Since 1959

Affordable clean water using advanced materials

Thalappil Pradeep

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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

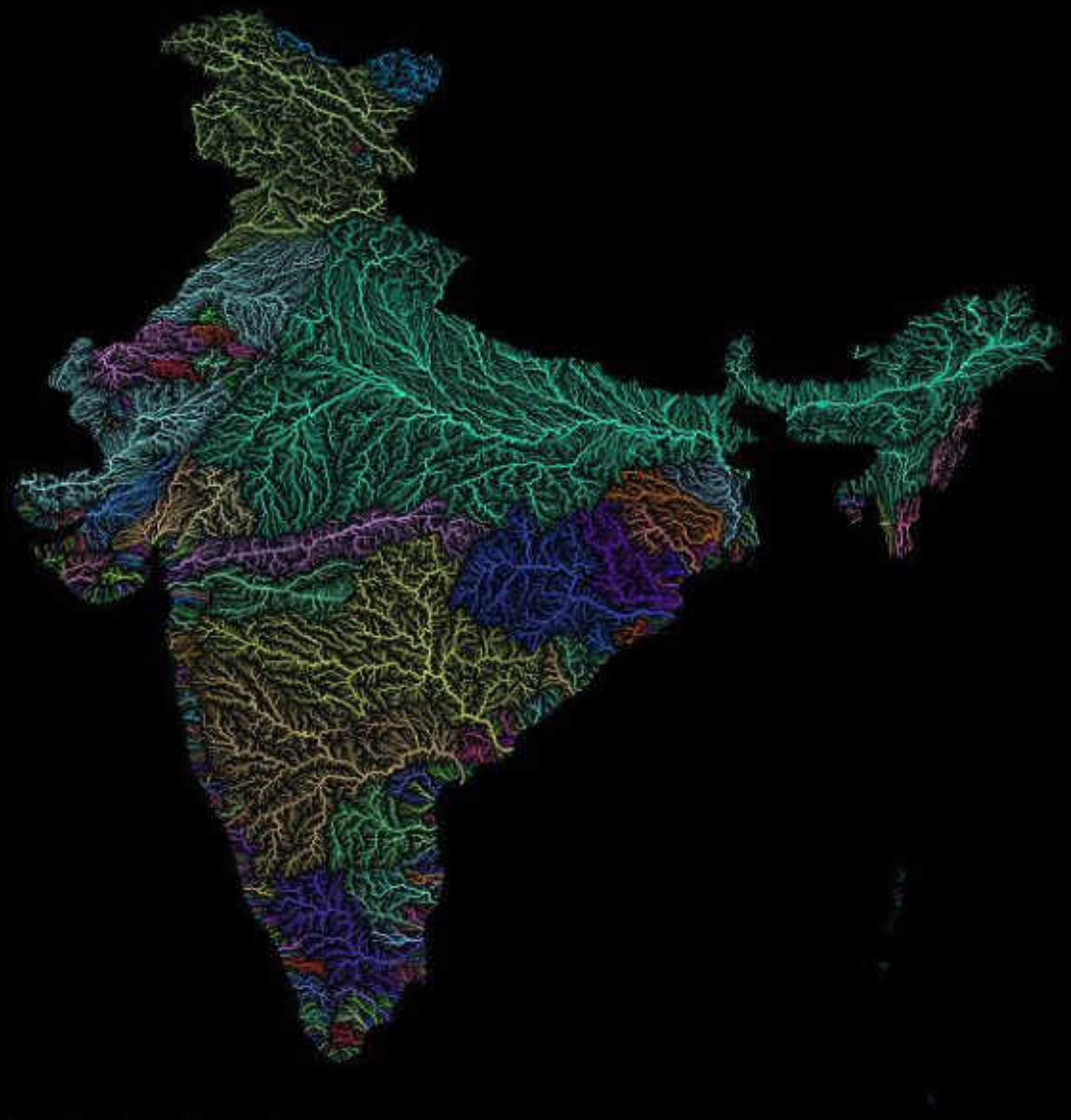
International Centre for Clean Water

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

Water is the most important inheritance of our planet

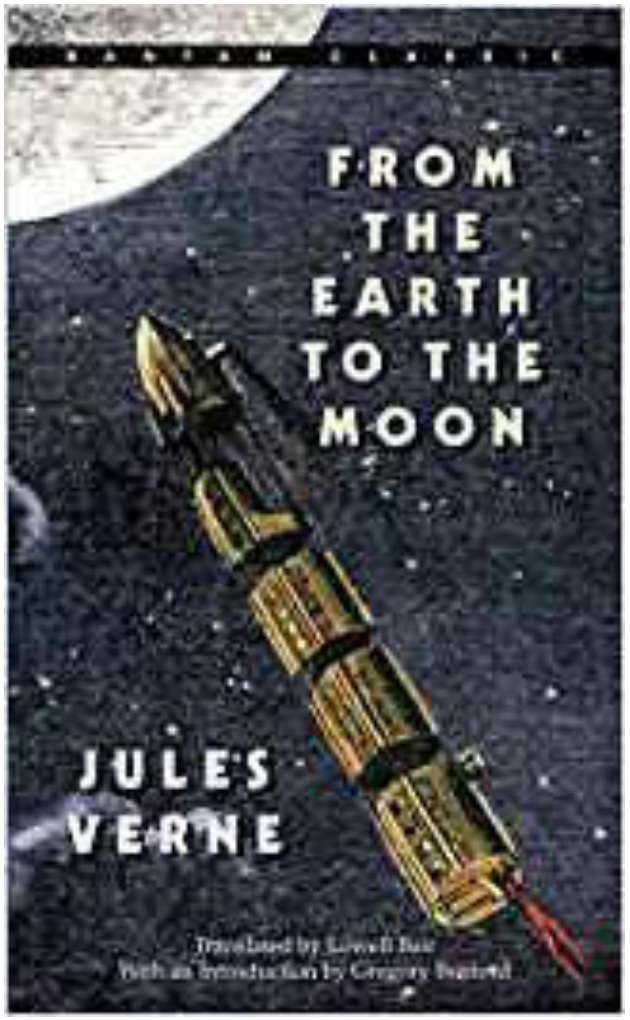
Water is at the entre of action

There is water in everything we do.



From S. Vishwanath

Our dreams become reality with materials



Water purification, history

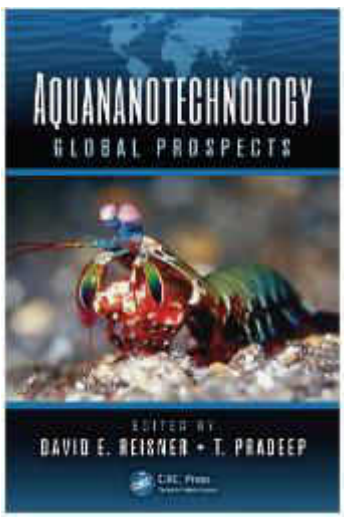
Important milestones in the history of water purification (1800–2007) from the perspective of noble metal nanoparticles in water treatment (compiled from multiple sources on the World Wide Web).

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	*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 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)

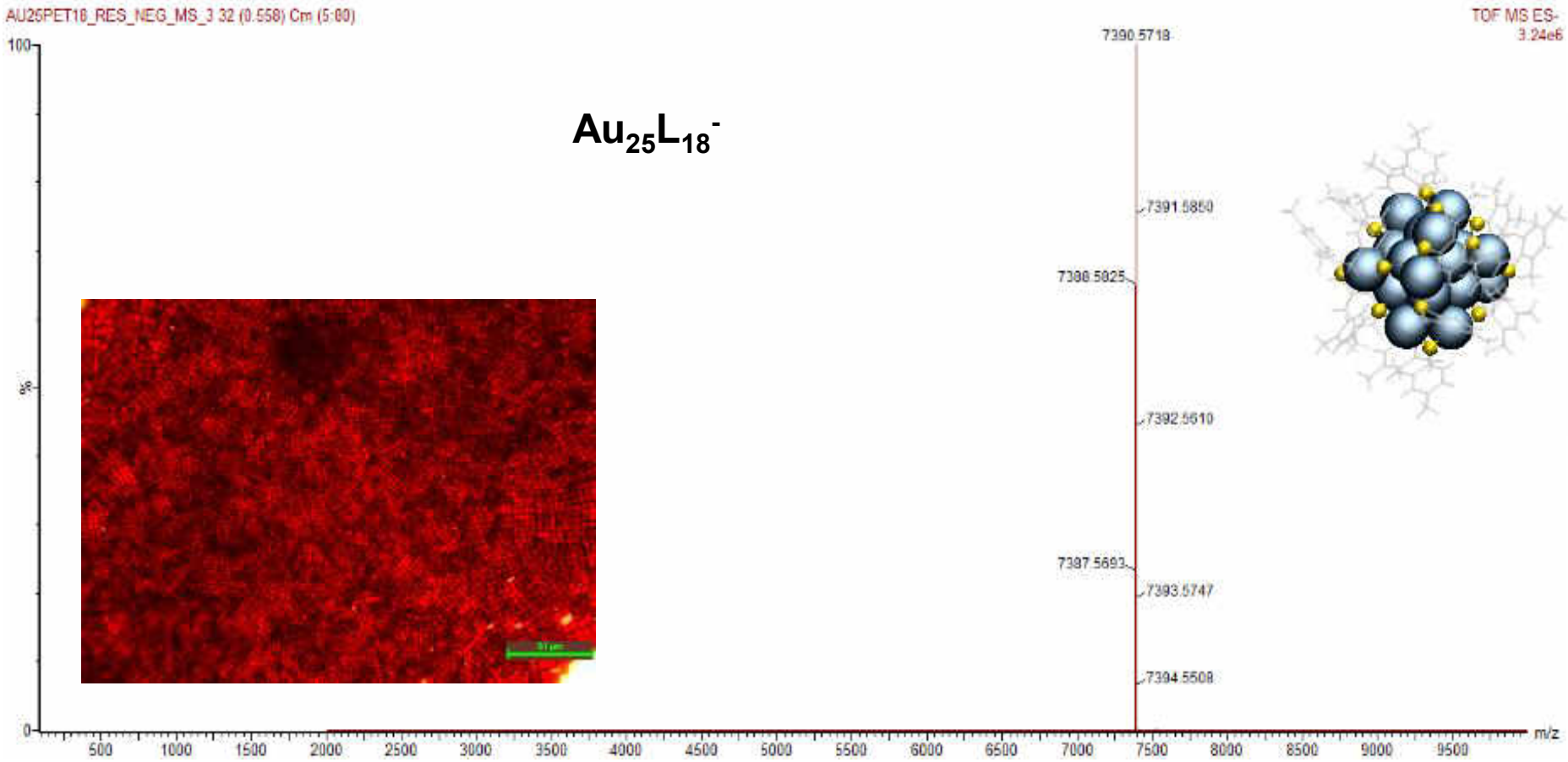
T. Pradeep and Anshup, *Thin Solid Films*, 2009

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

PNAS PNAS

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

Mohan Udhaya Sankar[1], Sahaja Aigal[1], Shihabudheen M. Maliyekkal[1], Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep[2]

Unit of Nanoscience and Thematic Unit of Excellen

n, Chennai 600 036, India

Edited by Eric Hoek, University of California, Los A

ved for review November 21, 2012)

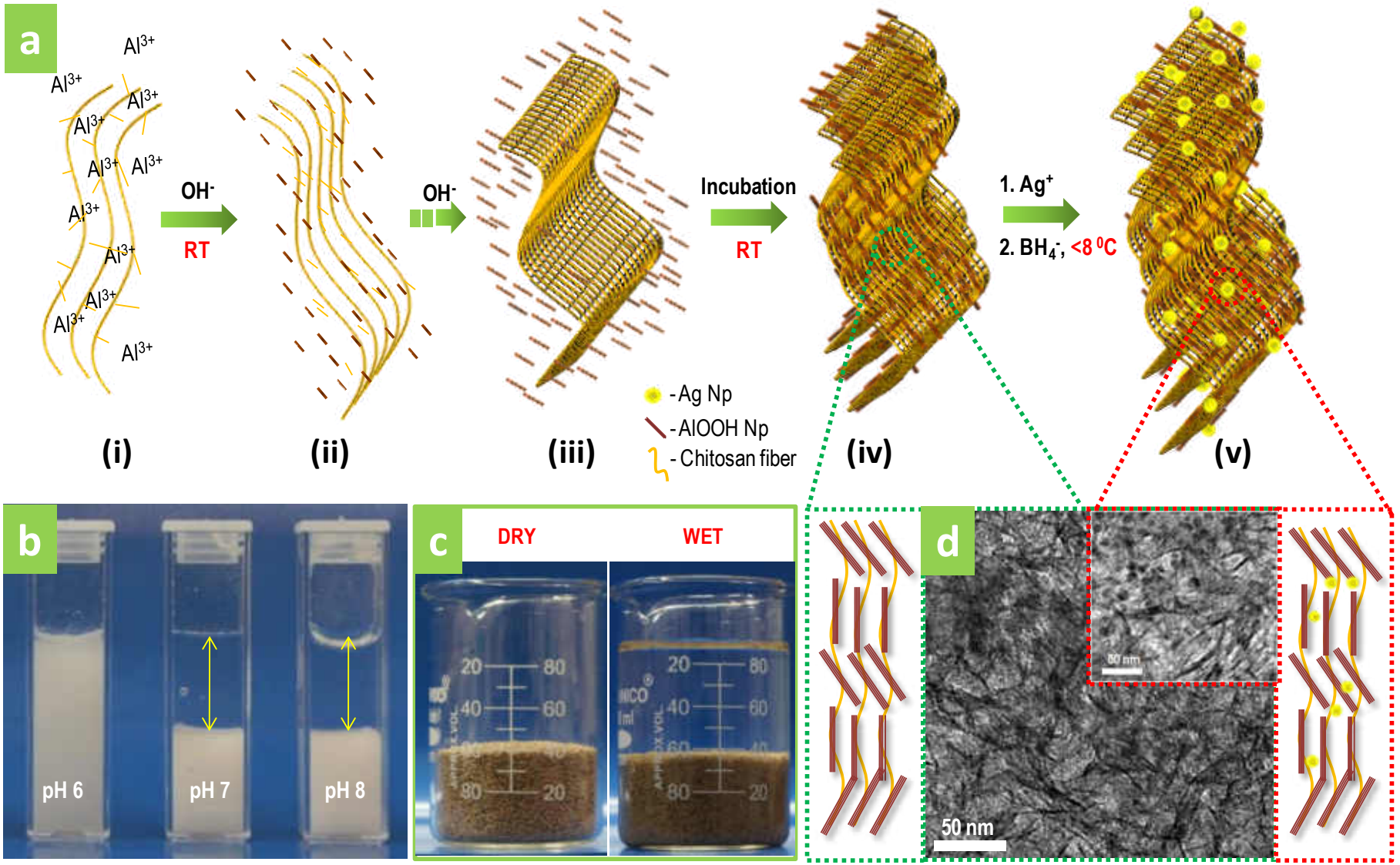
Creation of affordable materials for constant
water is one of the most promising ways to p
drinking water for all. Combining the capa
composites to scavenge toxic species such
other contaminants along with the above c
affordable, all-inclusive drinking water purif
without electricity. The critical problem in
synthesis of stable materials that can relea
uously in the presence of complex specie
drinking water that deposit and cause scal
surfaces. Here we show that such constant
be synthesized in a simple and effective fashio
out the use of electrical power. The nanocc
sand-like properties, such as higher shear str
forms. These materials have been used to d
water purifier to deliver clean drinking water
ily. The ability to prepare nanostructured c
ambient temperature has wide relevance f
water purification.

ble; and (*c*) continued retention
ix is difficult.
unique family of nanocrystalline
nular composite materials pre-
through an aqueous route. The
ition is attributed to abundant -O-
hitosan, which help in the crys-
and also ensure strong covalent
ace to the matrix. X-ray photo-
lrms that the composition is rich
sing hyperspectral imaging, the
g in the water was confirmed.
activate the silver nanoparticle
timicrobial activity in drinking
have been developed that can
water. We demonstrate an af-
e based on such composites de-
dergoing field trials in India, as
d eradication of the waterborne

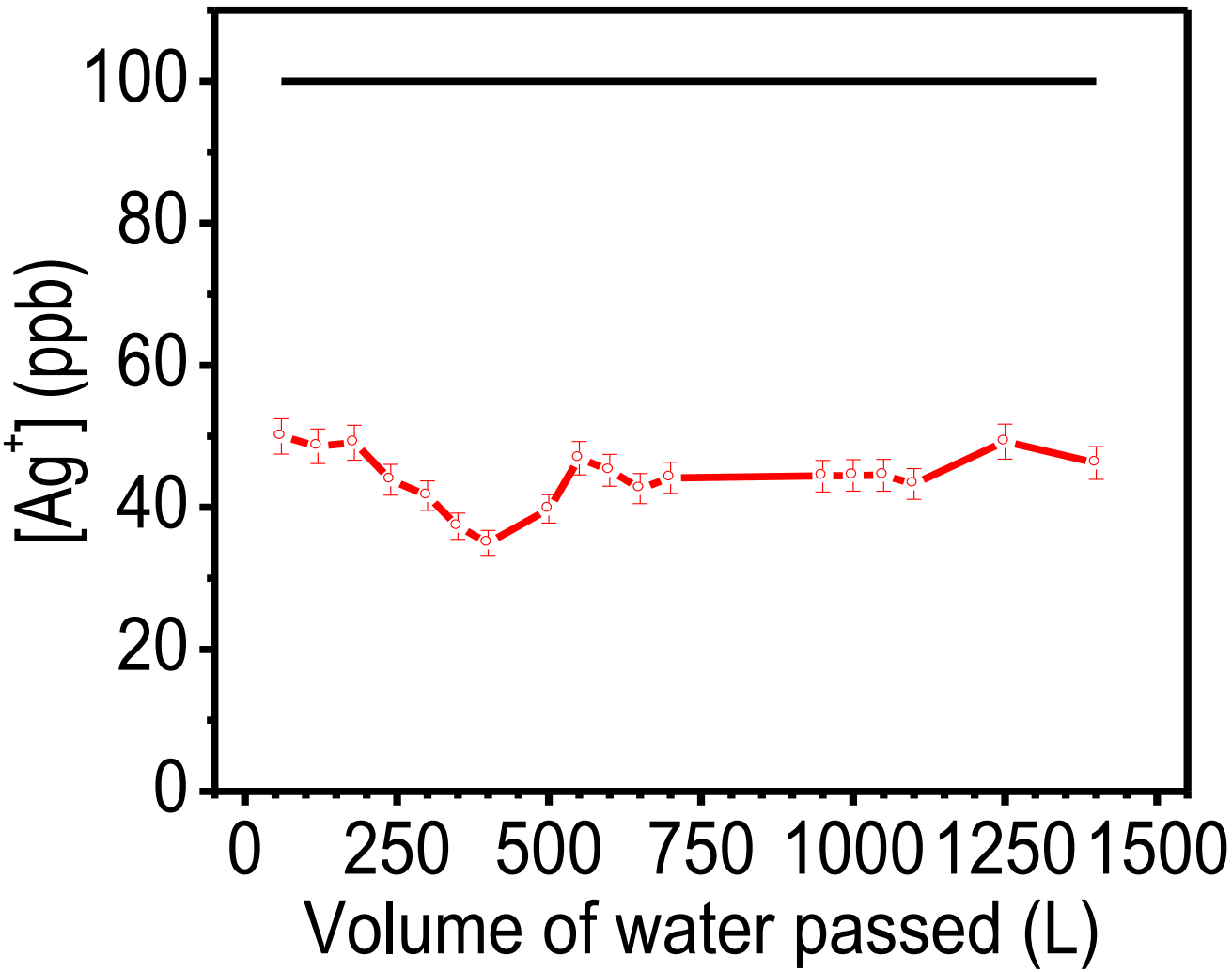
hybrid | green | appropriate technology | frugal science | developing world

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

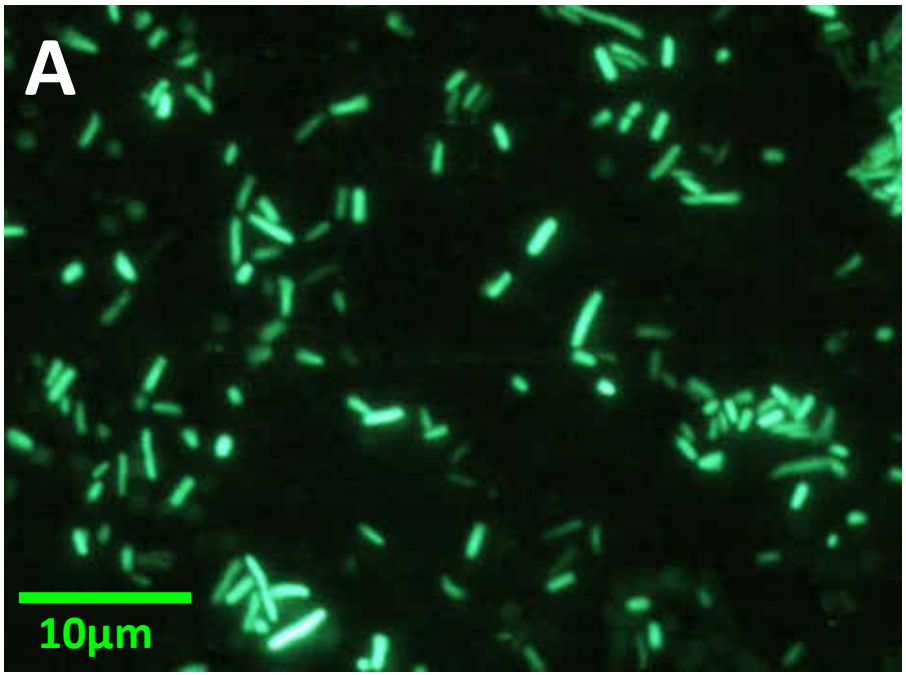
How to make?

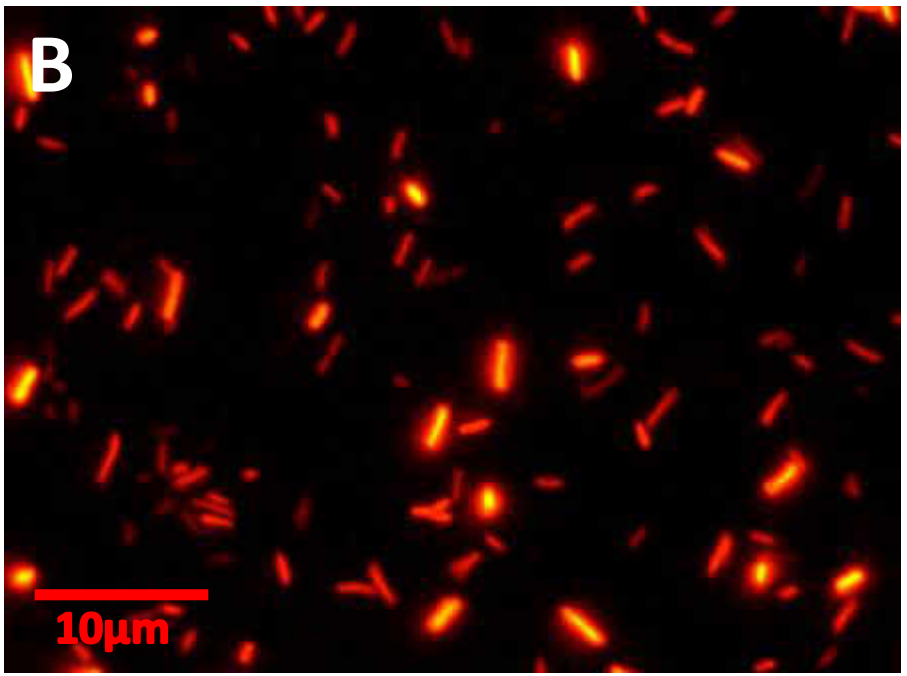

a
Al3+
OH-
RT
OH-
Incubation
RT
1. Ag+
2. BH4-, <8 0C
- Ag Np
- AlOOH Np
- Chitosan fiber
(i)
(ii)
(iii)
(iv)
(v)
b
pH 6
pH 7
pH 8
c
DRY
WET
d
50 nm

What is special?

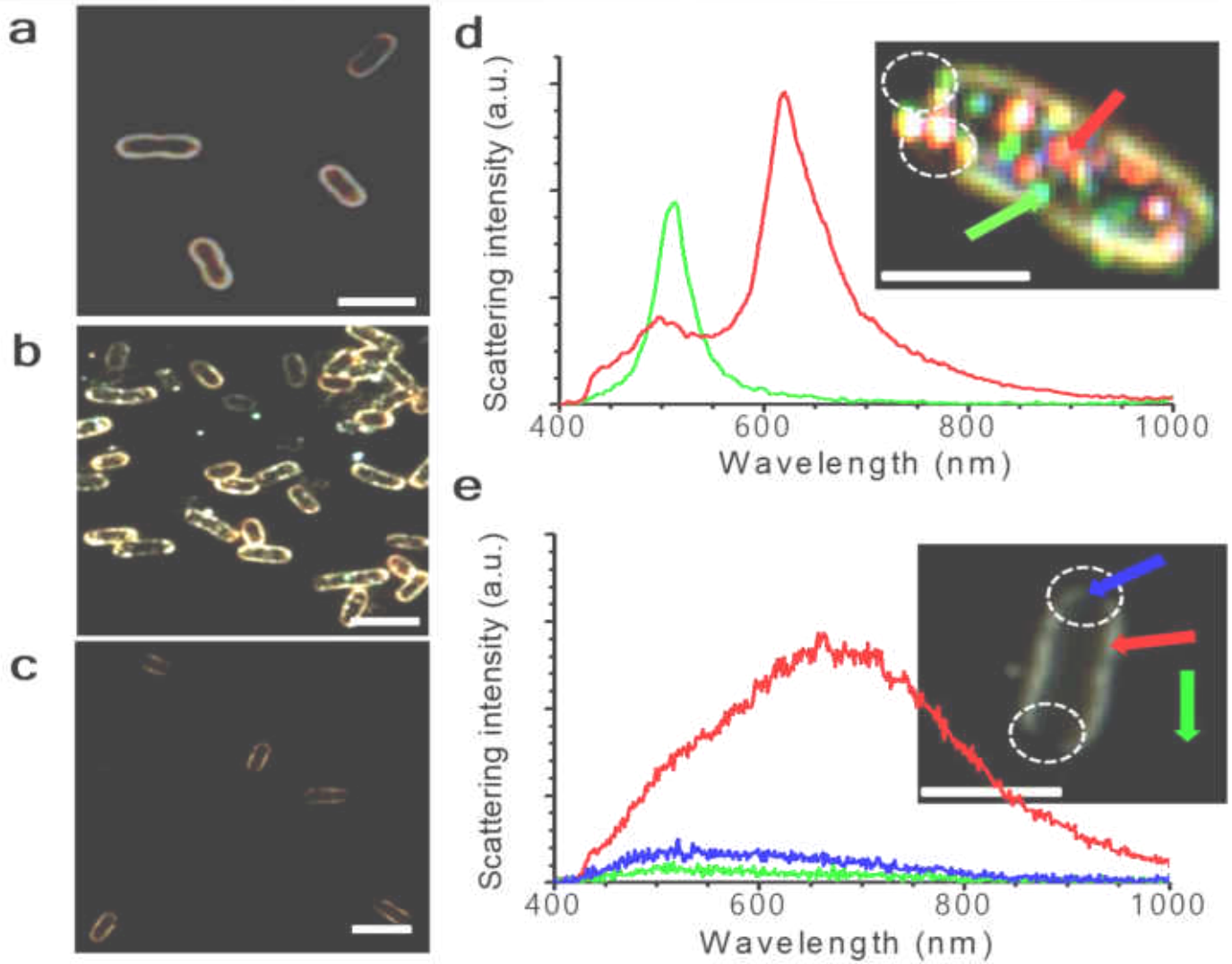


Live/dead staining experiments

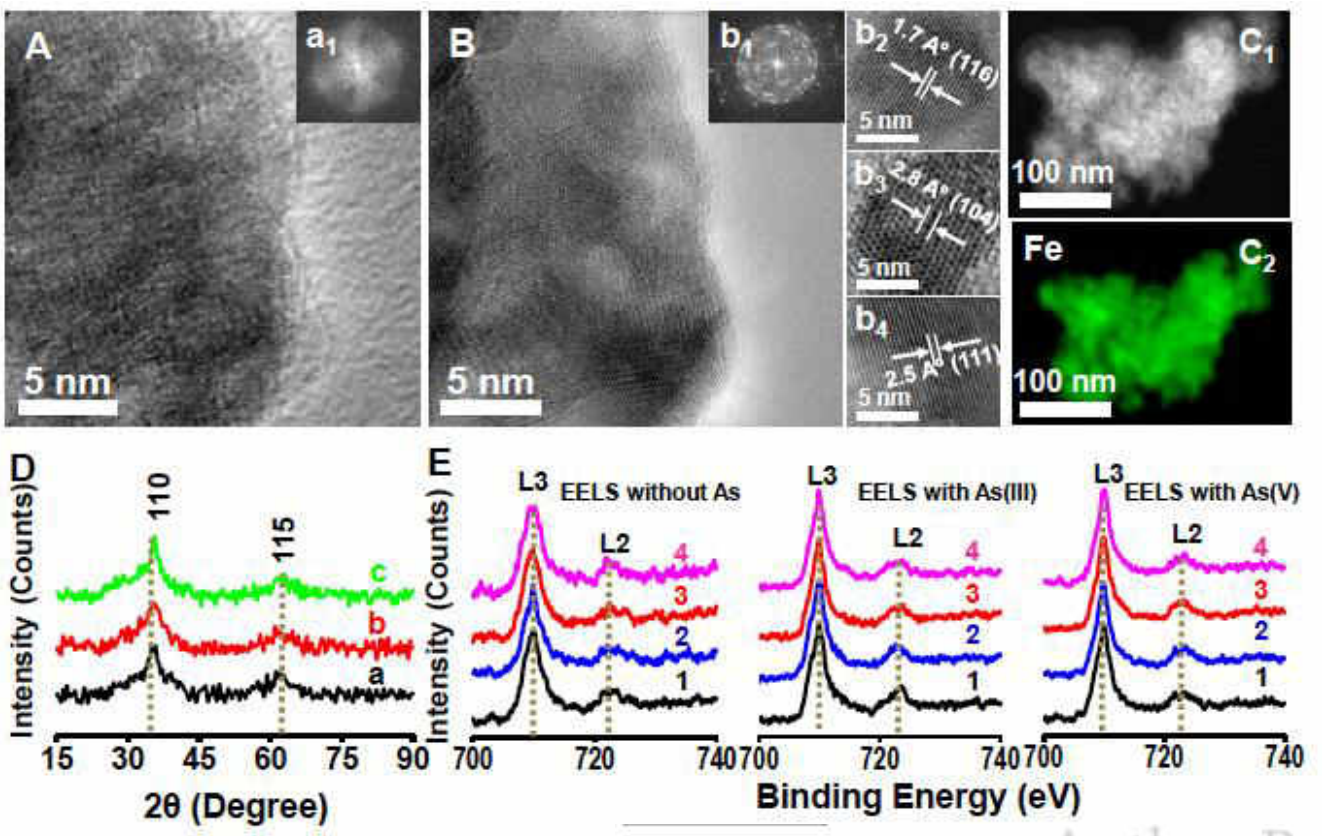




No nanotoxicity



Variety of materials



www.advmat.de
ADVANCED MATERIALS

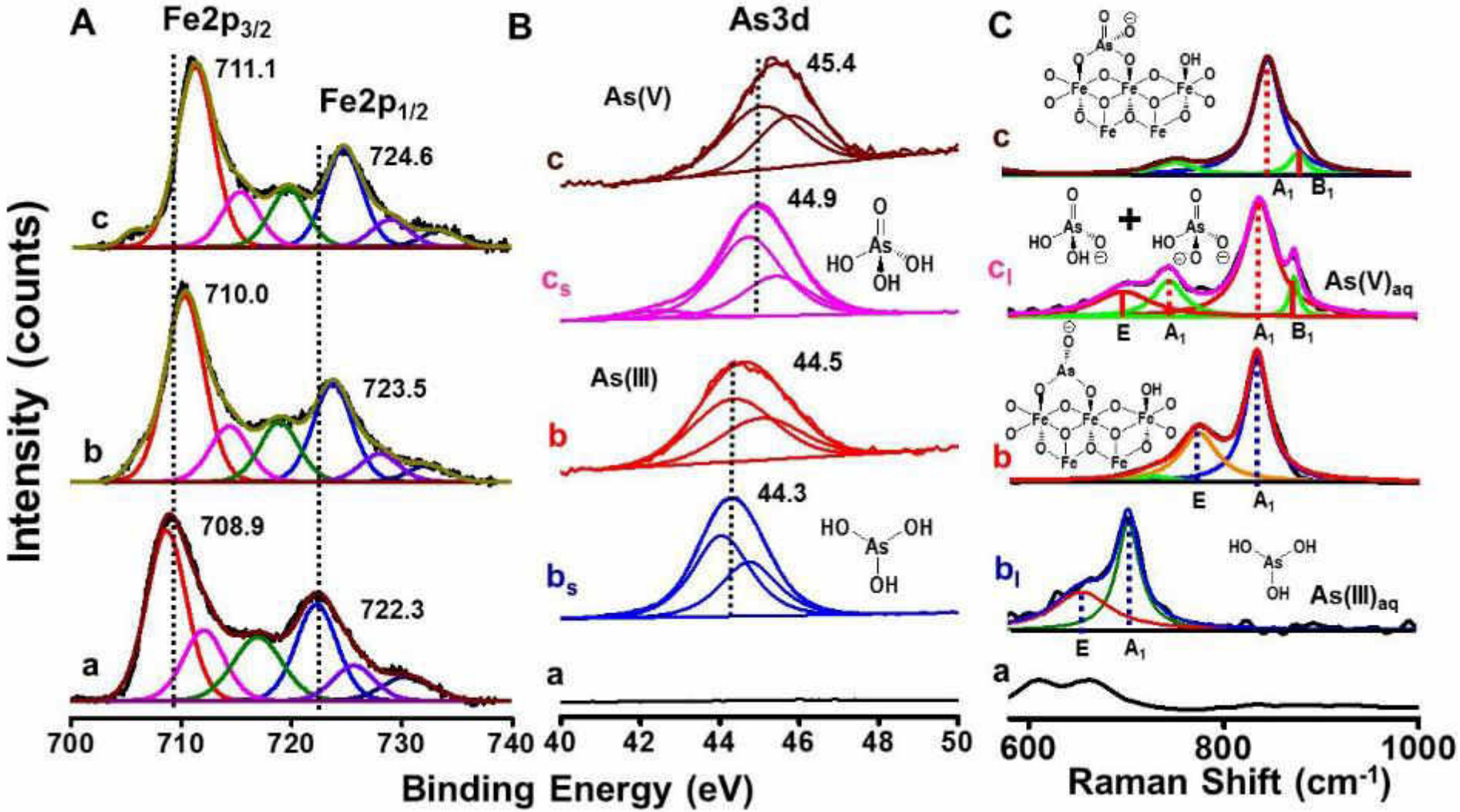
Confined Metastable 2-Line Ferrihydrite for Affordable Point-of-Use Arsenic Free Drinking Water

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

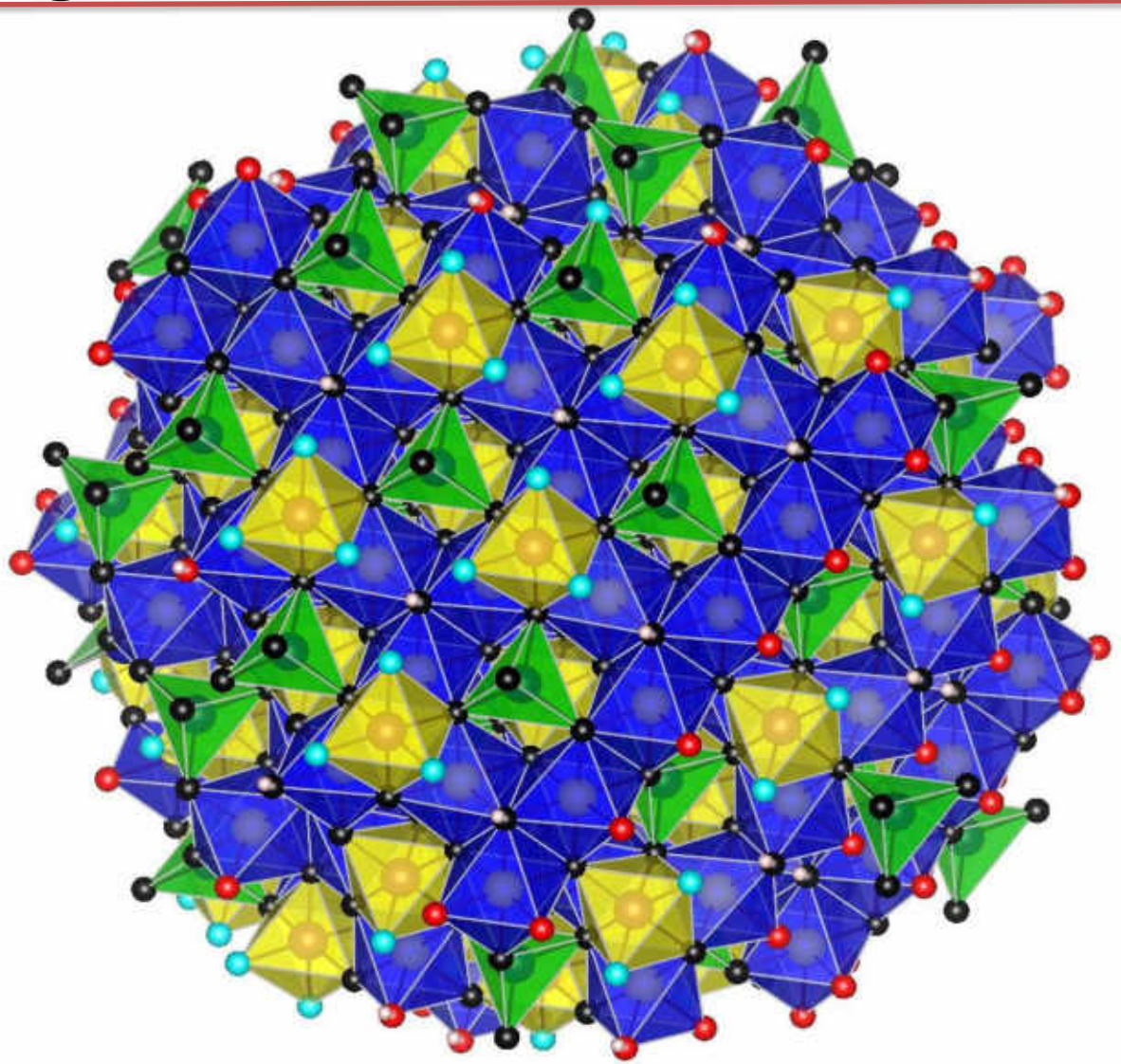
Communication

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

Mechanism

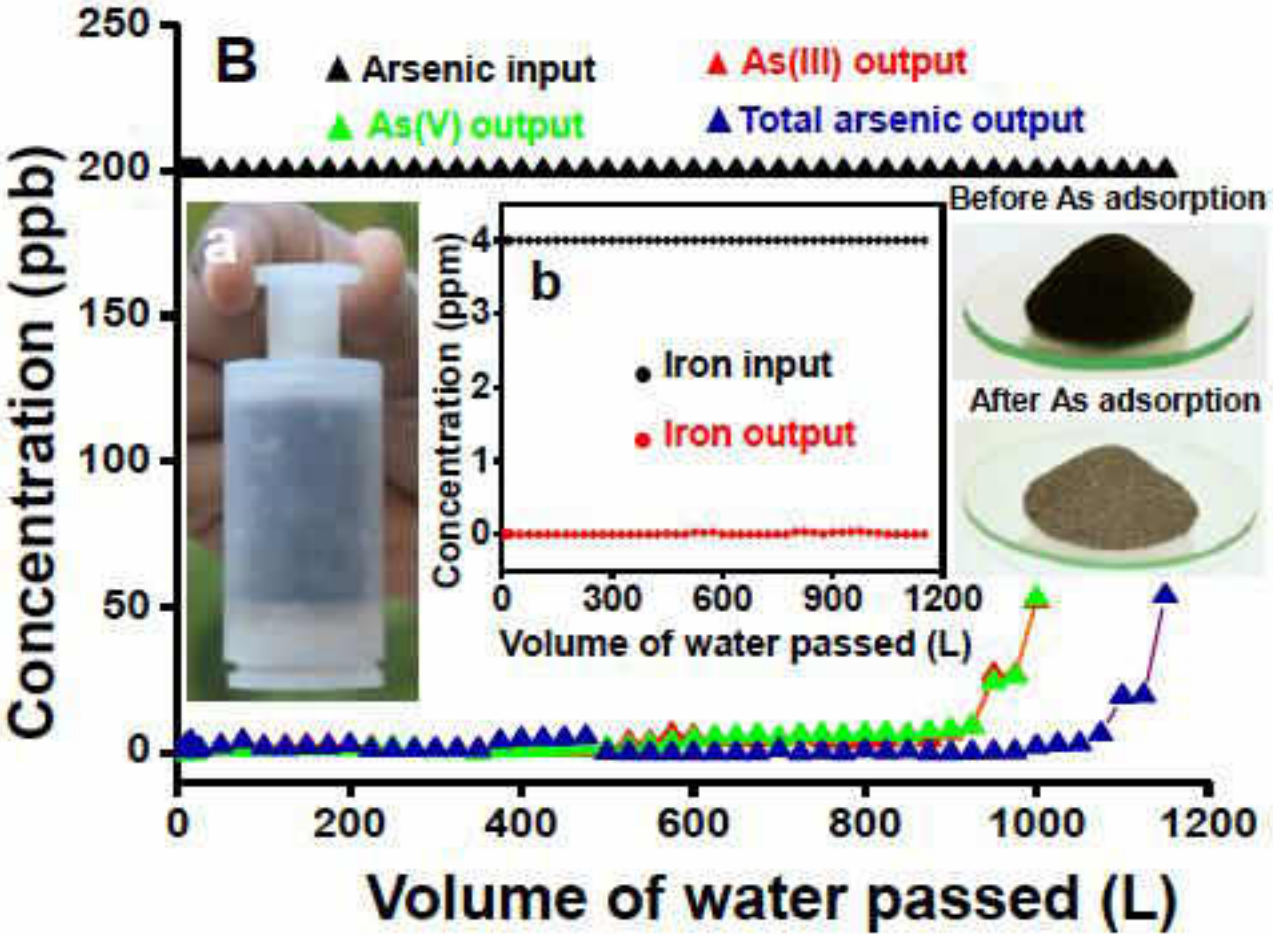

A
Fe2p3/2
711.1
Fe2p1/2
724.6
c
710.0
723.5
b
708.9
722.3
a
Intensity (counts)
700
710
720
730
740
B
As3d
As(V)
45.4
c
44.9
cs
As(III)
44.5
b
44.3
bs
a
40
42
44
46
48
50
Binding Energy (eV)
C
c
A1
B1
cl
As(V)aq
E
A1
A1
B1
b
E
A1
bl
As(III)aq
E
A1
a
600
800
1000
Raman Shift (cm-1)

Modeling surfaces



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

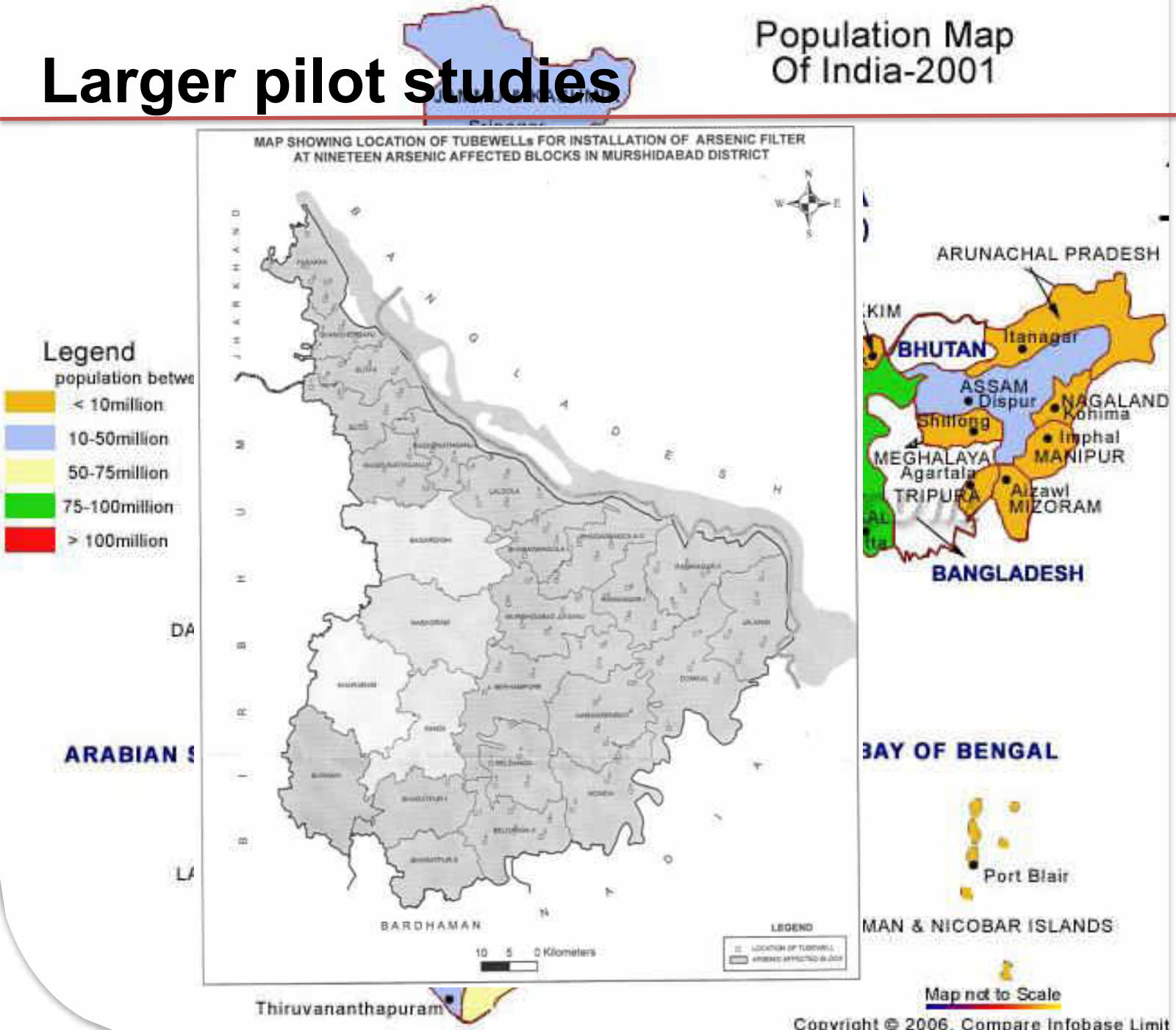
Lab studies



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

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

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

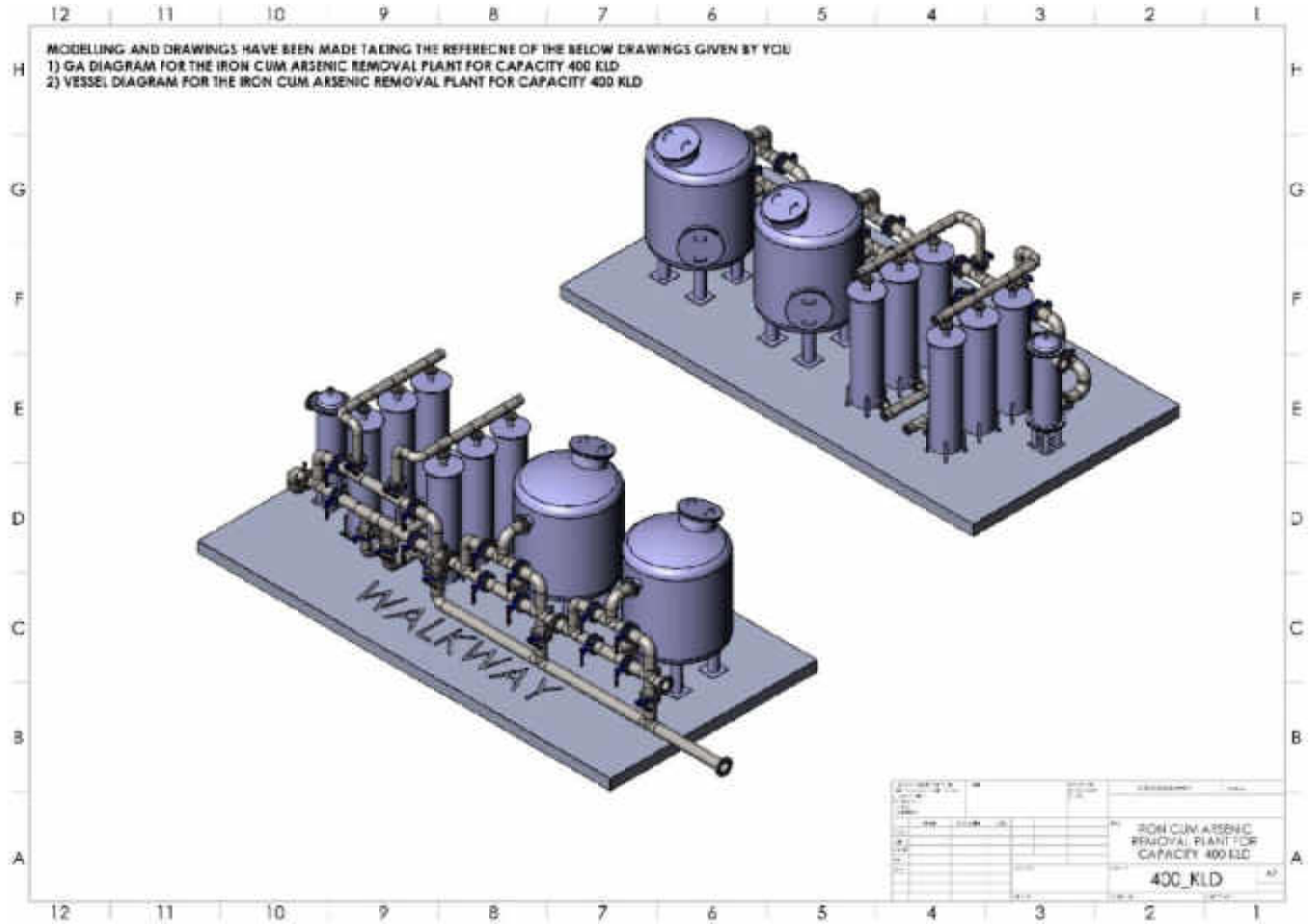
Capacity: above 1 MLD

5 schemes in use across India

Retrofitted Water Purification Plant

Capacity: 0.1-1 MLD

Over 180 units in use across India

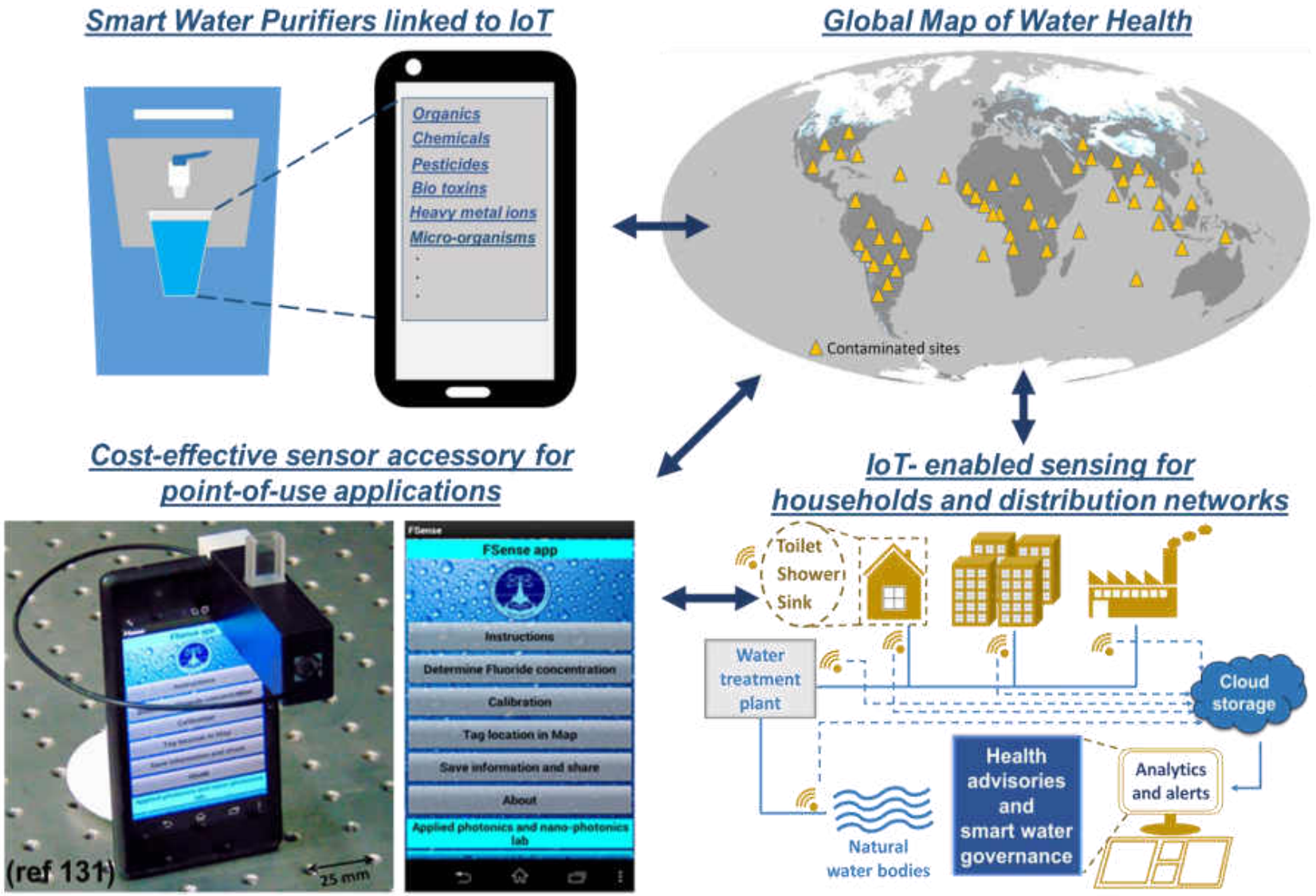

MODELLING AND DRAWINGS HAVE BEEN MADE TAKING THE REFERECNE OF THE BELOW DRAWINGS GIVEN BY YOU
1) GA DIAGRAM FOR THE IRON CUM ARSENIC REMOVAL PLANT FOR CAPACITY 400 KLD
2) VESSEL DIAGRAM FOR THE IRON CUM ARSENIC REMOVAL PLANT FOR CAPACITY 400 KLD
WALKWAY
IRON CUM ARSENIC REMOVAL PLANT FOR CAPACITY 400 KLD
400_KLD

Cleanwater at 2.1 paise per litre!

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

Sr.No.	Item/Description	Cost / Quantity	Remarks
	Design population	1,071	Plant capacity/70 LPCD
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

Smart water purifiers and big data



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

Waste management

Adsorbents conform to toxicity characteristic leaching procedure

Elemental waste goes back to local environment

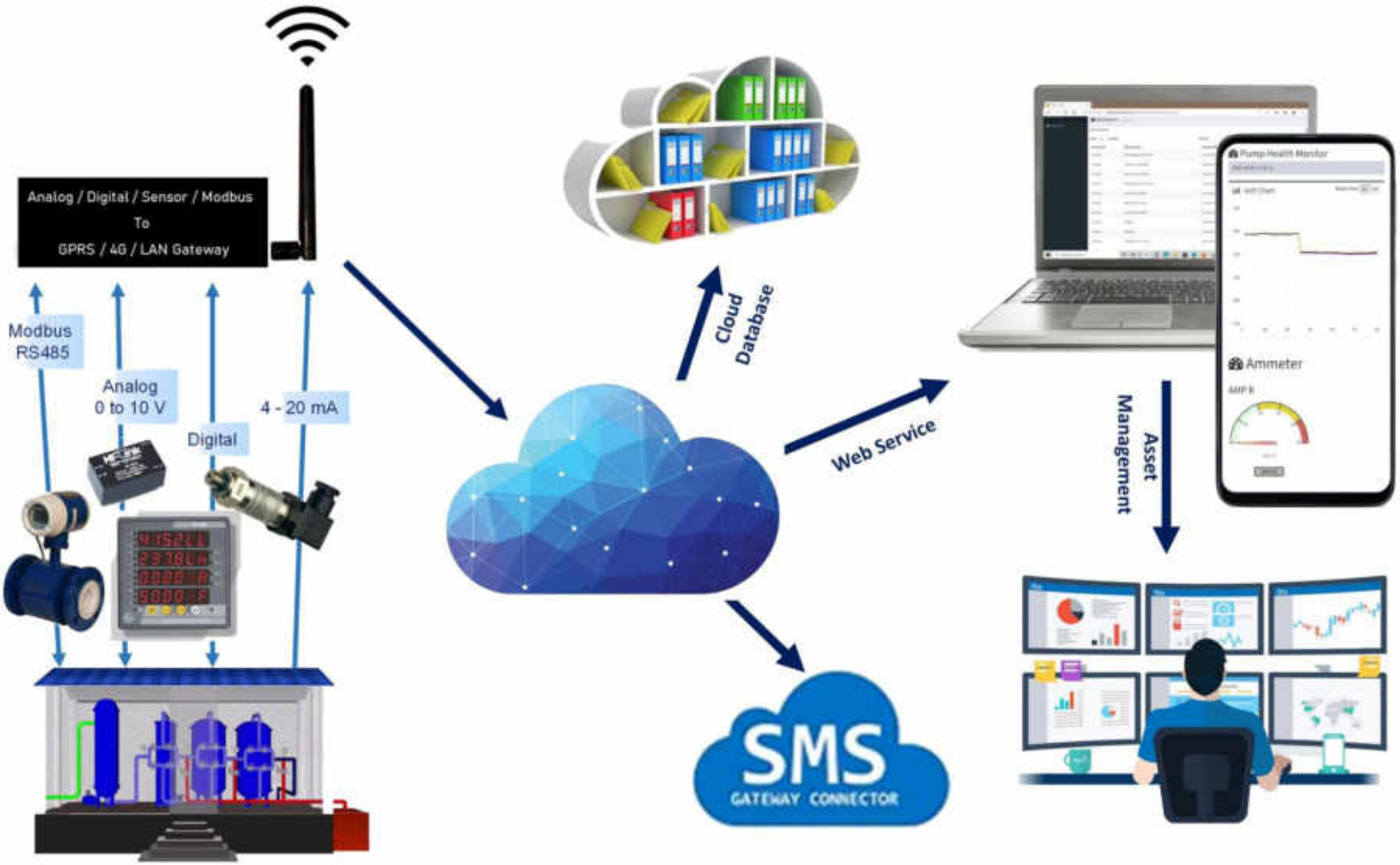
Safe disposal of arsenic (or any other) laden waste

Additional protection could be considered, if necessary

Exploring viable uses

Across the country

Components of IoT architecture implemented by DWSS, GoP

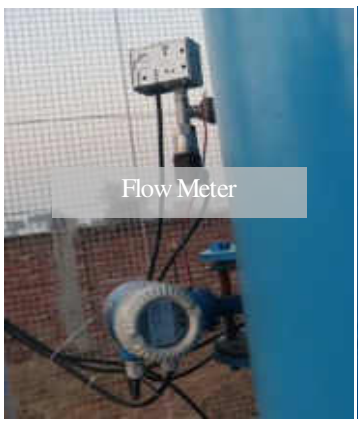


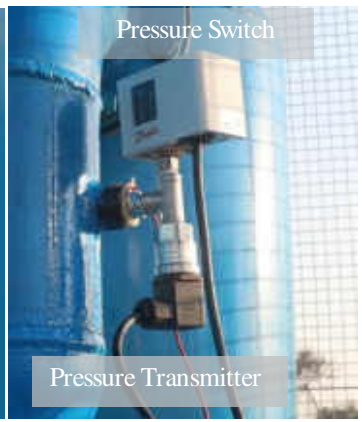
Typical IoT architecture comprises various sensors and meters, communication gateway, Cloud Server, SMS gateway, Webservices and mobile phone application for operator

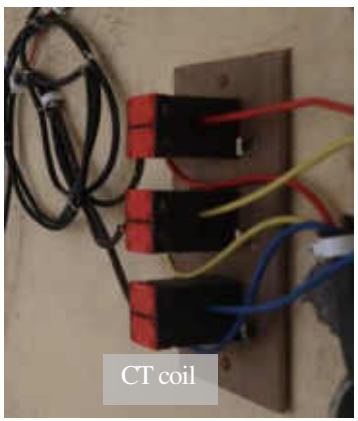
View of physical assets of IoT Platform

- IoT Gateway
- MFM Energy Meter
- Electromagnetic Flow meter
- Pressure transmitter
- Pressure Switch
- Pump Automation PLC Relay

All components run on 12VDC. Hence the infrastructure can be deployed with Solar panel anywhere

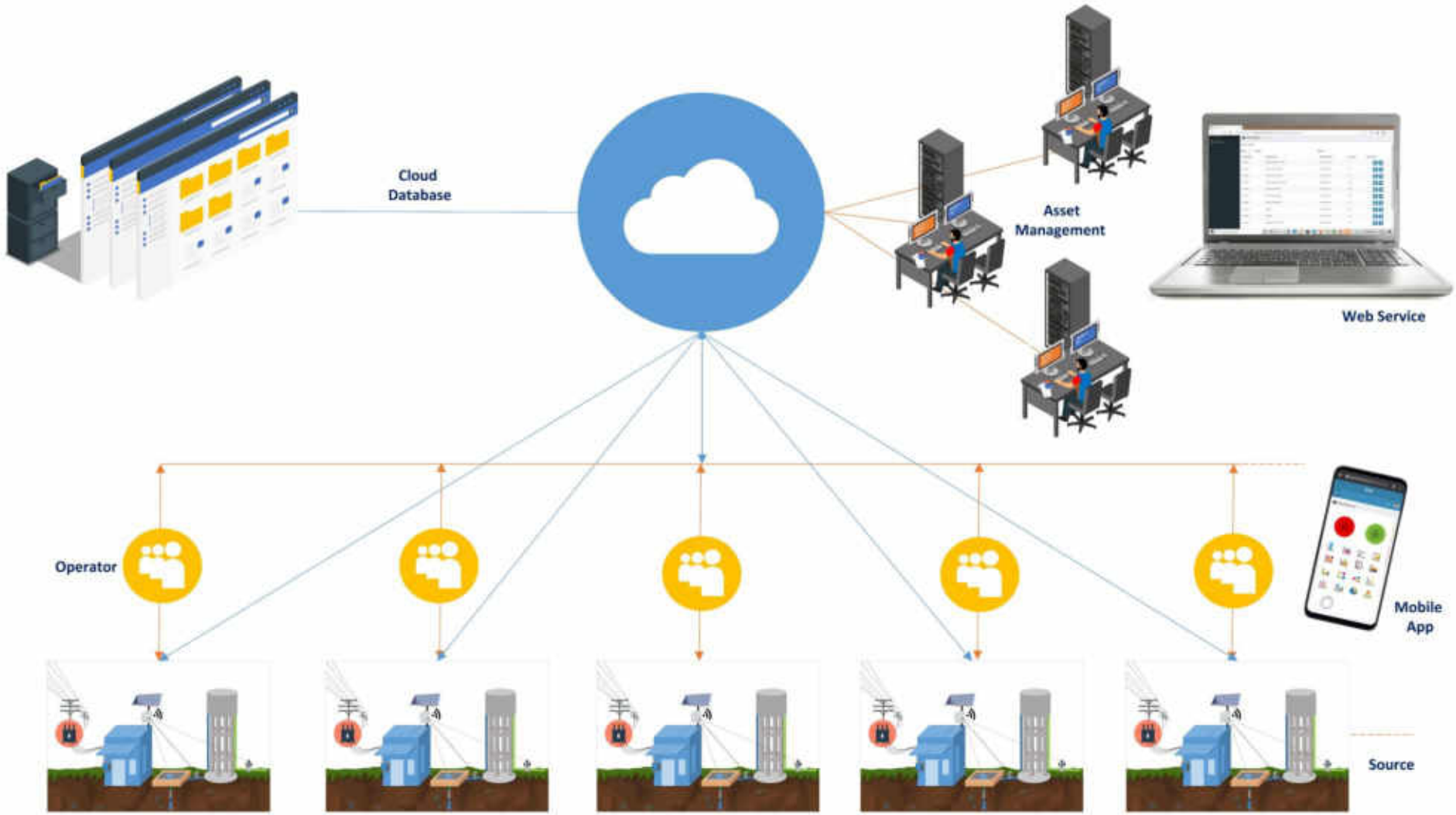




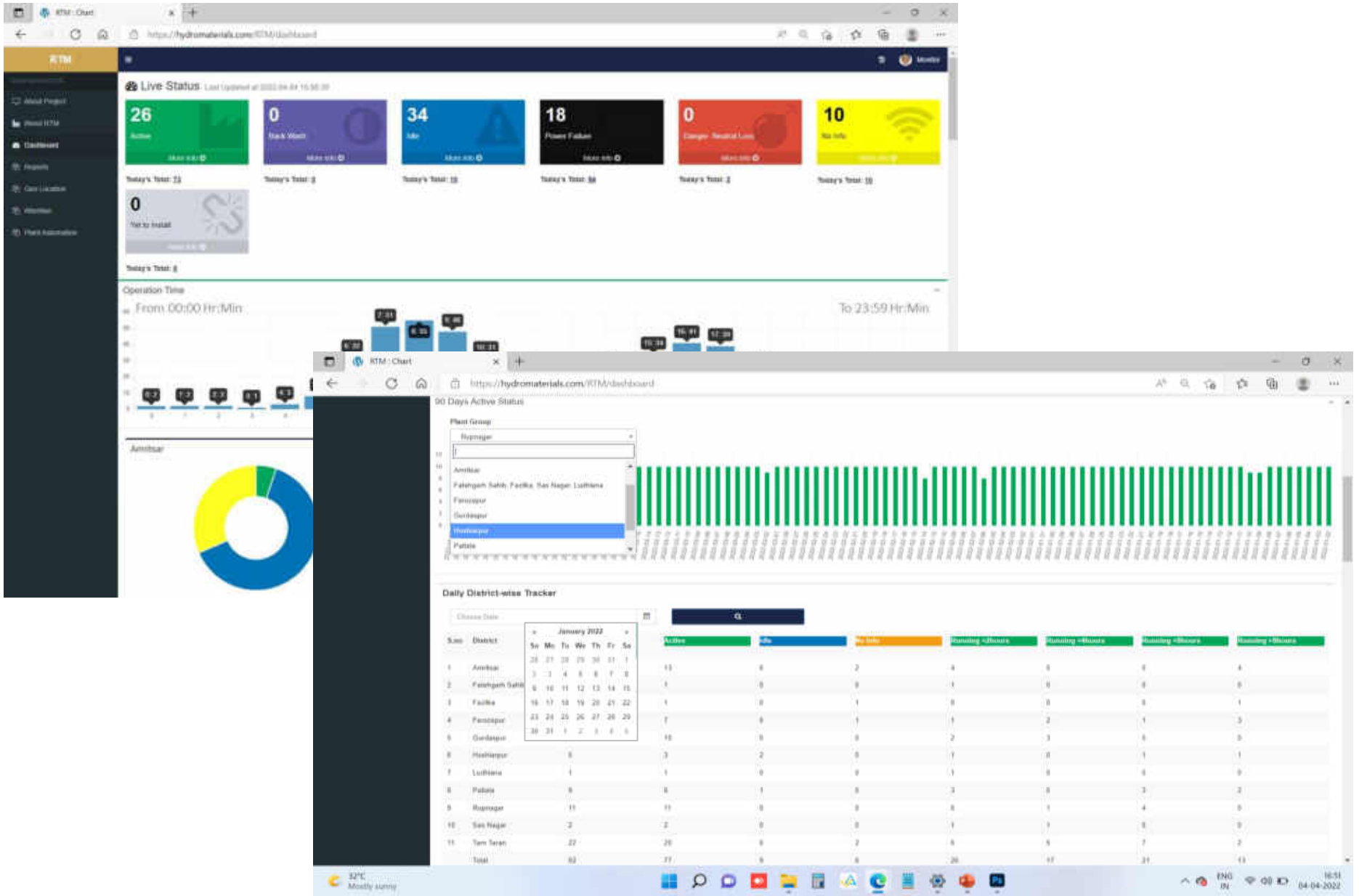


The installed IoT platform is not merely limited to the above mentioned sensor and meter. The infrastructure is expandable. Various water quality sensors and Server side semi-automation can be implemented as and when needed.

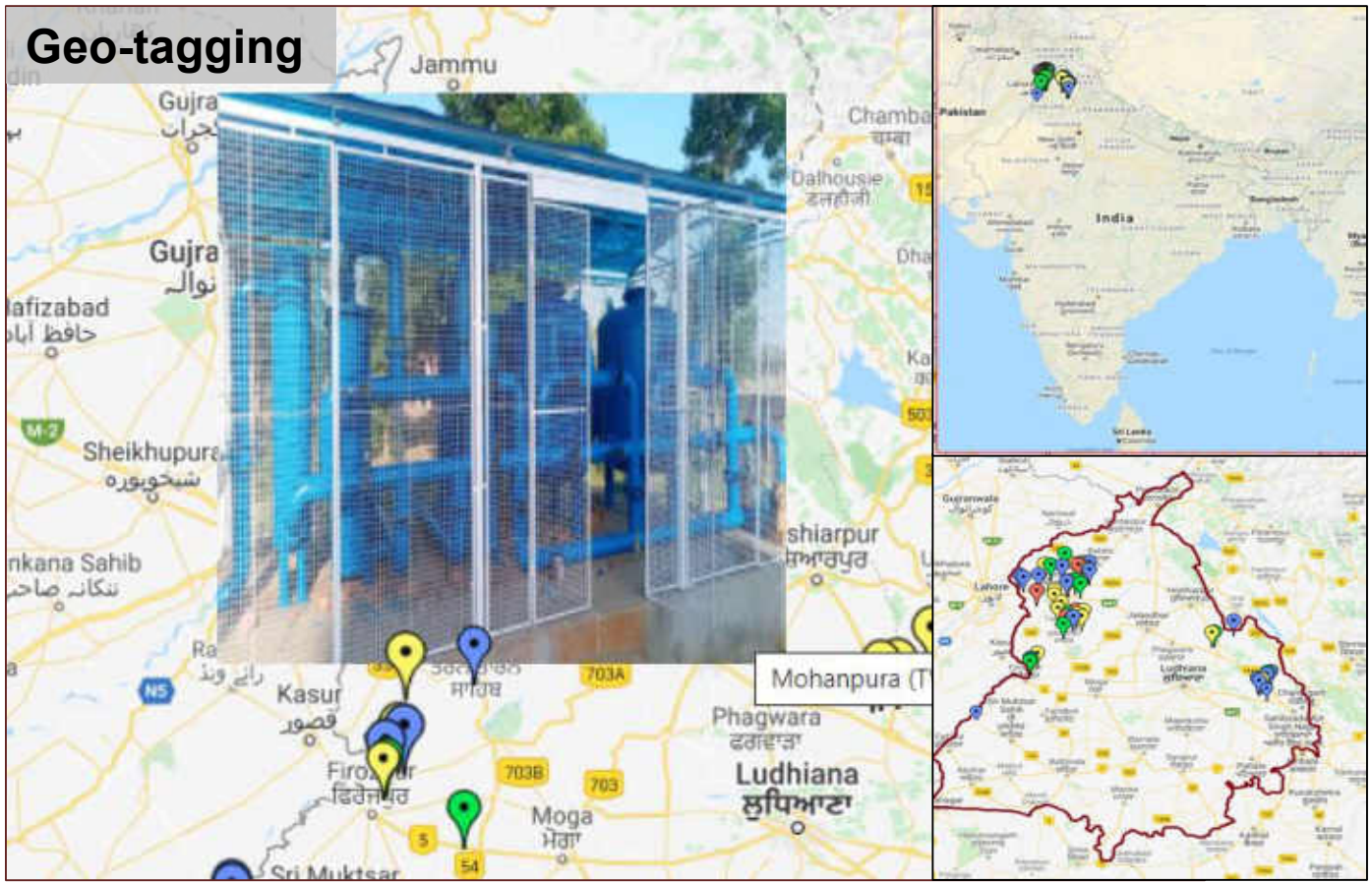
Phase 2: Server-side Automation of water supply scheme retrofitted with AIRP



Server-side automation of Retrofitted AIRP with water supply scheme is being implemented at all sites. This includes manual and via mobile phone app operation by operator, webpage based control and scheduled operation from server-side. This is being implemented to ensure that neither supply is short nor it is over exploited.


RTM : Chart
https://hydromaterials.com/RTM/dashboard
RTM
Live Status
26
Active
0
Stock Wash
34
Idle
18
Power Failure
0
Danger: Residual Lives
10
No Info
0
Yet to Install
Operation Time
From 00:00 Hr:Min
To 23:59 Hr:Min
Amritsar
90 Days Active Status
Plant Group
Rupnagar
Amritsar
Fatehgarh Sahib, Faziika, San Nagar, Ludhiana
Ferozpur
Gurdaspur
Hoshiarpur
Patiala
Daily District-wise Tracker
January 2022
Sno
District
Active
Idle
No Info
Running <8hours
Running <8hours
Running <8hours
Running <8hours
Amritsar
Fatehgarh Sahib
Faziika
Ferozpur
Gurdaspur
Hoshiarpur
Ludhiana
Patiala
Rupnagar
San Nagar
Tarn Taran
Total
32°C
Mostly sunny
ENG
IN
16:51
04-04-2022

Geo-tagging


Jammu
Gujra
Gujra
Sheikhupura
Kasur
Ludhiana
Moga
Phagwara
Mohanpura
India
Pakistan
Lahore

RTM : Chart

https://hydromaterials.com/RTM/plantchart/22

RTM

Monitor

Volt Chart

Real time On Off

Minimum Volt : 214.35 Maximum Volt : 242.18

Flow Meter

Total Flow : 54032 Cu.m

Last Run : 18.432 Cu.m on

Last Run : 16.02 amps on 2022-04-04 16:54:16

Last Run : 16.36 amps on 2022-04-04 16:54:16

Last Run : 15.85 amps on 2022-04-04 16:54:16

Day-wise Average Current of Pump(Ampere)

Day-wise Total Pump Running Time(hours/day)

Day-wise Total treated water quantity(Cu.m/day)

Day-Wise Average Inlet Pressure (psi)

Pressure Status

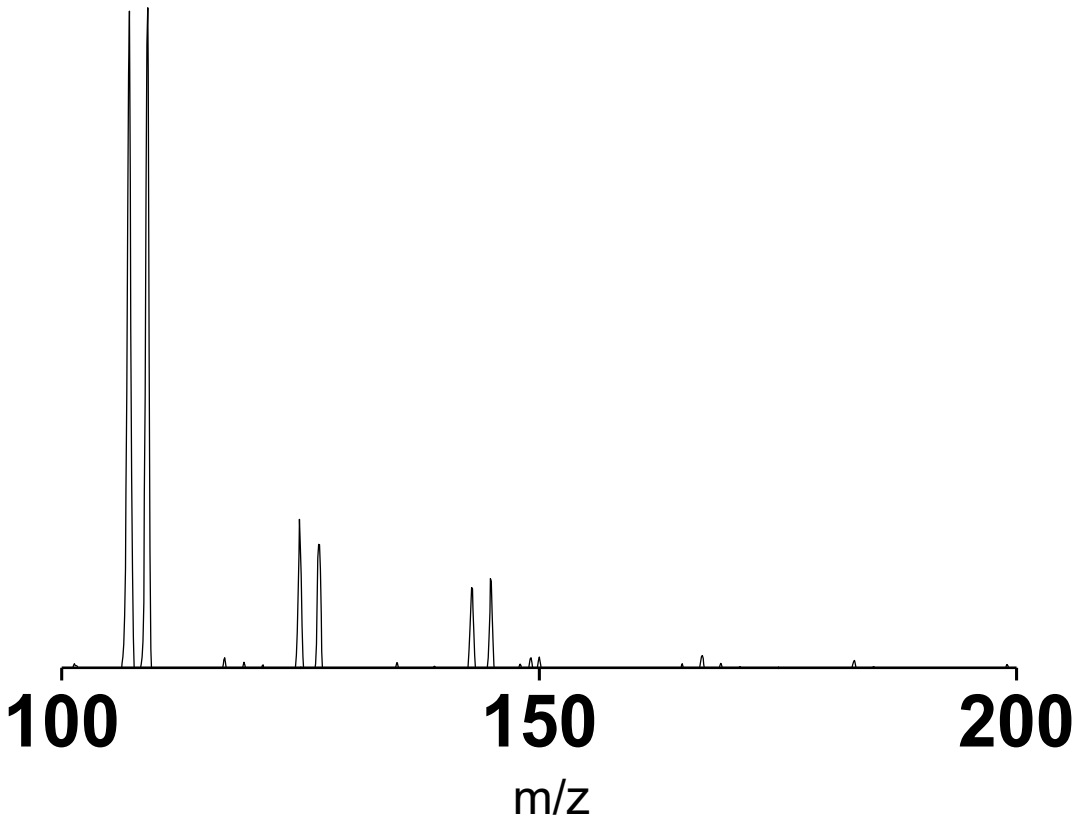
Day-wise Average Flow Rate

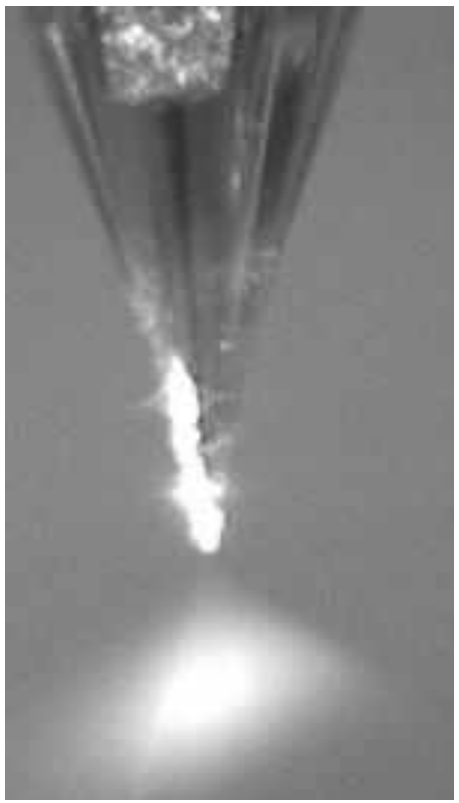
Today Running Hour

#	Task	Start Time	End Time	Minutes
1	Run 1	2022-04-04 03:37:39	2022-04-04 03:46:39	9
2	Run 2	2022-04-04 05:51:55	2022-04-04 10:31:02	279.12
3	Run 3	2022-04-04 15:39:16	2022-04-04 16:54:17	75.02
	Total			363.14

Head Loss

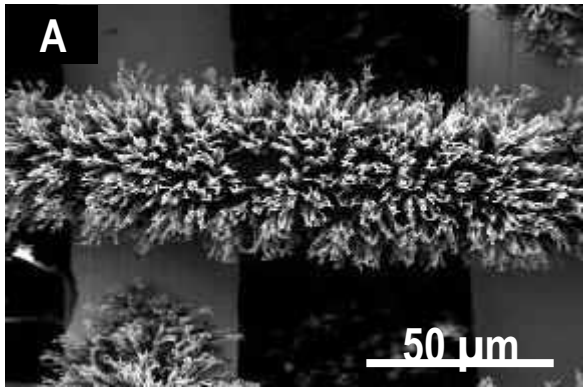
Atmospheric water harvesting

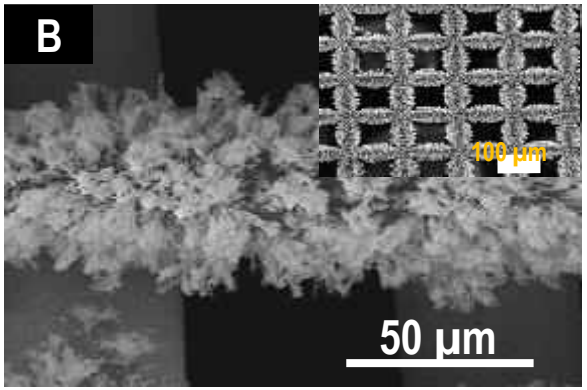


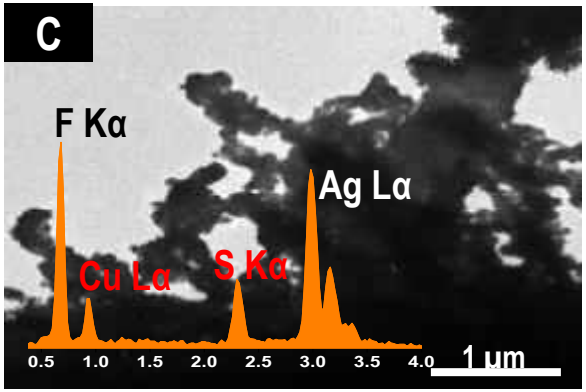


New harvesters

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

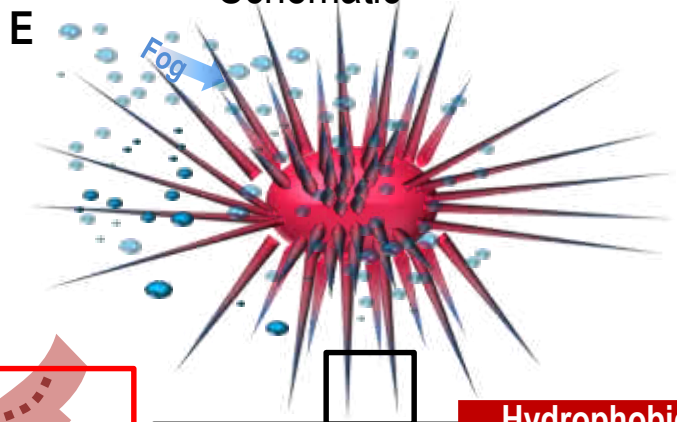




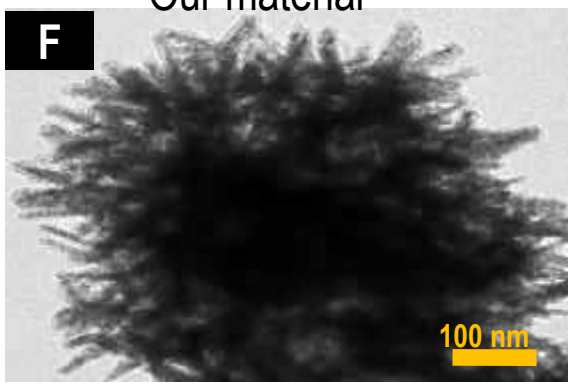


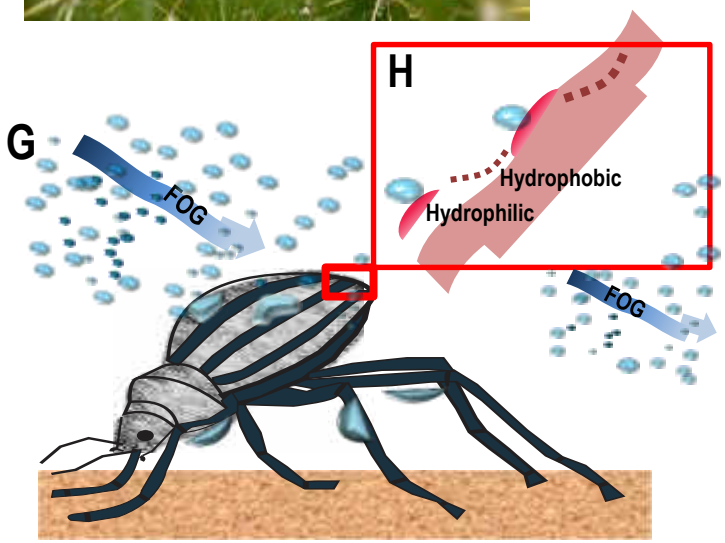
Nature

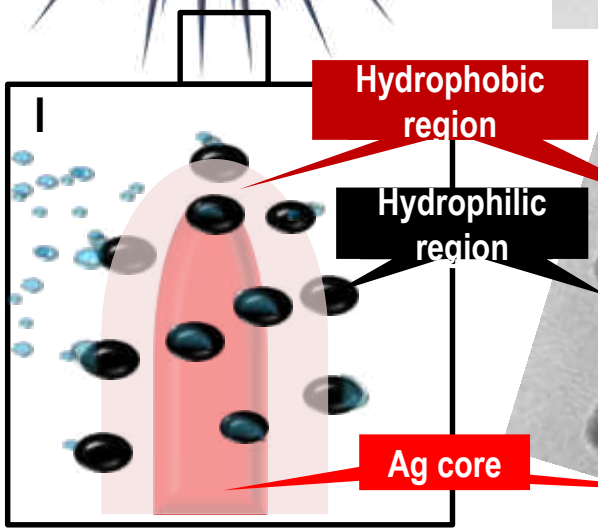
Schematic



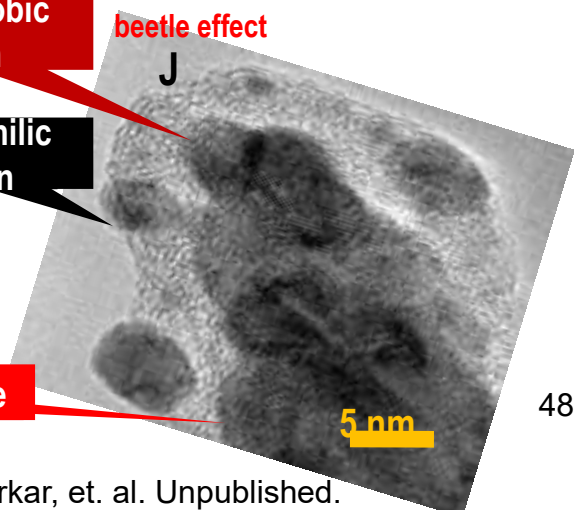
Our material



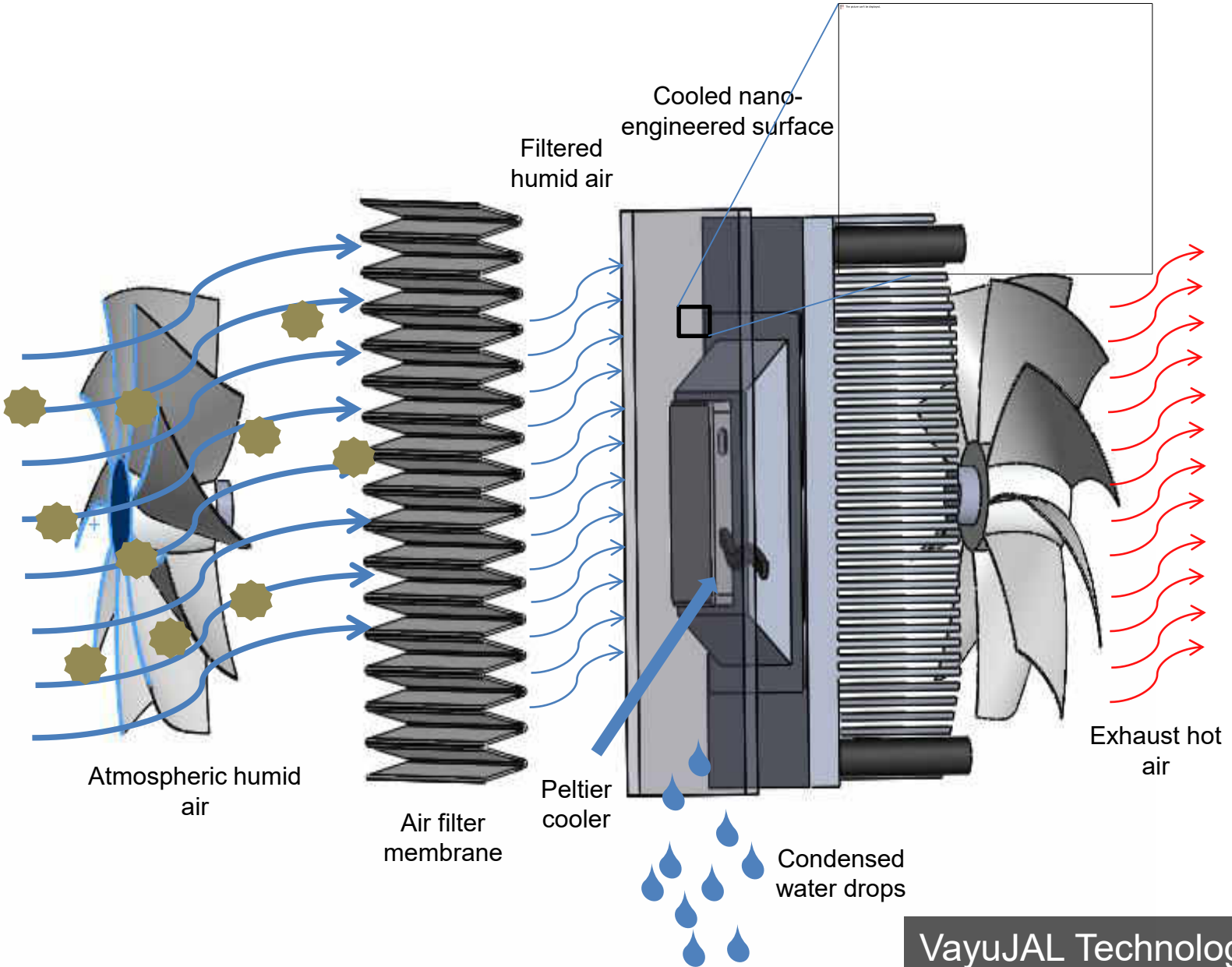




Combination of cactus and Namib desert beetle effect



Depanjan Sarkar, et. al. Unpublished.



VayuJAL Technologies Pvt. Ltd.

Ramesh Kumar Soni and Ankit Nagar

Products in the field

35 LPD

120 LPD

400 LPD

1000 LPD

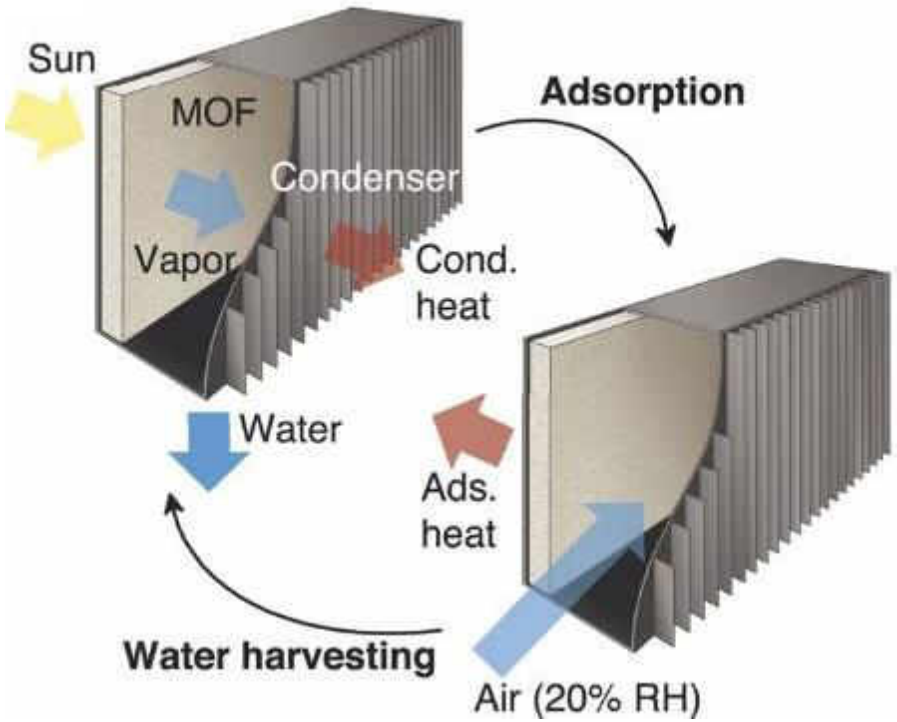
2000 LPD

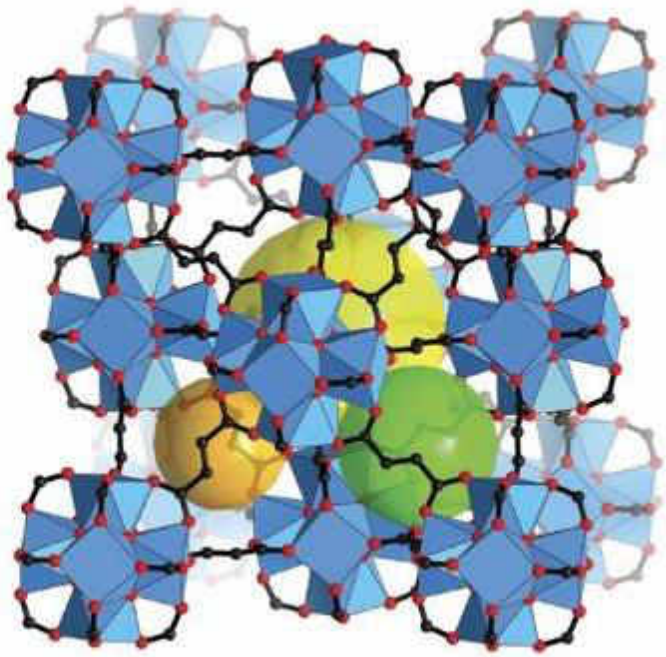
(LPD: Litres per day)

July 2023

Sustainable atmospheric water harvesting

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

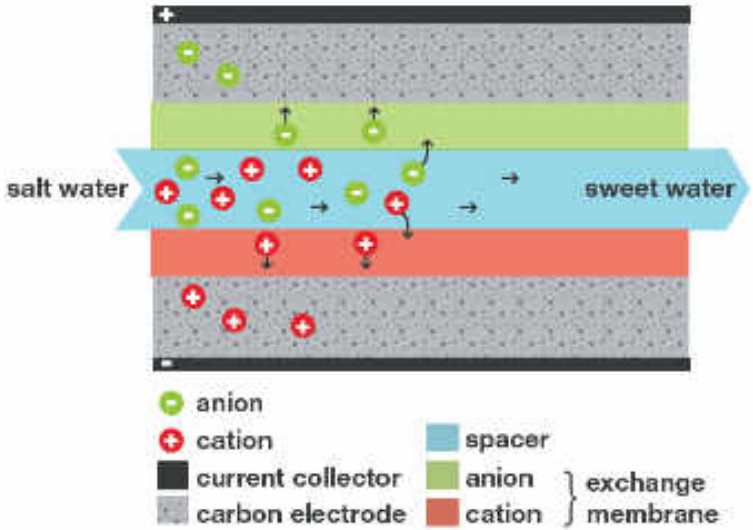


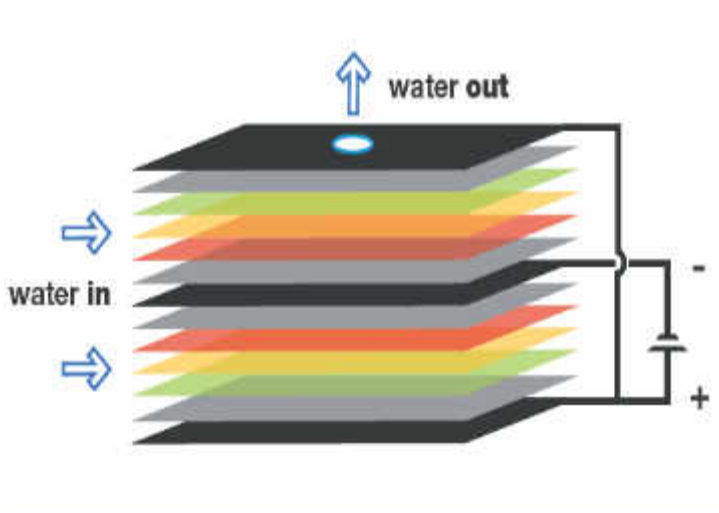


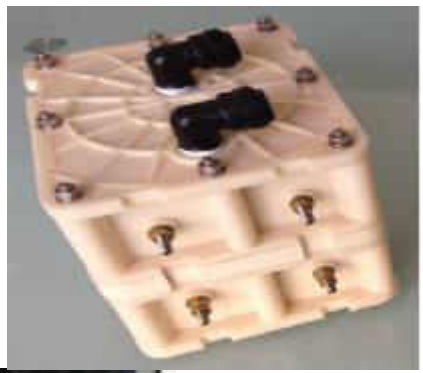
Porous metal-organic framework (MOF-801, $Zr_6O_4(OH)_4(fumarate)_6$)

Kim Hyunho, et al. *Science,* 356 (6336) 2017

Capacitive Desalination (CDI)



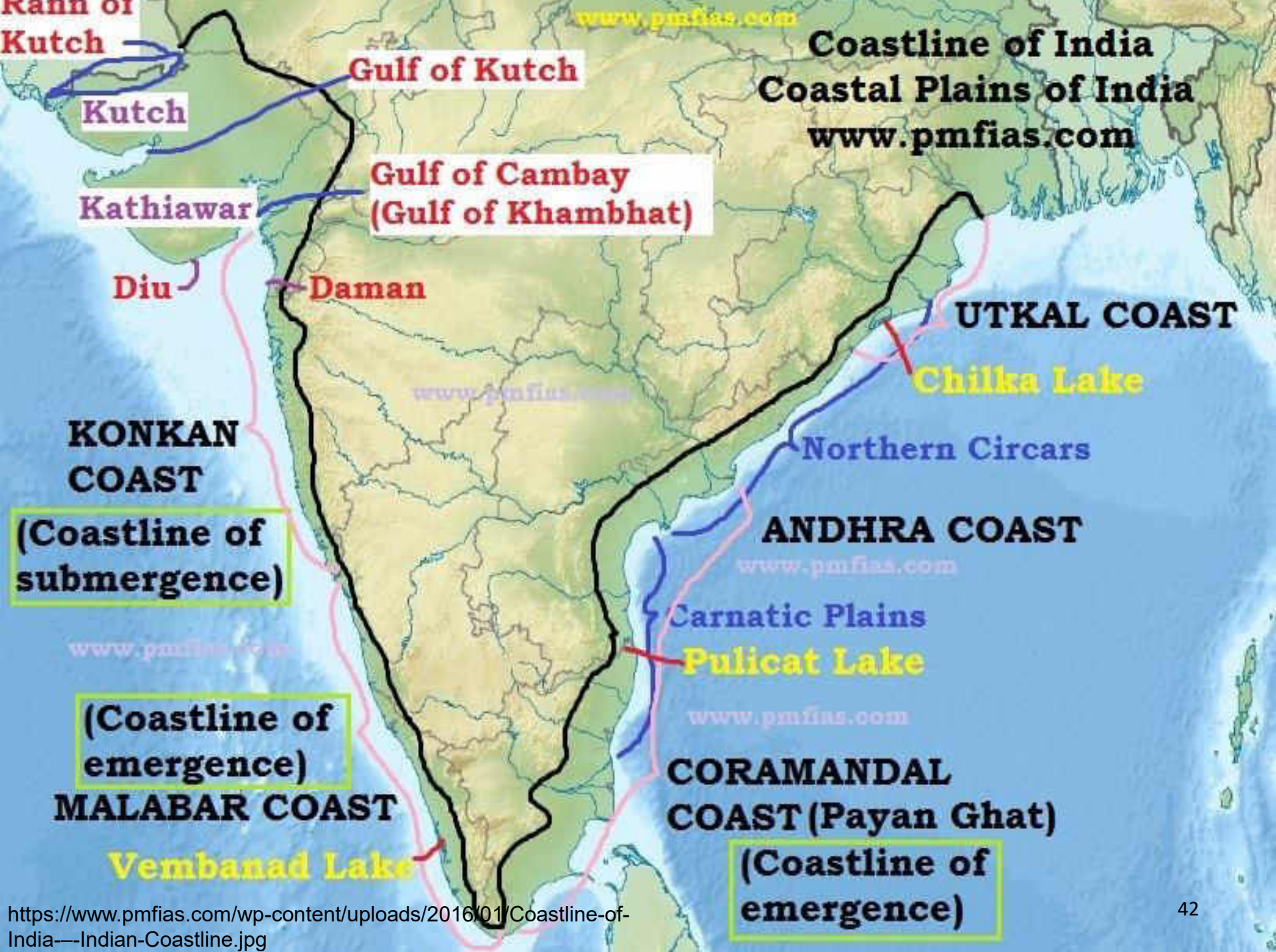




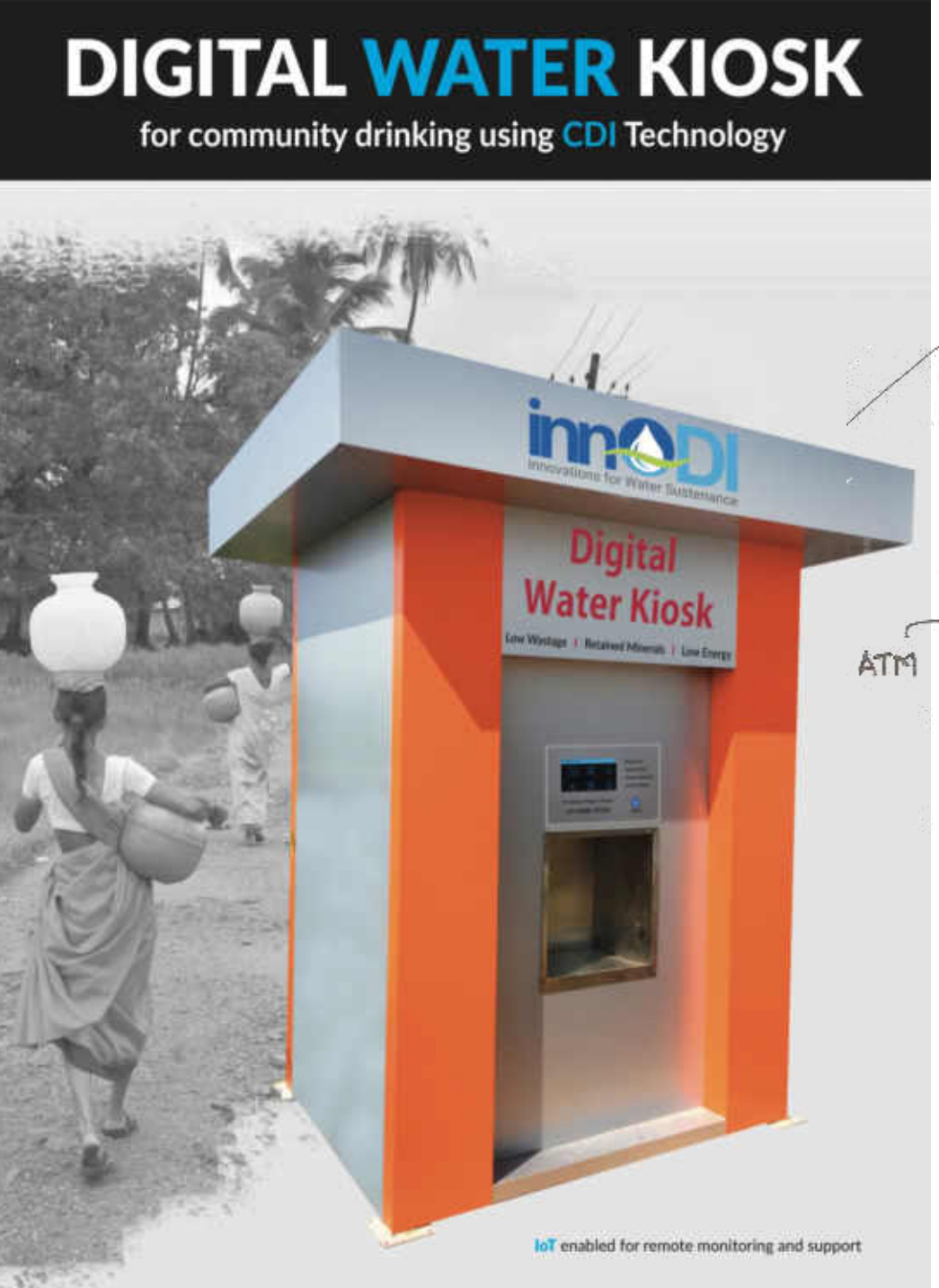
innODI

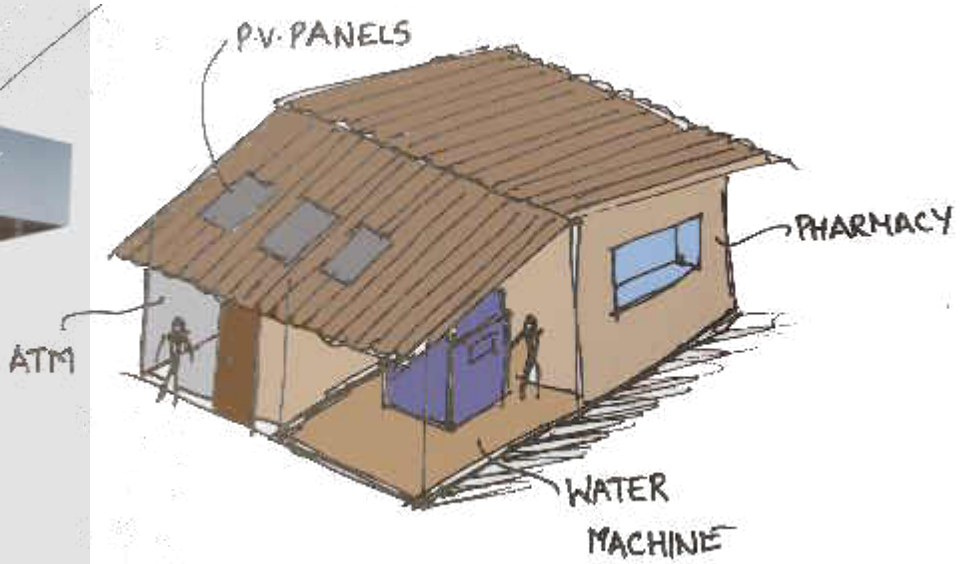
Our new company

Soujit Sengupta, Rabiul Islam and others



https://www.pmfias.com/wp-content/uploads/2016/01/Coastline-of-India-–-Indian-Coastline.jpg

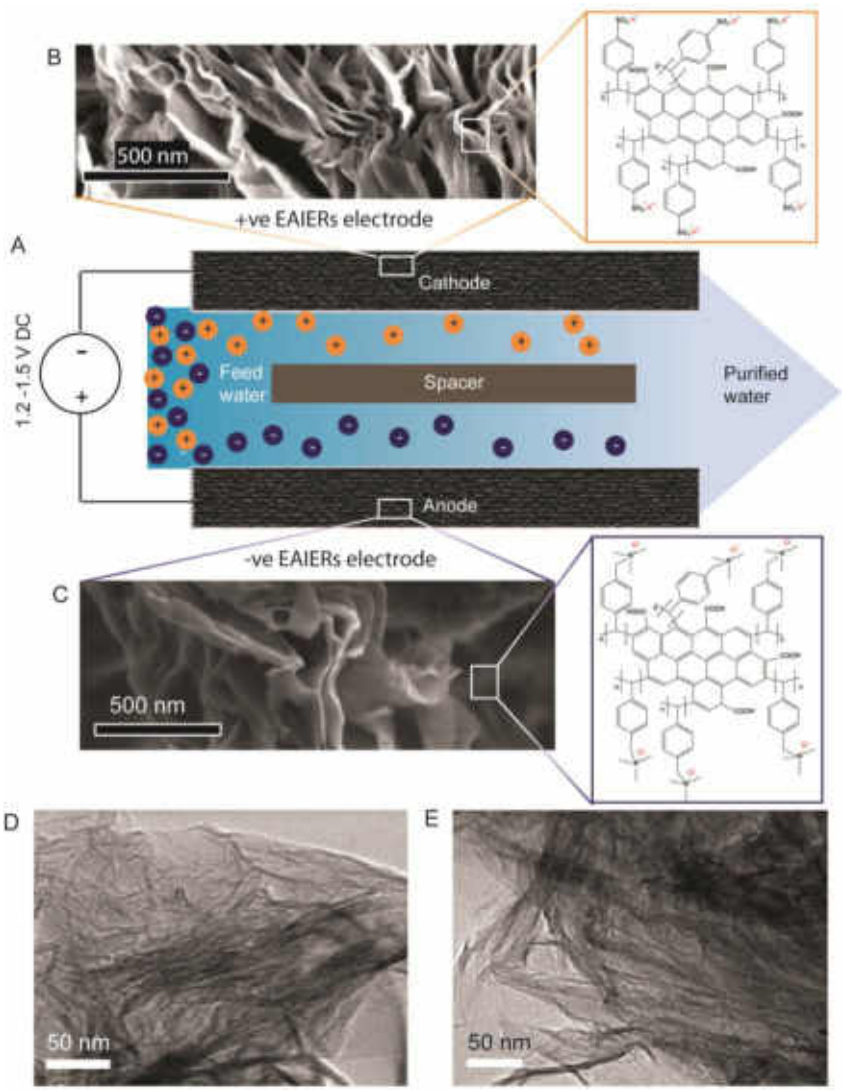




Products under implementation

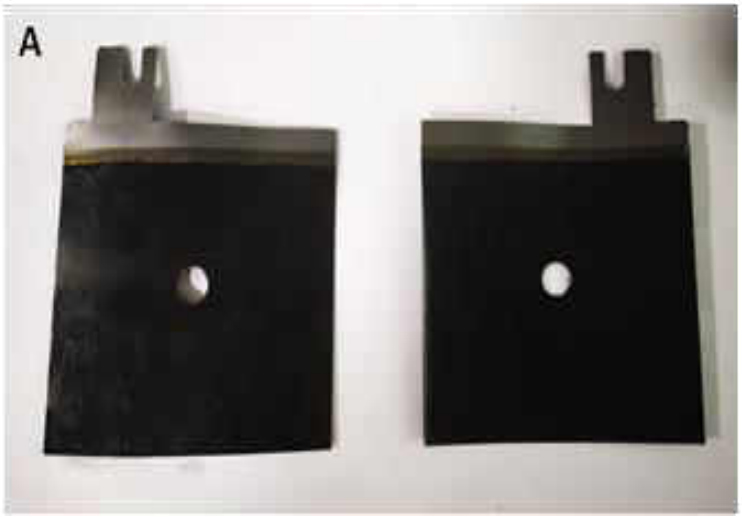
Vijay Sampath and Tullio Servida

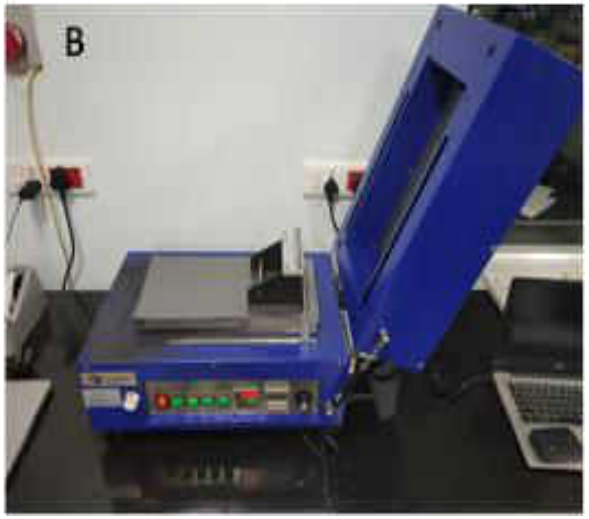
A Covalently Integrated Reduced Graphene Oxide -Ion Exchange Resin Electrode for Efficient CDI

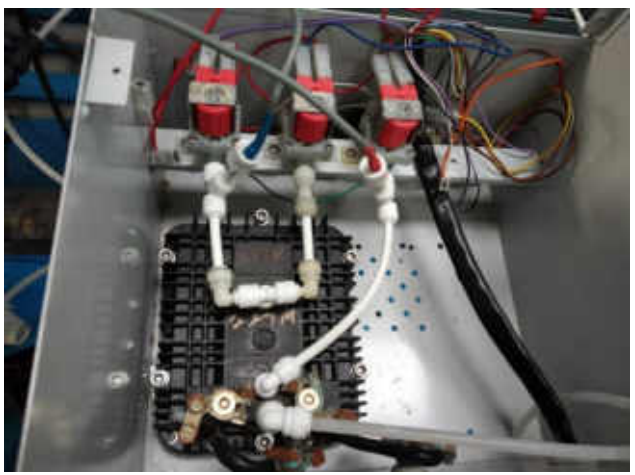


Rabiul *et al., Adv. Mater. Interfaces* **2021**, *8,* 2001998

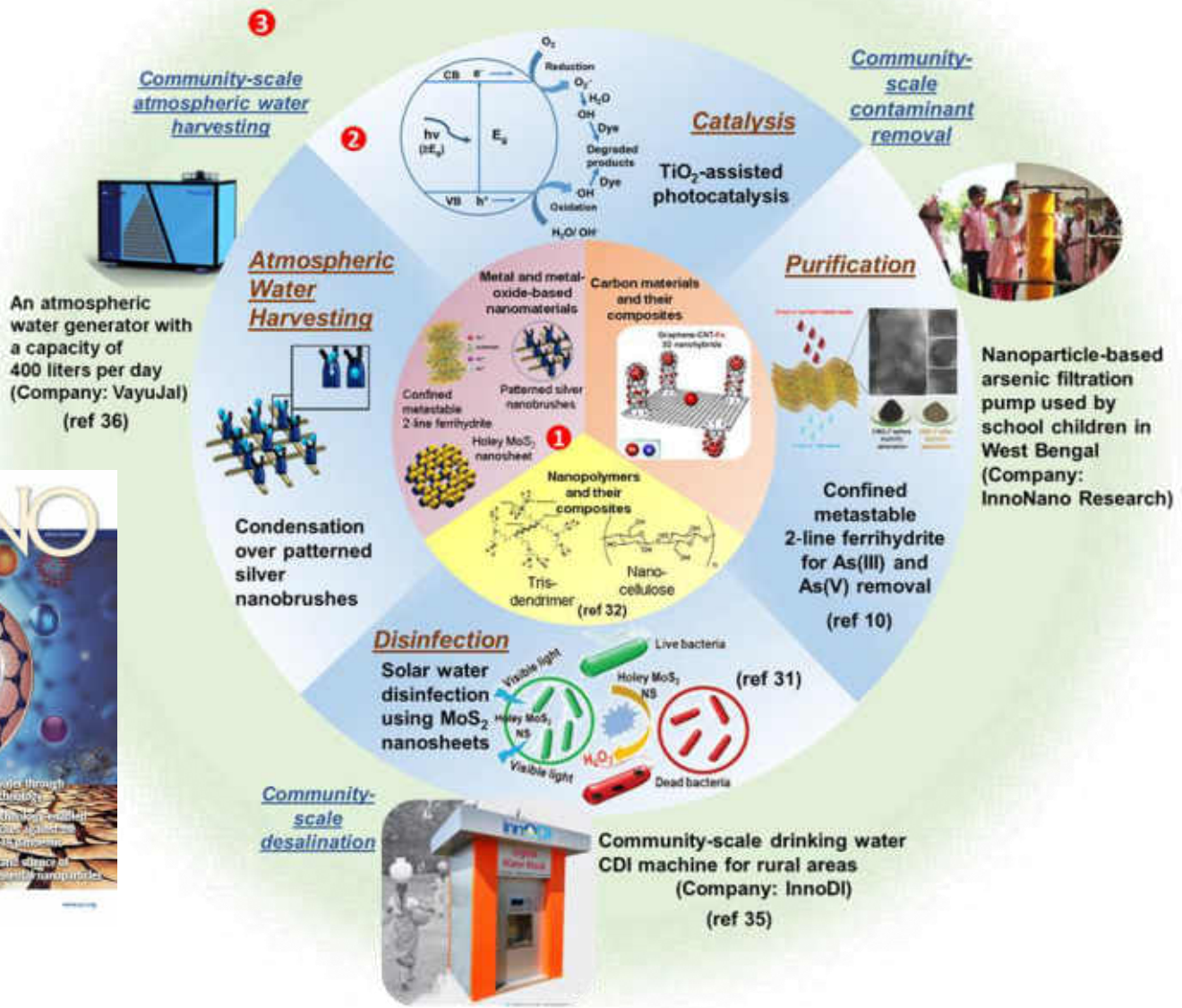
Various stages of electrode preparation







Evolution of materials to products

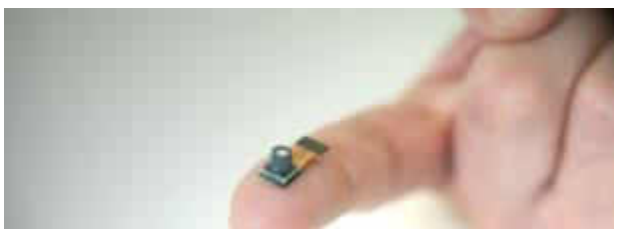


Ankit Nagar and T. Pradeep 14(2020). *ACS Nano*, 6420-6435

Sensors and new opportunities

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

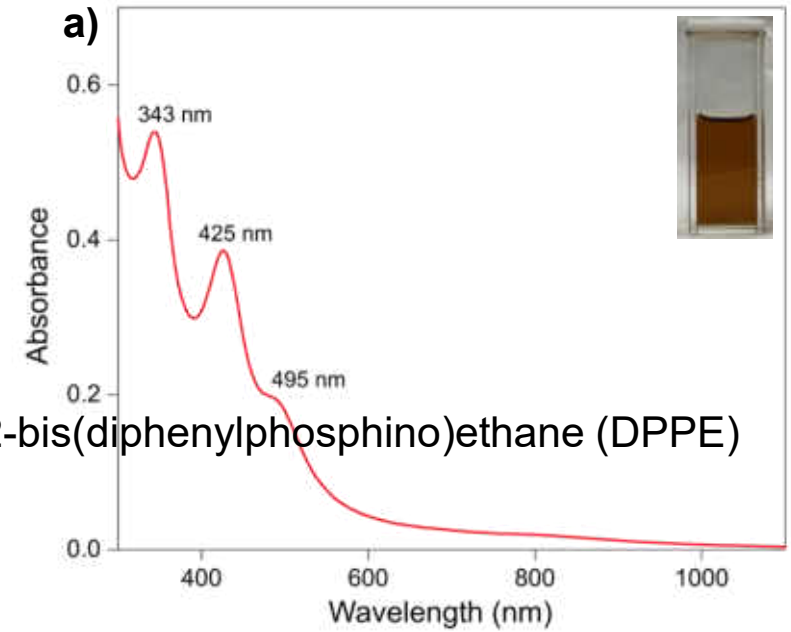
Ultra compact Low Cost
Spectral Sensor Module
~ Billions units (? 2027)



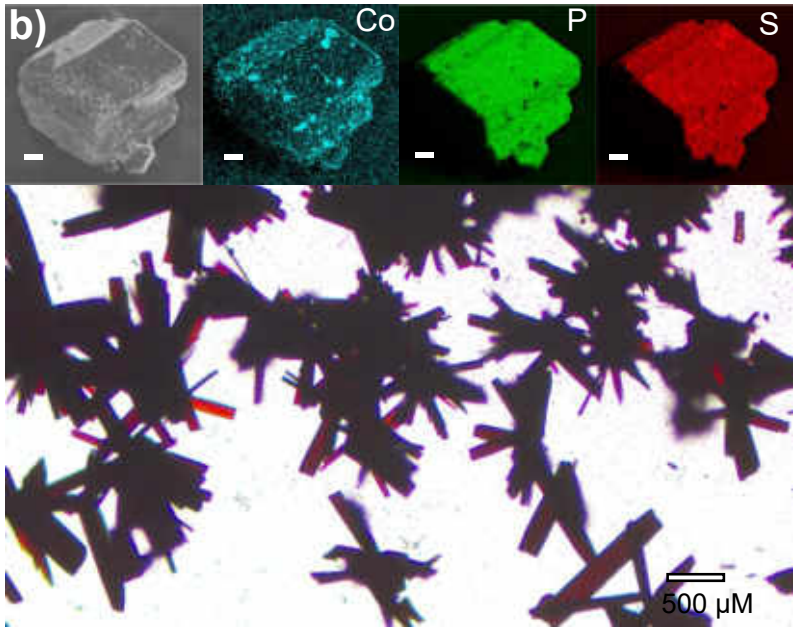
Water quality measurement – In the pipeline

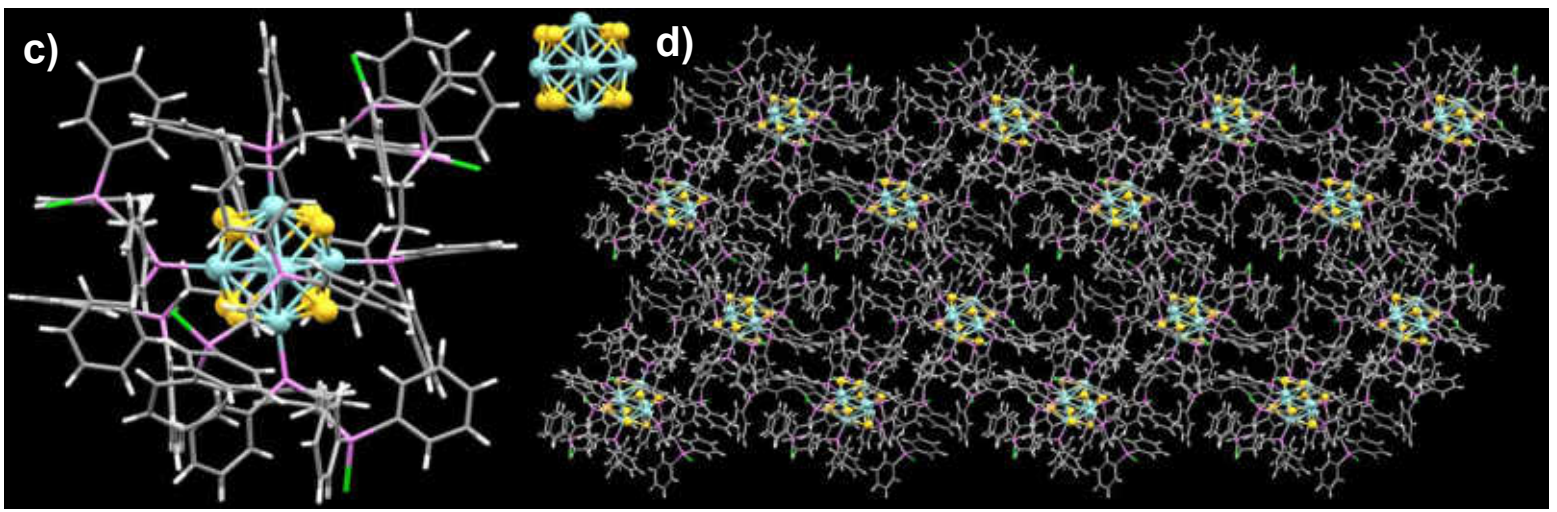
nanoλ

New electrodes - Aligned nanoplates of Co_6S_8

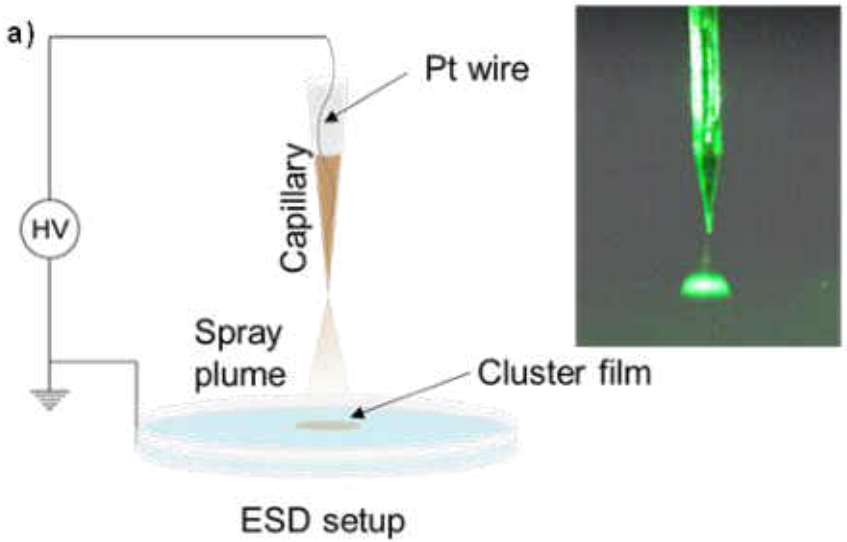


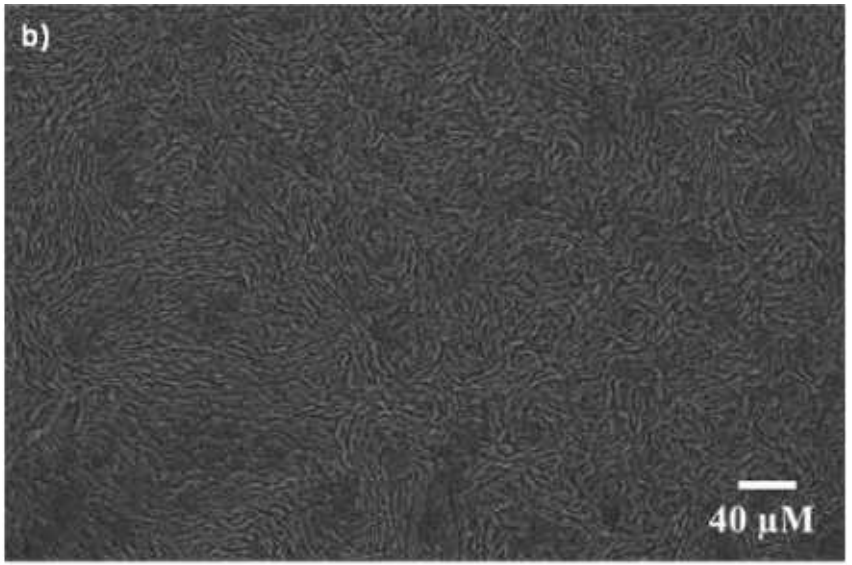
1,2-bis(diphenylphosphino)ethane (DPPE)

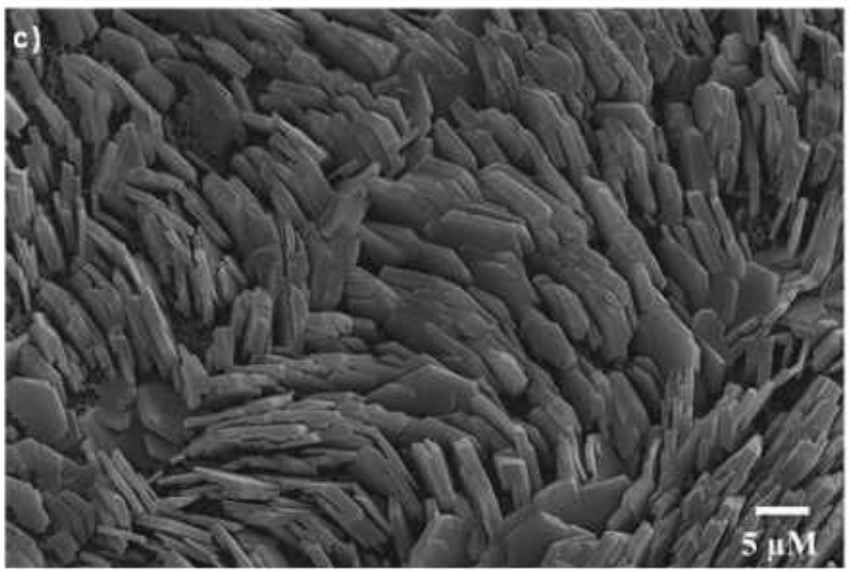


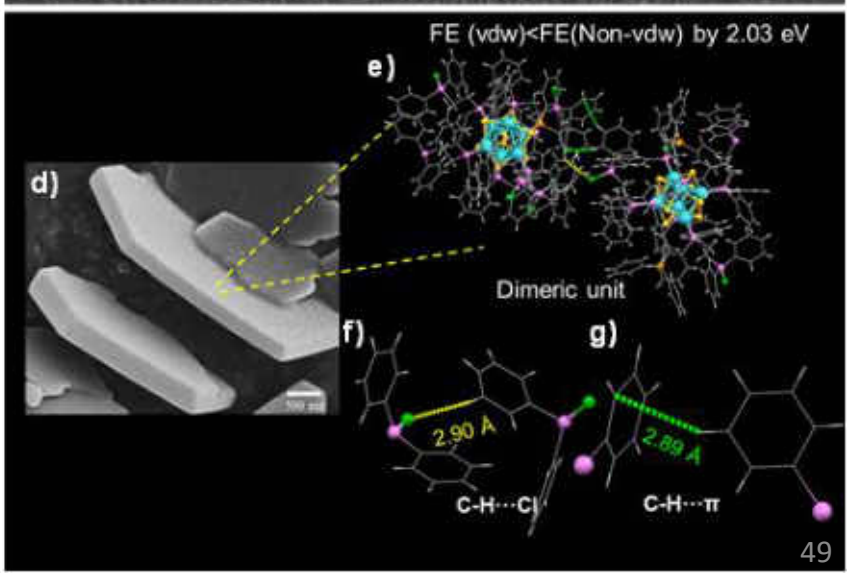


Electrospray deposition

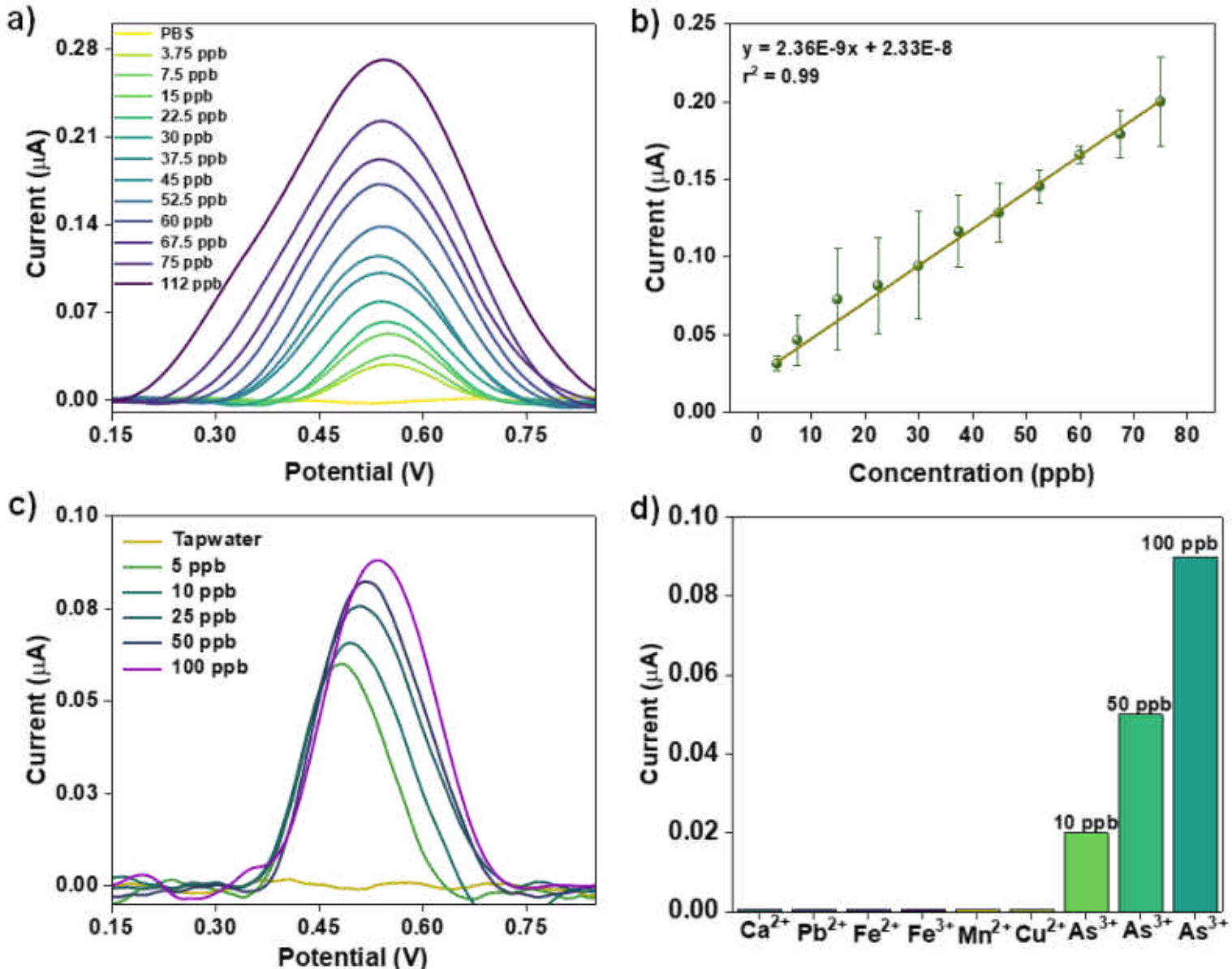




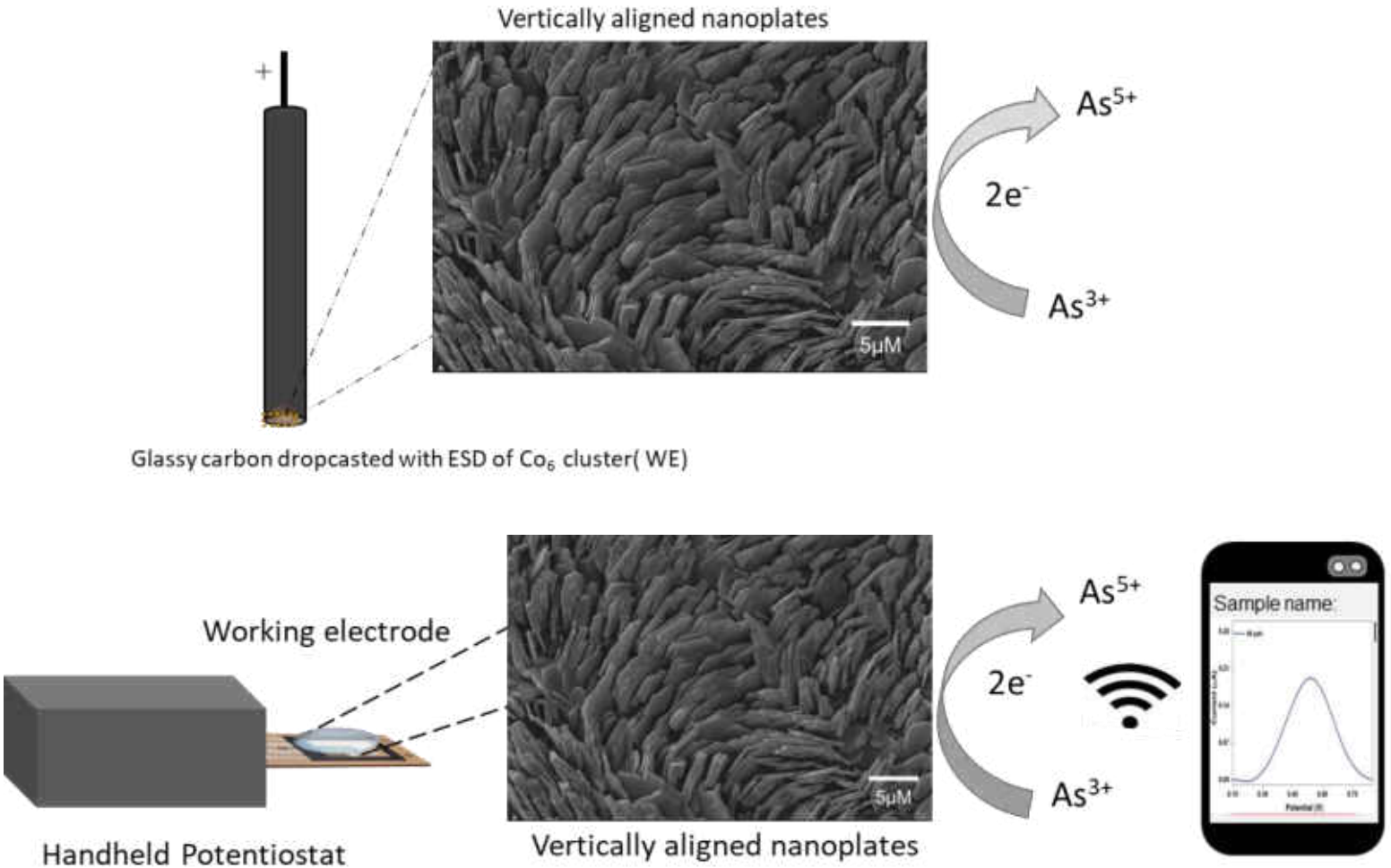




Sensing

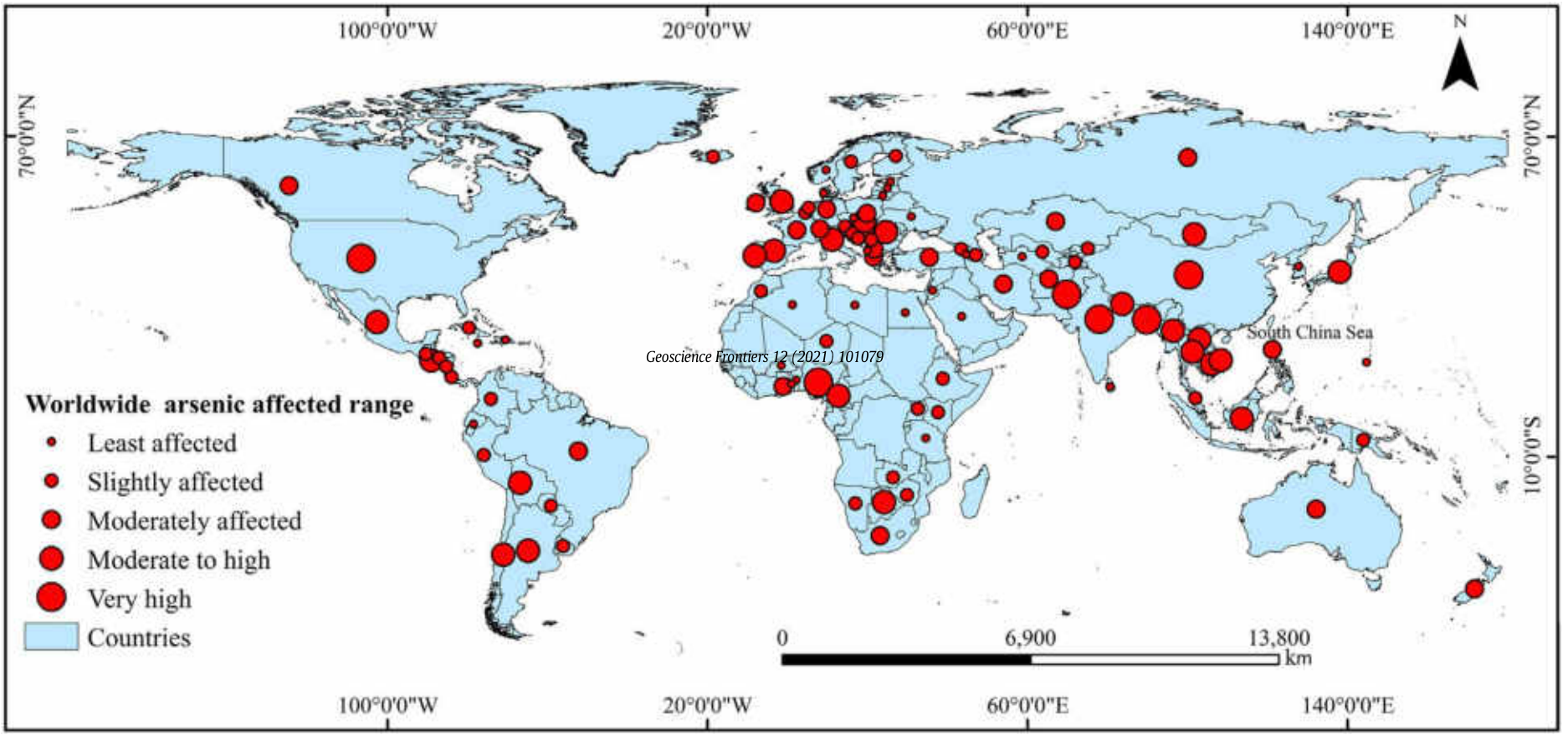

a)
PBS
3.75 ppb
7.5 ppb
15 ppb
22.5 ppb
30 ppb
37.5 ppb
45 ppb
52.5 ppb
60 ppb
67.5 ppb
75 ppb
112 ppb
Current (μA)
Potential (V)
b)
y = 2.36E-9x + 2.33E-8
r² = 0.99
Current (μA)
Concentration (ppb)
c)
Tapwater
5 ppb
10 ppb
25 ppb
50 ppb
100 ppb
Current (μA)
Potential (V)
d)
100 ppb
50 ppb
10 ppb
Current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

Working electrode



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

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.

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

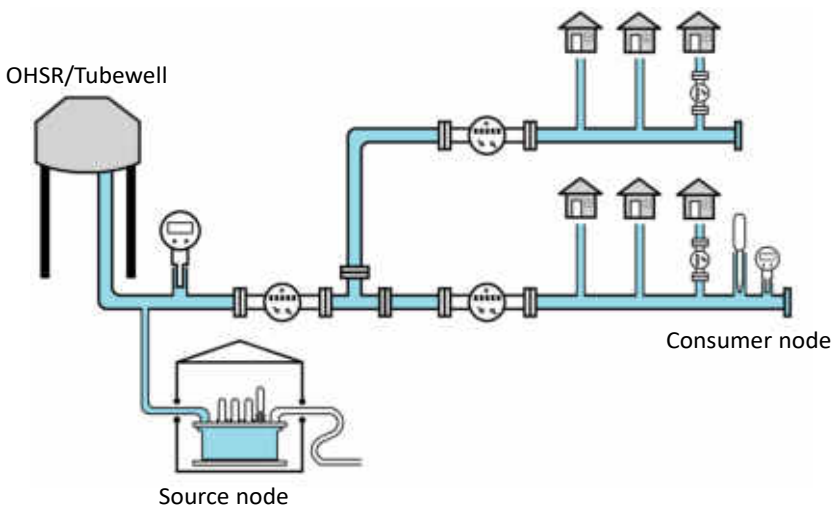
Installation model as per NJJM specifications

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

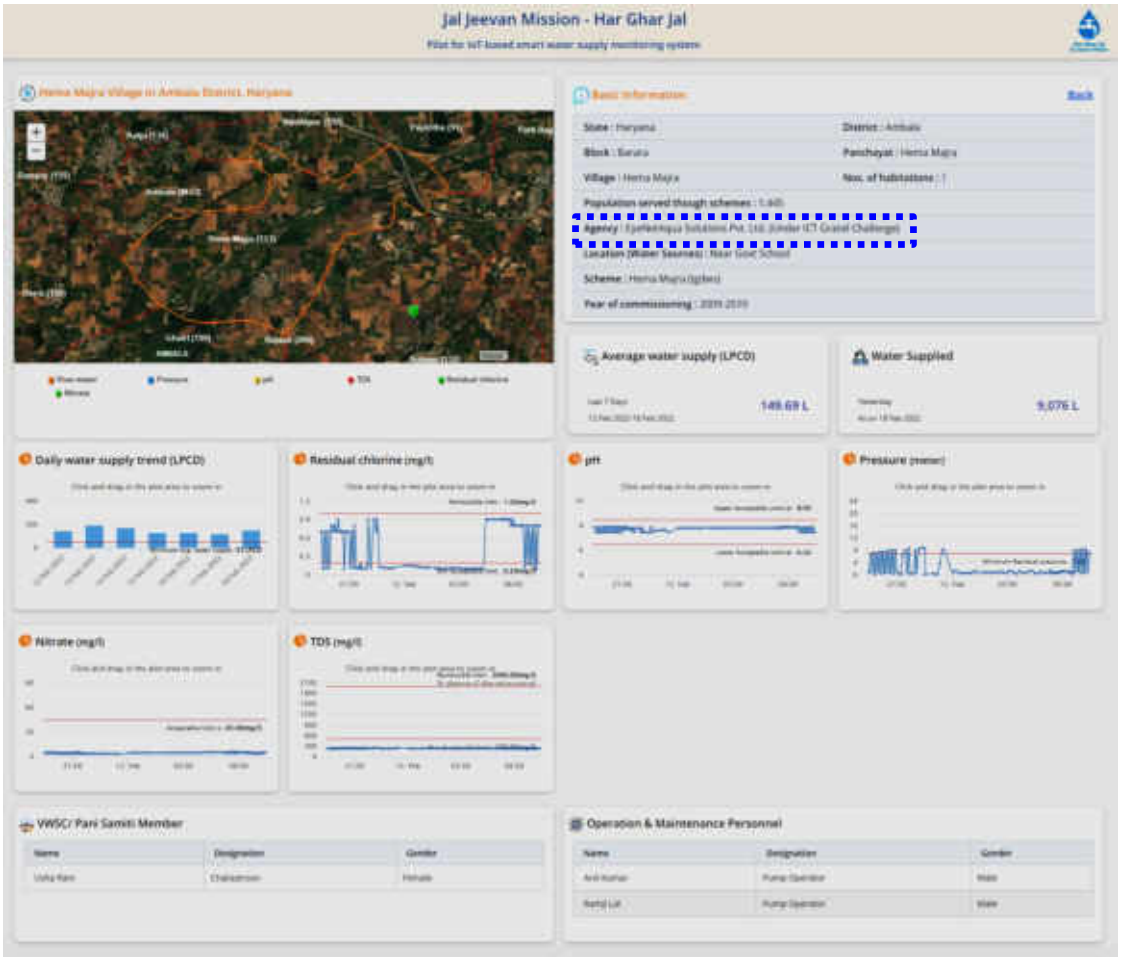


EyeNetAqua Solutions Pvt. Ltd.

An ICCW incubated company

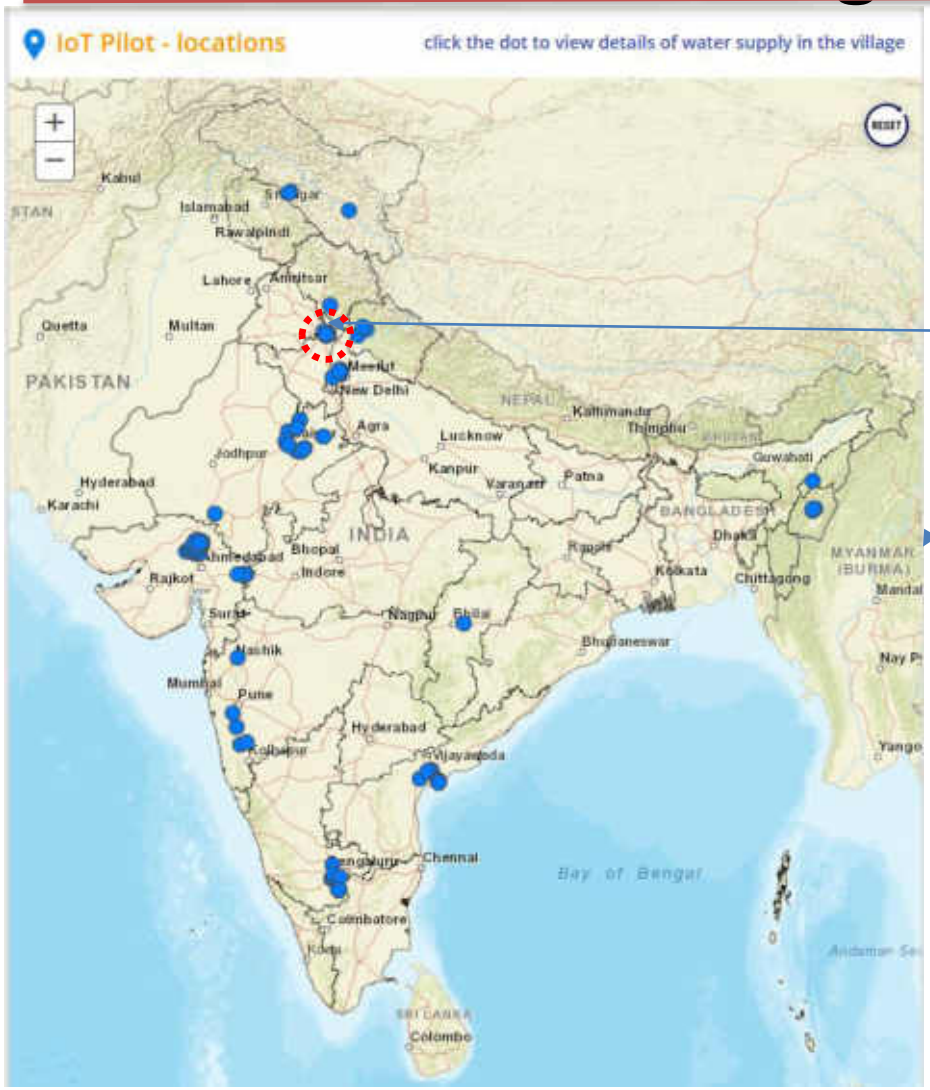
Eye of internet on quality, quantity and compliance for all

Real time water quality



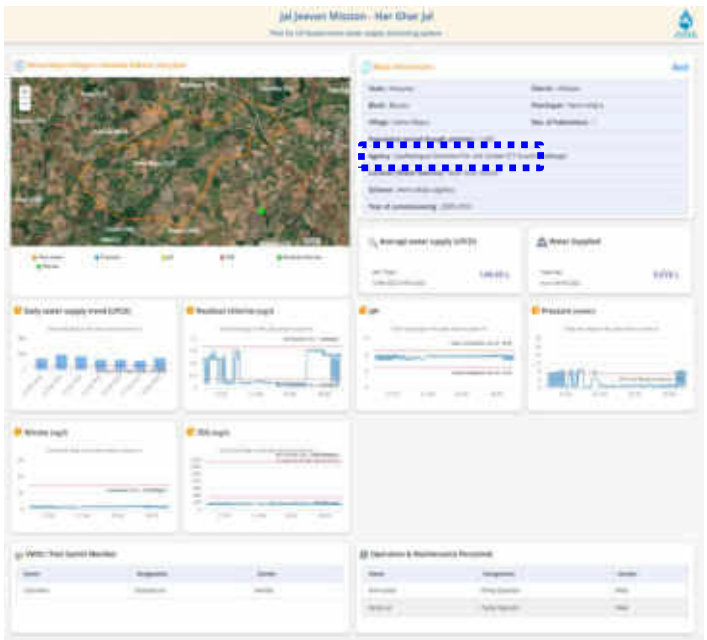
Snapshot of water quality analysers

India’s water is being monitored



IITM/IISc

Installations made by four companies

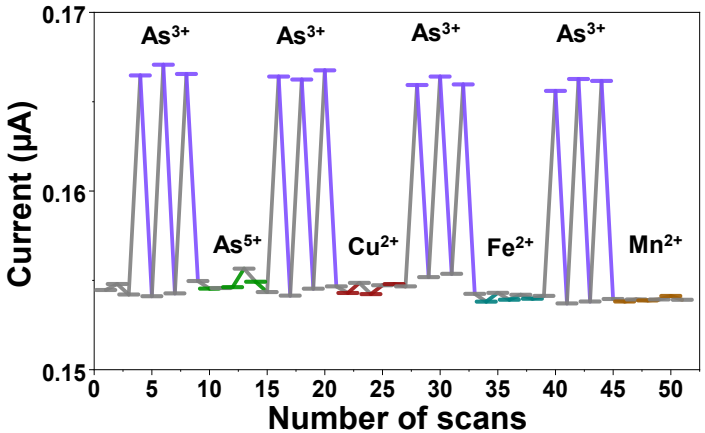


Mobile unit - A reagent free mobile water quality analyser

A drop-and-sense reagent free arsenic sensing test strips

IIT Madras patented
Arsenic sensing technology

Reagent free, Reusable test strip with selective arsenic sensing
Drop-and-sense technology with no pretreatment of samples



Publication and Patents

ACS APPLIED NANO MATERIALS

www.acsanm.org Article

Selective and Practical Graphene-Based Arsenite Sensor at 10 ppb

Sourav Kanti Jana,† Kamalesh Chaudhari,† Md Rabiul Islam, Ganapati Natarajan, Tripti Ahuja, Anirban Som, Ganesan Paramasivam, Addanki Raghavendra, Chennu Sudhakar, and Thalappil Pradeep*

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(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
09 December 2021 (09.12.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/245689 A2

US 20230273151A1

(19) United States
(12) Patent Application Publication
PRADEEP et al.

(10) Pub. No.: US 2023/0273151 A1
(43) Pub. Date: Aug. 31, 2023

(54) A POINT-OF-CARE (POC) AMPEROMETRIC DEVICE FOR SELECTIVE ARSENIC SENSING

(71) Applicant: INDIAN INSTITUTE OF TECHNOLOGY MADRAS (IIT MADRAS), Chennai (IN)

(72) Inventors: Thalappil PRADEEP, Chennai (IN); Sourav KANTI JANA, Chennai (IN); Kamalesh CHAUDHARI, Chennai (IN); Md Rabiul ISLAM, Chennai (IN)

Publication Classification

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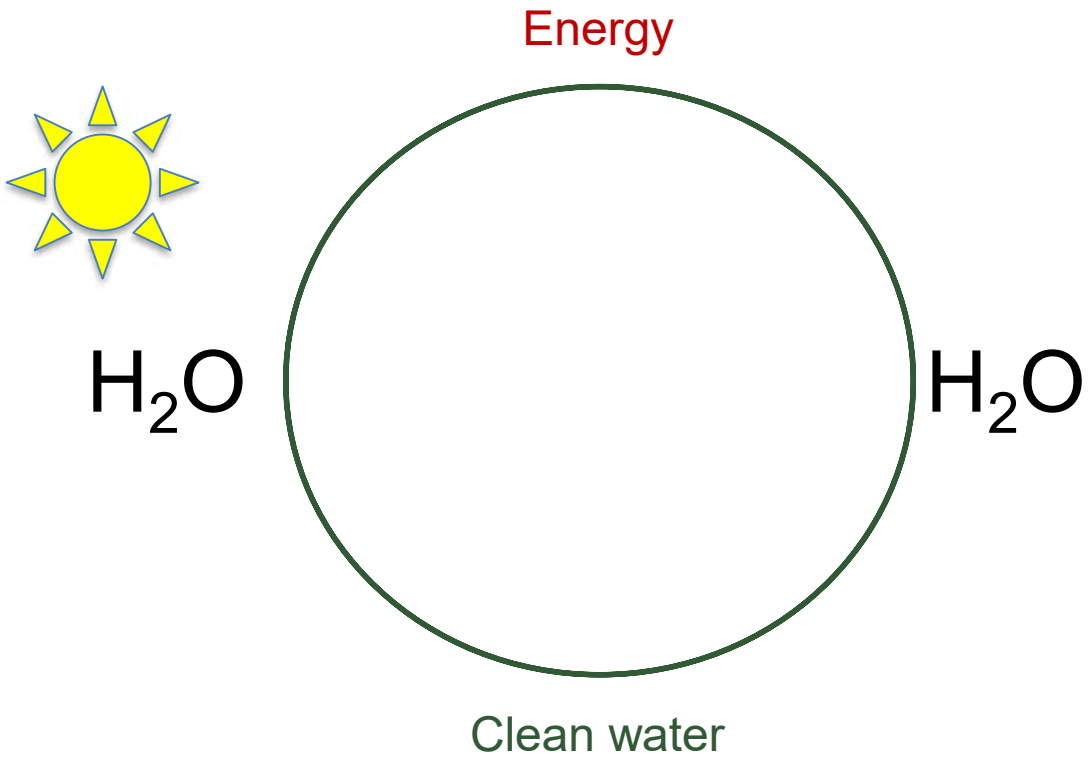
G01N 27/30 (2006.01)
G01N 33/18 (2006.01)

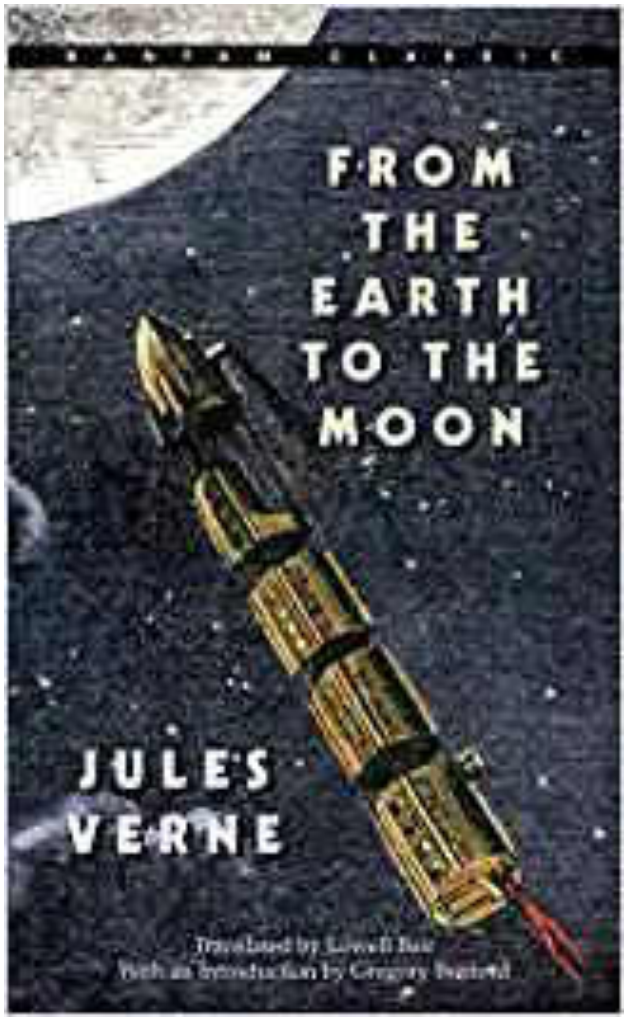
(52) U.S. Cl.
CPC *G01N 27/4161* (2013.01); *G01N 27/307* (2013.01); *G01N 27/308* (2013.01); *G01N 33/1813* (2013.01)

(57) ABSTRACT


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:

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

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

Indian Institute of Technology Madras

Bhaskar Ramamurthi/V. Kamakoti

Associate Editor

ACS Sustainable Chemistry & Engineering

Thank you all