Department of Science & Technology
Government of India

PHOTO-IRRADIATION AND ADSORPTION BASED NOVEL INNOVATIONS FOR WATER-TREATMENT

Rita S Dhodapkar **Kevin McGuigan**

EU-India Water Tech Event
29 January 2024

PANIWATER OBJECTIVES

PANIWATER aims to develop, deploy and validate, six **prototype technologies** for the **removal of contaminants of emerging concern** from **wastewater** and **drinking water.**

List of partners and technologies

	Beneficiary	Technology	Country
1	Royal College of Surgeons in Ireland	TJC	Ireland (IE)
2	CSIR National Environmental Engineering Research Institute	MFR, SPPP,PES TJC	India (IN)
3	University Rey Juan Carlos	TJC	Spain (ES)
4	Birla Institute of Technology & Science, Pilani, K Birla Goa Campus	**FAU**	India (IN)
5	Maynooth University	TJC FAU	Ireland (IE)
6	Society for Development Alternatives	TJC MFR	India (IN)
7	INNOVA SRL	Innovation management	Italy (IT)
8	KWALITY Photonics P LTD	**FAU**	India (IN)
9	CIEMAT-Plataforma Solar de Almeria	SPPP	Spain (ES)
10	Affordable Water Solutions	EOD	India (IN)
11	University of Cyprus	SPPP	Cyprus (CY)
12	University of Ulster	PES	United Kingdom (UK)
13	Institute of Technology Sligo	TJC	Ireland (IE)
14	AQUASOIL SRL	MFR	Italy (IT)
15	Università del Salento	MFR	Italy (IT)
16	New University of Buckinghamshire	TJC	United Kingdom (UK)
17	University of Santiago de Compostela	TJC	Spain (ES)
18	Society for Technology & Action for Rural Advancement	SPPP, FAU	India (IN)

PANI WATER पानी

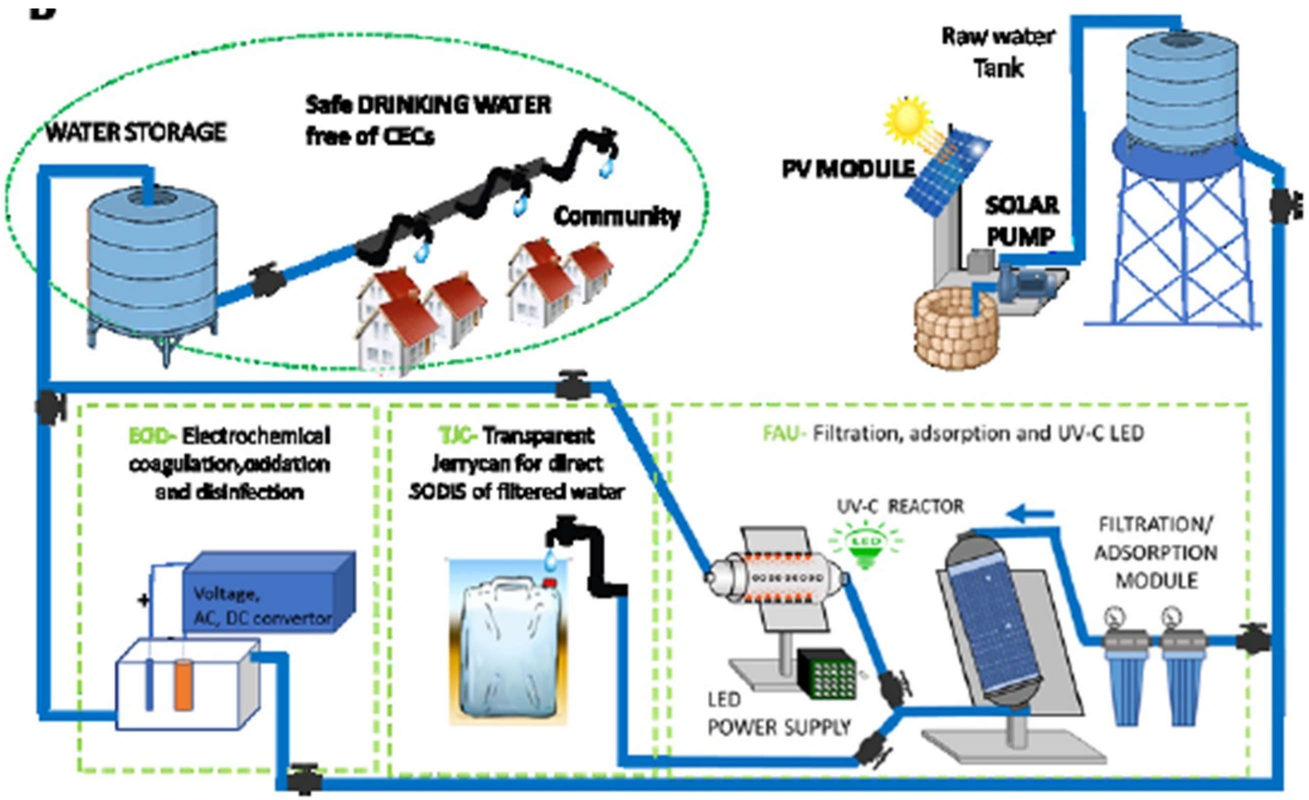
Drinking water technologies

Design and evaluation of:

a) A solar photovoltaic powered system, which combines filtration, adsorption and UVC LED processes (FAU) for drinking water purification with 300 L/h capacity for peri-urban communities with drinking water accessibility and quality challenges.

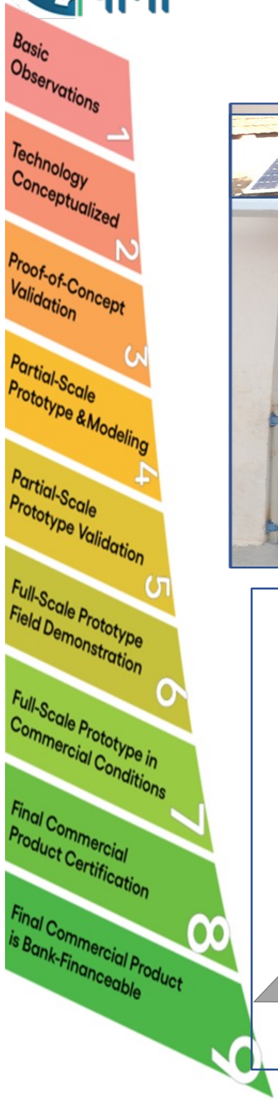
b) A 20-L UV transparent jerrycan (TJC) for solar water disinfection (SODIS) at household level for rural communities in severe drinking water scarce challenged areas.

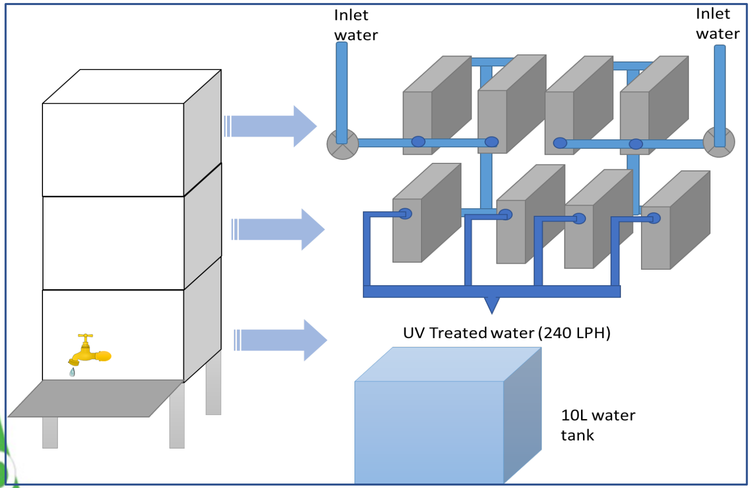
c) A solar powered multi contaminant water purification plant for rural community that combines electro coagulation, oxidation and disinfection (EOD) to meet water quality challenges and treats geogenic and microbial contaminants .



Filtration, Adsorption and UVC LED processes (FAU) for drinking water purification with 300 L/h capacity, TRL: 5

Product : UVC LED Kiosk (solar photovoltaic powered)





- UVC LED (276 nm) – **Capable to work under submersible condition & rapid dissipation of heat (Patent filed)**,
- Requires no external cooling
- Solar powered UV LED kiosk (240-300 L/h) and UV LED wall mount unit (30 L/h).
- Long term stable irradiance of UVC
- Cost of fabrication : INR 0.13 million
- OPEX: INR 9 /m^3
- Consumables: INR 200/6 – 8 months
- User acceptance high
- Meets Bacteriological Quality as per Drinking water standard IS 10500

Flow rate: 240 LPH
Performance limits : Turbidity<5 NTU, TOC: <10 ppm

Novelty and Innovation

UVC LED System for Water Treatment: For the developed UV LED design- Application No. 202111046524-ABG/BITS-G/062021-14, Laxman Govind Raikar, Nupur Vijay Salve, Jemi Kamlesh Gandhi, Kopuri Vijaykumar Gupta, Halan Prakash

Wall Mount FAU

TRL : 5

PANIWATER Wall mounted FAU, with UVC LED

MRP: INR13,000

Operation cost : INR 6/m3

Cost of commercial UVC Smart Purifier~ 10,000

Commercial UVC LED ~ 26,000

Meets Bacteriological Quality as per Drinking water standard IS 10500

Flow rate: 30 LPH
Performance limits : Turbidity<5 NTU, TOC: <10 ppm

Market status

- Ready to market

UV LED status

- High life time 10k – 20k h
- Mercury free
- Low maintenance

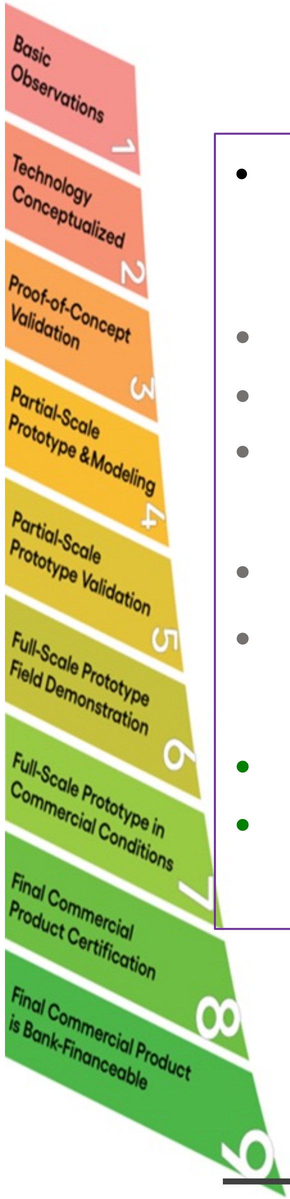
UV Hg lamp status

- Low life time -5k h
- Toxic mercury (100-200 mg in each lamp)
- High maintenance

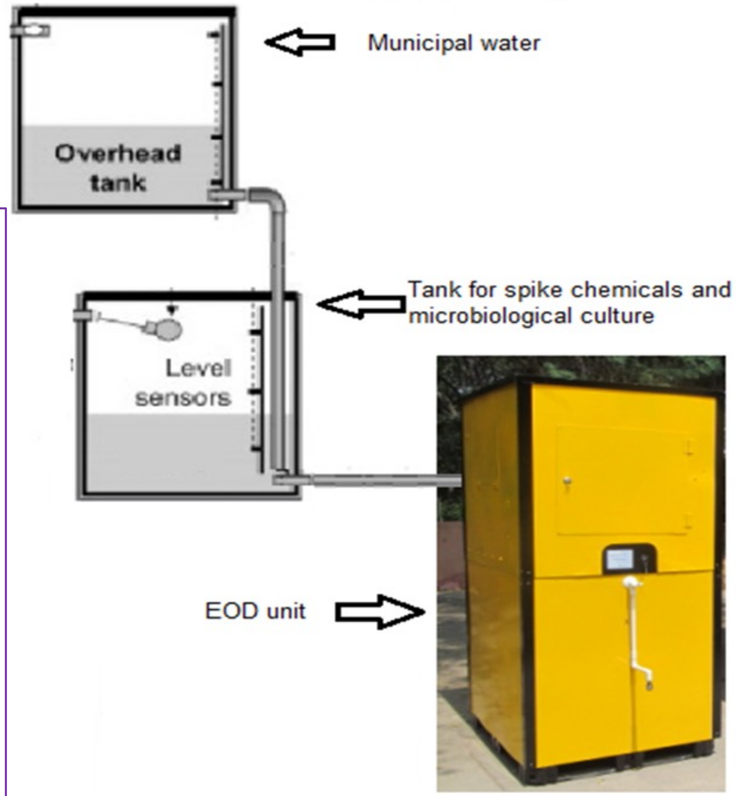
Novelty and Innovation

UVC LED System for Water Treatment: For the developed UV LED design- Application No. 202111046524-ABG/BITS-G/062021-14, Laxman Govind Raikar, Nupur Vijay Salve, Jemi Kamlesh Gandhi, Kopuri Vijaykumar Gupta, Halan Prakash

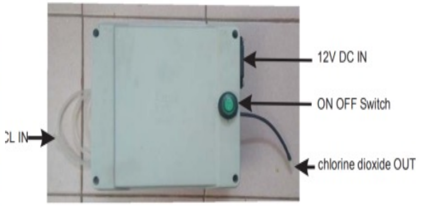
Electro coagulation, Oxidation, and Disinfection (EOD) (Capacity- 500L/day) TRL -5

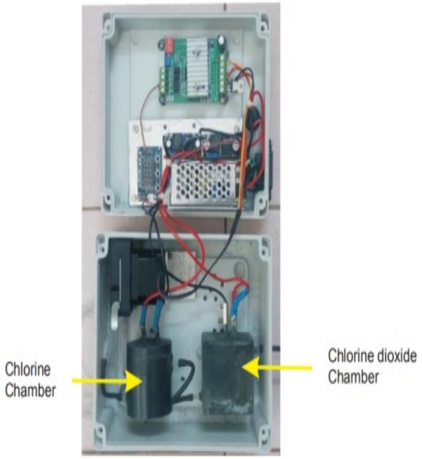


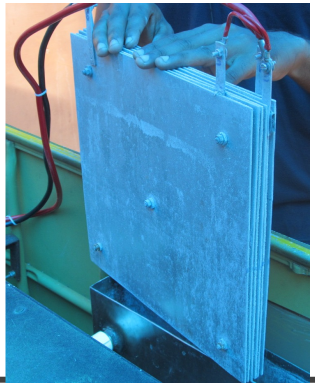
- Effective for removals of **turbidity, arsenic, fluoride and heavy metals & Bacteriological contamination (per** drinking water standards: IS 10500)
- low maintenance and low running cost
- Only consumables are electrodes and electrolytes
- Electrode performance is dependent on hardness Average **Life time of electrodes 4-6 month.**
- GPRS facility remote monitoring module
- Center processing board (combines and controls all electronics process)
- **Cost of electrodes per set: INR 1750**
- **Cost of EOD INR 0.45 M**



Water Kiosk & Solar Panel

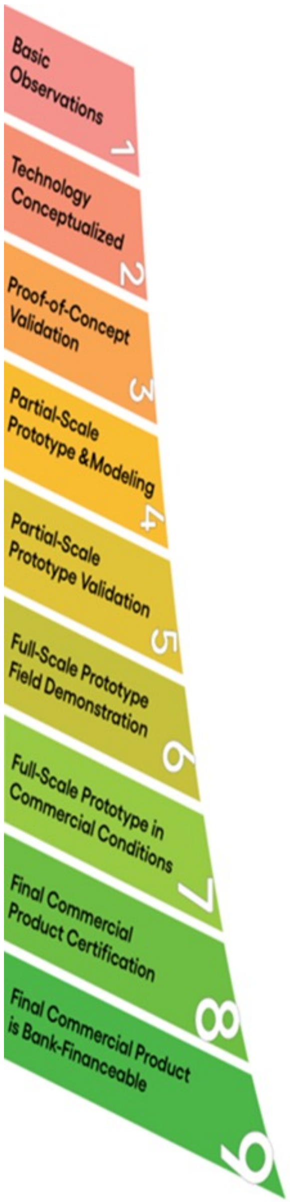






Electrolysis chamber

10 L Transparent Jerrycan (TJC) for Solar Water Disinfection (SODIS) of Drinking Water



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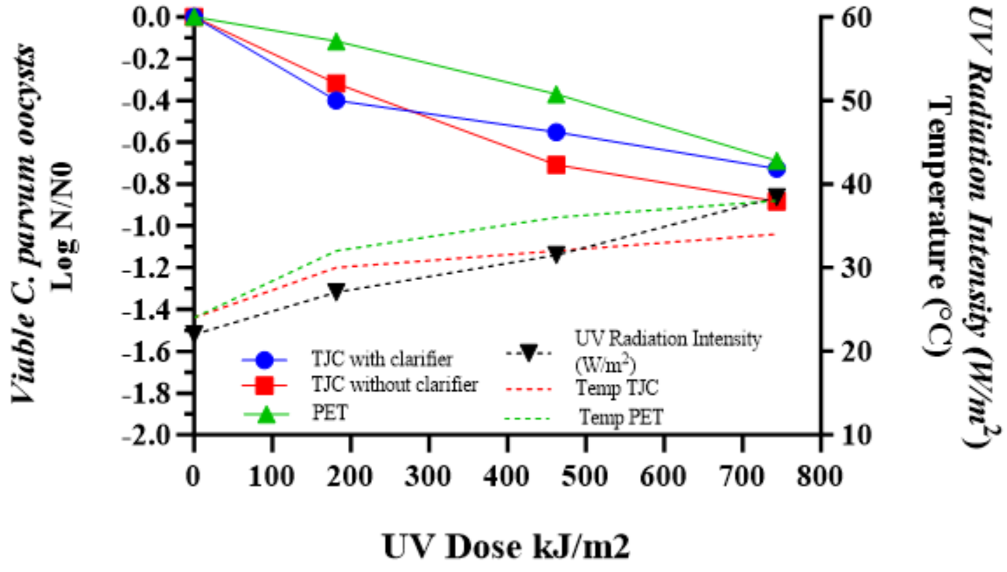
ELSEVIER

Good optical transparency is not an essential requirement for effective solar water disinfection (SODIS) containers

B. Sawant[a,*,1], M.J. Abeledo-Lameiro[b,1], Á. García Gil[c], S. Couso-Pérez[d], S. Sharma[e], U. Sethia[e], R. Marasini[f], L. Buck[f], M.I. Polo-López[b], I. Oller Alberola[b], J. Marugán[c], H. Gómez-Couso[d,g], E. Ares-Mazás[d], K. Vijaya Lakshmi[e], S. Pal[h,i], R. Dhodapkar[j], K.G. McGuigan[a]

Joint EU/India publication



C. parvum **inactivation profiles in TJC2 with and without clarifier in Spain**

- Studies demonstrated that 10 L polypropylene TJCs were effective at inactivating waterborne pathogens.
- Good optical transparency is not necessary for SODIS efficacy. Translucency is sufficient
- Toxicity studies show leachates from plastic, not a concern
- Suitable for short term use in emergency/disaster situations

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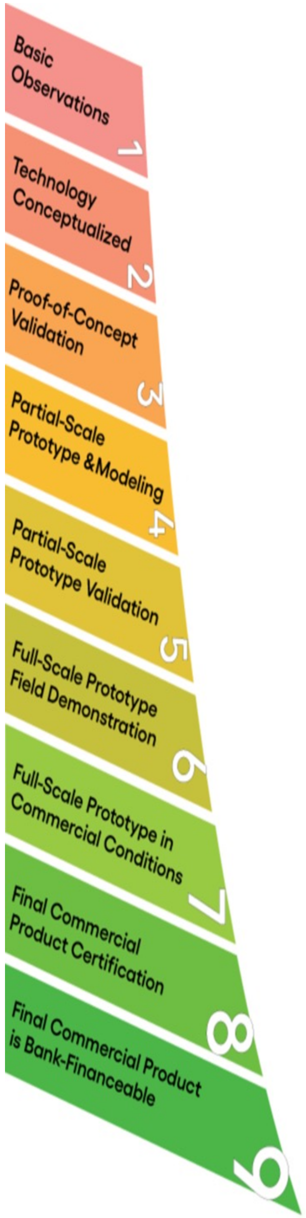
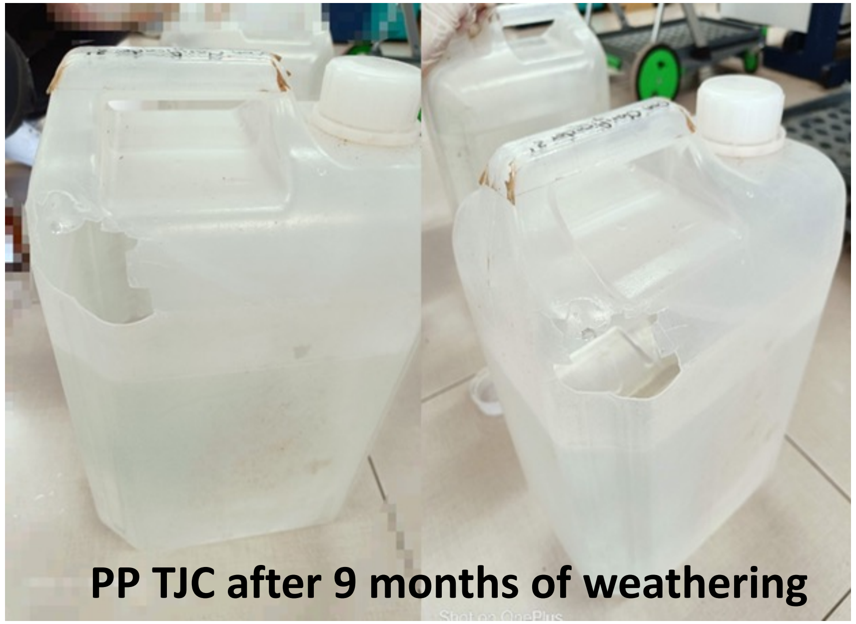
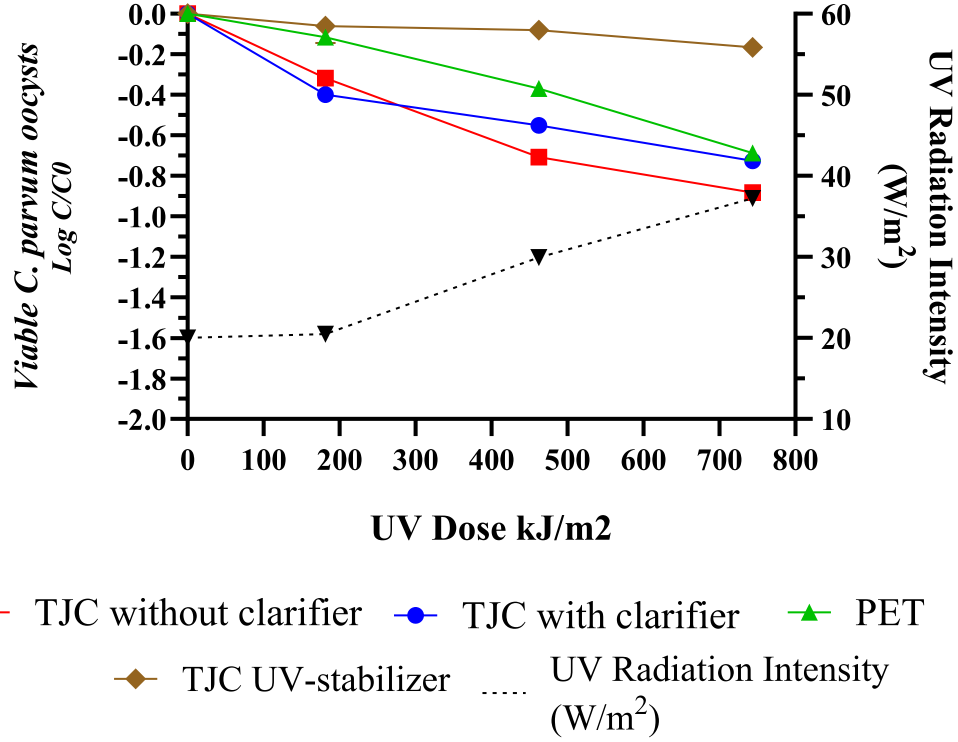


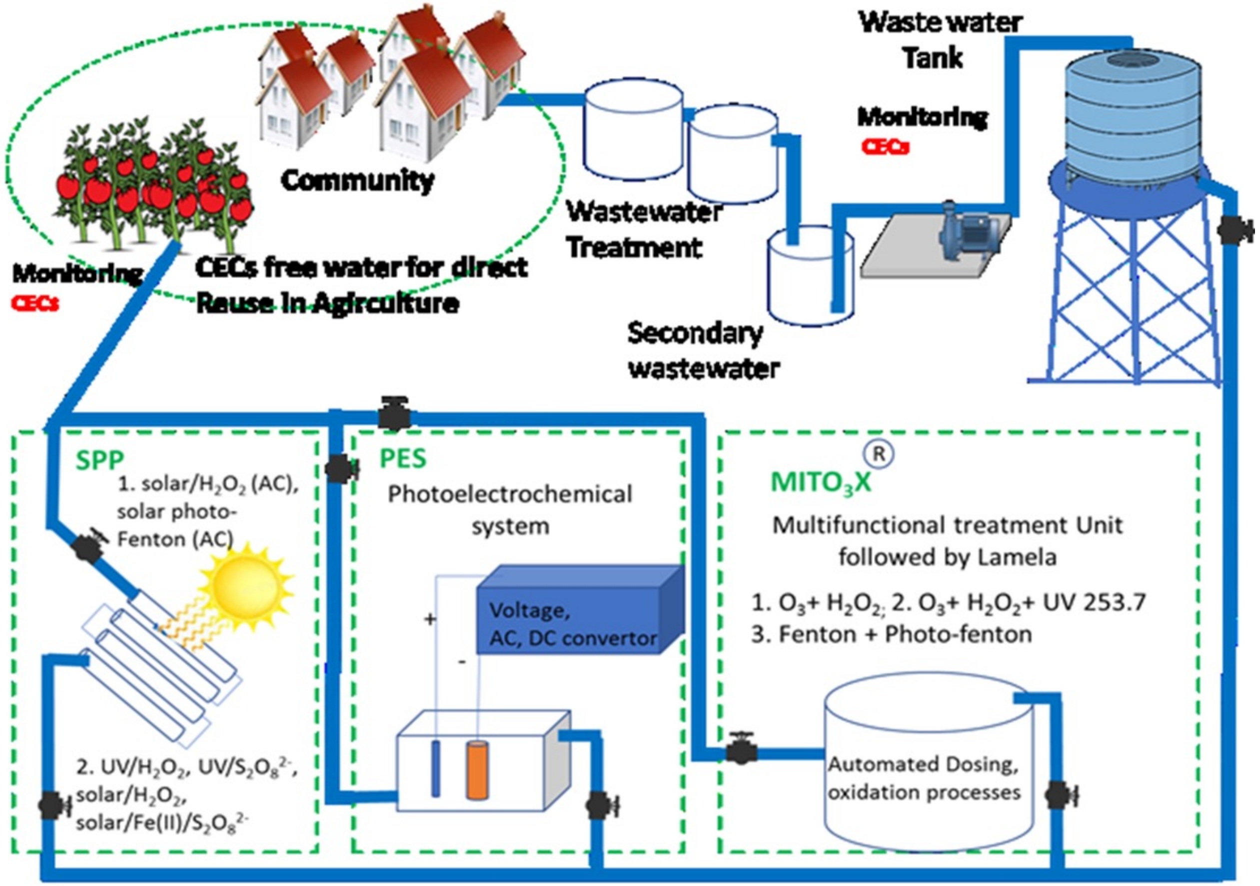




- Early prototypes exhibited good microbicidal efficacy, but poor environmental weathering durability.
- Later prototypes were unable to reach an acceptable compromise between efficacy & durability.
- Materials examined were PET, polypropylene (PP) and polylactic acid (PLA)
- 4 different prototype TJC designs were studied & tested. None were suitable for field demonstration
- Polypropylene is no longer considered suitable for long term SODIS TJC applications
- Rotary moulding with PLA or PMMA materials should be investigated

Fit-for-Purpose Wastewater Treatment

- **Profiling and Quantification of Untreated and Conventionally Treated domestic wastewater for microcontaminants: Contaminant of Emerging Concern (CECs), Indicator pathogens, Antibiotic resistant Bacteria (ARB) and Antibiotic resistant Genes (ARB)**
- **Demonstration of Multifunctional reactor (MFR) (50 m³/d) to remove contaminants of emerging concern (CECs), pathogens, ARGs and ARBs from UWTPs effluents for sustainable direct reuse in agriculture .**
- **Design and demonstrate tertiary/ advanced level treatment to conventional systems by Solar Powered Photolytic Plant (2m³/d) photon-driven oxidation processes.**
- **Development of photo electrochemical systems (PES, solar driven PV integrated) for disinfection and decontamination and designed to remove organic matter, CECs and microorganisms, including antibiotics and ARB from secondary effluents of an urban wastewater treatment plant at pilot scale with focus on costs minimization.**



Presence of Emerging contaminants in Sewage Treatment Plants

- Data on the occurrence of contaminants of emerging concerns (CECs) such as pharmaceuticals and personal care products (PPCPs) and antibiotic resistant bacteria (ARB) and antibiotic resistant genes (ARGs) in sewage is scarce in Indian perspective.
- A quantitative contamination profiling of selected PPCPs and antibiotic resistance in untreated and biologically-treated sewage from sewage treatment plants, located in northern and central part of India.
- CECs were detected both in untreated and treated samples (0.4 – 1340 µg/ L)
- 65 Pharmaceuticals , 14 Antibiotic Residues , 20 Pesticides , 3 Sweeteners identified in treated wastewaters from WWTP effluents and Irrigation canals
- Treated effluents cater resistant bacteria to commonly used antibiotics
- ARG copies identified in effluent and resistance genes persist.
- The results obtained in this study help evaluate health and ecological risks associated with the presence of CECs in treated sewage used for irrigation and frame future policies

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ELSEVIER

Profiling of emerging contaminants and antibiotic resistance in sewage treatment plants: An Indian perspective

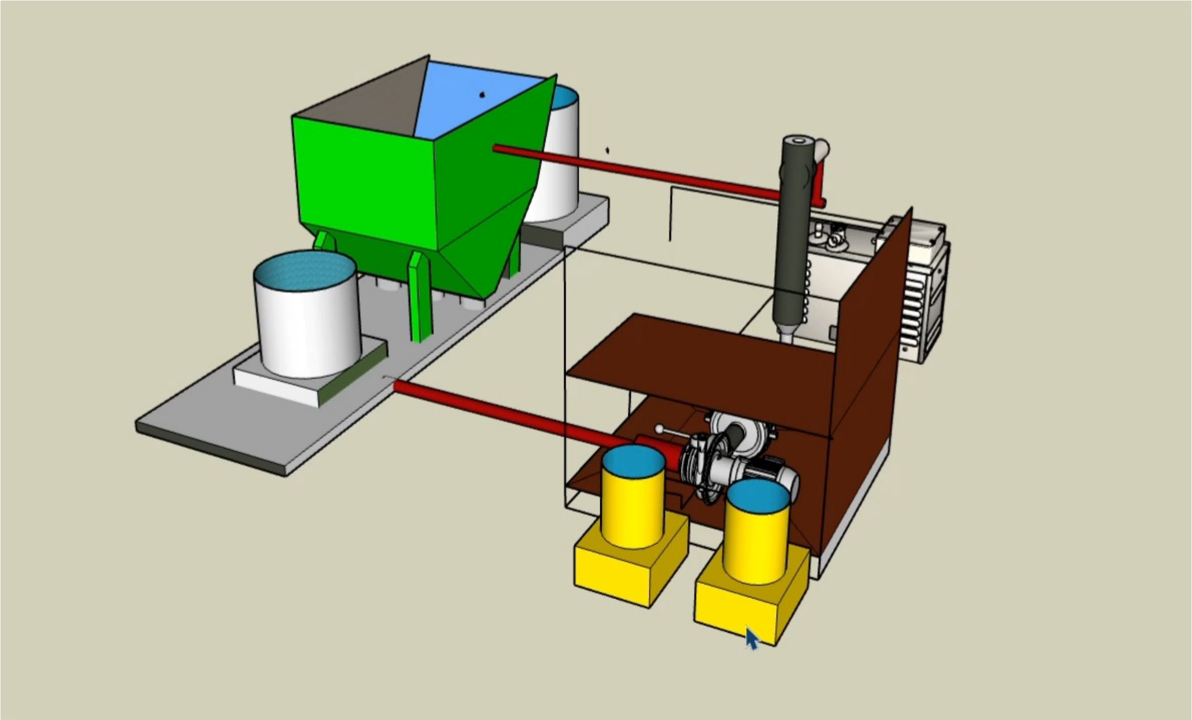
Priyam Saxena [a,1], Isha Hiwrale [a,1], Sanchita Das [a,b,1], Varun Shukla [a], Lakshay Tyagi [a], Sukdeb Pal [c,d,**], Nishant Dafale [b,d,*], Rita Dhodapkar [a,d,***]

(One or two samples may also be tested for emerging contaminants involving presence of pesticides, personal care products and antibiotics etc. as these are becoming important in future treatment processes. Such tests shall provide a good baseline data).

https://nmcg.nic.in/ 2018

Multi functional Reactor : 50m^3/day TRL: 6

- ✓ Dual step multifunctional reactor Combination of optimized physicochemical treatment & Advanced Oxidation Process
- ✓ Unique Fluid dynamics and residence time allows complete mixing of effluent with oxidants
- ✓ Full utilization of oxidants with optimized reaction times
- ✓ Minimum maintenance, low electricity consumption and reduced sludge volume



❑ **Innovation**

Rapid mixing under high-pressure reduces consumption of reagents

Allows simultaneous use of liquid and gaseous reagents

Low footprint

Reduced operational cost

Can be retrofitted with wastewater treatment systems

Accurate dosing with appropriate sensors can be integrated

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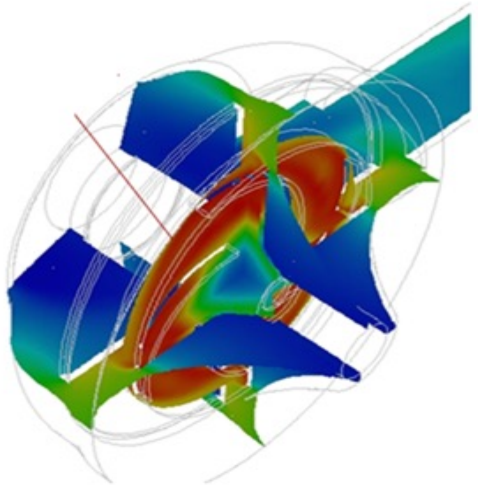
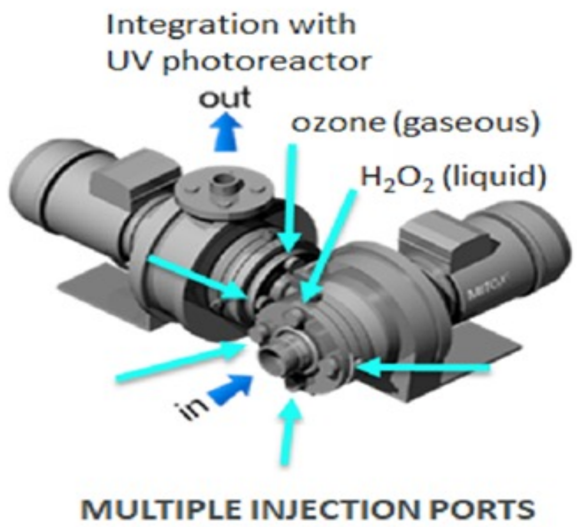
- **MITO3X technology**





- It allows simultaneous dosage of multiple treatment agents in multiple phases (gas/liquid/solids)
- It achieves high mixing rates (G>100,000 s^{-1}) which enhances mass transfer considerably
- It can be easily integrated in existing plants due to its small footprint
- It has been proven at full scale for tertiary treatment

See: https://www.youtube.com/watch?v=QvLdD_3MZlk&t=47s

Demo Unit: Sewage treatment plant Vayusena Nagar, Air force Maintenance Command, Nagpur

Equalisation Tank

MBBR unit

Clarifier

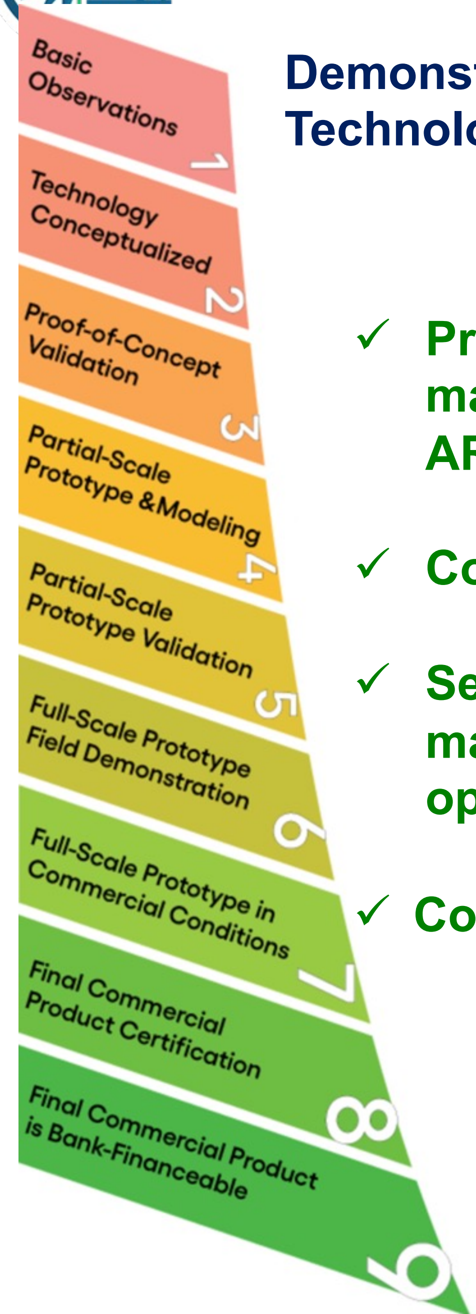
Dual Media Filtration

Inlet to MFR
COD≤ 50 mg/L
BOD≤ 10 mg/L
TSS≤ 10 mg/L
FC≤ 230/100mL

- Capital cost for system integration INR 0.25 Million / 50m3/day
- Capital cost MITO3X: 0.46 Million Euros (~ INR 4.1 Cr)
- Operational cost 1.5L /Year
- Revenue generation stems through recovery and reuse of water resource

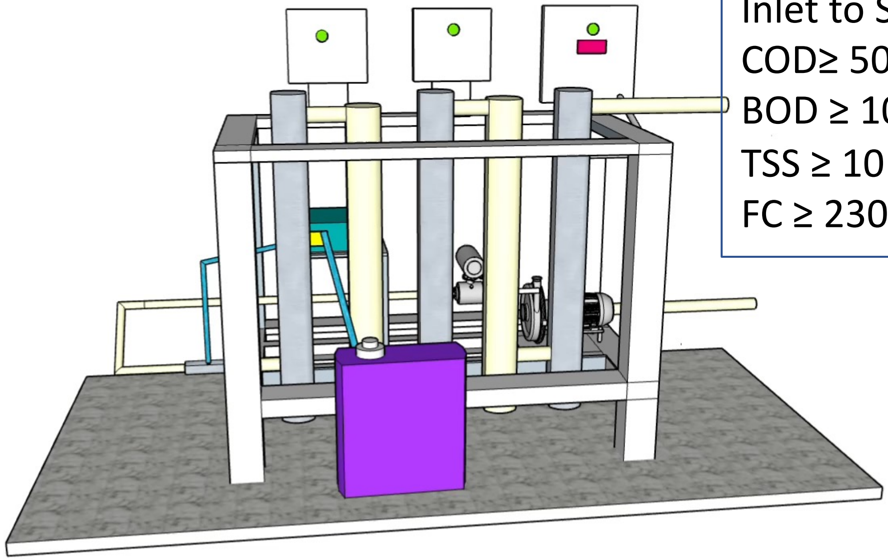
Irrigation Grade Water Resource for Reuse

Solar Powered Photolytic Plant : 2m^3/day TRL 6



Demonstration Site : Bhandewadi WWTP at Nagpur
Technology tested both in India and EU

- ✓ Process Optimisation for achieving maximum removal of CECs including ARGs & ARBs
- ✓ Controlled dosing of per-oxidant
- ✓ Serpentine Up-flow design ensures maximum exposure to UVC to achieve optimum performance
- ✓ Continuous mode of operation



Inlet to SPPP
COD≥ 50 mg/L
BOD ≥ 10 mg/L
TSS ≥ 10 mg/L
FC ≥ 230/100mL

PANI WATER पानी

Solar Powered Photolytic Plant : $2 m^3$/day TRL 6

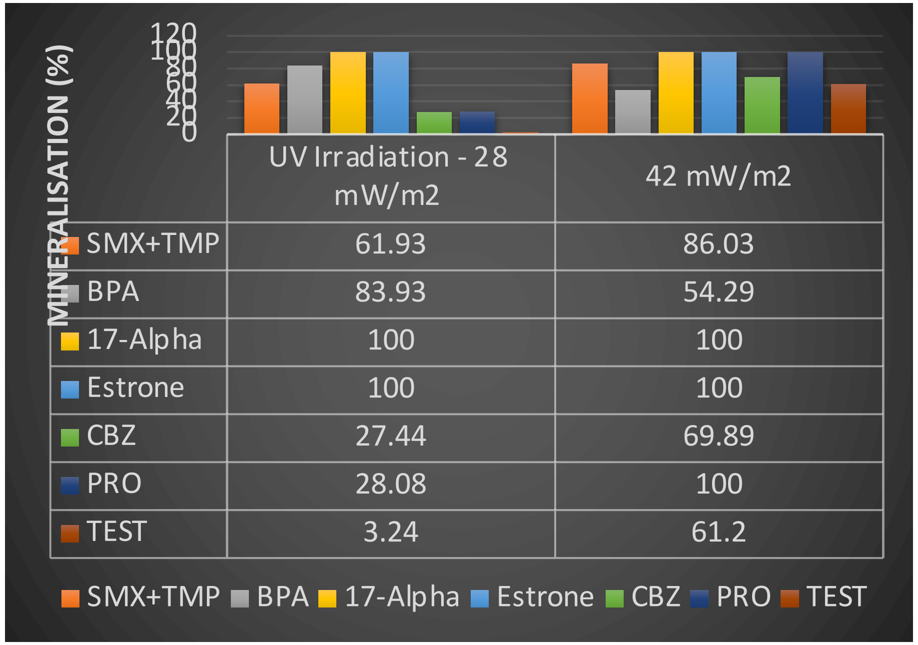
Technology tested both in India and Spain

≥ 80% Total CECs removals

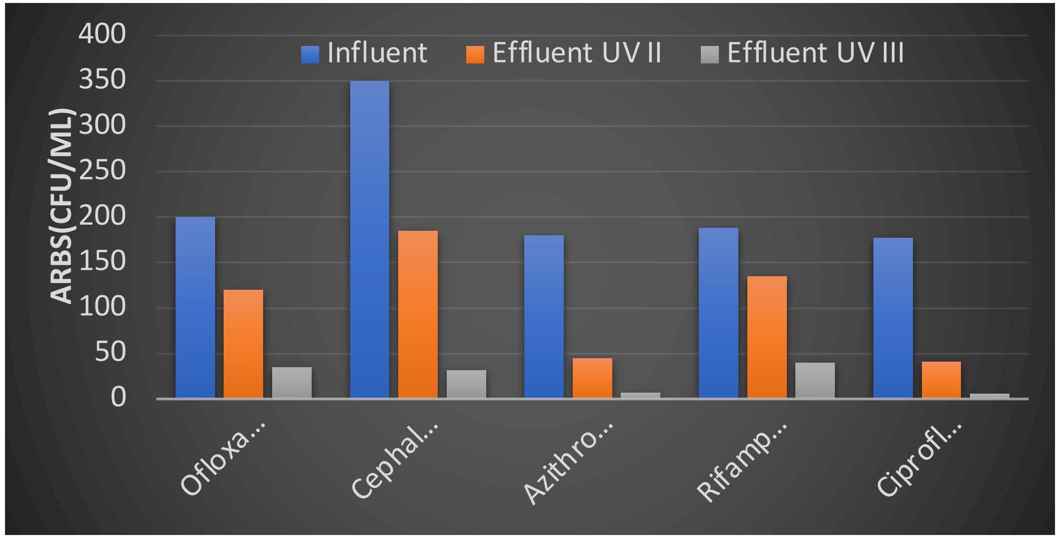
Resistance against ciprofloxacin and azithromycin reduced significantly after UV treatment

Decrease in the count of indicator bacterial load observed in effluent after passing through optimized UV-C lamps.

The qPCR results show a decrease in the number of ARG copies in effluent, resistance genes are still present



	UV Irradiation - 28 mW/m2	42 mW/m2
SMX+TMP	61.93	86.03
BPA	83.93	54.29
17-Alpha	100	100
Estrone	100	100
CBZ	27.44	69.89
PRO	28.08	100
TEST	3.24	61.2



@ Demonstration Site, Bhandewadi WWTP, Nagpur

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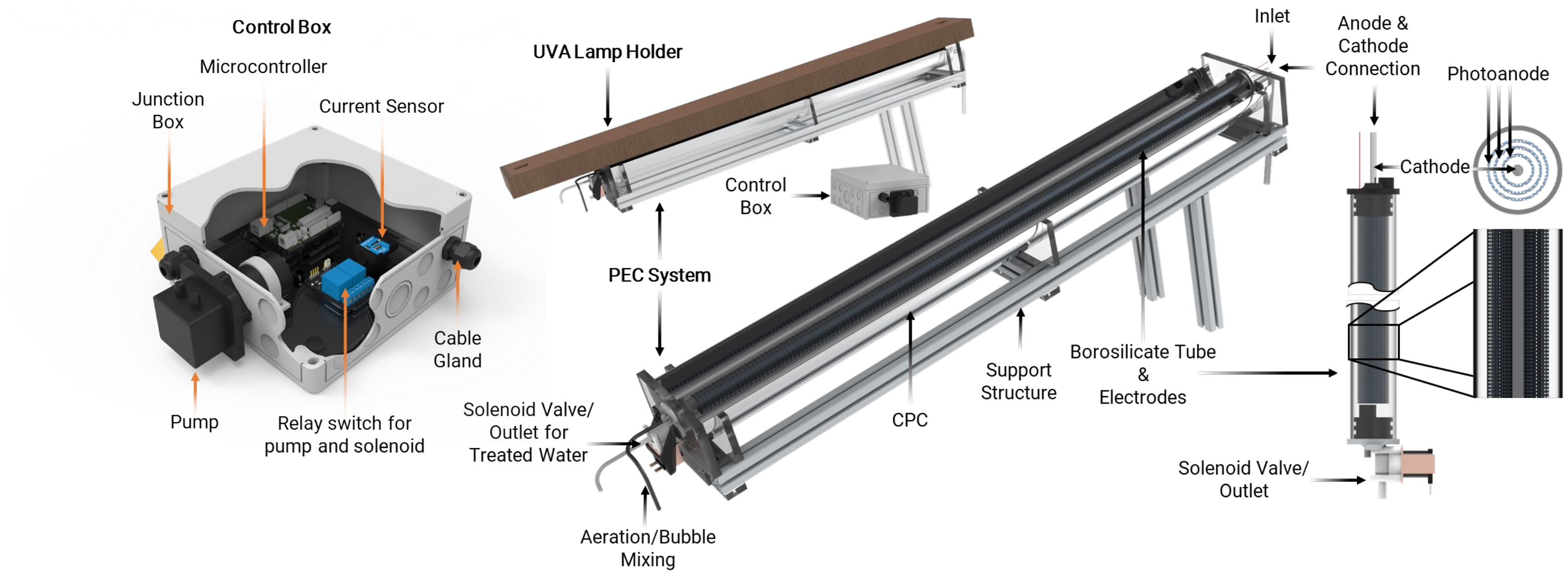
Photoelectrocatalysis Water Treatment

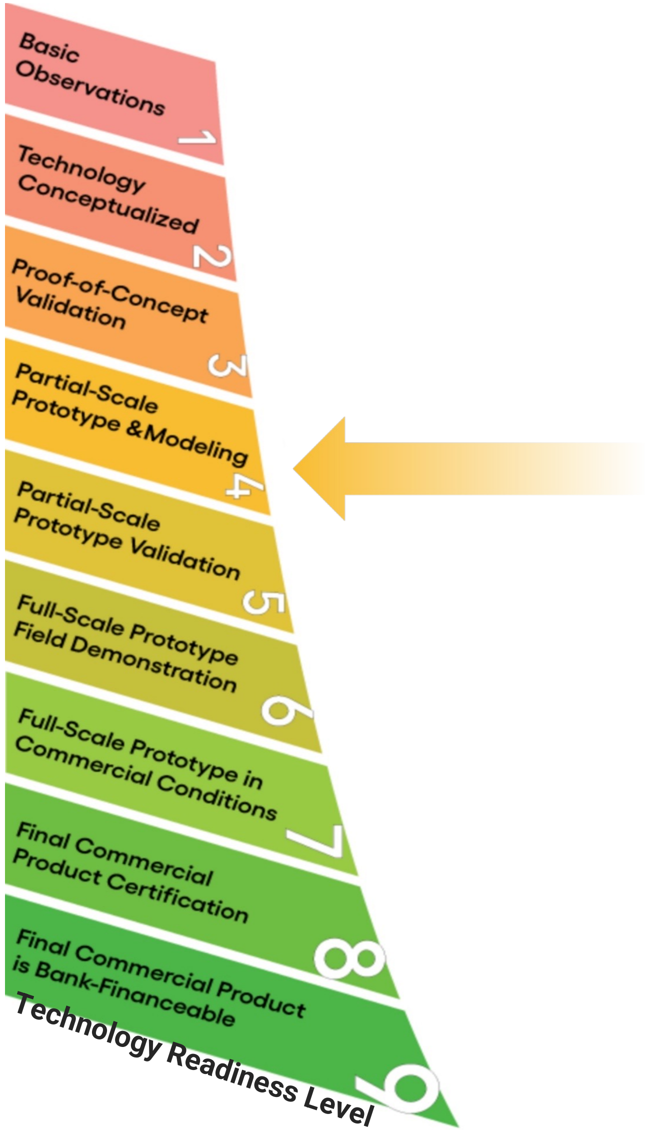
Automated PEC Prototype



Advantages of Photoelectrocatalysis Water Treatment

- Generate oxidating agents that work against microorganisms and chemical pollutants that current treatment technologies cannot remove
- Doesn’t require the addition of chemicals
- Can operate at lower current and voltages, lower energy consumption

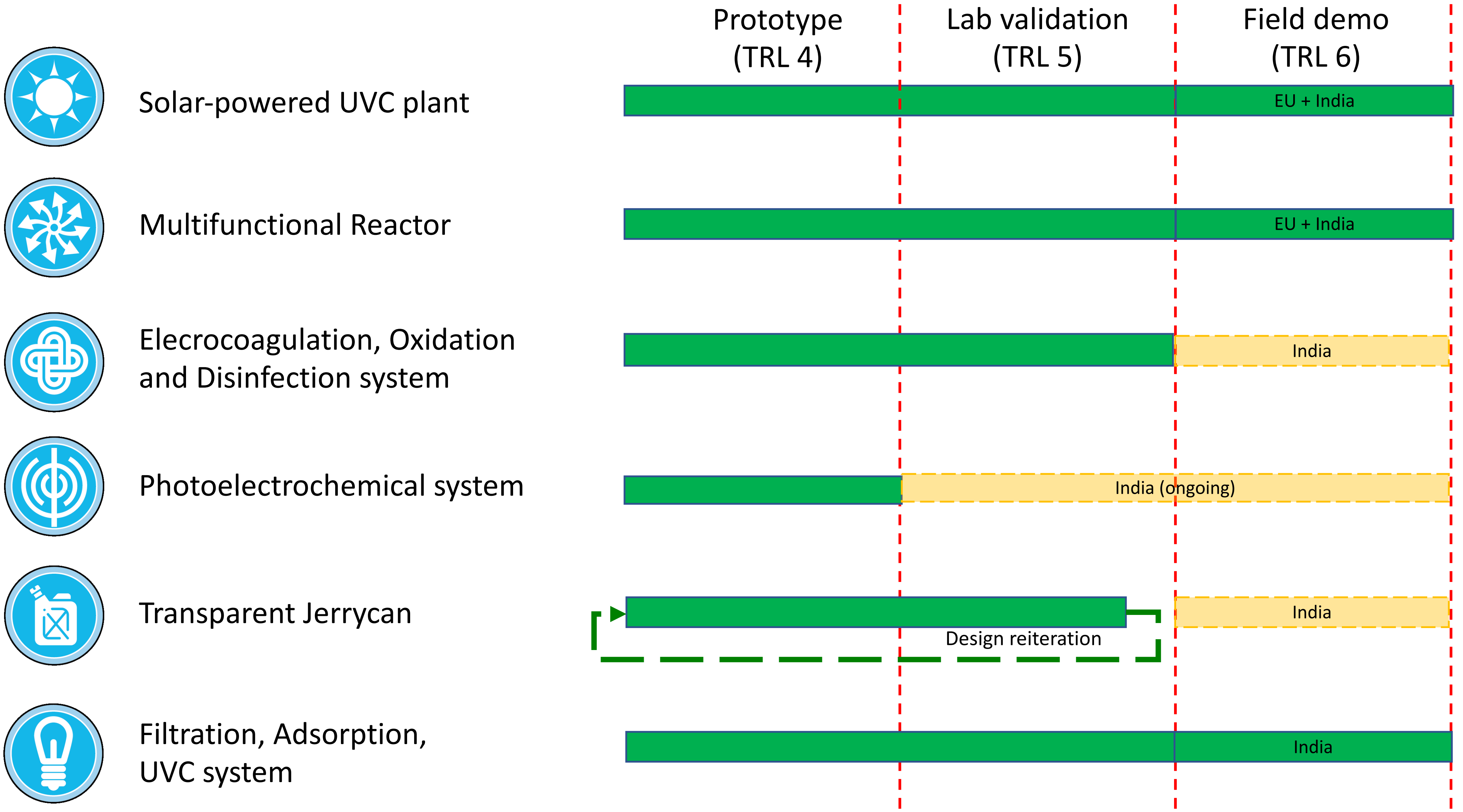
Photoelectrocatalysis Water Treatment



Currently, photoelectrocatalysis is at TRL 4 technology, with pilot scale studies conducted in CSIR-NEERI in partnership with Ulster University, UK

More work is needed to evaluate the lifespan of the system and thus the effective cost per litre, as well as quality assurance and automation which is currently in development

Technology Readiness



IP readiness

Solar-powered UVC plant

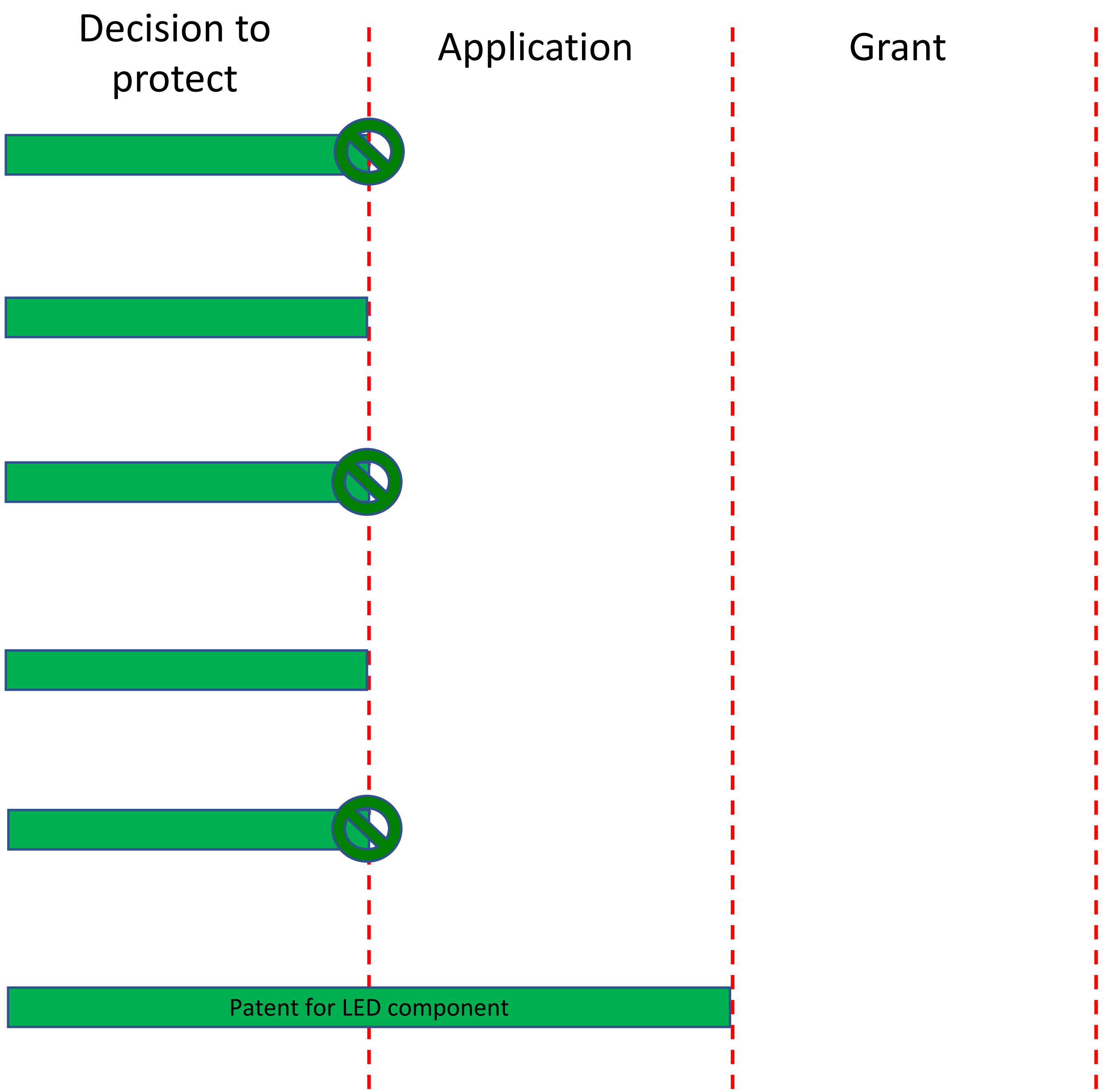
Multifunctional Reactor

Elecrocoagulation, Oxidation and Disinfection system

Photoelectrochemical system

Transparent Jerrycan

Filtration, Adsorption, UVC system



Market readiness

	Product dossier	Cost analysis	Stakeholder engagement		
Solar-powered UVC plant	Performance & SOP	CapEX / OpEX INR	Manufacturer	End-user	Distributor
Multifunctional Reactor	Performance & SOP	CapEX / OpEX	Manufacturer	End-user	Distributor
Elecrocoagulation, Oxidation and Disinfection system	Performance & SOP	CapEX / OpEX INR	Manufacturer	End-user	Distributor
Photoelectrochemical system	Performance & SOP	CapEX / OpEX INR	Manufacturer	End-user	Distributor
Transparent Jerrycan	Performance & SOP	CapEX / OpEX INR	Manufacturer	End-users	Distributor
Filtration, Adsorption, UVC system	Performance & SOP	CapEX / OpEX	Manufacturer	End-users	Distributor

Decentralised drinking water and wastewater treatment in India

USD 553.36 million India Market Size in 2024	**USD 865.27 million** India Market Size in 2029
6.64% CAGR (2018-2023)	**9.35%** CAGR (2023-2028)

Thank You

Market Entry points – Wastewater tech

- Existing decentralised systems lacking advanced tetiary treatment

	CaPEX	OpEX (1 year)	Capacity
Bankers Colony, Nhuj, Gujarat	15 lakhs 19,000 USD	1.5 Lakhs 1,900 USD	30 m^3 / day

2 Chambered settlers

↓

Anaerobic baffled reactor

↓

Planted filter → **Advanced III (MFR, SPP, PES**

↓ (Planted filter → Polishing pond) / ↓ (Advanced III → Irrigation)

Polishing pond

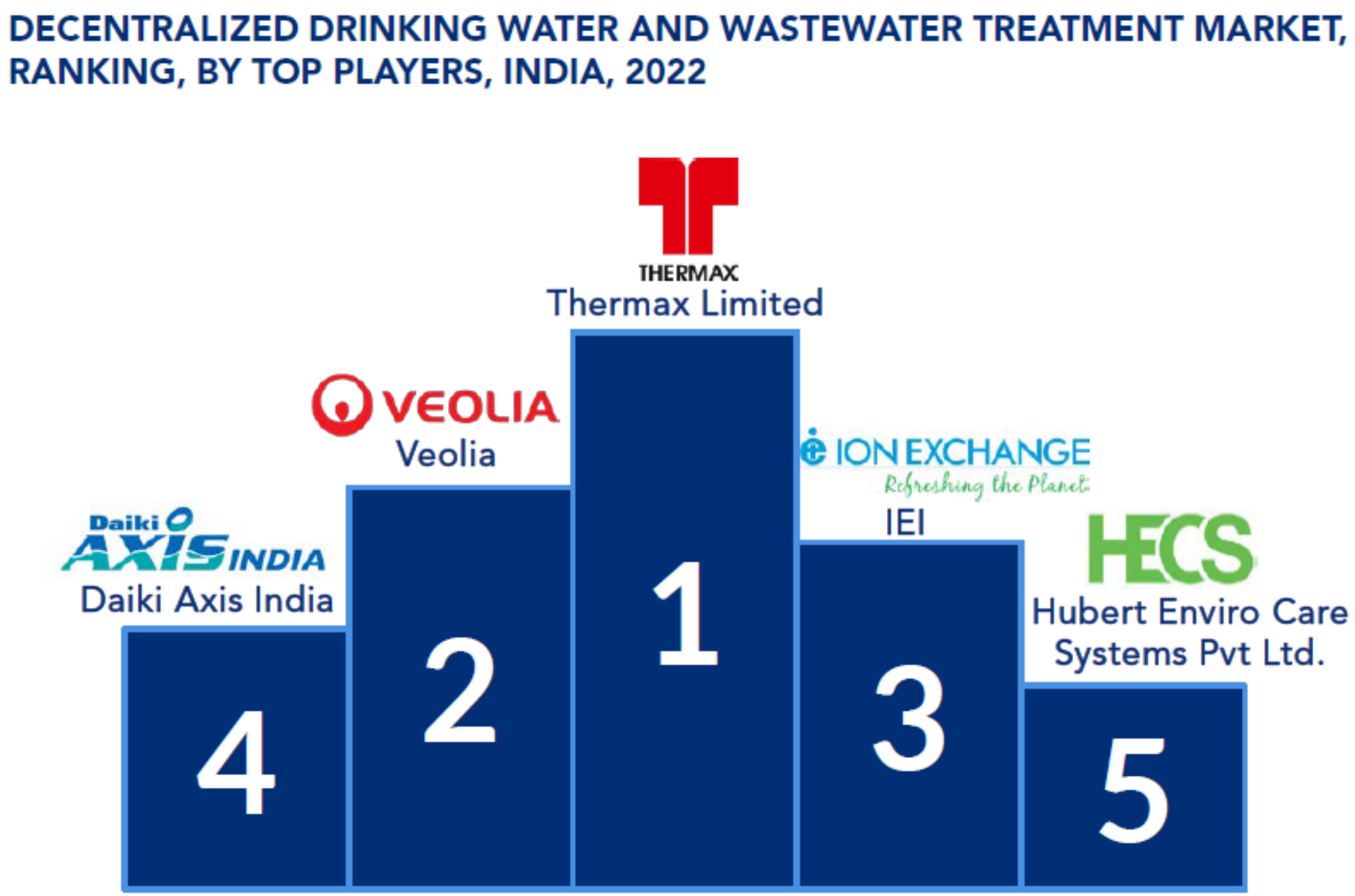
↓

Storm water drain

Irrigation

Market Entry points – Wastewater tech

- Partnership with major players (IP Transfer)



Market Entry points – Drinking water tech

- Through international, national and state outreach initiatives

Examples

Case studies on best practices adopted by states

Case study 1: Community Managed Water Supply Programme: Bringing drinking water to the doorsteps of people in rural Gujarat

Overview

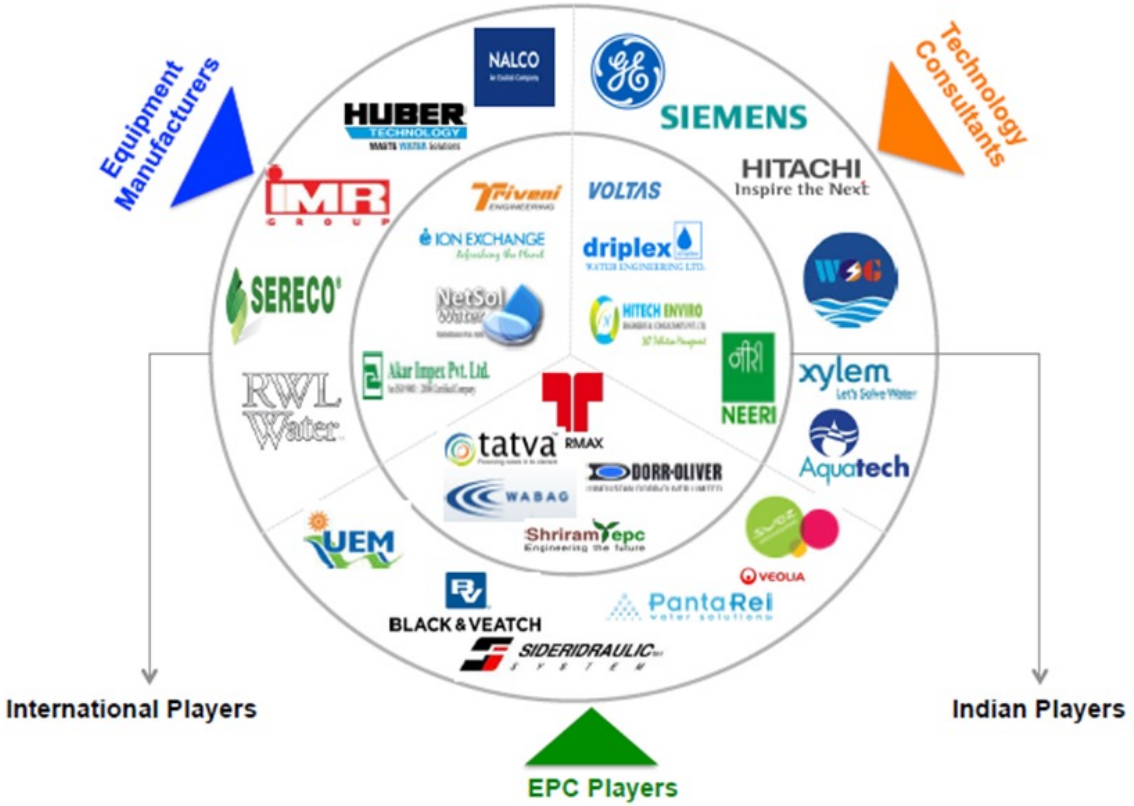
Gujarat's rural water supply programme, led by the state's Water and Sanitation Management Organisation (WASMO), aims to supply the village community with adequate, regular and safe water through household-level tap water connectivity, including households of people from backward communities. The programme strives to build a sustainable model through building capacity of village communities and empowering them to manage water resources themselves. The programme is based on a unique cost-sharing model, where the community partially shares the cost, owns the drinking water supply assets, and holds the operation and maintenance responsibilities.

As a result of this programme, Gujarat has achieved a 100% score in the 'Rural drinking water' theme of the Water Index, implying that it provides clean water to all of its ~35 million rural residents[87].

Initiatives and organisations
• Naandi Fundation
• Water for the people
• Sarvajal
• Jal Jevaan mission
• Water.org
• Gram Vikas
• Safe Water Network
• DROP Foundation
• Swajal
• Drop4Drop
• Elixir Foundation
• Charity water
• WASMO

Market Entry points – Drinking water tech

- Partnership with major players (IP Transfer)



National
• Thermax India
• Hindustan Dorr-Oliver Limited
• SFC Environmental Technologies Private Ltd
• Ion Exchange India
• Voltas
• VATech Wabag
• Sahrpoorji Pallonji
• Kent RO
• Hinudstan UNILEVER

International
• GE Water & Process Technologies
• W.O.G. Technologies
• Siemens Water Technologies
• Toshiba Water Solutions
• Veolia

Market Entry points – Wastewater tech

- Existing decentralised systems lacking advanced tetiary treatment

Examples

	CaPEX	OpEX (1 year)	Capacity
Bankers Colony, Nhuj, Gujarat	15 lakhs 19,000 USD	1.5 Lakhs 1,900 USD	30 m^3 / day
Kulgaon-Badlapur, District Thane, Maharashtra	4 lakhs 5,400 USD	0.7 lakhs 800 USD	7 m^3 / day
Camphill, Bannerghatta Road, Bangalore	5.5 lakhs 7,000 USD	0.8 lakhs 900 USD	9 m^3 / day
Delhi Jal Board, Varunalaya, New Delhi	16 Lakhs 20,300 USD	1.5 Lakhs 1,900 USD	8 m^3 / day