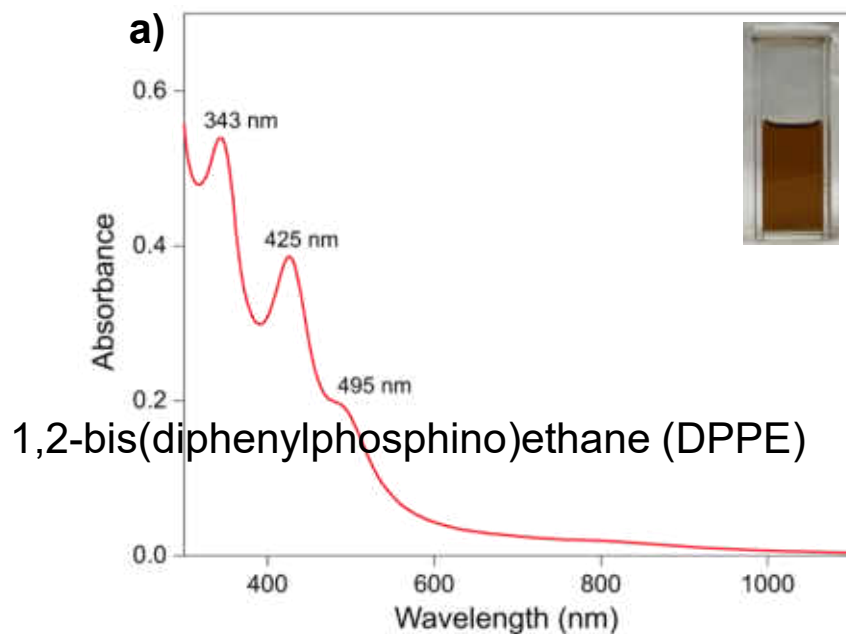
**Ultra compact Low Cost
Spectral Sensor Module**
~ **Billions units** (? 2027)



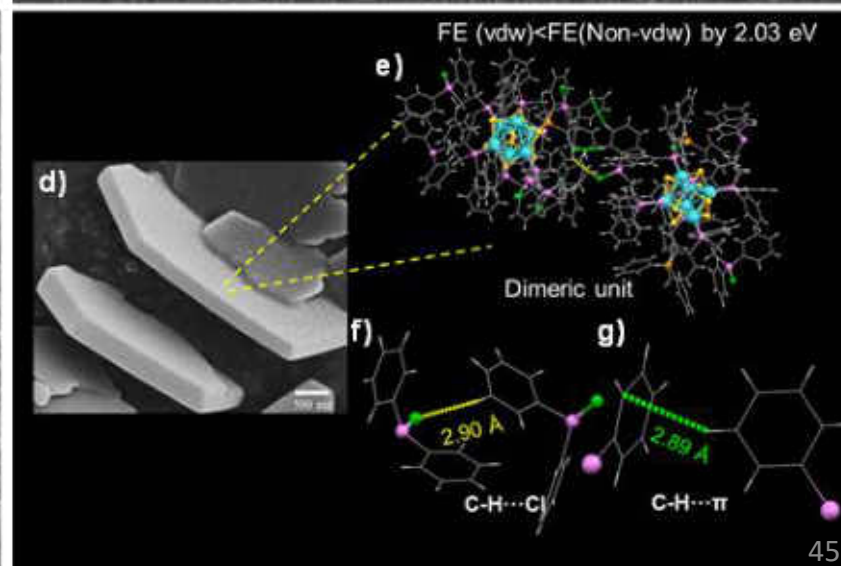
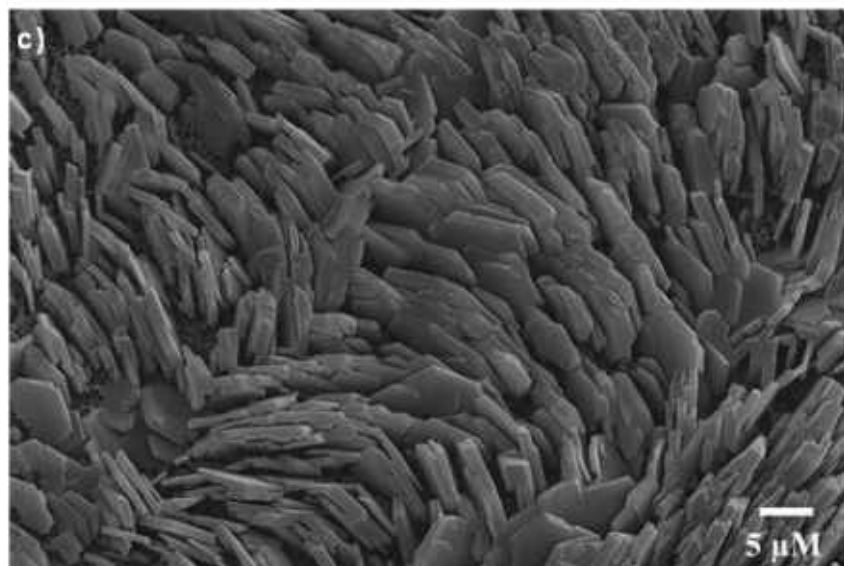
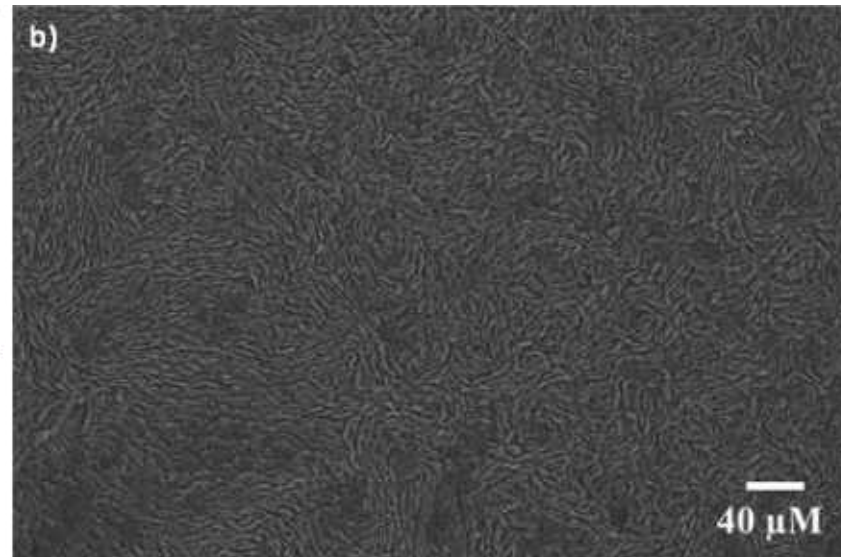
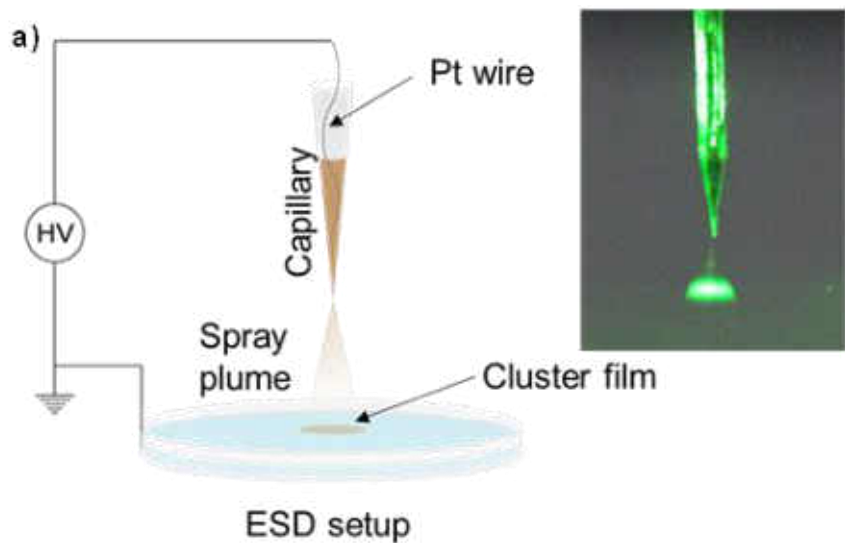
Water quality measurement – In the pipeline

nano λ

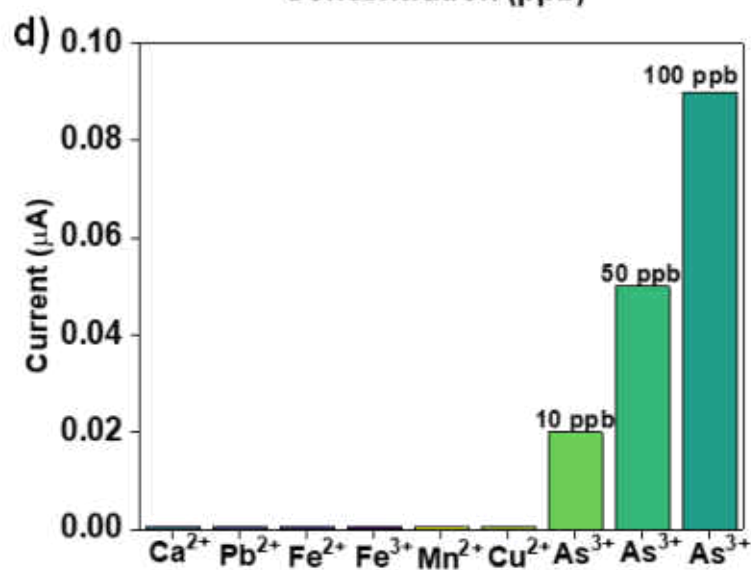
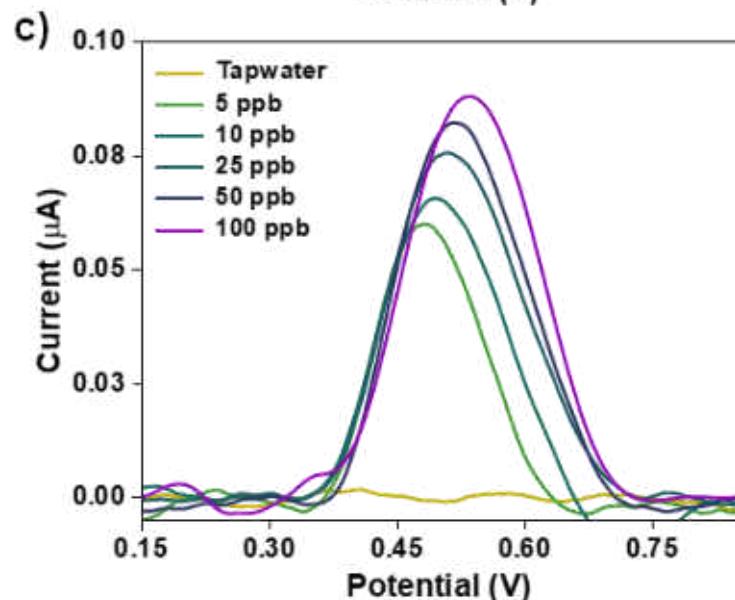
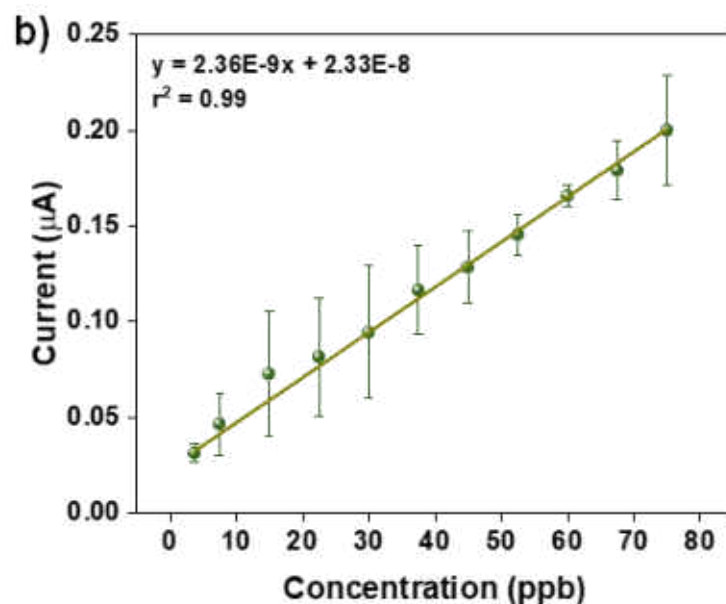
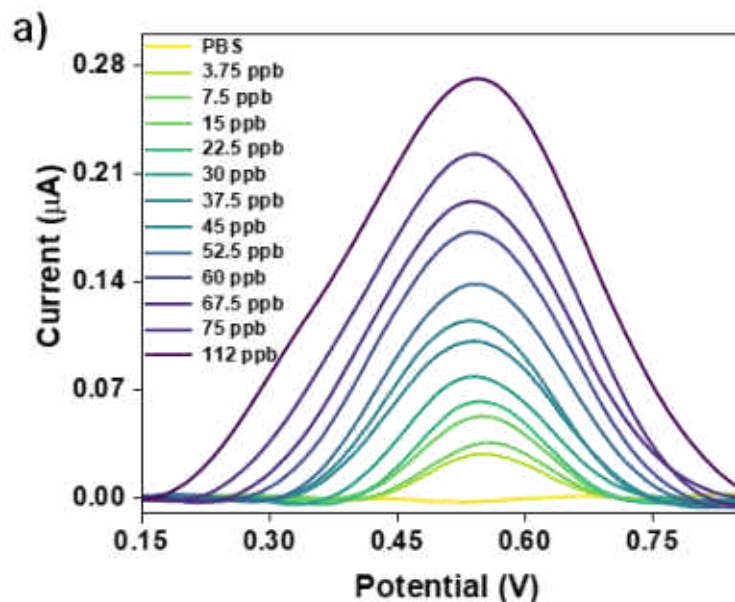
New electrodes - Aligned nanoplates of Co_6S_8



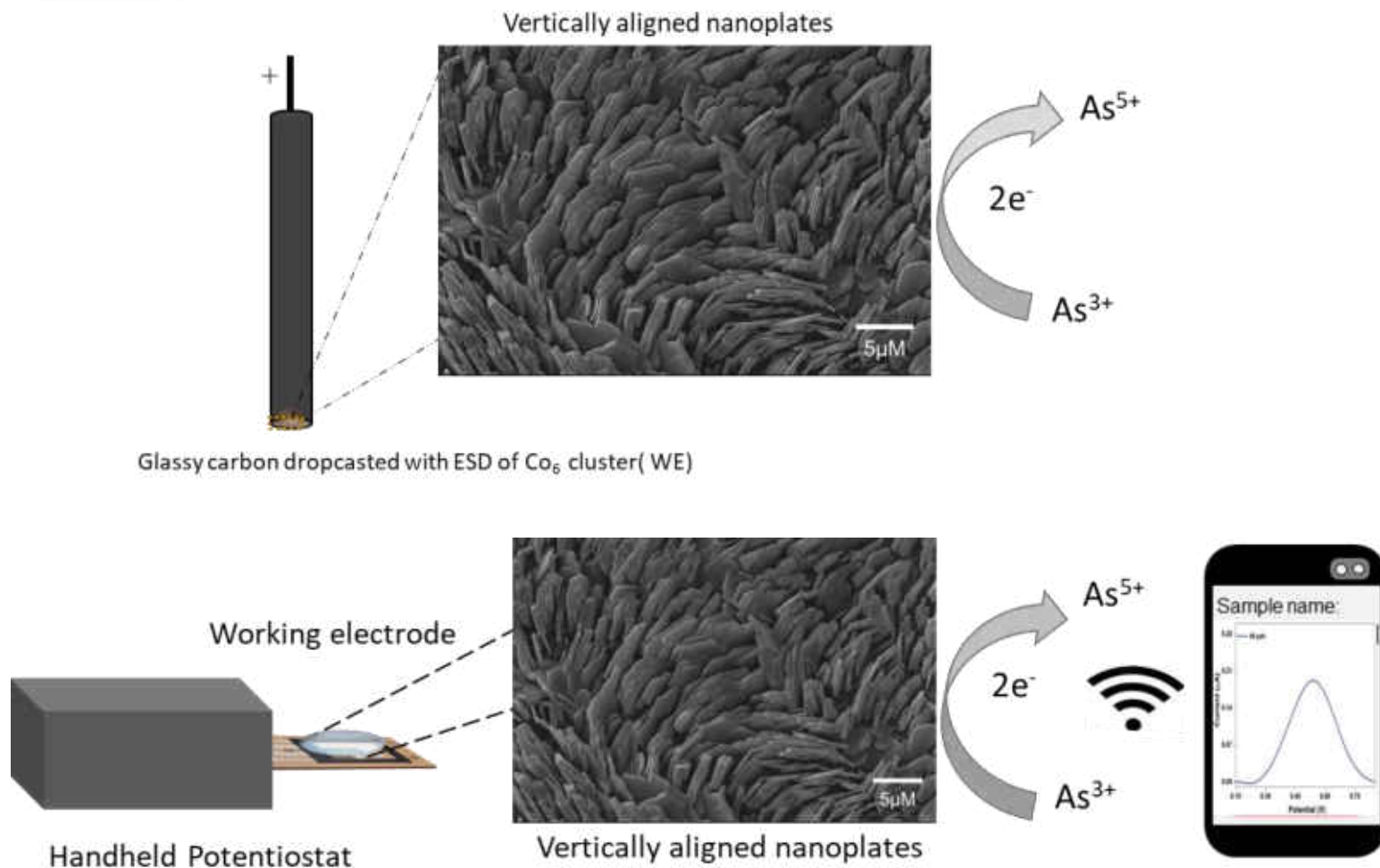
Electrospray deposition



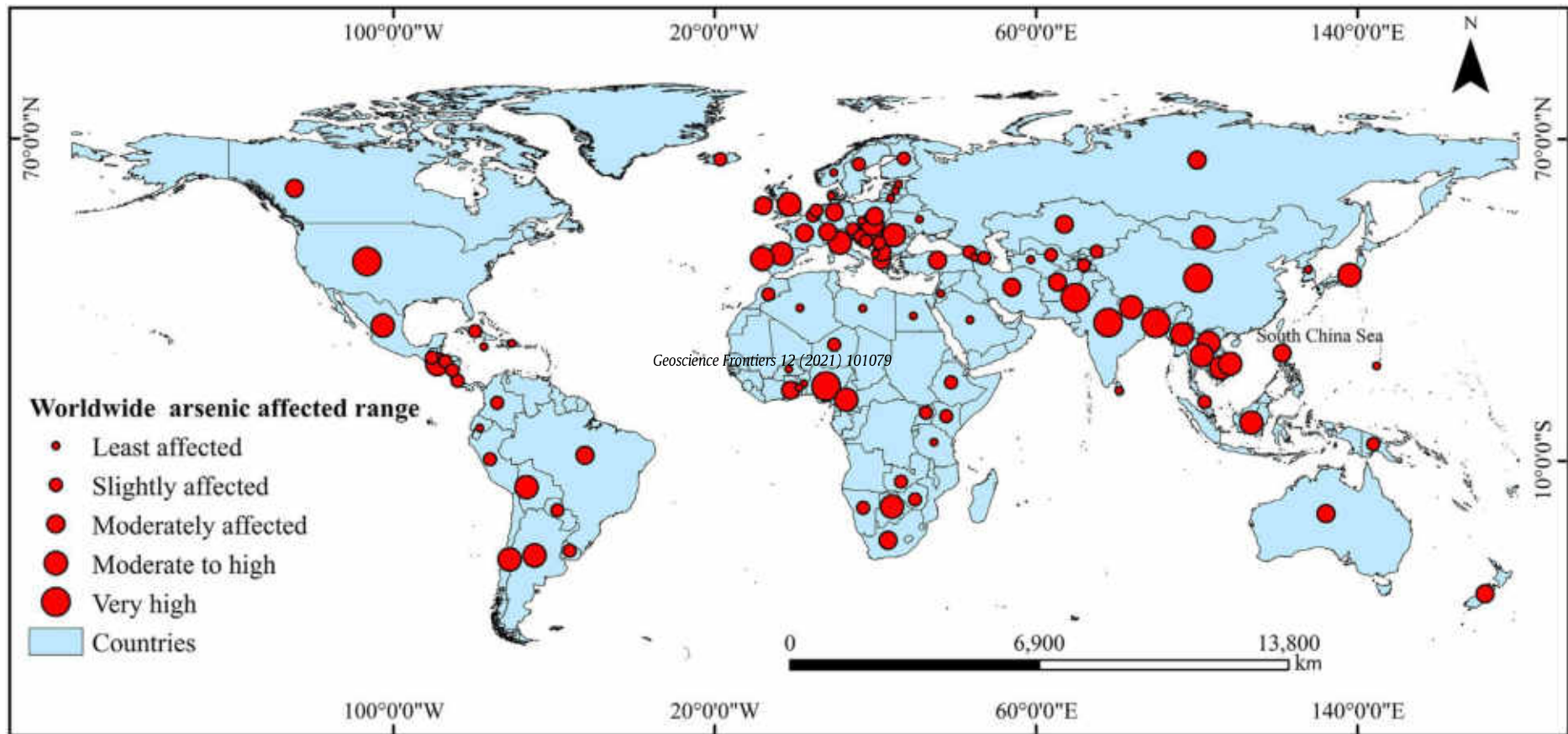
Sensing



Working electrode



Arsenic poisoning across the world



Monitoring in the field

**EyeNetAqua Solutions Pvt.
Ltd.**

An ICCW incubated company

Eye of internet on quality, quantity and compliance
for all

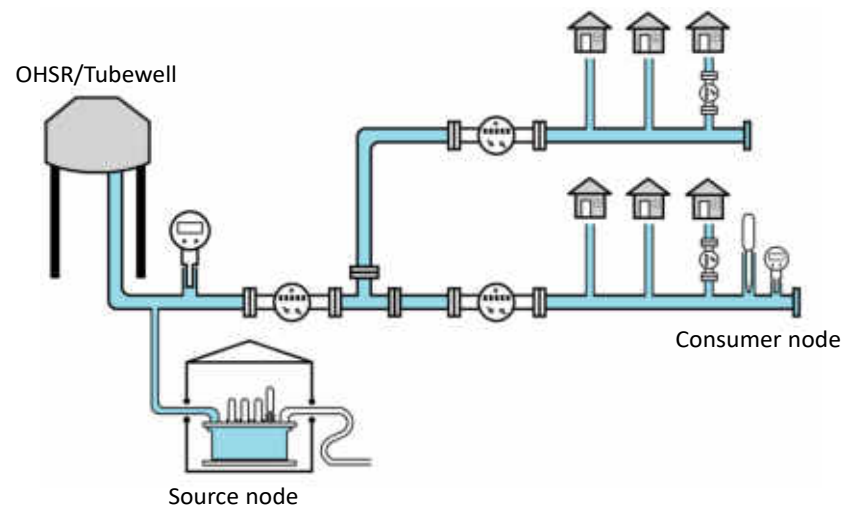


EyeNetAqua Solutions Private Limited

Installation model as per NJJM specifications

Tubewell/OHSR (Source node) :

1. Flow meter (80-150mm) x 1
2. Pressure sensor x 1
3. pH sensor x 1
4. TDS sensor x 1
5. Residual Chlorine sensor x 1
6. In-house MVP of Free Residual Chlorine sensor x 1

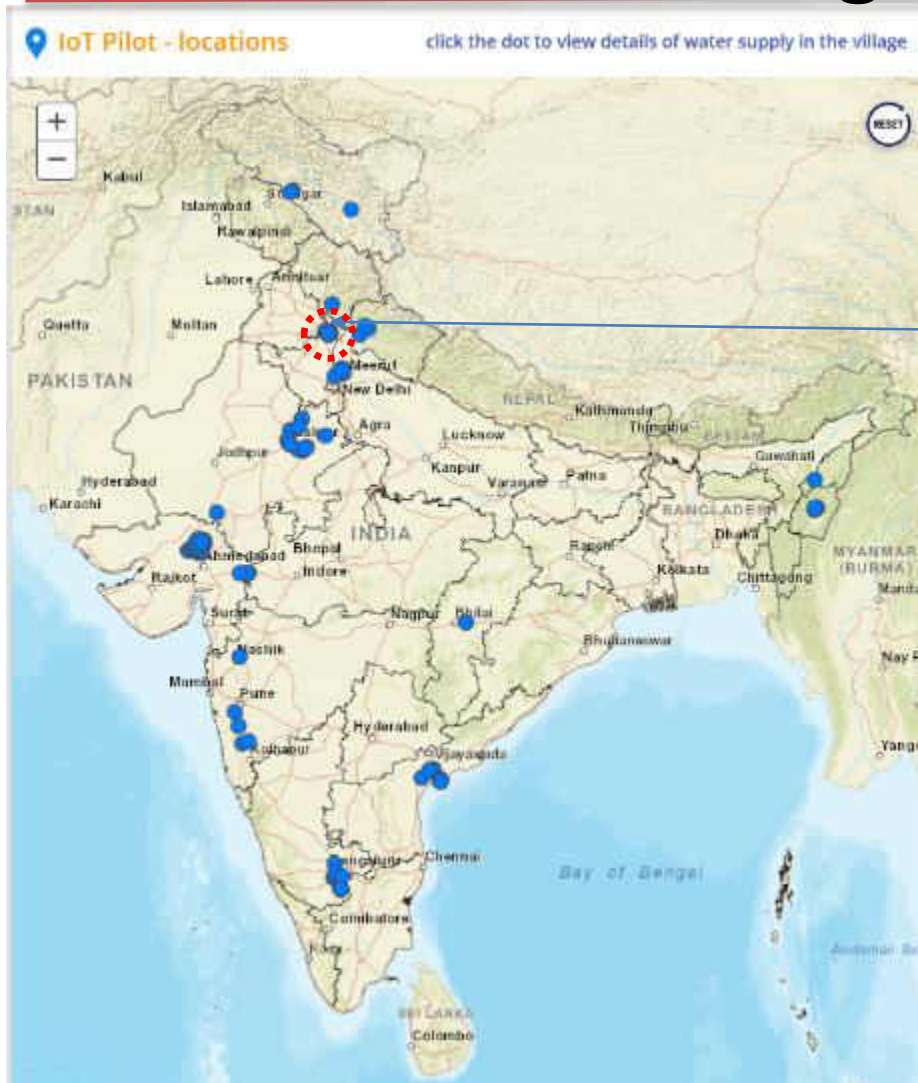


Consumer tap (End tail node) :

1. Flow meter (15-20mm) x 1
2. Pressure sensor x 1
3. Residual Chlorine sensor x 1
4. In-house MVP of Free Residual Chlorine sensor x 1

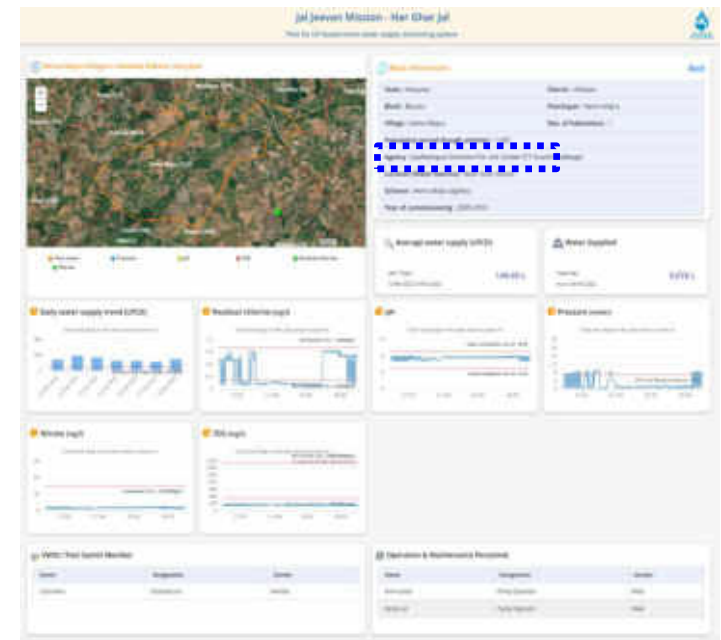


India's water is being monitored



IITM/IISc

Installations made by four companies



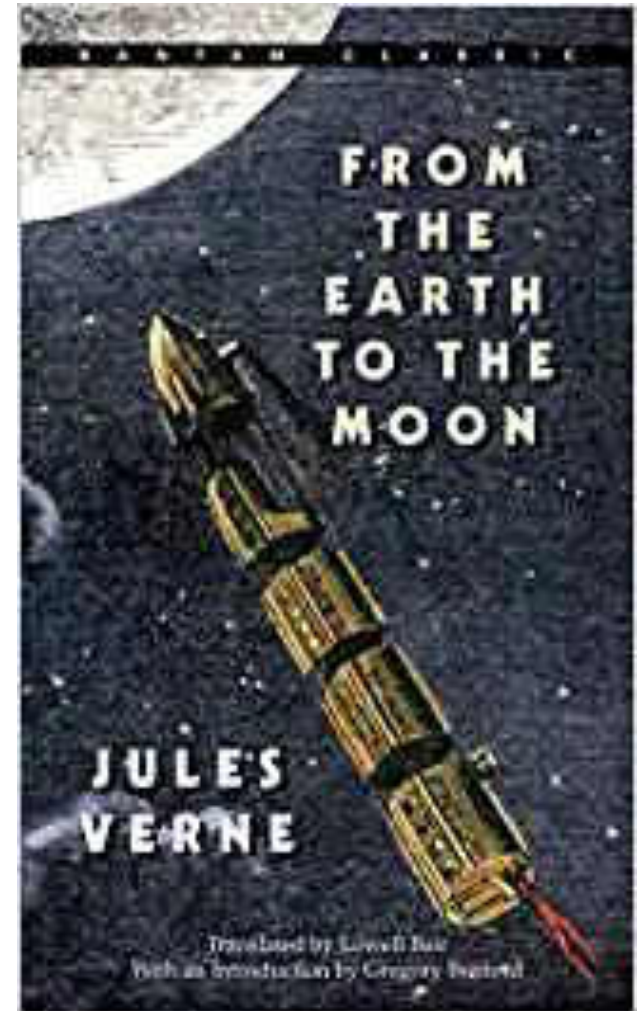
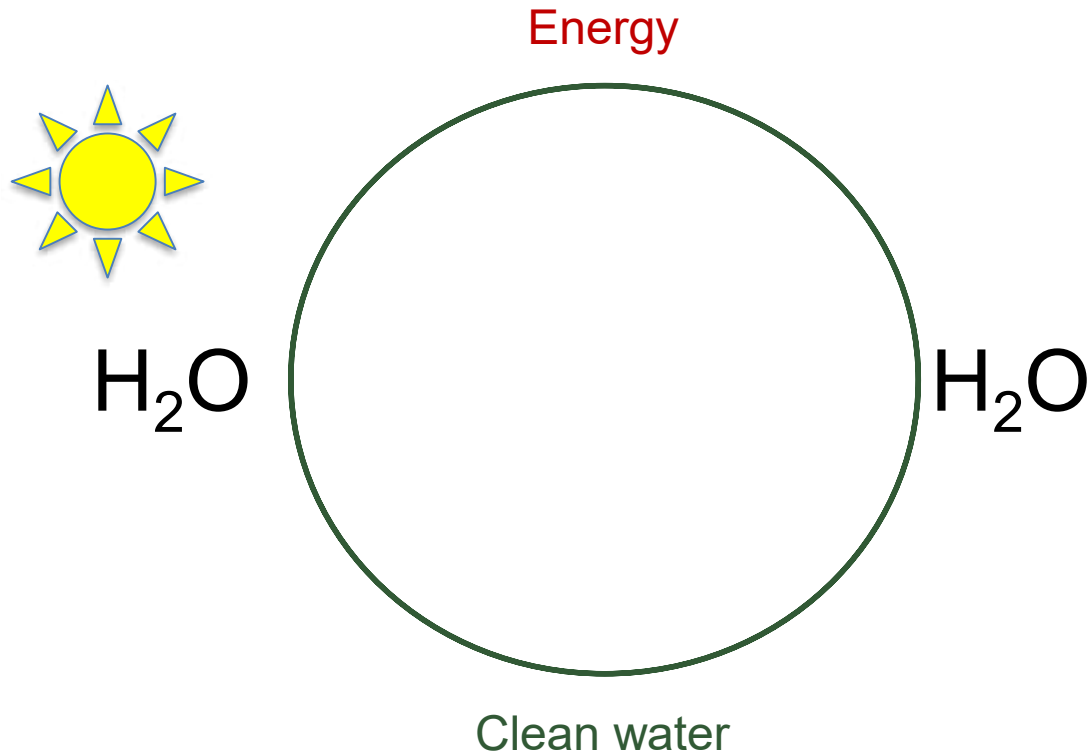
A wide-angle photograph of a large, open green field under a bright blue sky with scattered white clouds. In the background, there is a tall, grey metal water tower with a spiral staircase. To the left, there are some trees and a small building. In the foreground, there is a large black oval shape containing the word "Policy".

Policy



<https://www.youtube.com/watch?v=fiJyptbXBtM>

Our dreams become reality with materials



Affordable, inclusive, sustainable and contextual excellence



International Centre for Clean Water



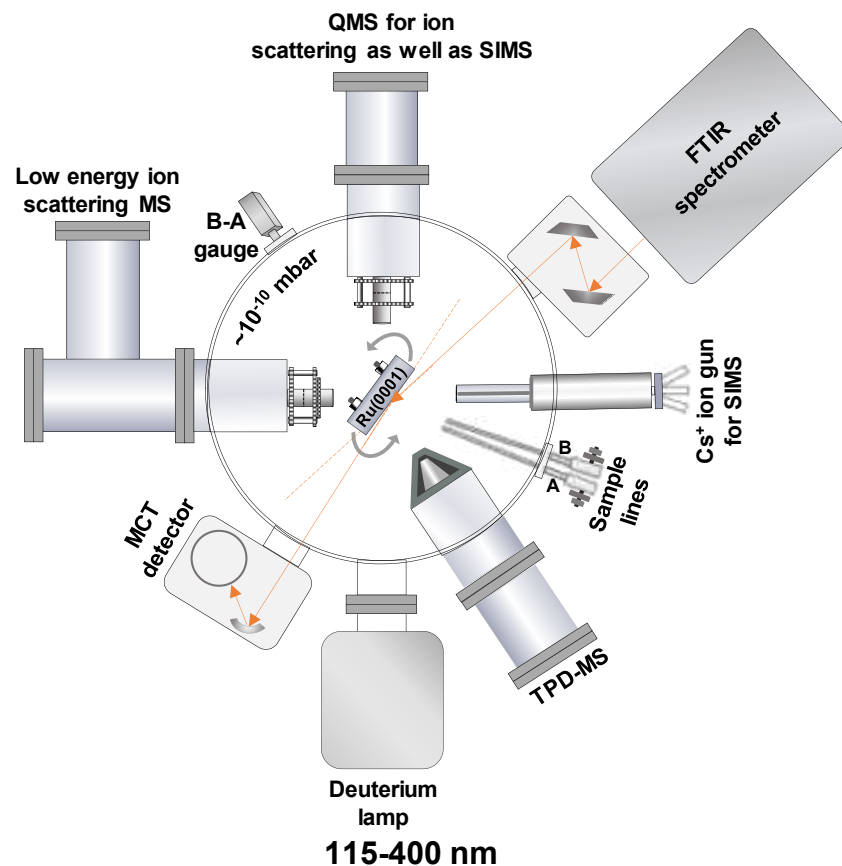
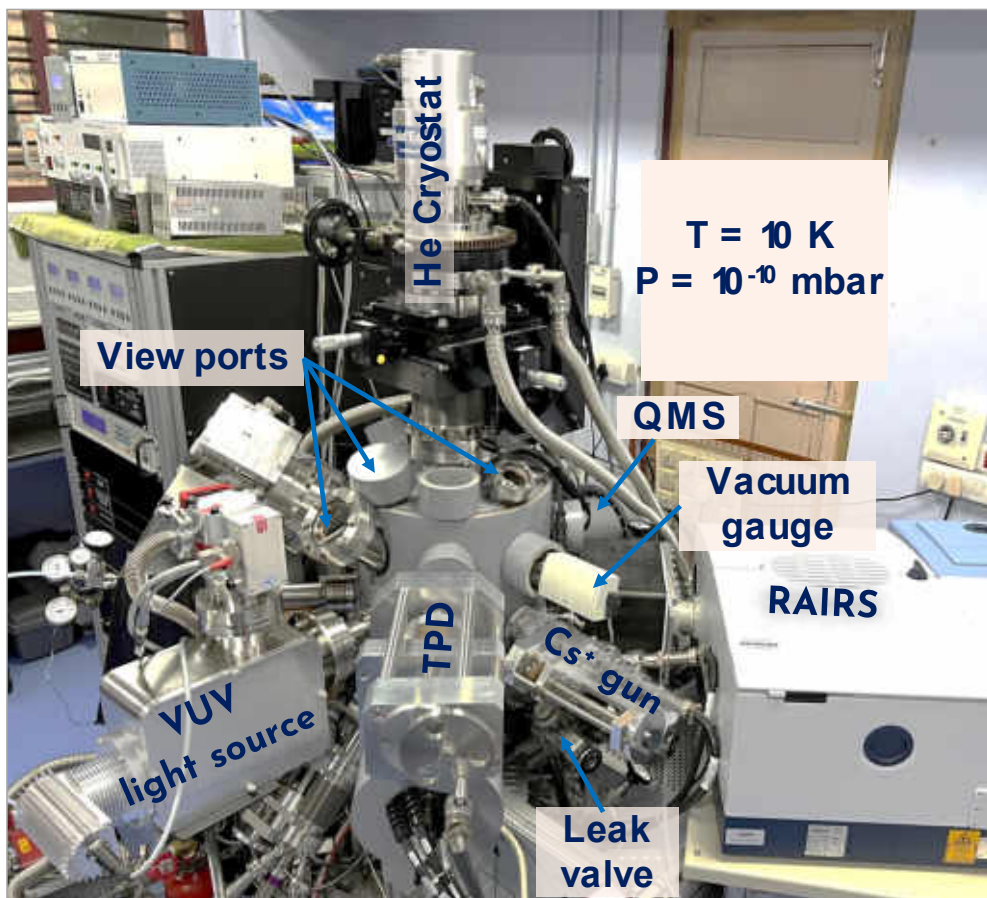
IIT Madras Research Park

Clathrate hydrates

Ice – why should we care?

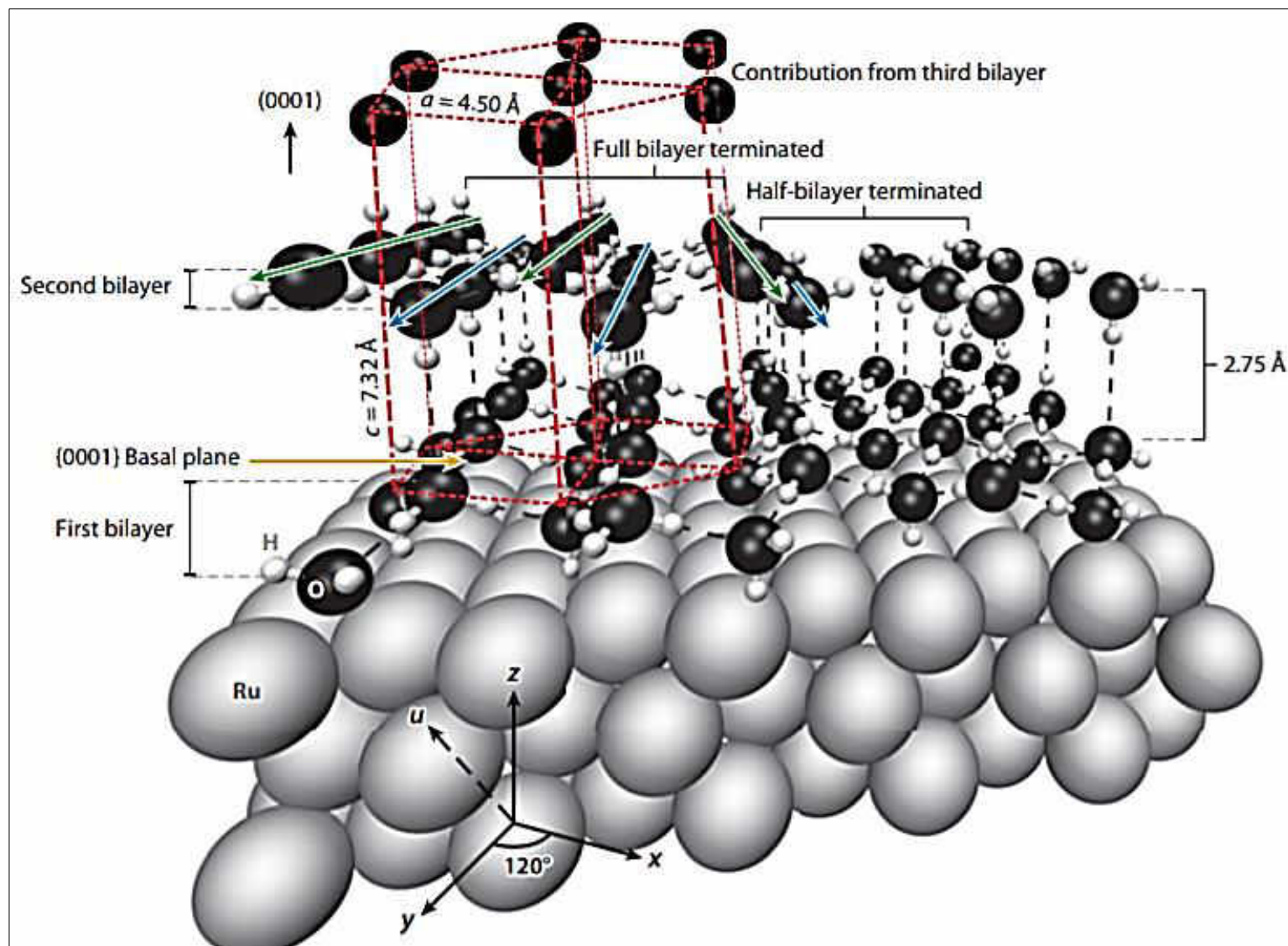
- **Ice is big in scale - 10 percent of the land area on Earth is covered with glacial ice. Glacierized areas cover over 15 million square kilometers.**
- **Ice is there everywhere, including in space - naturally**
- **Ice could be a vehicle for life on Earth - astrobiology**
- **Ice can make clathrates**
- **Water is not understood – especially in its condensed form**
- **Condensed molecular solids are all ices**

Instrumentation



Bag, S. et al., *Rev. Sci. Instrum.* **2014**, 85, 014103/1-014103/7

Viswakarma, G. et al., *J. Phys. Chem. Lett.*, **2023**, 14, 2823–2829



Instrumentation



Formation and Transformation of Clathrate Hydrates under Interstellar Conditions

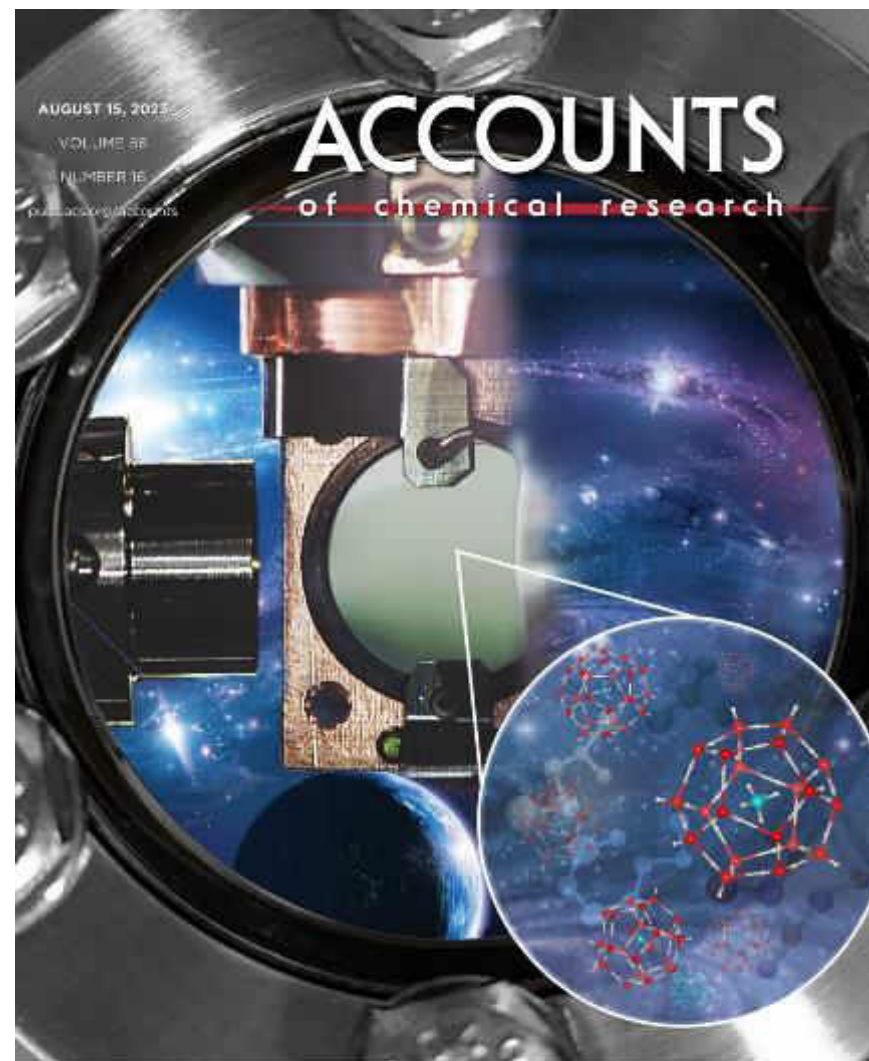
Jyotirmoy Ghosh, Gaurav Vishwakarma, Rajnish Kumar,* and Thalappil Pradeep*



Cite This: <https://doi.org/10.1021/acs.accounts.3c00317>

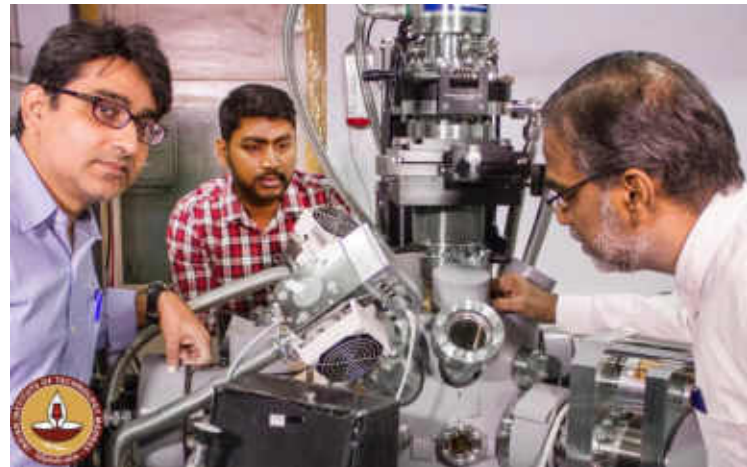


Read Online

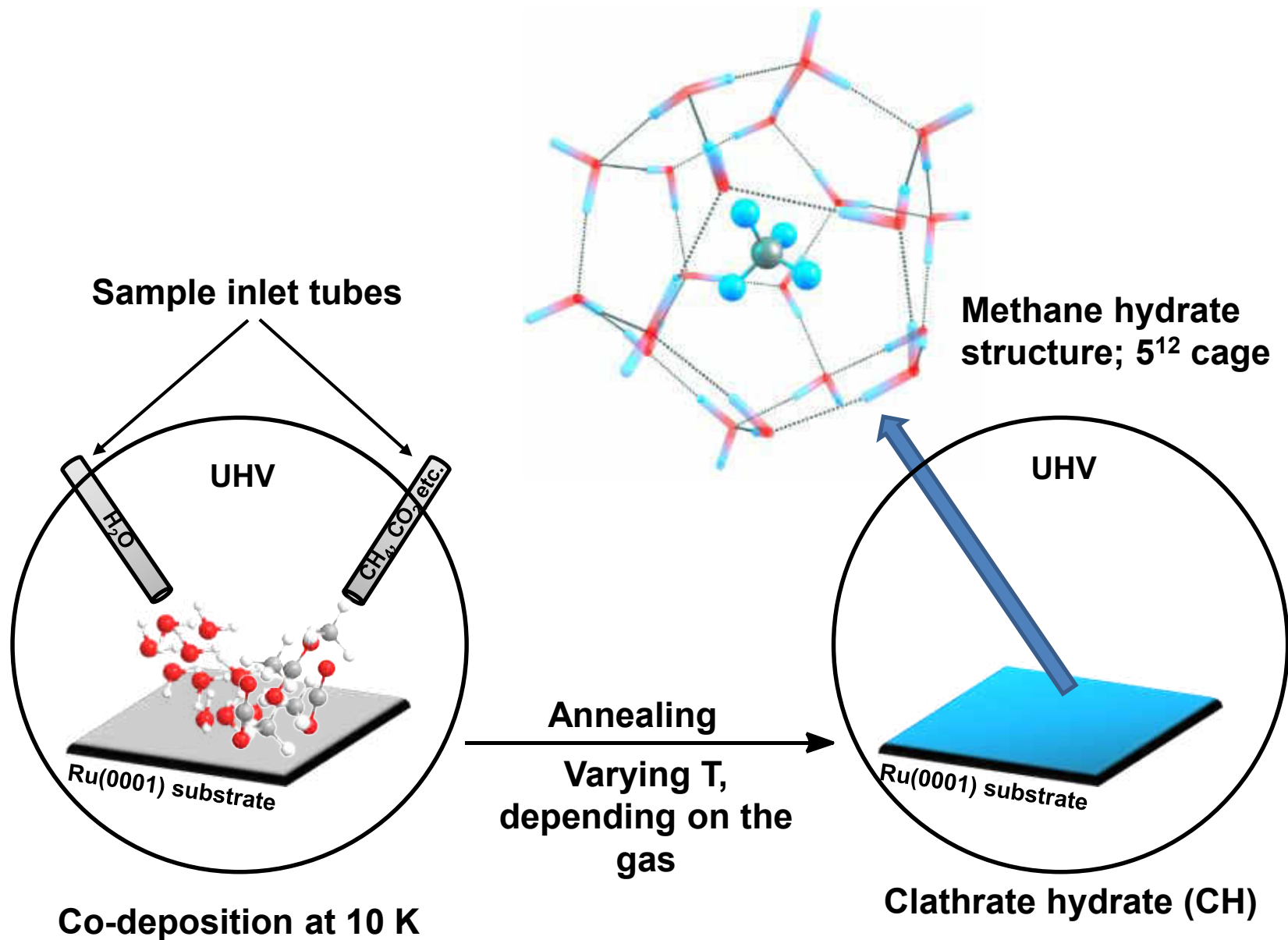


Clathrate hydrates in interstellar environment

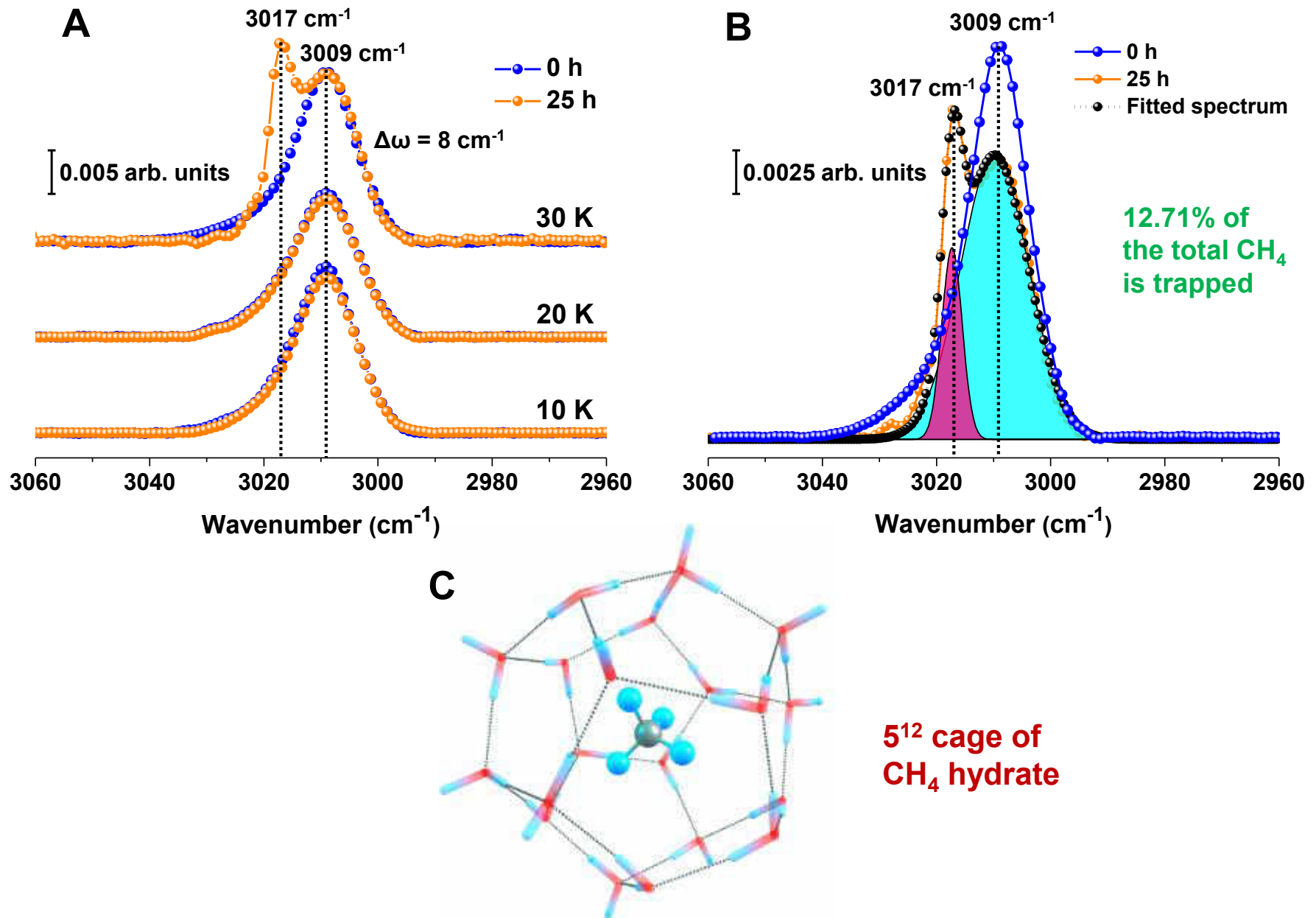
Ghosh, J. et al., *Proc. Natl. Acad. Sci. U.S.A.*, **2019**, 116, 1526-1531



Experimental method

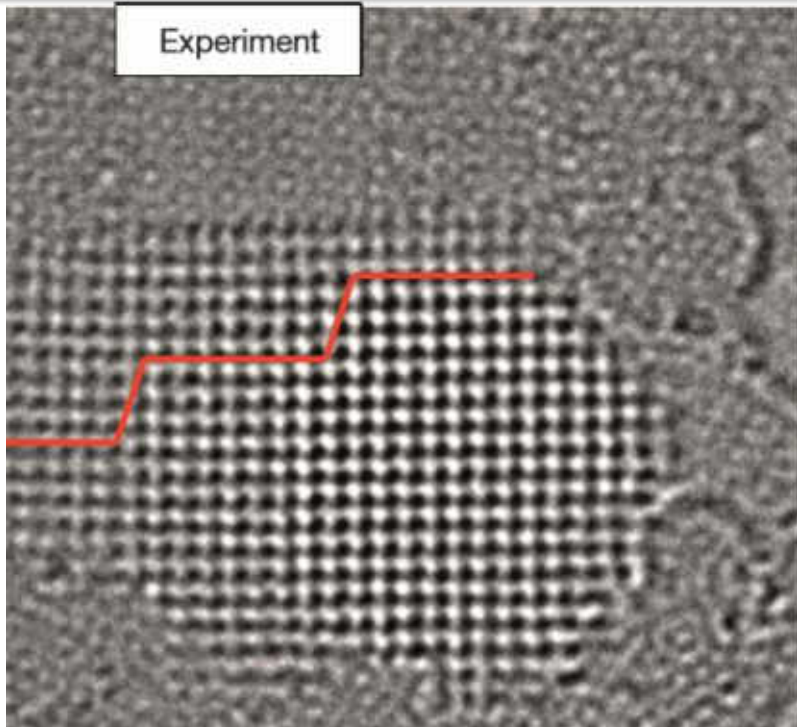


Clathrate hydrates in interstellar environment

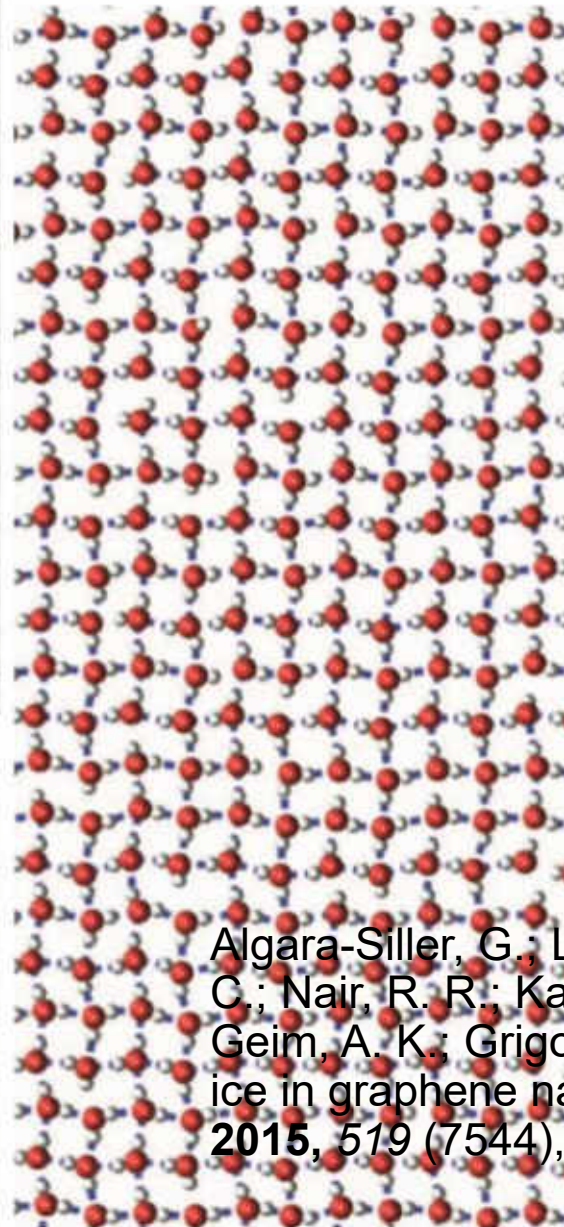
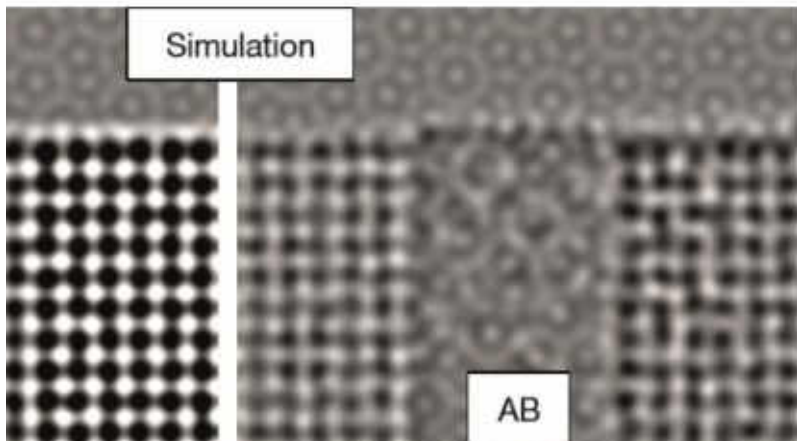


Future

Observing clathrate hydrates?



c

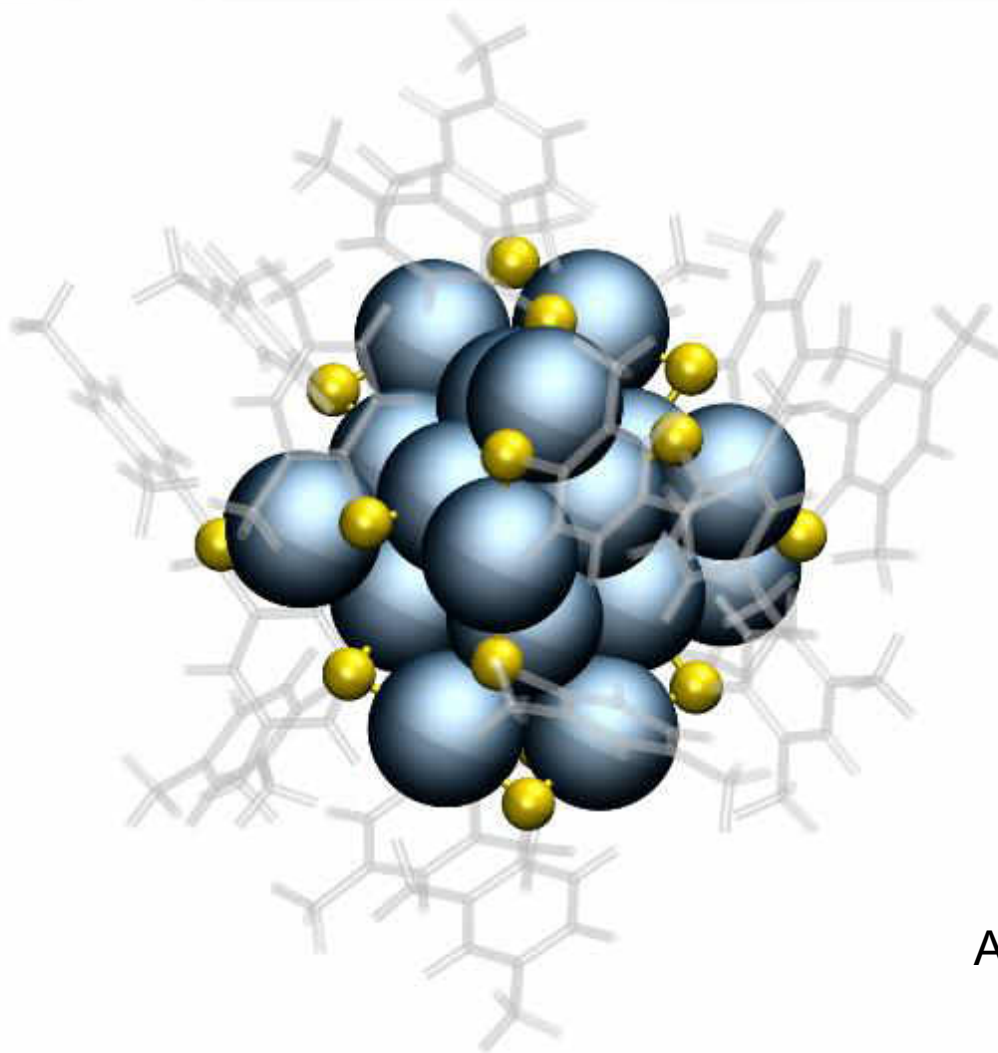


Algara-Siller, G.; Lehtinen, O.; Wang, F. C.; Nair, R. R.; Kaiser, U.; Wu, H. A.; Geim, A. K.; Grigorieva, I. V., Square ice in graphene nanocapillaries. *Nature* **2015**, 519 (7544), 443-445.



Atomically Precise Clusters

New molecules



$\text{Au}_{25}, \text{Ag}_{25}, \text{Ag}_{29}$


They make high quality crystals



Atomically Precise Clusters of Noble Metals: Emerging Link between Atoms and Nanoparticles

Indranath Chakraborty[†] and Thalappil Pradeep^{*†}

DST Unit of Nanoscience (DST UNS) and Thematic Unit of Excellence, Department of Chemistry, Indian Institute of Technology Madras, Chennai 600036, India

 Supporting Information

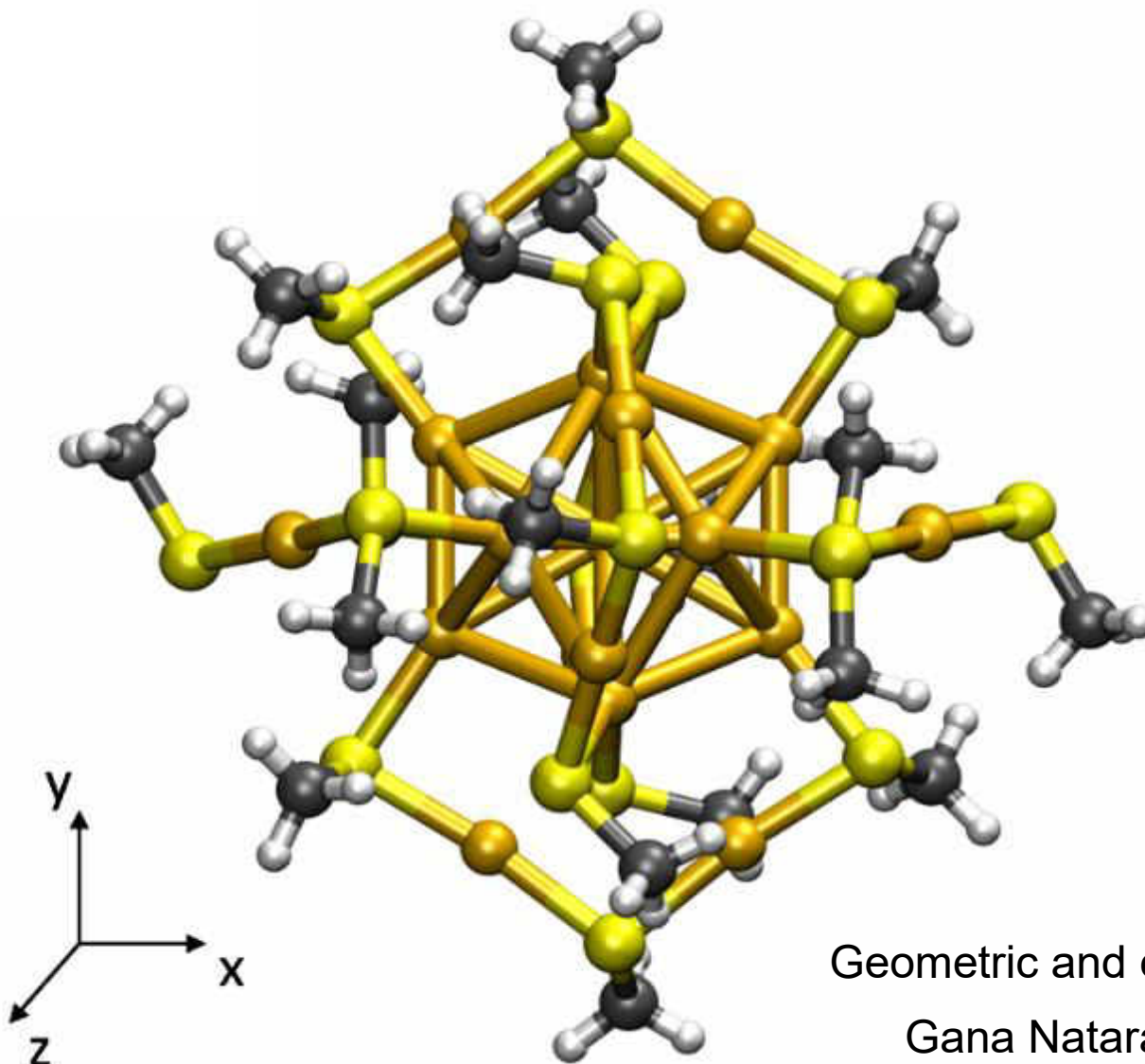
Citations: >1700

ABSTRACT: Atomically precise pieces of matter of nanometer dimensions composed of noble metals are new categories of materials with many unusual properties. Over 100 molecules of this kind with formulas such as $\text{Au}_{25}(\text{SR})_{18}$, $\text{Au}_{38}(\text{SR})_{24}$, and $\text{Au}_{102}(\text{SR})_{44}$ as well as $\text{Ag}_{25}(\text{SR})_{18}$, $\text{Ag}_{29}(\text{S}_2\text{R})_{12}$, and $\text{Ag}_{44}(\text{SR})_{30}$ (often with a few counterions to compensate charges) are known now. They can be made reproducibly with robust synthetic protocols, resulting in colored solutions, yielding powders or diffractable crystals. They are distinctly different from nanoparticles in their spectroscopic properties such as optical absorption and emission, showing well-defined features, just like molecules. They show isotopically resolved molecular ion peaks in mass spectra and provide diverse information when examined through multiple instrumental methods. Most important of these properties is luminescence, often in the visible–near-infrared window, useful in biological applications. Luminescence in the visible region, especially by clusters protected with proteins, with a large Stokes shift, has been used for various sensing applications, down to a few tens of molecules/ions, in air and water. Catalytic properties of clusters, especially oxidation of organic substrates, have been examined. Materials science of these systems presents numerous possibilities and is fast evolving. Computational insights have given reasons for their stability and unusual properties. The molecular nature of these materials is unequivocally manifested in a few recent studies such as intercluster reactions forming precise clusters. These systems manifest properties of the core, of the ligand shell, as well as that of the integrated system. They are better described as protected molecules or *aspicules*, where *aspis* means shield and *cules* refers to molecules, implying that they are “shielded molecules”. In order to understand their diverse properties, a nomenclature has been introduced with which it is possible to draw their structures with positional labels on paper, with some training. Research in this area is captured here, based on the publications available up to December 2016.



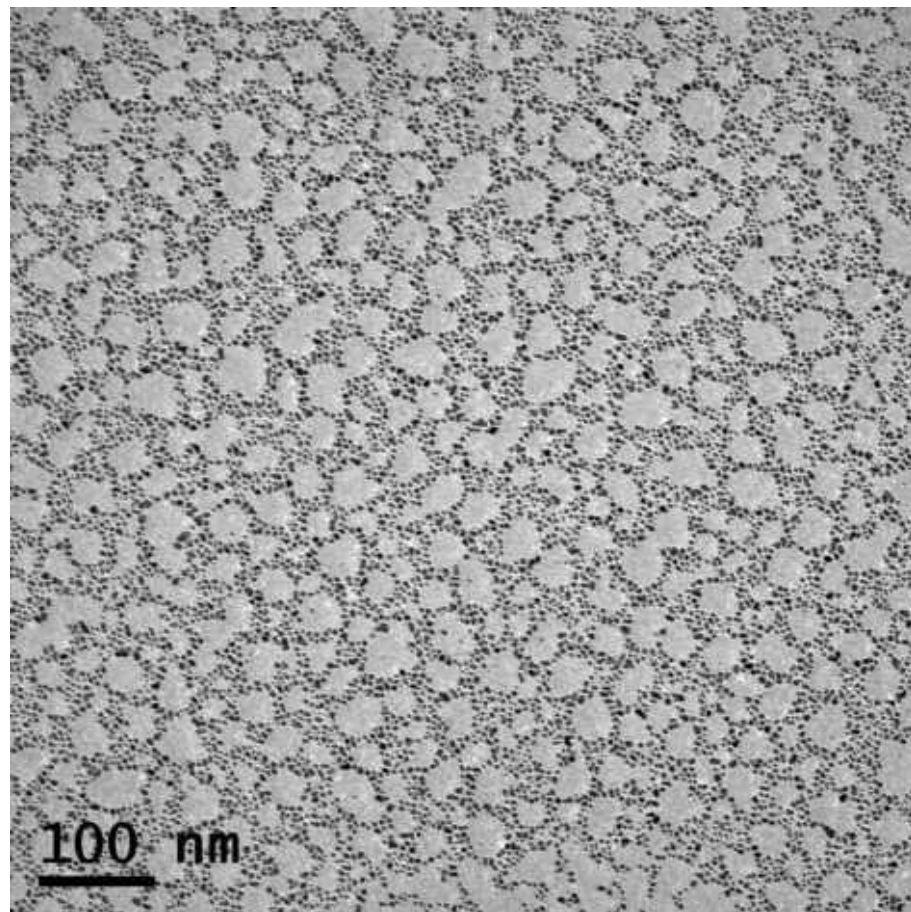
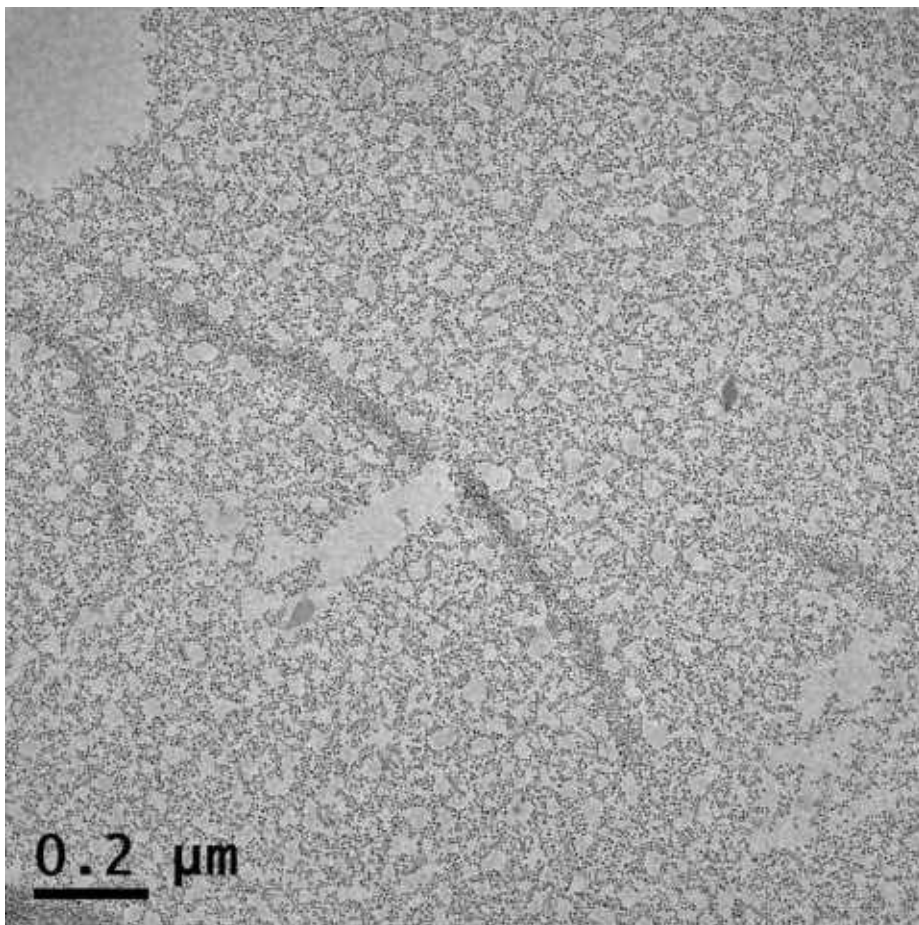
Also the pioneering work of R. W. Murray, Robert L. Whetten, Uzi Landman, Tatuya Tsukuda, Yuichi Negishi, Hannu Hakkinen, Rongchao Jin, Nanfeng Zheng, Terry Bigioni, Osman Bakr, Kornberg, Jianping Xie, C. M. Aikens, Thomas Buergi, Amala Dass, Ackerson, De-en Jiang, A. W. Castleman Jr., H. Schmidbauer, ... Robin Ras, Olli Ikkala

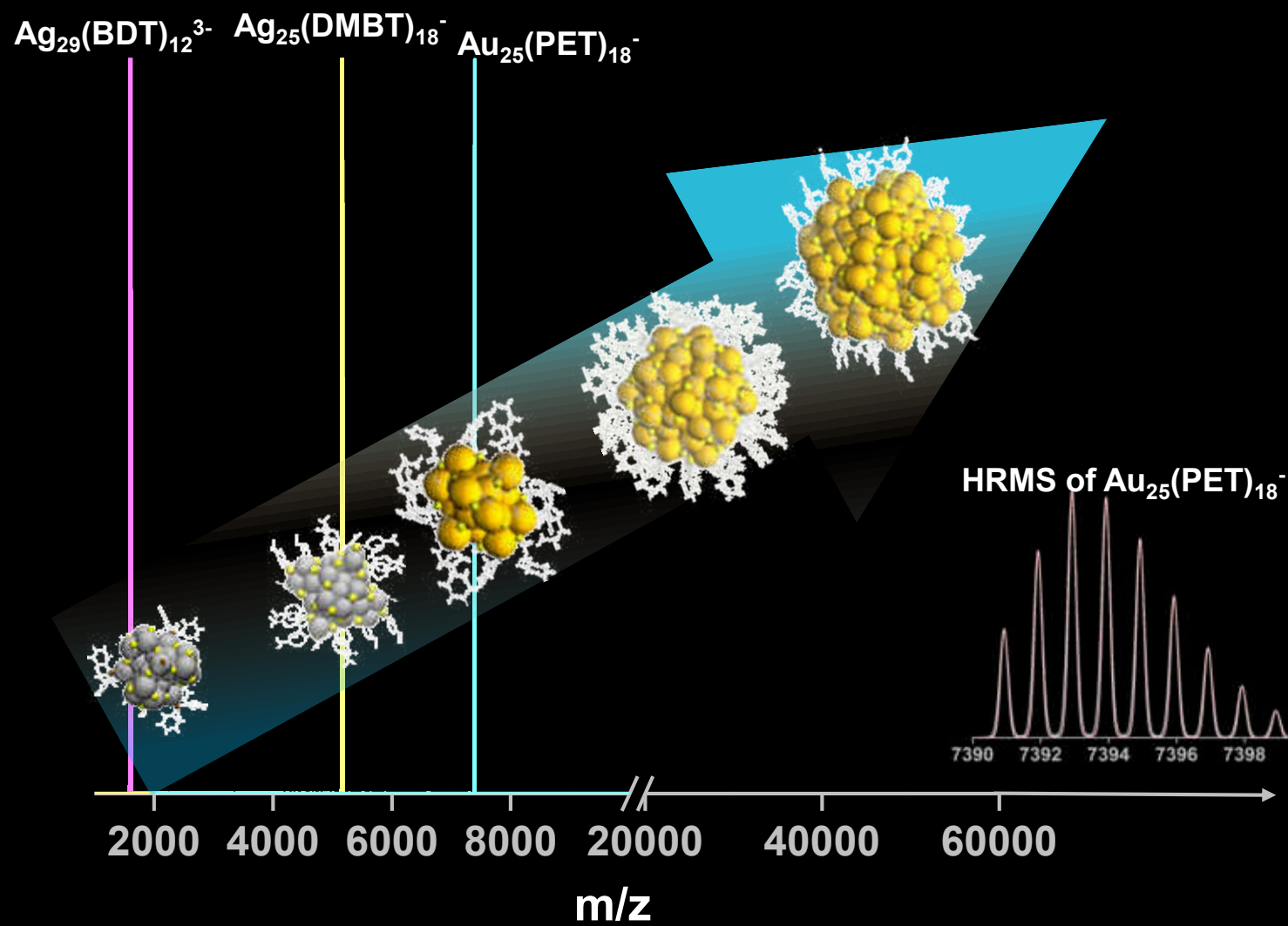
Molecular structure



Geometric and electronic shells
Gana Natarajan

TEM images of Au₂₅ and Au₁₄₄





Edited by
Thalappil Pradeep


ATOMICALLY PRECISE METAL NANOCCLUSERS

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grc.org/atomically-precise-nanochemistry-conference/2024/

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Collaborators



Tatsuya Tsukuda
Keisaku Kimura
Yuichi Negishi
Uzi Landman
Hannu Hakkinen
Rob Whetten

Shiv Khanna



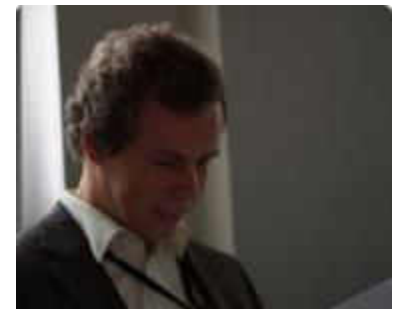
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Manfred Kappes



Nonappa



Tomas Base



Olli Ikkala



Horst Hahn



Biswarup Pathak



K. V. Adarsh



G. U. Kulkarni



Vivek Polshettiwar



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

Funding: Department of Science and Technology, Government of India

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Indian Institute of Technology Madras



Associate Editor

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Manswita Mandal for help with the slides

My lessons

- Look into local issues.
- Use every opportunity to visit an industry.
- Keep friends from other disciplines.
- Follow your urge. Your most important companion is just you.
- Never compromise on work. 24x7.
- Throw away ideas for others because you cannot solve all.
- Words kill

An ocean of opportunities

Water presents a unique opportunity to find a purpose in life.



Earthrise, taken on December 24, 1968, by Apollo astronaut William Anders.
From Wikipedia