ODTÜ METU

SolarTwins

ODAK2023 Kick-Off Event

Sunrise for Concentrating Solar Thermal (CST) in Turkey

METU, Ankara, Turkey. 26th of February 2020

# Solar Water Treatment Unit

CIEMAT-Plataforma Solar de Almería

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Ciemat
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PSA

# Solar Treatment of Water Unit

**CIEMAT-Plataforma Solar de Almería**

# Research: water purification and other solar photochemical processes

1. **Solar photocatalytic and photochemical** processes as tertiary treatment of wastewater. Removal of pollutants and water pathogens.

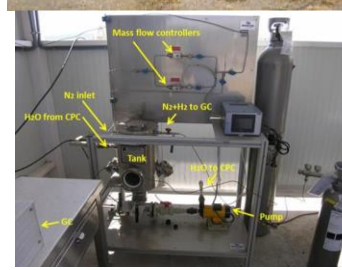
2. **Integration of Solar Advanced Oxidation Processes with Advanced treatment technologies** (NF & UF, Ozone, UV-C, Bio-treatment, etc.) for remediation of industrial wastewaters with **hazardous pollutants and pathogens** with the aim of improving the **water treatment efficiency and reducing operating costs**.

3. Assessment of **photocatalytic efficiency of new materials** under real solar light conditions, and their use in solar **CPC-reactors** (pilot scale).

4. **Solar photocatalytic generation of Hydrogen** using Vis-light active materials: pilot scale solar reactor for testing.

5. Using **solar photocatalytic and photochemical processes for water disinfection**. Several types of contaminated water sources with a number of water pathogens.

6. Development, testing and assessment of **new concepts of solar photo-reactors (pilot, demo)** for either water decontamination or disinfection for different end-purposes, water reclamation & reuse (irrigation and industry), drinking water, etc.




**…leading research in wastewater treatment at pilot & demo scale with solar energy**

# Water-Energy-Food Nexus (WEF)

- **According to FAO, agriculture consumes 70% of fresh water used worldwide**. Approximately **75% of water withdrawal for industrial use are focused on energy production** (UNESCO, 2014 )
- Food production and its worldwide supply demand around 30% of the global energy consumption ( FAO, 2011 ). **90% of global energy generation requires an intensive consumption of water**. ( UNESCO, 2014 )
- In 2050 it is foreseen an increase of **55% on the global water demand,** mainly due to the increasing production demand (400%).
- In 2050 it is foreseen that more than **40% of the worldwide population would live in sever hydric stress zones** ( OCDE, 2012 )
- In 2035, **water withdrawal for energy production would increase in 20% and the water consumption in 85%**, powered by the change into more efficient energy plants with advance refrigeration systems. ( IEA, 2012).
- **Nowadays almost 800 million of people suffer malnutrion**. In 2050 worldwide production of food will require an increase of 50% for the more than 9 million of people that will leave in our planet ( FAO / FIDA / UNICEF / PMA / OMS, 2017).
- Between **3.000 - 5.000 litres of water are required to produced 1 kg of rice**, 2.000 litres for 1 kg of soya, 900 litres for 1 kg of wheat and 500 litres for 1 kg of potatoes. ( WWF ).

# Industrial WW contamination. Water footprint

Industrial processes

Direct discharge to the environment without any treatment

Wastewater Treatment Plant (WWTP)

**PROBLEMS**

- Accumulation of persistent compounds (pesticides, pharmaceuticals….) in the activated sludge.
- Low efficiencies due to toxic and/or biorecalcitrant compounds.

→ Control of processes

→ Alternative treatments

- Adapted/advanced biological treatments
- AOPs
- Combination BIO/AOP or AOP/BIO

# CECs into the Environment


**EMERGING CONTAMINANTS**

- Until recently unknown
- Commonly use
- Emerging risks (EDCs, antibiotics)
- Unregulated

**WWTPs**

**INCOMPLETE REMOVAL**

**CONTINUOUS INTRODUCTION INTO THE ENVIRONMENT**

**NATURAL WATERS**

**(ng-µg/L)**

**Photochemical transformations**

↓

**TRANSFORMATION PRODUCTS**

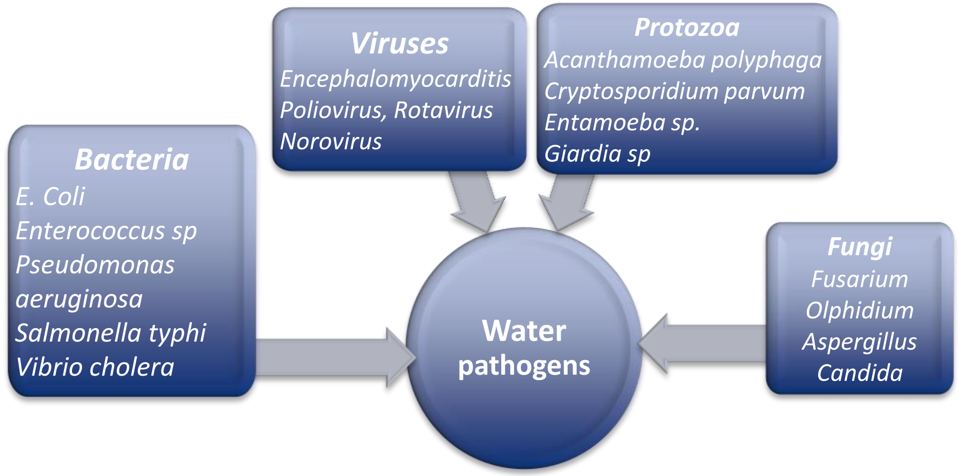
# Water Microbial Contamination

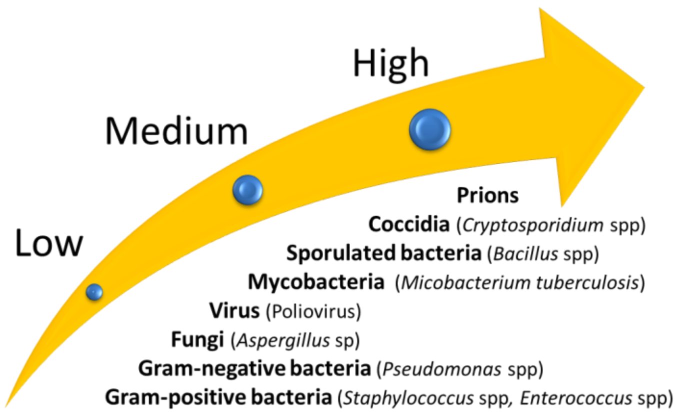
Well

Reservoir

Rivers

Lakes




**ANTIBIOTIC RESISTANT BACTERIA**

Summary of priority pathogen list reported by the WHO (Publication date: 27 February 2017) (http://www.who.int/medicines/publications/global-priority-list-antibiotic-resistant-bacteria/en/)

# Solar Advanced Oxidation Processes

**$TiO_2$/UVA** (Carey et al., 1976)

$$TiO_2 \xrightarrow{h\nu} TiO_2(e^- + h^+)$$

$$h^+ + H_2O \rightarrow {}^{\bullet}\mathbf{OH} + H^+$$

$$e^- + O_2 \rightarrow O_2^{\bullet -}$$

**Fe(III)-Fe(II)/UVA**

Aquacomplexes Fe(III) + hn → $^{\bullet}$***OH***
(Mazellier et al., 1997a,b; Brand et al., 1998, 2000; Mailhot et al., 1999)
Aquacomplexes Fe(II) + hn → $^{\bullet}$***OH*** (Benkelberg and Warneck, 1995)

**Fenton** (J. Chem. Soc., 1894)

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^- + {}^{\bullet}OH$$

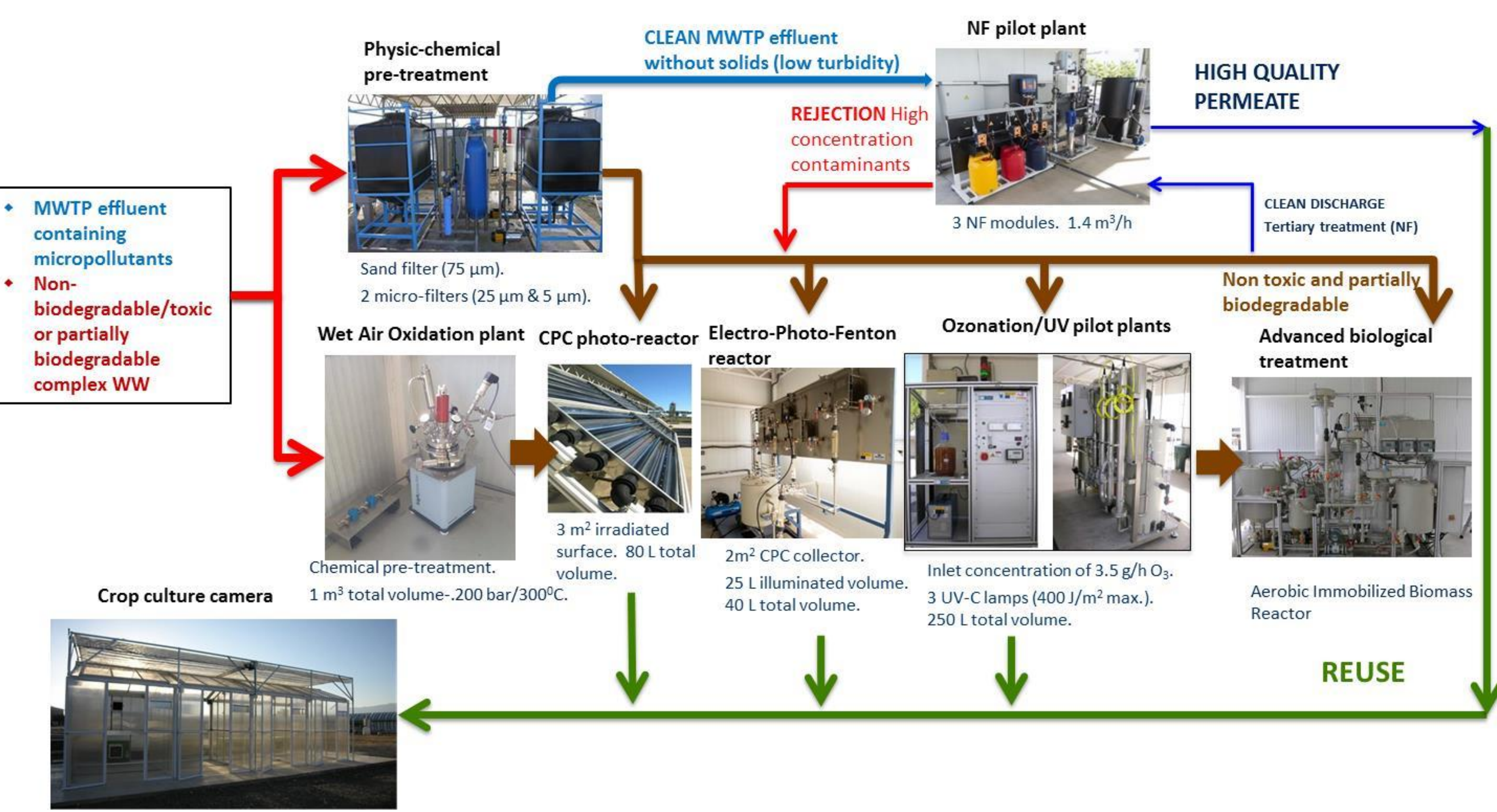
**Photo-Fenton** (several authors, early 90s)

$$Fe^{3+} + H_2O \xrightarrow{h\nu} Fe^{2+} + H^+ + {}^{\bullet}OH$$

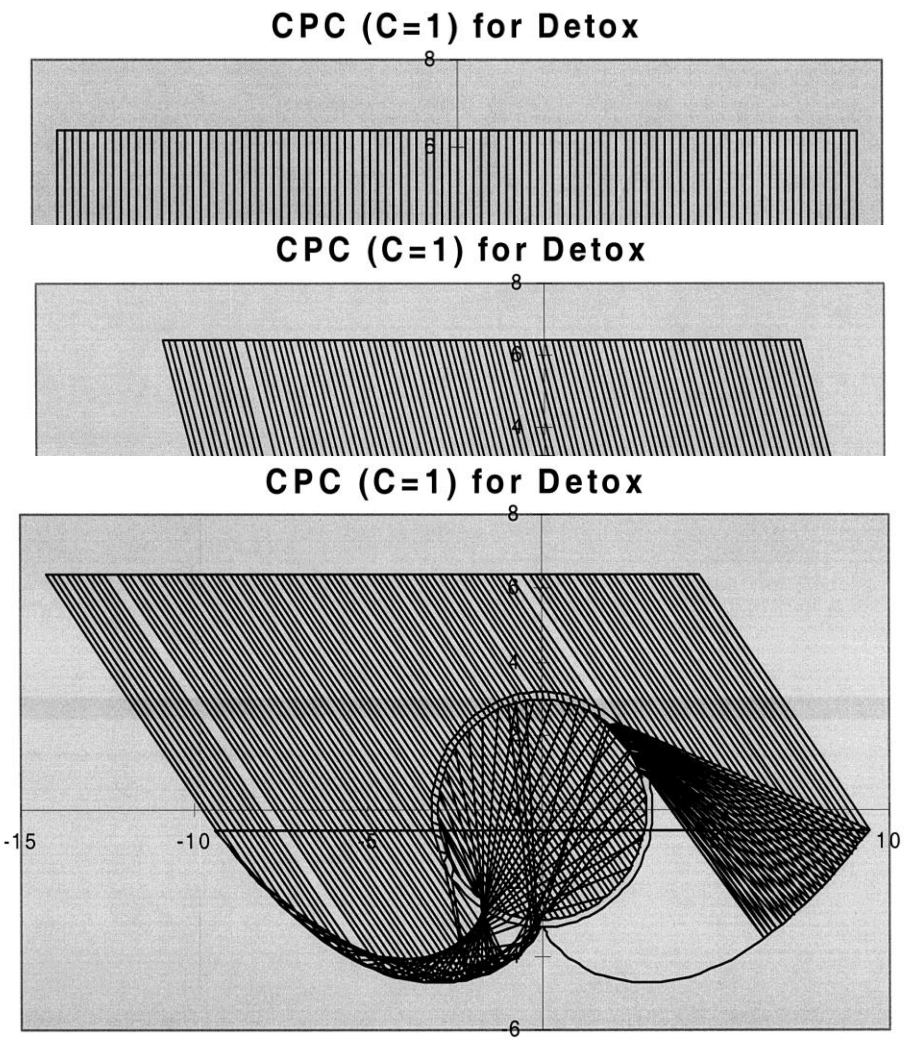
**$H_2O_2$/UVA**

$H_2O_2$ + hv → 2 $^{\bullet}$***OH*** for l<280 nm
(Goldstein et al., 2007)

# Integration of Advanced Technologies for Wastewater Treatment and Reuse



# Technical and engineering aspects of solar photo-reactors




## 1 Sun CPCs

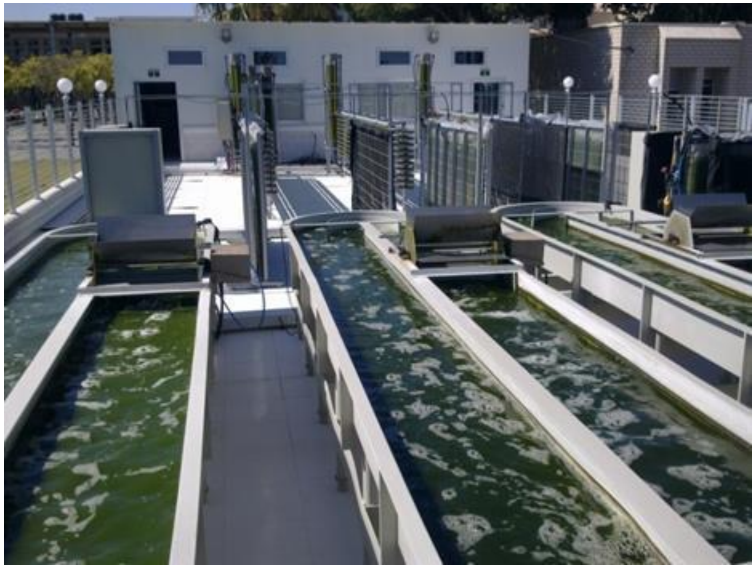
### 1 Sun CPCs

- ✓ ***Turbulent flow conditions***
- ✓ ***No vaporization of volatile compounds***
- ✓ ***No solar tracking***
- ✓ ***No overheating***
- ✓ ***Direct and Diffuse radiation***
- ✓ ***Low cost***
- ✓ ***Weatherproof (no contamination)***

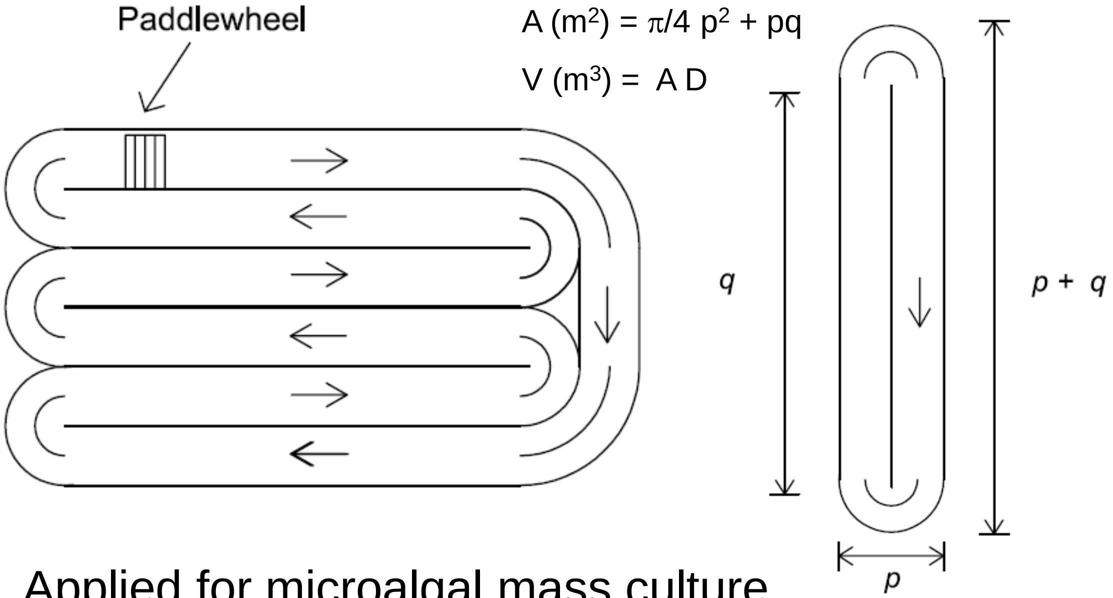
*Appl. Catal. B: Environ.*, **37**, 1-15, 2002. Most cited paper 2002-2006.

# Alternative photoreactor: Raceway Pond Reactors

In Raceway Pond Reactors (RPR) liquid depth can be easily varied



Microalgal cultures in RPR and TPBR. Almería.



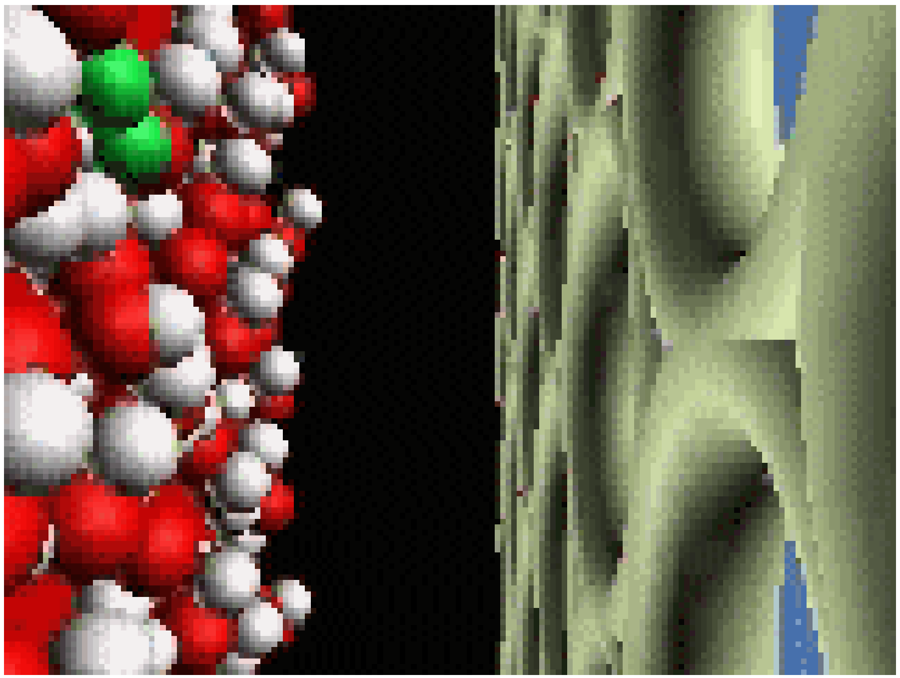

Applied for microalgal mass culture

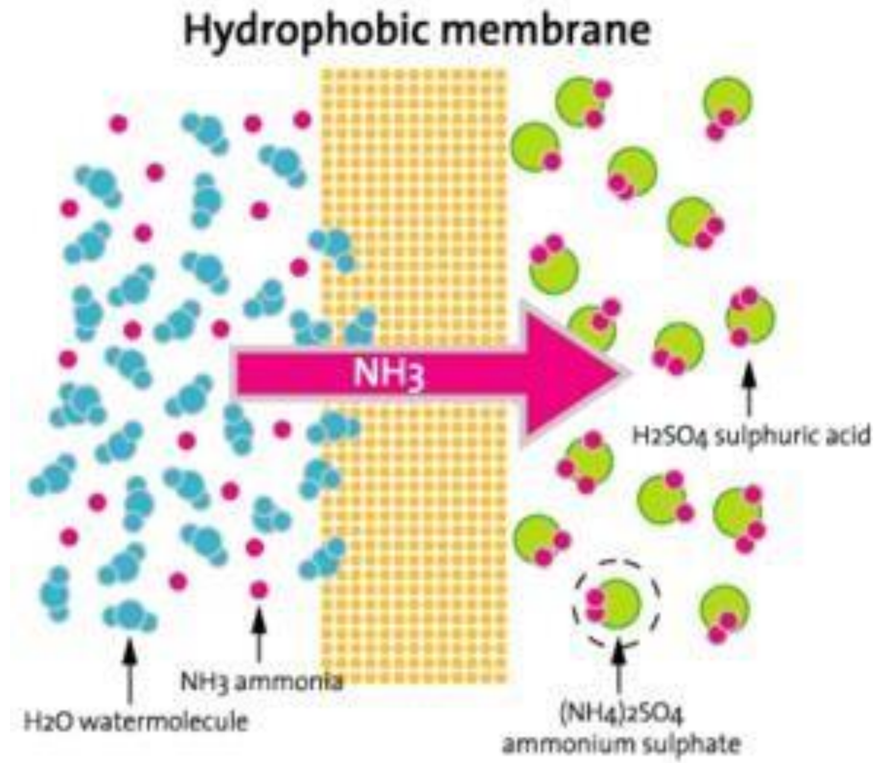
$q \geq 10\ p$

Low cost materials, mainly plastic liners. Construction cost ~ **10 €/m²**

Production costs in RPR are markedly lower than in tubular photobioreactors for microalgal applications

# Membrane Distillation






membrane.

In collaboration with Solar Desalination Unit at PSA

# Combination of technologies: Solar membrane distillation for ammonium recovery

## Application to a secondary outlet of real water of the WWTP of Maia (Porto)

| pH | Q, mL/min | $[NH_4^+]$, mg/L | $[H_2SO_4]$, M | T cell permeate, ºC | T cell retentate, ºC |
|---|---|---|---|---|---|
| 12 | 300 | 200 | 0.01 | 20 | 80 |

| $NH_4^+$ recovery, % | Interval flux, Kg/(m²·h) | V permeate, mL |
|---|---|---|
| 54.5 | 25.8 | 600 |

# Guidelines and recommendations for WW reclamation and reuse for crops irrigation

## Regulations

Italy, Cyprus, Portugal, Greece, France, Israel, Australia, California…

**SPAIN**

MINISTERIO DE LA PRESIDENCIA

21092 *REAL DECRETO 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas.*

**EU** **Harmonisation of requirements for water reuse**

EUROPEAN COMMISSION

Brussels, 28.5.2018
COM(2018) 337 final

2018/0169 (COD)

Proposal for a

REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on minimum requirements for water reuse

- Classes of reclaimed water quality (crop category and irrigation method)
- *E. coli*; BOD5, TSS, Turbidity, Others (*Legionella spp*, Intestinal nematodes)
- Minimum requirements for monitoring
- Eventually: heavy metals, pesticides, DBPs, pharmaceuticals, CECs, anti-microbial resistance

# Fresh-cut Industry: WW reuse for crops irrigation

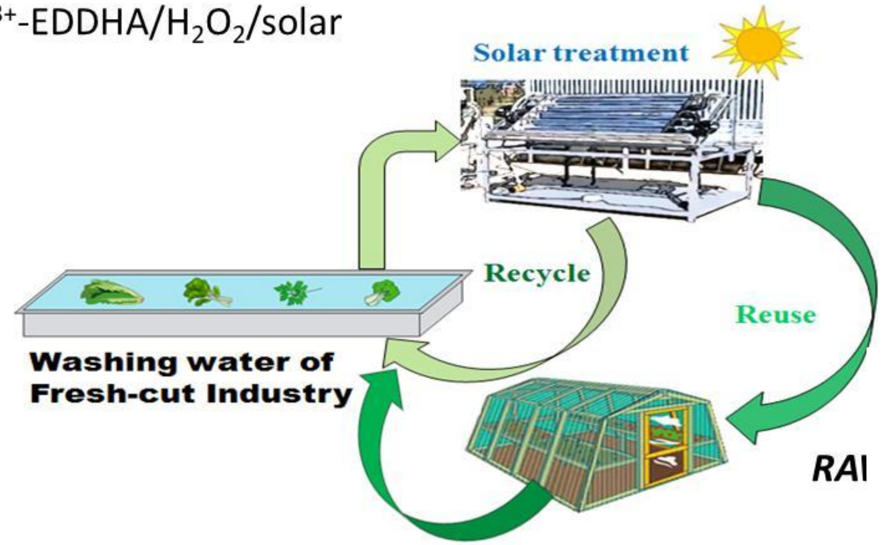
***TREATMENTS:***

- $H_2O_2$/solar
- $Fe^{3+}$-EDDHA/solar
- $Fe^{3+}$-EDDHA/$H_2O_2$/solar

***TARGETS:***

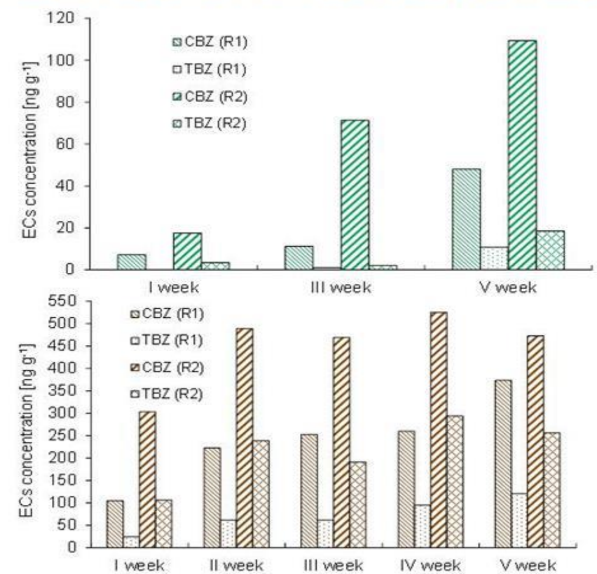
- *E. coli* O157:H7 and *Salmonella enteritidis*
- *8 OMCs*

| Compound | λ | $t_r$ (min) |
|---|---|---|
| Thiamethoxam | 250 | 3.0 |
| Imidacloprid | 273 | 3.4 |
| Simazine | 230 | 4.2 |
| Atrazine | 230 | 4.7 |
| Azoxystrobin | 214 | 5.4 |
| Terbutryn | 230 | 5.6 |
| Procymidone | 214 | 5.8 |
| Buprofezin | 250 | 6.9 |




WWTP effluent irrigation

CECs uptake by lettuce leaves (top) and soil (bottom) for different treatment time samples, for 5 weeks



# Key Messages

- Water scarcity and bad water quality are problems affecting all over the world, which makes it crucial to **find alternative water sources**, such as municipal wastewater. Municipal wastewater treatment, jointly with desalination, mean a key strategy for trying to maintain high human life quality.

- A deep evaluation on the specific problem to be solved must be done just to focus on the optimum treatment option.

- Normally, different **(solar) AOPs** based technologies show highly efficiency as tertiary treatment for **CECs, ARB & ARG elimination**, but economic and life cycle assessments must support the final selection.

- Advance analysis of treated wastewater as well as contaminant transfer to crops must be carried out for ensuring a **"safe reuse".**

# Solar Water Treatment Unit

1 Professor (**Sixto Malato-Head of the Unit**);

5 PhD (3 senior, 2 PostDoc), 3 technicians, PhD students 5 ± 2 and 15-20 visitors/year

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