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Phoenix

Novel pilot-scale photocatalytic nanofiltration reactor for agricultural wastewater treatment

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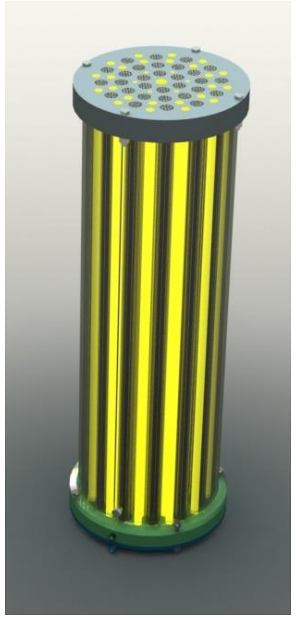


WORKSHOP

"Innovative solutions for the regeneration of urban and industrial wastewater"

October 21st 2024

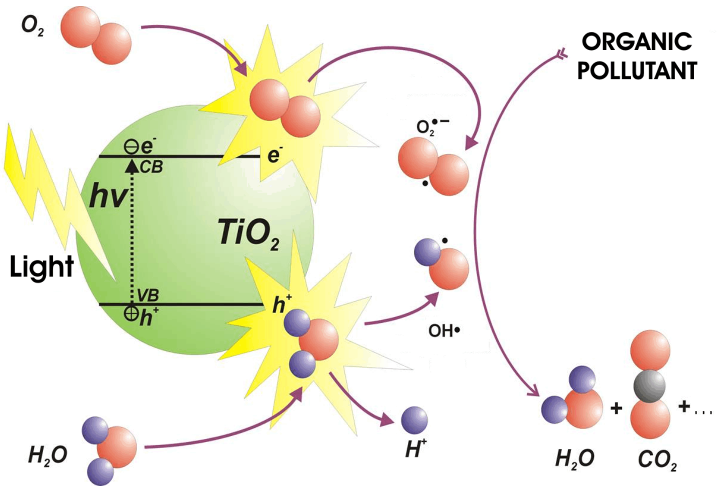
Palacio de Exposiciones y Congresos Cabo de Gata-Ciudad de Almería

- Retrospection of the Photocatalytic Nanofiltration Technology.
- Aspects of the design and deployment phase.
- The benefits of the technology for the abatement of organic micropollutants in water.
- Results form the operation phase at the TRL6.
- Technoeconomic analysis

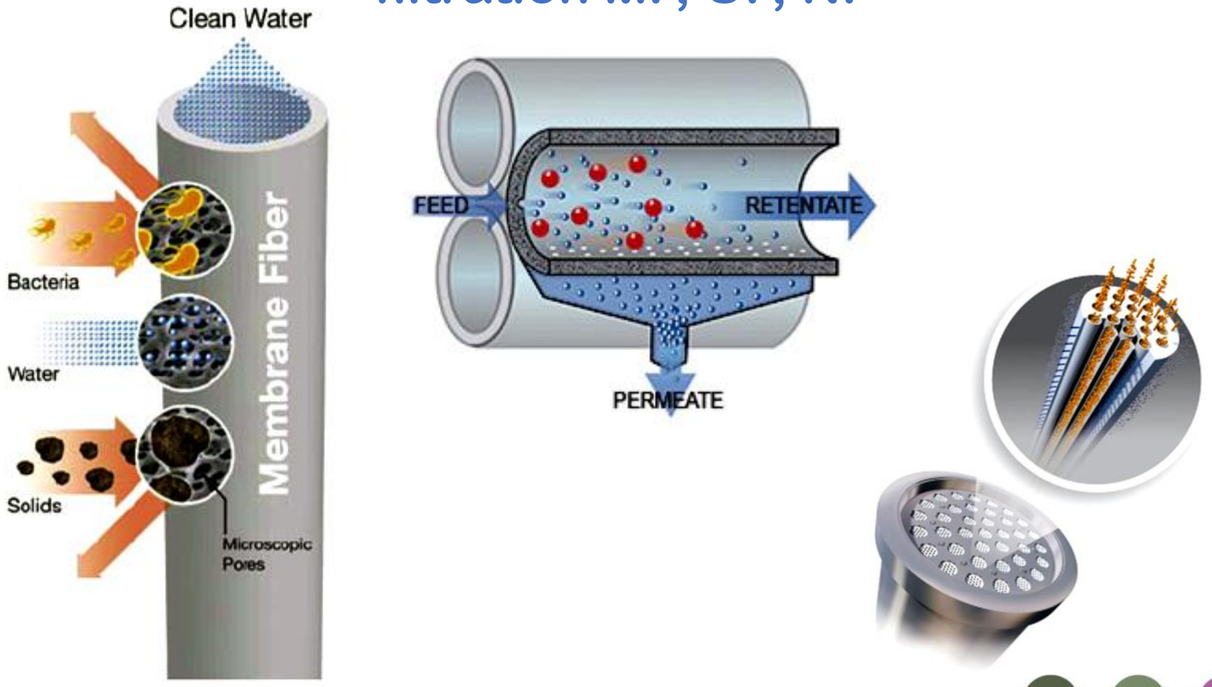
2010: Clean Water project (FP7). Concept - Can we integrate the two processes synergistically?

Clean Water-227017
FP7-ENV-NMP-2008-2

Photocatalysis



Pressure driven membrane filtration MF, UF, NF



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Requirements

Photocatalytic membrane

Module (reactor) – tangential flow filtration and simultaneous irradiation of membrane's surfaces

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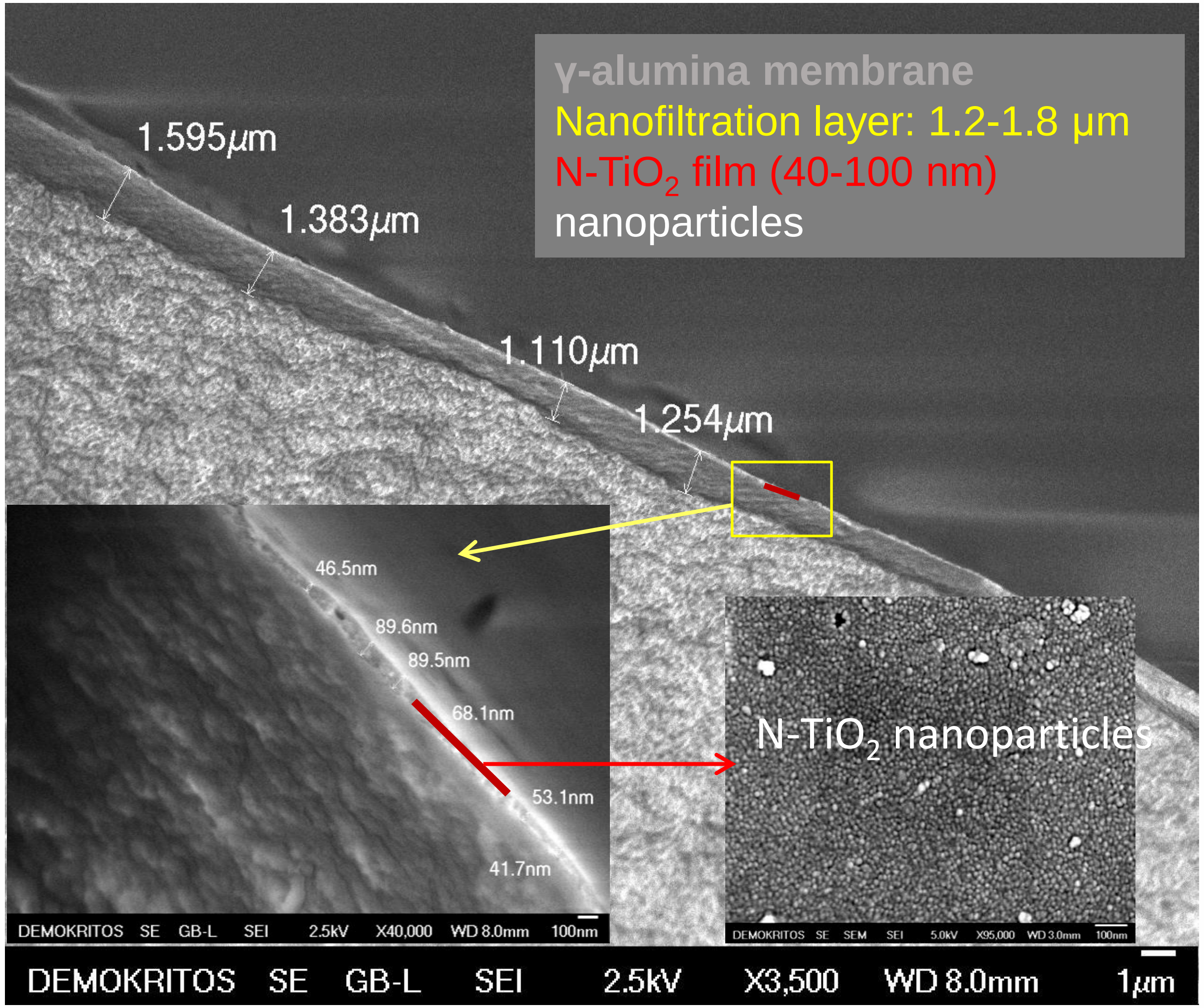
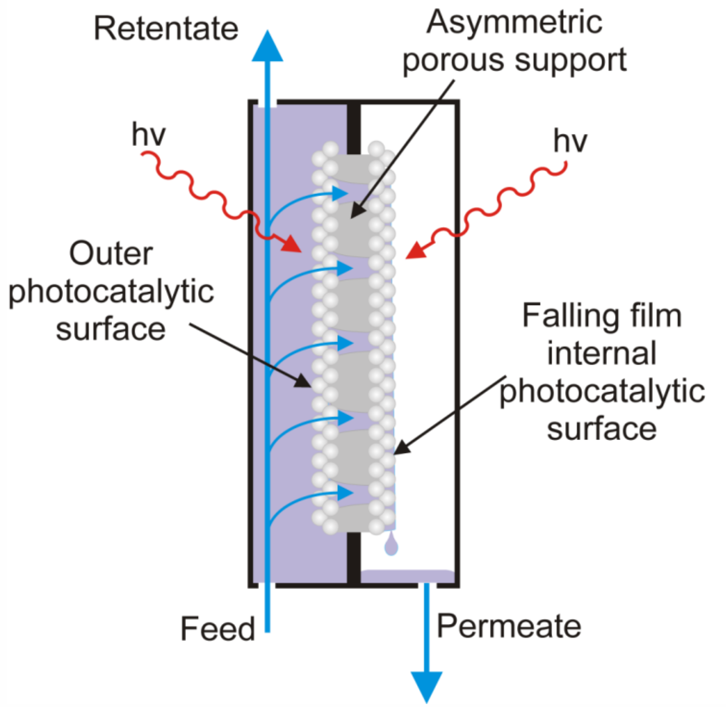
Photocatalytic membrane

Sol gel-dip coating, wash coating and CVD approaches

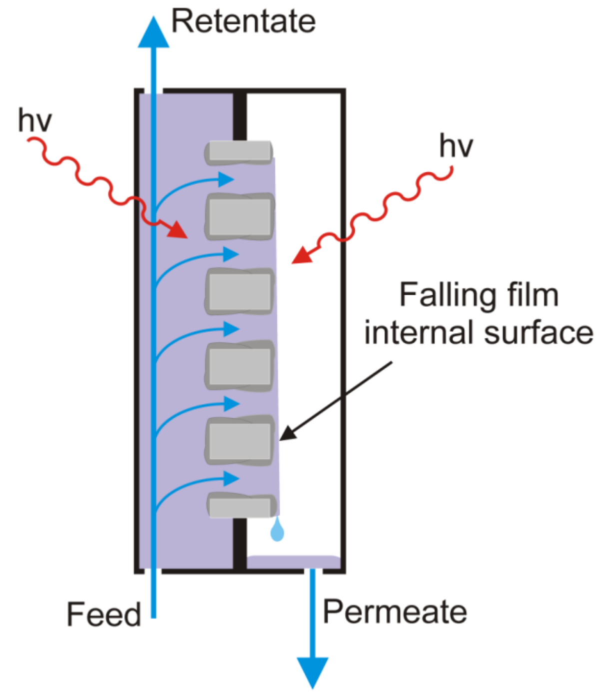


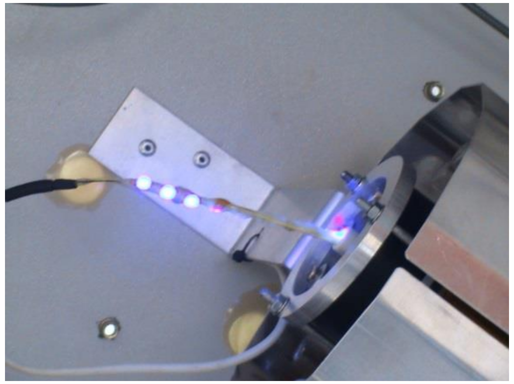
Module (reactor)

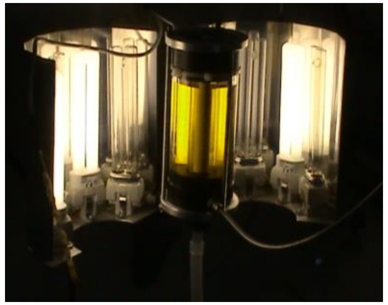
Membrane with deposited TiO_2 nanoparticles developed via CVD



Membrane with nanocrystalline TiO_2 films developed layer by layer via CVD







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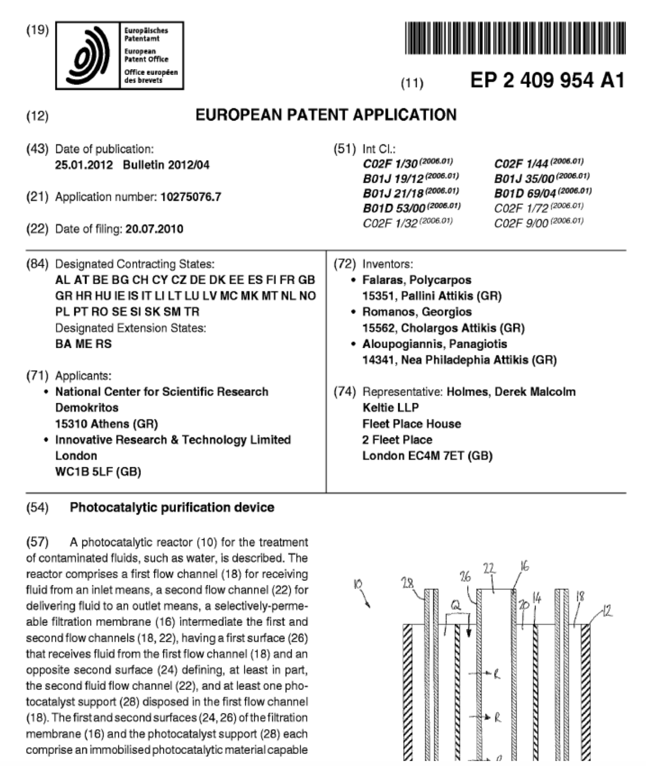
Rapid progress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(54) **Photocatalytic purification device**

(57) A photocatalytic reactor (10) for the treatment of contaminated fluids, such as water, is described. The reactor comprises a first flow channel (18) for receiving fluid from an inlet means, a second flow channel (22) for delivering fluid to an outlet means, a selectively-permeable filtration membrane (16) intermediate the first and second flow channels (18, 22), having a first surface (26) that receives fluid from the first flow channel (18) and an opposite second surface (24) defining, at least in part, the second fluid flow channel (22), and at least one photocatalyst support (28) disposed in the first flow channel (18). The first and second surfaces (24, 26) of the filtration membrane (16) and the photocatalyst support (28) each comprise an immobilised photocatalytic material capable

1 EP Patent

+20 publications in high impact factor journals

1 International Prize

International Prize

arab news

US, Spanish and Greek scientists win Prince Sultan water award

The Prince Sultan bin Abdulaziz International Prizes for Water for 2014

- The creativity prize (groups from Princenton and Colorado Universities)
- The surface water prize (group from Arizona State University)
- **The alternative water resources prize (group from NCSR “Demokritos”)**
- The ground water prize (Institute for Environmental Assessment and Water Research, Spain.
- The water management and protection prize (University of California in Los Angeles)

With the LIFE project we had the opportunity to validate the PNFR technology at the TRL6

LifepureagroH_2O – Innovative photocatalytic nanofiltration technology for pollutant removal and water reuse of agro-industrial effluents

Budget for the deployment of a system to treat 20 t/day of wastewater from the agrifood industry 750K€

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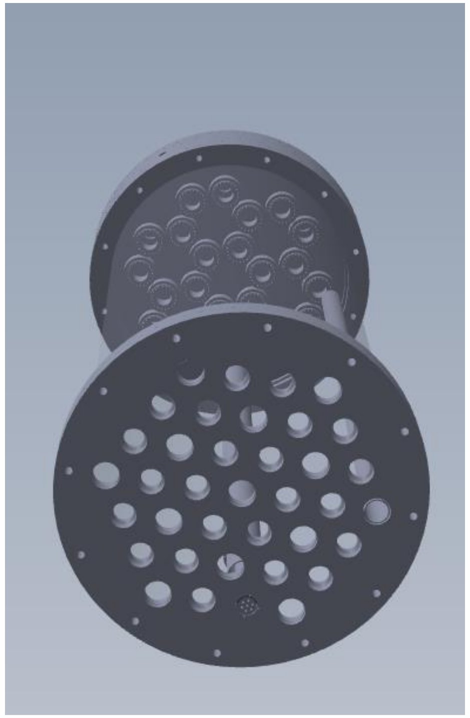
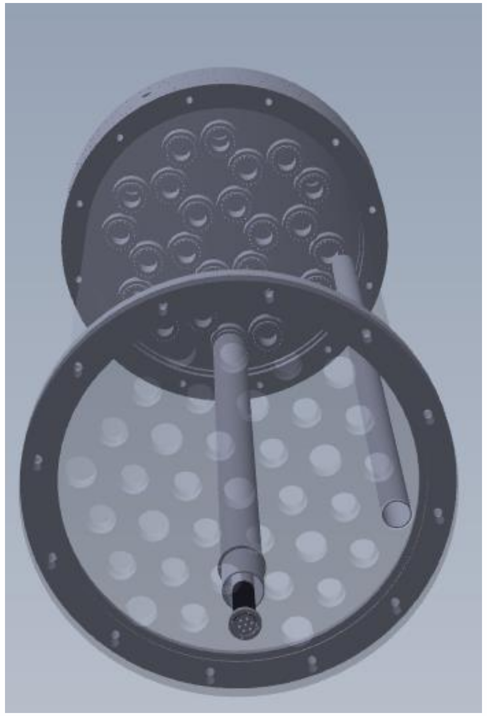
Targets of the design and deployment phase.

- Dimension and number of photocatalytic membranes
- Irradiation system
- Enhance the photocatalytic surface per reactor volume
- Design the module internals





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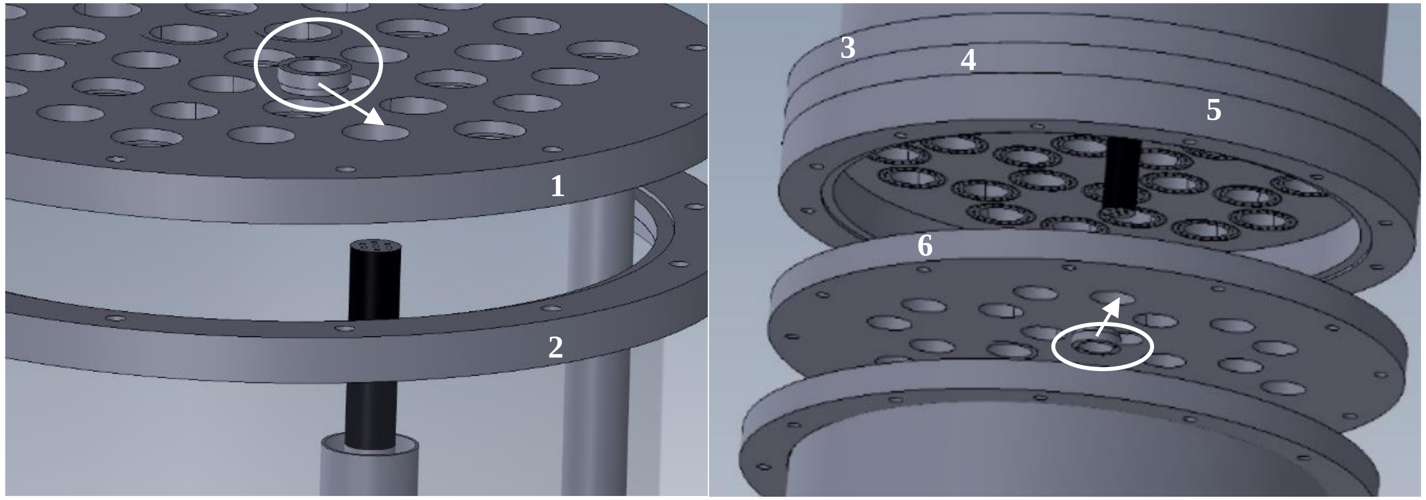
Results of the design phase.

Number of modules: 8

Number of p. membranes per module: 12

Number of immersed UV sources per module: 7

Length of photocatalytic fibers per module: 360 m

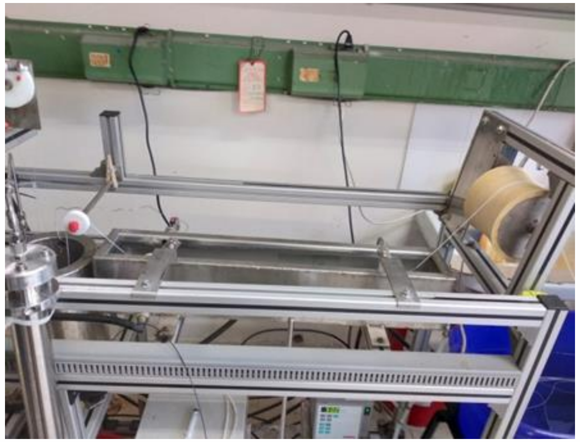


3 flow channels enclosing a total photocatalytic surface of 3.6 m^2

Deployment phase-Photocatalytic fibers.

Preparation of the PVDF/TiO_2 solution

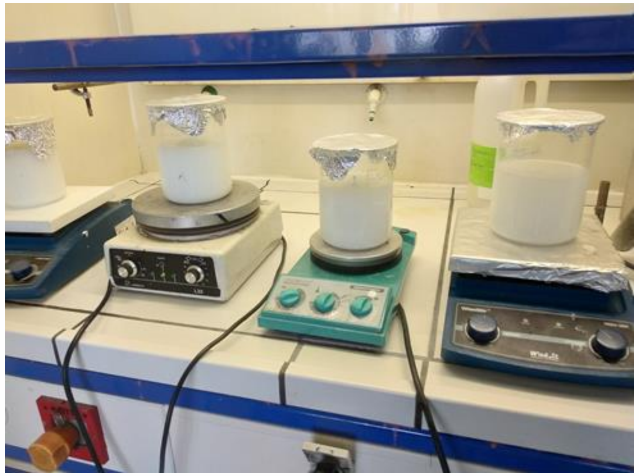
Extrusion of the photocatalytic fibers with the dry-wet phase inversion process in spinneret set up



Assemble the photocatalytic fibers on glass-tubes inserted to the reactor

Deployment phase-Photocatalytic membranes.

Preparation of the wash-coating TiO_2 slurries



Perform the wash coating and drying process of the monoliths.

Heating to stabilise the photocatalytic layers

Reactors assembly

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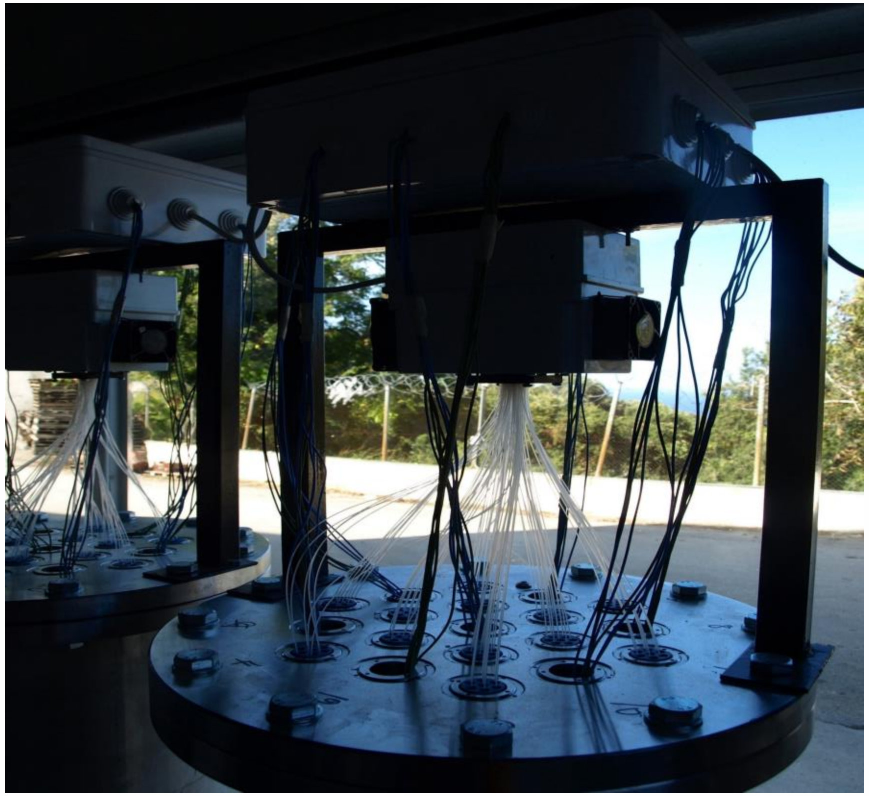
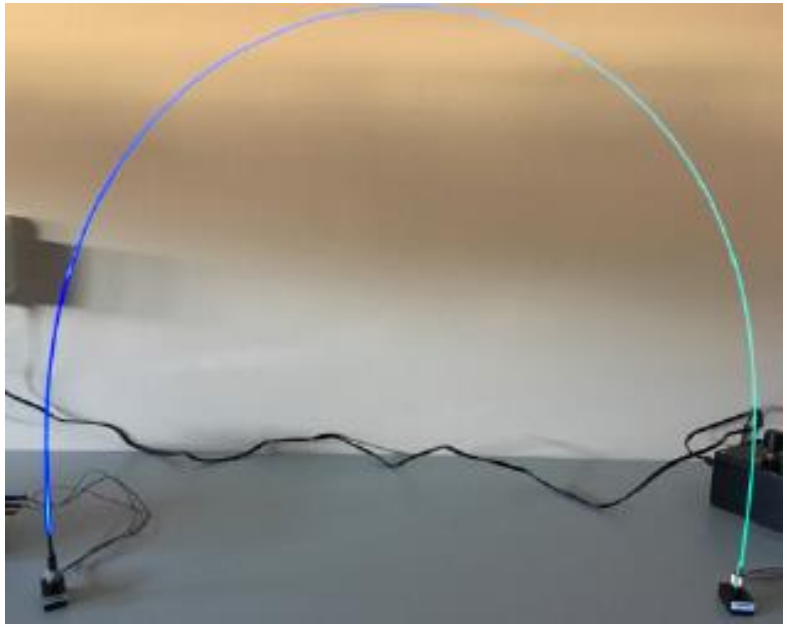
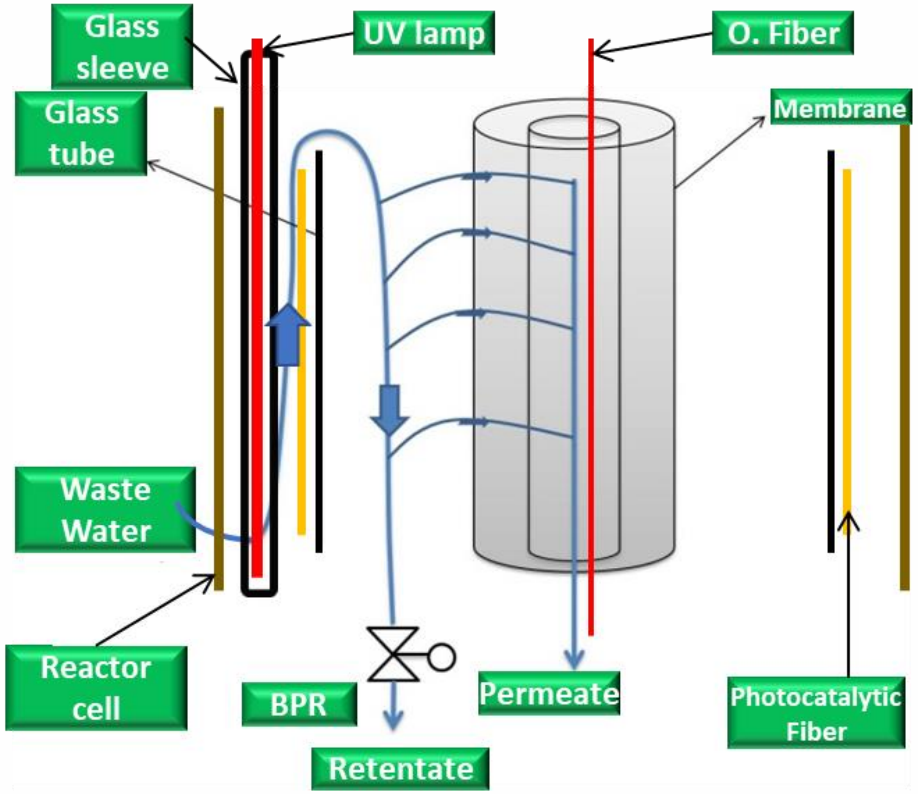
Irradiation system

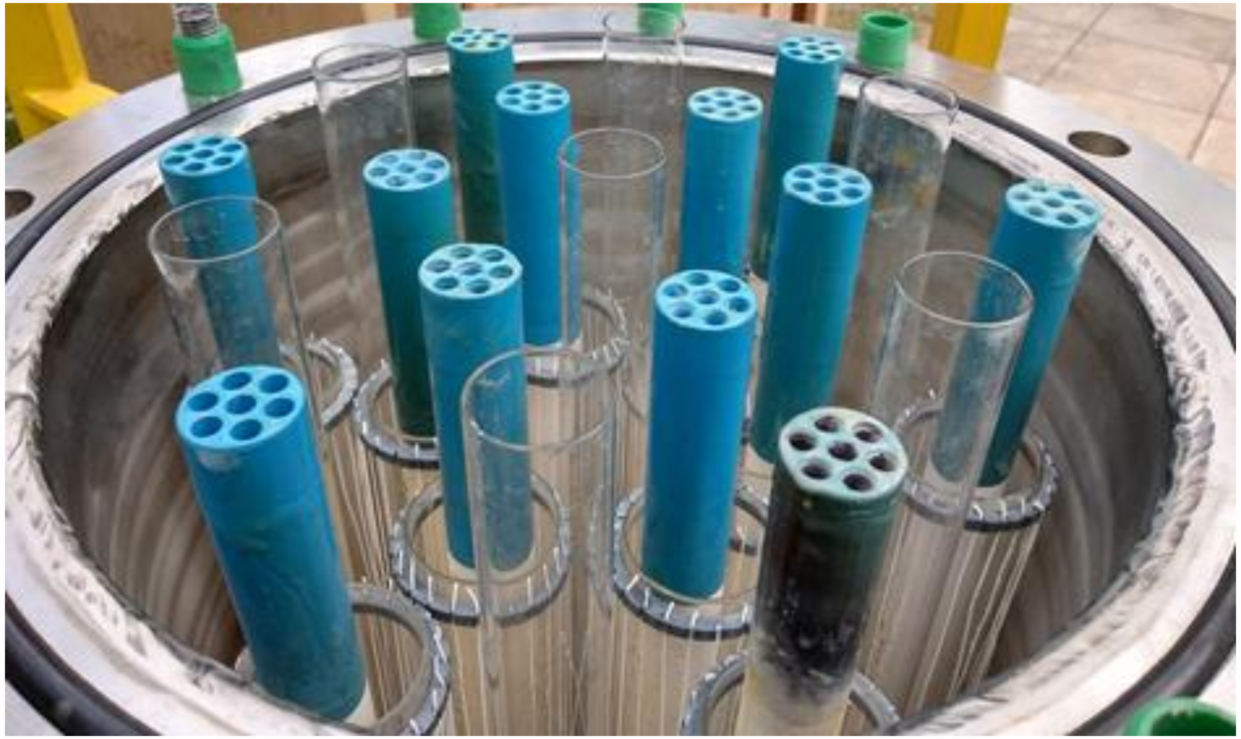


Side Glowing Optic Fibers coupled with HP UV LED chip modules

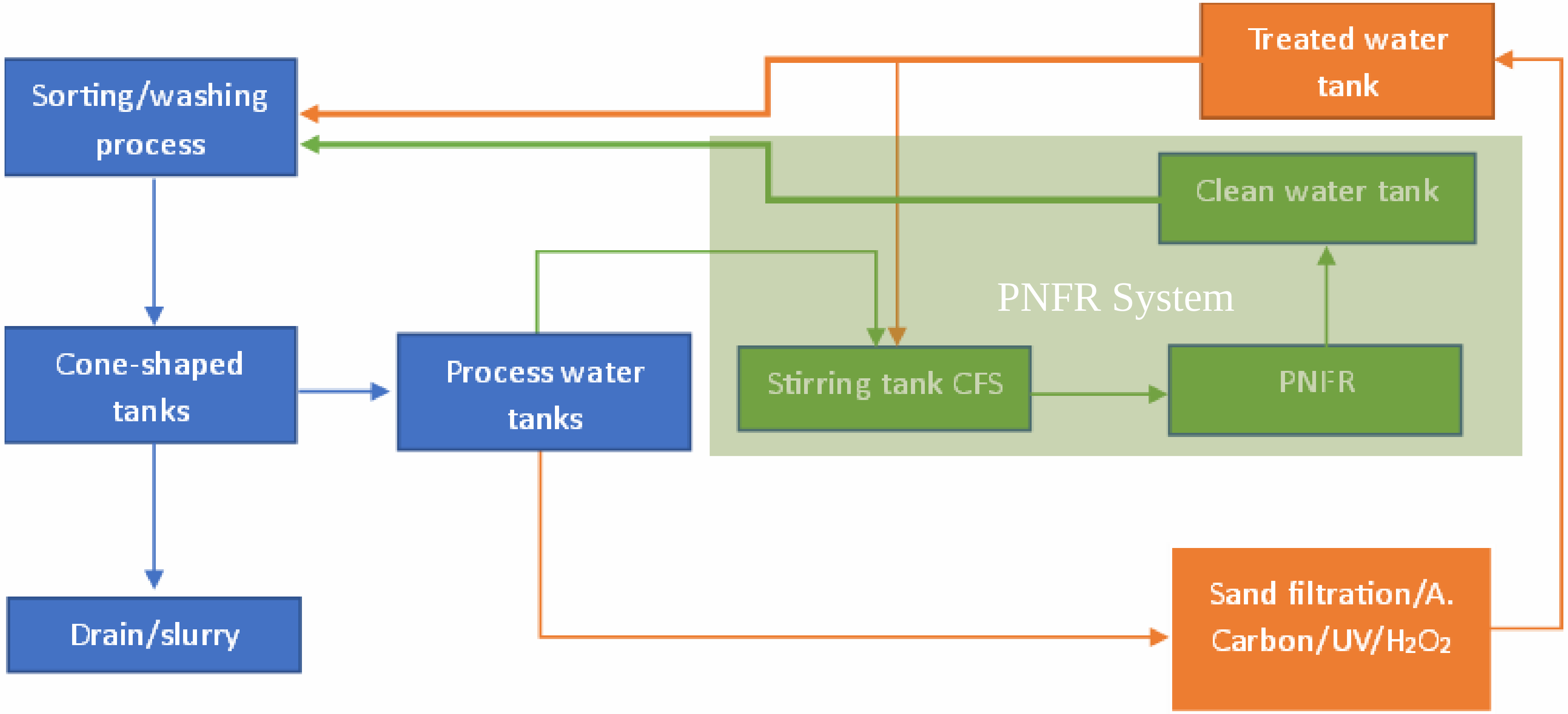


Operation principle





Overview of the process at Zagorin



Overview of the process at Zagorin

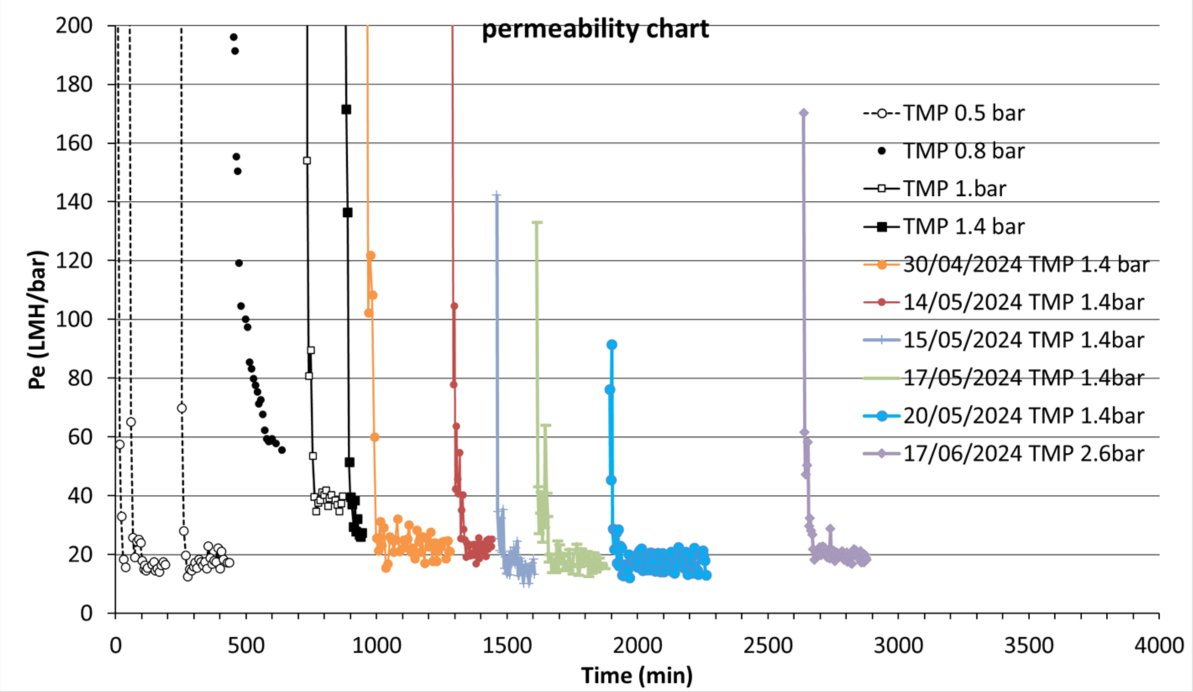
Benefits

- Addresses the competitive action of the organic loading which consumes sorption sites, and oxidising radicals.

- The photocatalytic activity on the photocatalytic fibers and the shell surface of the membranes concludes to a retentate effluent that is less concentrated than the feed.

- Addresses the demand for very frequent regeneration replacement of the membranes since the molecules attached on the membrane surface are photodegraded.

Results



FEED

Pesticides 20 ppb

COD 24 mg/L, TOC 5 mg/L, BOD 10 mg/L, TSS 15 mg/L, Turbidity 12 FNU,

- **The permeability remains stable for 10 days on stream.**
- **Improvement of all physicochemical parameters of water (by 75%) (COD, BOD, TOC, Turbidity, S.Solids)**
- **HM are effectively rejected 80-85%.**
- **Achieves in average 55-60% removal efficiency of 30 different types of pesticides while for certain types the removal reaches 100%.**

Technoeconomics

Calculation of the currently achieved LCOW by the PNFR technology based on the cost of electricity in Greece and the data from the so far industrial scale operation in the Agrifood sector.

Electricity	Power of the equipment kW	Hrs (15 m^3)	kWh (15 m^3)	KWh (150 m^3)	Operational cost (1) €/m^3	LCOW %
UV-LEDs	0.8	8	6.4		0.13	3.75
UV lamps	1.68	8	13.44		0.28	7.88
Pressure pumps	1.23	8	9.84		0.2	5.77
Submersible pumps	0.23	8	1.84		0.038	1.08
Stirrer	7.5	0.11	0.81		0.017	0.48
Boiler	33.5	1		33.5	0.069	1.96
				Total	**0.735**	**20.9%**
Chemicals	€/kg	Kg (15 m^3)	Kg (150 m^3)	Kg (450 m^3)	Operational cost (2) €/m^3	
$Al(SO_4)_3$	0.15	0.5			0.005	0.14
NaOH	4		6		0.16	4.55
NaOCl	1.4		3		0.028	0.80
HNO_3	6			6	0.08	2.28
				Total	**0.273**	**7.77%**
Transport of Waste	Means of waste transport	Cost of transport €/m^3	Waste generated per 15 m^3 (m^3)		Operational cost (3) €/m^3	
	Truck	3.5	0.5		0.117	3.33
				Total	**0.117**	**3.33%**
Capital Cost	Construction Cost	Lifetime	Interest from water reuse		Capital Cost	
	€	Yrs	%		€/m^3	
	289163	25	1		2.39	68
				Total	**2.39**	**68%**
Levelized cost of water based on CAPEX and OPEX			**LCOW**	**€/m^3**	**3.515**	

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DEMOKRITOS

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CIESOL Solar Energy Research Center Joint Center UAL - PSA CIEMAT

Cítricos del Andarax S.A.

Thank you for your attention

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