



Solar photocatalytic water disinfection. Case study: *Fusarium*.

Polo-López M.I., Fernández-Ibáñez P., García-Fernández I.
Plataforma solar de Almeria (CIEMAT), Almería, Spain





Introduction

Solar photocatalysis description

Solar reactors

Experimental methodology

TiO₂

- Inactivation mechanism
- *F. solani* (microconidia) results
- *F. equiseti* (macroconidia, chlamydo spores) results

H₂O₂

- Inactivation mechanism
- *F. equiseti* (chlamydo spores) results

Conclusions



Test facilities at PSA

development of applications technologies.



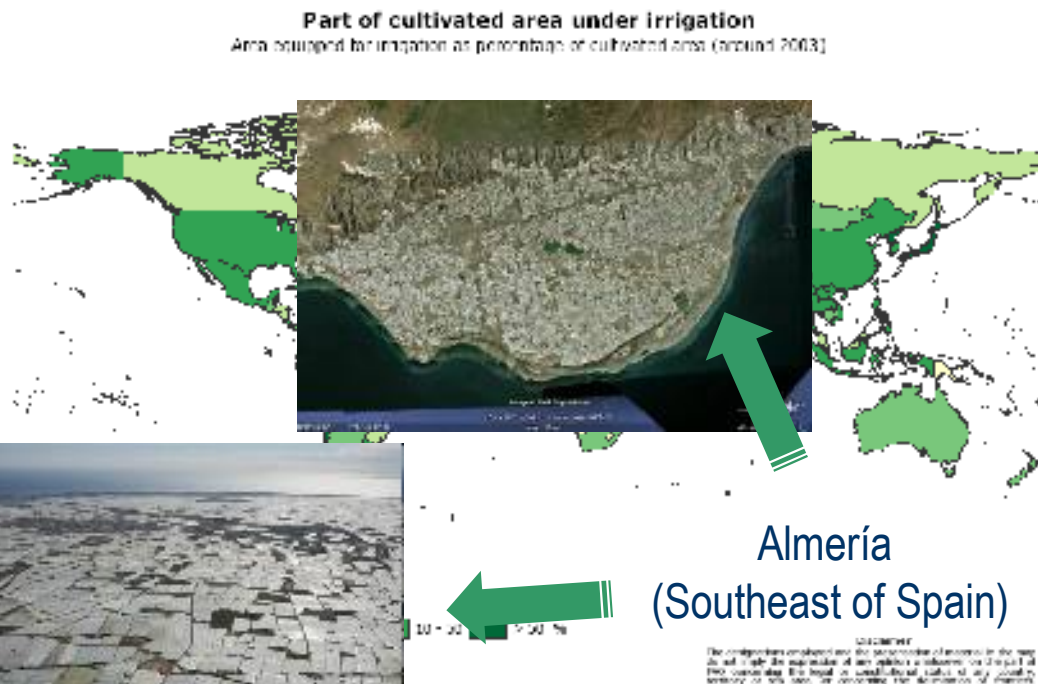
Importance of water in human feeding

WHO recognised the **disinfection** as one of the most **important barriers** for protection of **public health**.

According to **FAO**, agriculture consumes **70%** of fresh water used worldwide



The **daily drinking-water** requirement per person is only **2 - 4 liters**, it is often forgotten that it still takes **2000 to 5000 liters** of water to produce a **person's daily food** requirement (FAO, 2008).



Phytopathogens in water: a problem

PROBLEM: *Accumulation of phytopathogens in water*

Water sources for agriculture:

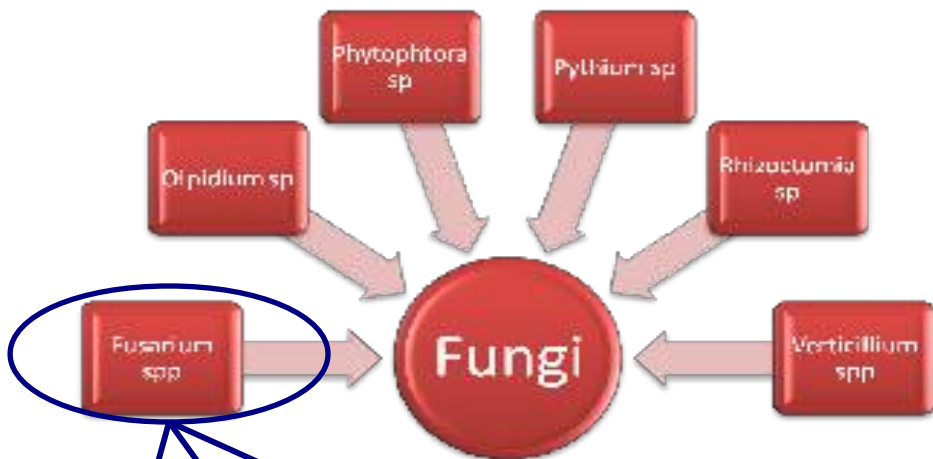
Well water



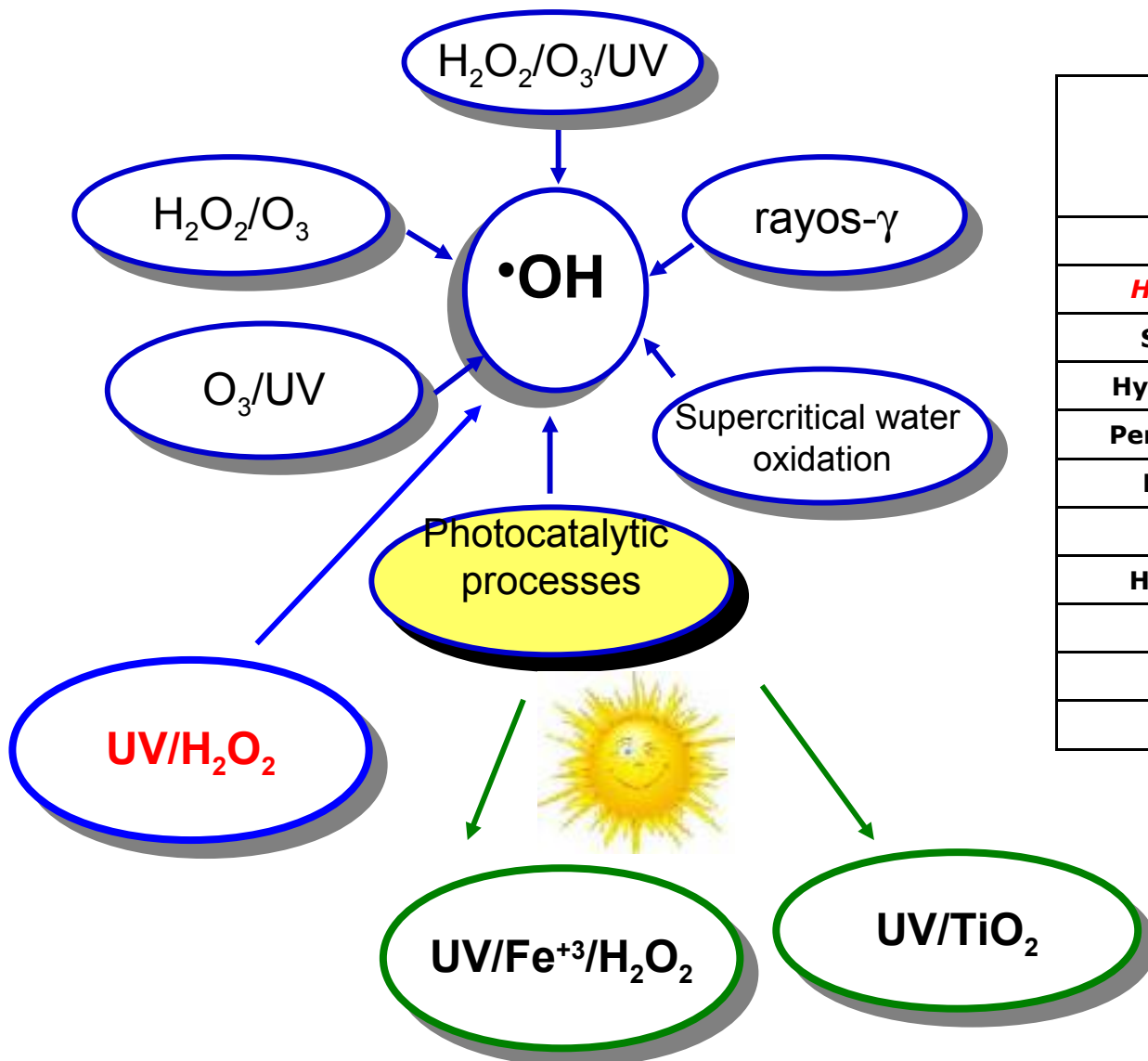
Reservoirs



Wastewater treatment plant



Advanced Oxidation Processes



| Specie | Oxidation potential ref. HgCl_2 (V) |
|-------------------------|-------------------------------------------------|
| Fluorine | 2.23 |
| Hydroxyl radical | 2.06 |
| Singlet oxygen | 1.78 |
| Hydrogen peroxide | 1.31 |
| Perhydroxyl radical | 1.25 |
| Permanganate | 1.24 |
| Chlordioxide | 1.15 |
| Hypochloric acid | 1.10 |
| Chlorine | 1.00 |
| Bromine | 0.80 |
| Iodine | 0.54 |

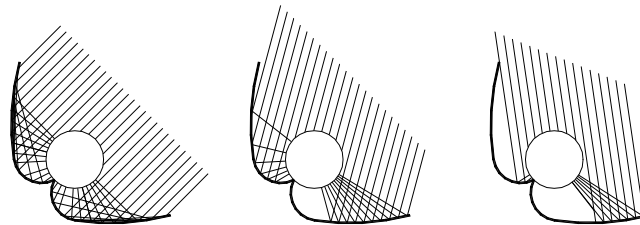
Solar CPC reactor



Non-concentrate technology



Concentrate technology



Compound Parabolic Collector technology

- Static
- Low cost
- No concentration



Glass tube + CPC mirror

(aluminium anodized quality MIRO SUN)

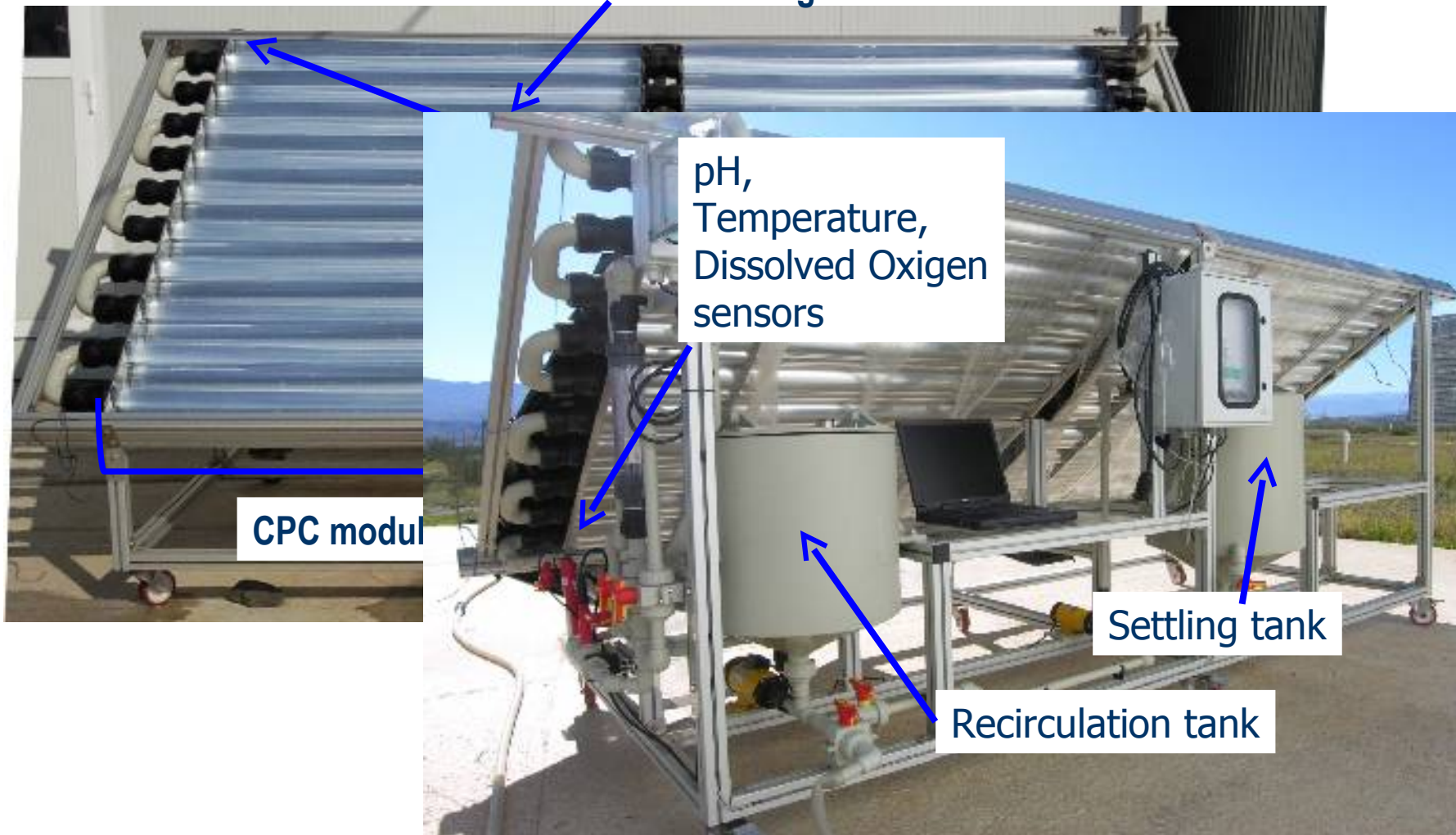
➤ Solar UV direct concentration

+ Solar UV diffuse concentration

Solar CPC reactor

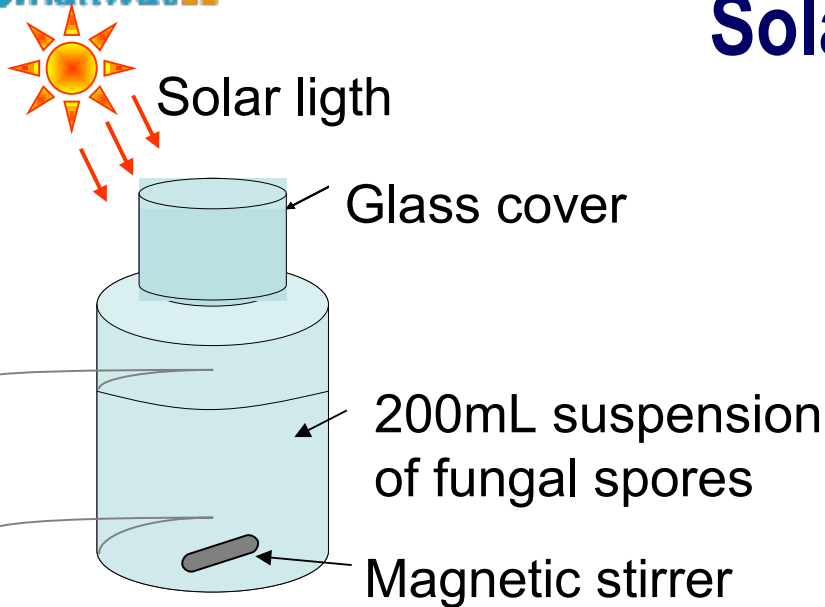


20 Borosilicate glass tubes



Polo-López M.I. et al. *J Chemical Technology and Biotechnology*. **85**, 1038-1048, (2010).

Solar reactor



| Physical characteristics of solar photo-reactor systems used in the experiments | | |
|---------------------------------------------------------------------------------|----------------------------------------|------------------------|
| | 60 L CPC reactor | Solar bottle reactor |
| Total number of tubes/bottle | 20 | 1 |
| Total length of tube | 1.5 m | 0.15 m |
| Irradiate length of tube | 1.4 m | 0.12 m |
| External diameter of the tube | 0.05 m | 0.05 m |
| Tube thickness | 0.0025 m | 0.002 m |
| UVA-transmission of borosilicate | 90% (cut-off at 280 nm) | |
| Total treatment volume | 60 L | 0.2 L |
| Total irradiate volume | 45 L | 0.2 L |
| Illuminated surface | 4.5 m ² | 0.0095 m ² |
| Flow rate | 30 L min | 100 r.p.m. |
| Flow velocity | 0.31 m s ⁻¹ | 0.24 m s ⁻¹ |
| Agitation | Centrifugal pump | Magnetic stirrer |
| Irradiation (clear days) | Natural solar light collected by CPC 1 | Natural solar light |

Drawing of 250 mL glass bottle reactor.

Methodology

Catalyst preparation.



8. F. solani colonies counting



Radiometer

2. Inoculation of culture & catalyst.

3. Dark recirculation.

*7. Spread in malta agar.
Incubated: 2 days, 28 °C*

6. Experiment starting.

Solar collector covering.



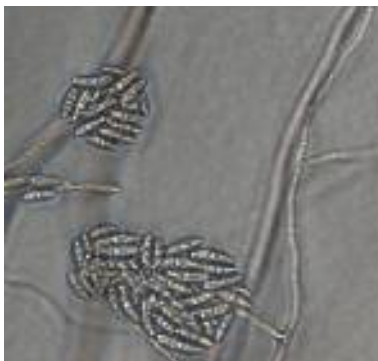
remove the cover.



Fusarium sp



Microconidia



Macroconidia



Chlamydospore



Colonies obtained in acidified malt agar corresponding to a photocatalysis experiment:

Time: 0 min.



60 min.



120 min.



180 min.



240 min.



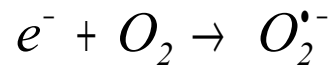
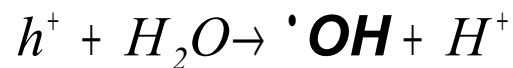
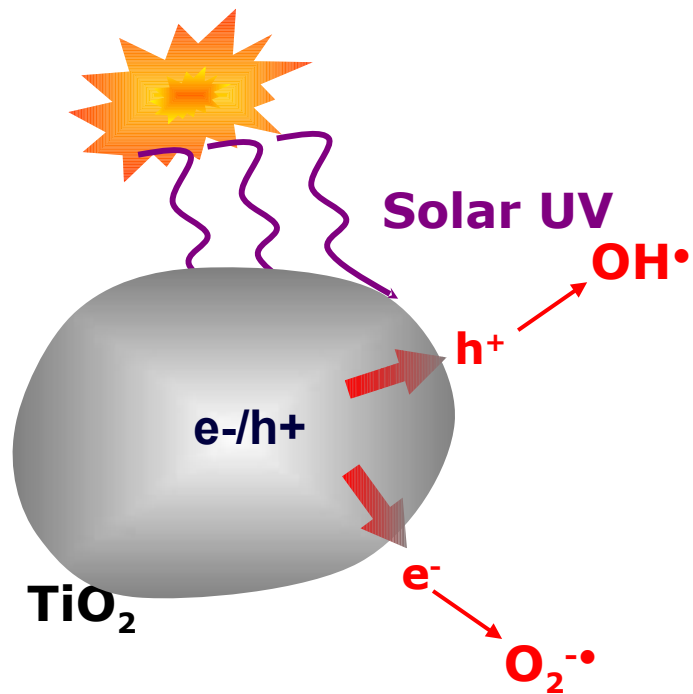
300 min.



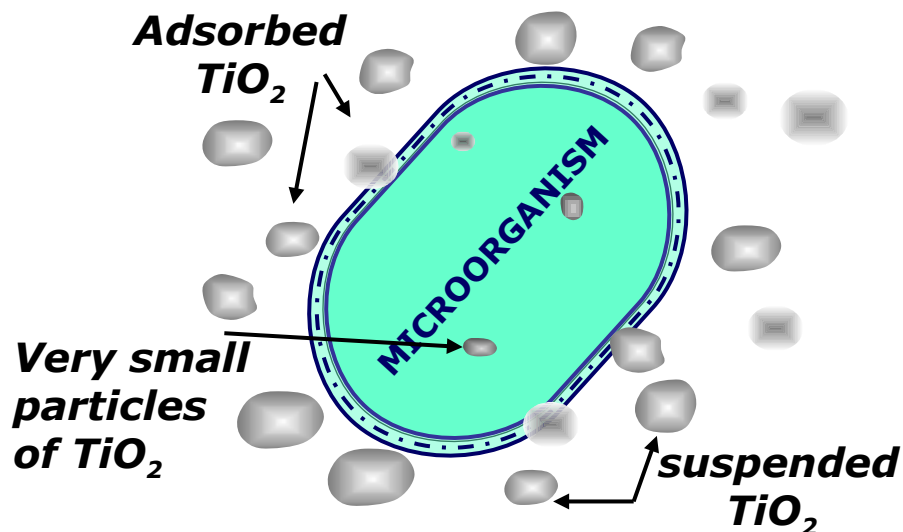
Titanium Dioxide (TiO₂/UV-Vis)

Solar Photocatalytic Processes

Titanium Dioxide (TiO₂)



(Carey et al., 1976)



Blanco, Fernandez-Ibáñez, Malato J. *Solar Energy Engineering* 129 (2007) 4-15.

TiO₂ Results: *F. solani* (microconidia)



Solar photocatalysis

TiO₂ concentrations: 0, 50, 100, 250 mg/L

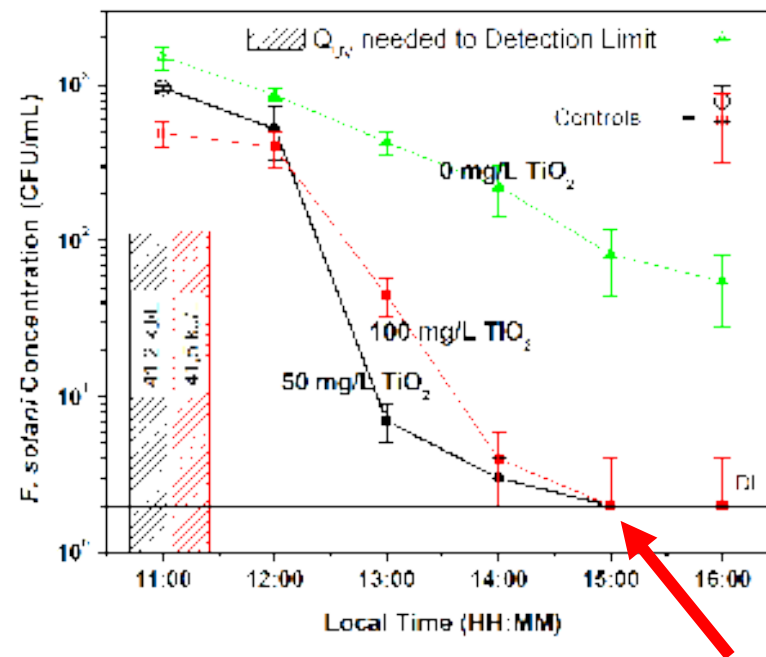
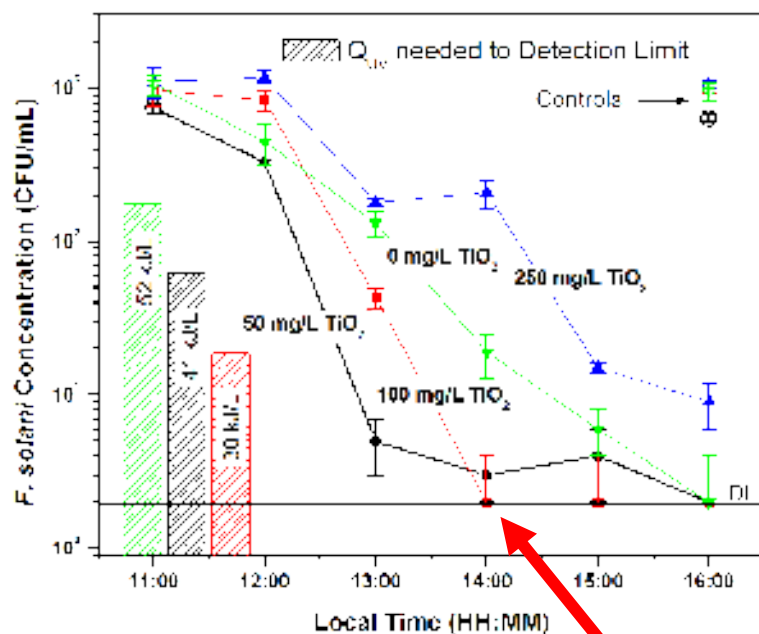
- 30 L/min
- V = 60 L

F. solani microconidia



DISTILLED WATER

WELL WATER



Polo-López M.I. et al. *J Chemical Technology and Biotechnology*. **85**, 1038-1048, (2010).

TiO₂ Results: *F. equiseti*



(macroconidia and chlamydospores)

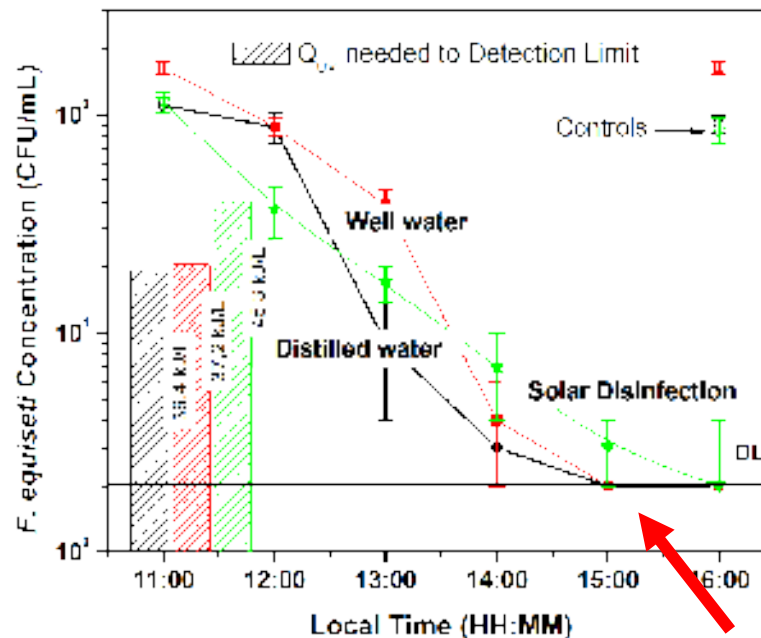
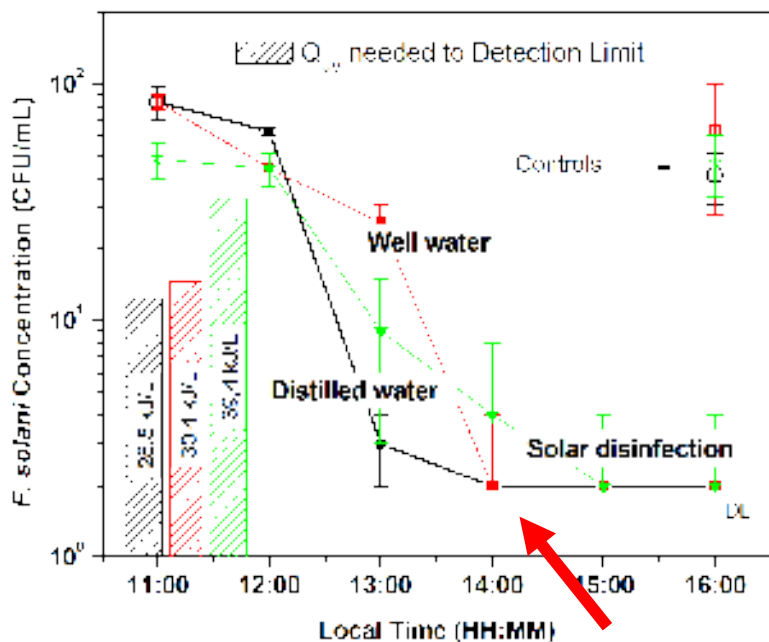


- Distilled and well water
- 30 L/min
- 100 mg/L of TiO₂



MACROCONIDIA

CHLAMYDOSPORE

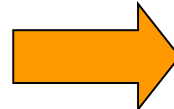
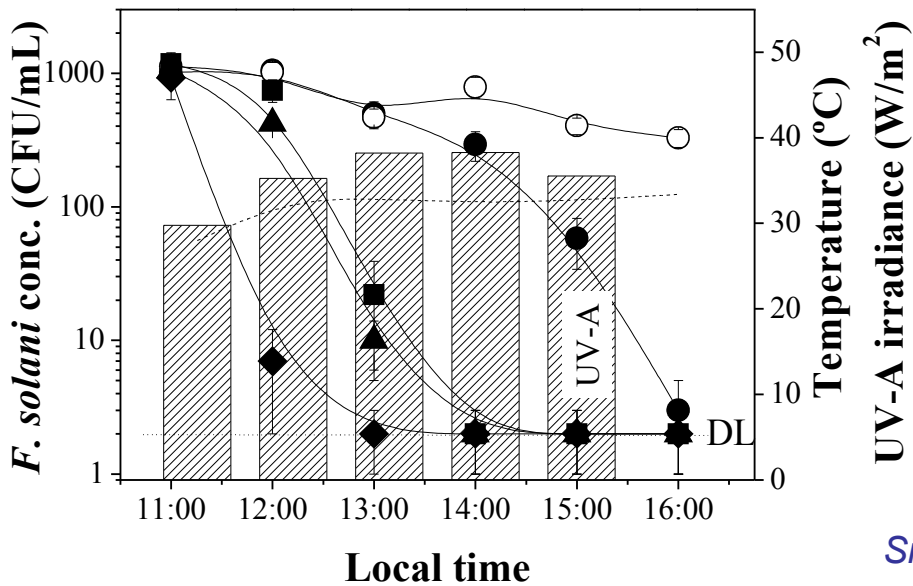
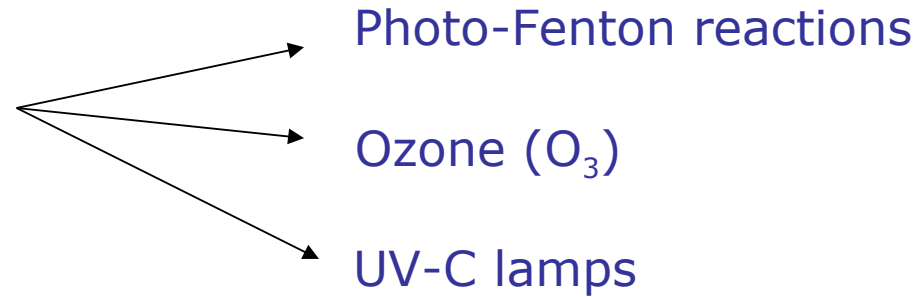
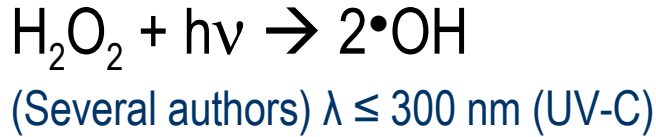


Polo-López M.I. et al. *J Chemical Technology and Biotechnology*. **85**, 1038-1048, (2010).

Hydrogen peroxide (H₂O₂/UV-Vis)

Solar Photoinduced Processes

Hydrogen peroxide (H₂O₂)



Fusarium solani

Solar bottle reactor of 200 mL with H₂O₂

- 0 mg/L (-○-)
- 5 mg/L (-●-)
- 50 mg/L (-■-)
- 100 mg/L (-▲-)
- 500 mg/L (-◆-)



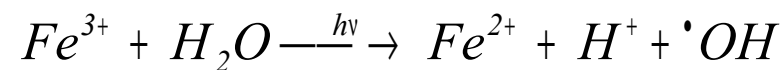
Sichel et al., *Water Research*, **43**,1841-1850 (2009)

Solar Photoinduced Processes

Hydrogen peroxide (H₂O₂)



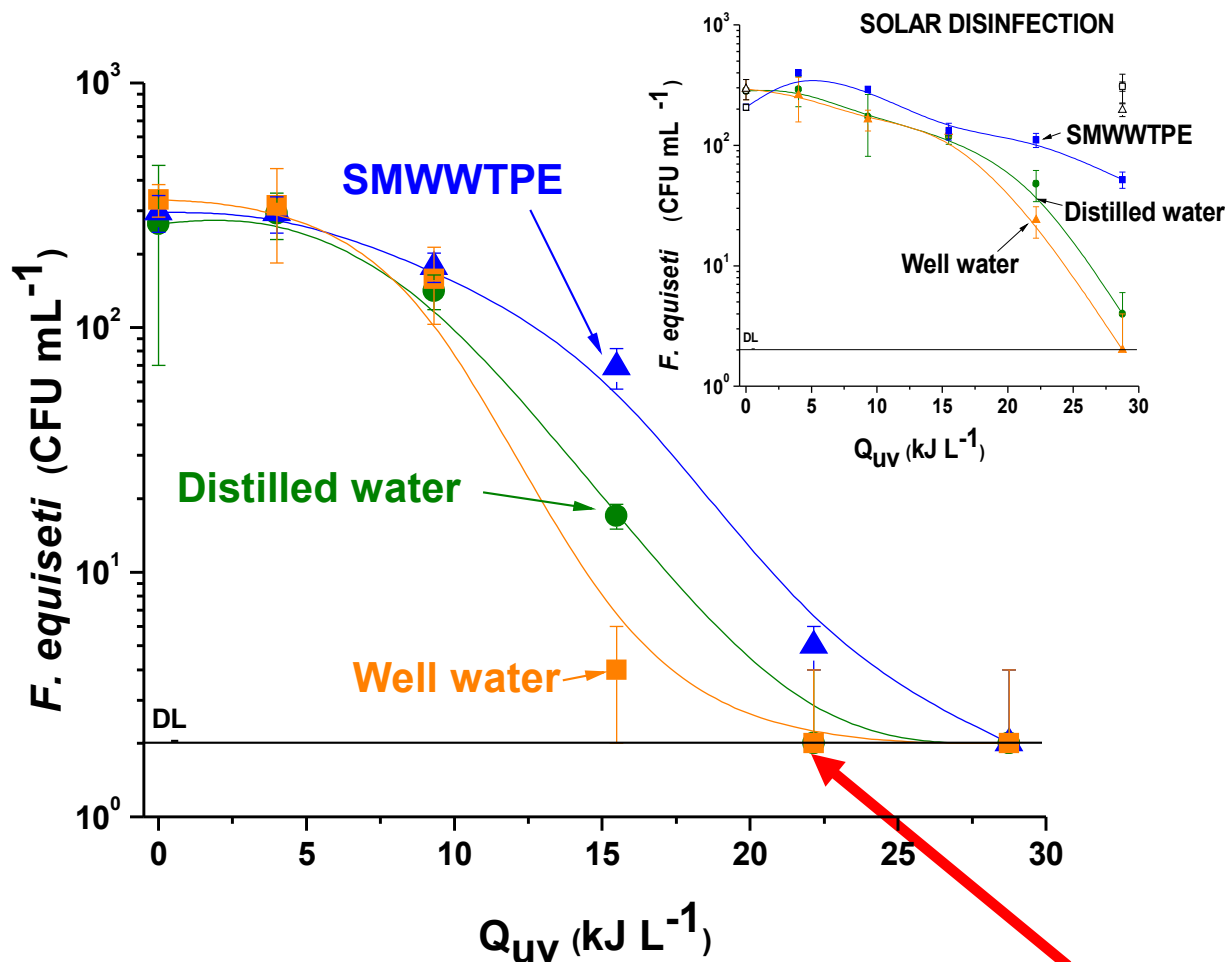
Inactivation mechanism: **Internal Fenton**



spore



H₂O₂/UV-Vis Results: *F. equiseti* (chlamydospores)

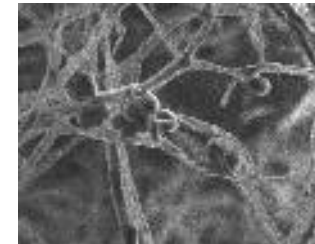
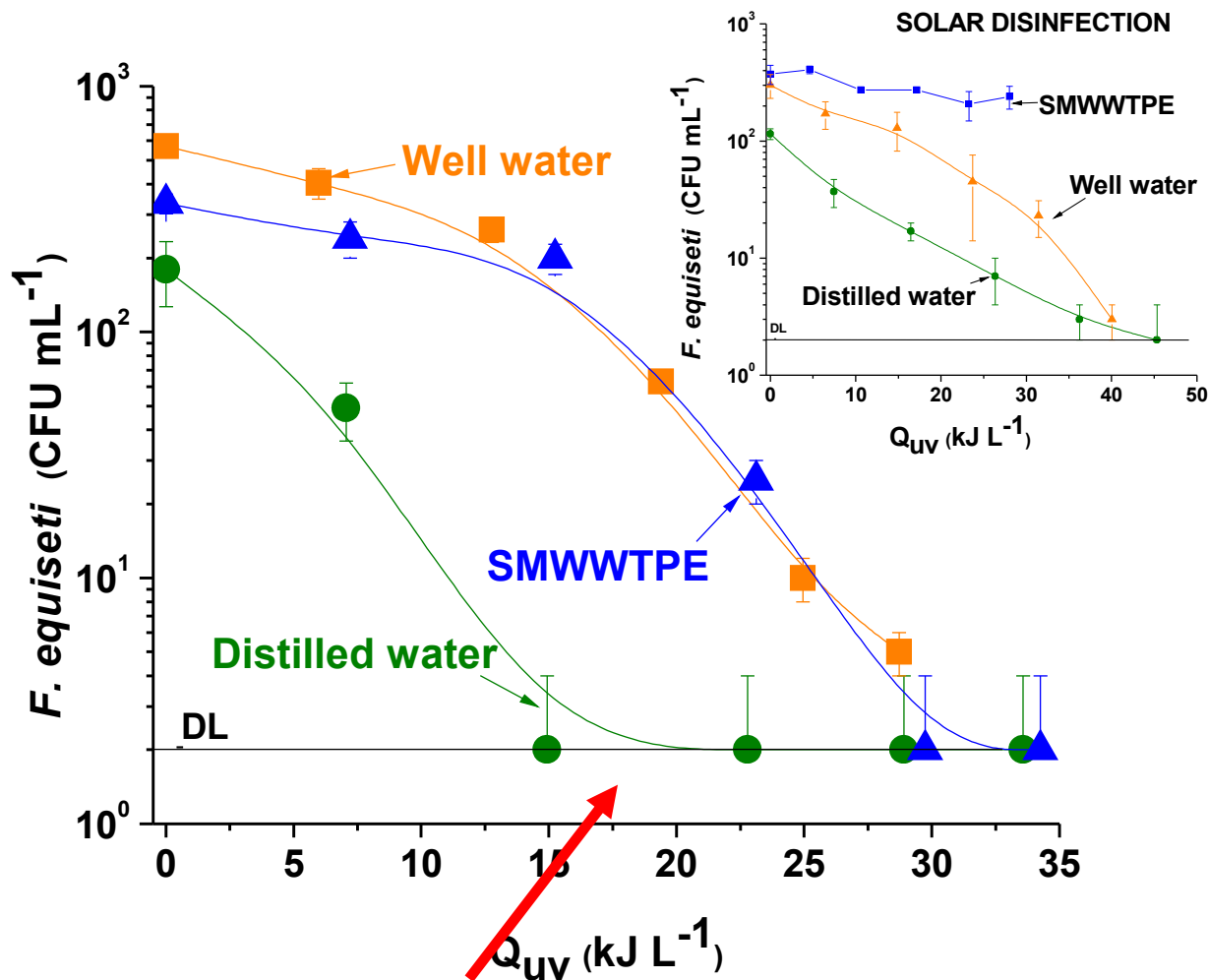


- 100 rpm
- Solar bottle reactor
- 10 mg/L of H₂O₂



Polo-López M.I. et al. Photochem. Photobiol. Sci. 10, 381-388, (2011).

H₂O₂/UV-Vis Results: *F. equiseti* (chlamydo spores)



- 30 L/min
- 10 mg/L of H₂O₂



Polo-López M.I. et al. Photochem. Photobiol. Sci. 10, 381-388, (2011).

Conclusions

- *Fusarium* spores in distilled and well water can be inactivated with TiO_2 slurry and with $\text{H}_2\text{O}_2/\text{UV-vis}$ in distilled, simulated wastewater effluent and well water at laboratory scale.
- It is possible to scale up the photocatalytic treatment to a CPC 60-L photo-reactor for further use and reuse of water for irrigate crops in agriculture.
- The reactor was also evaluated to find out the best operating parameters, which were found to be a flow rate of 30 L/min and TiO_2 concentration of 100 mg/L.
- For first time has been demonstrate that the use of low concentrations of hydrogen peroxide (10 mg/L) could be a good alternative to inactivate *Fusarium* spores in a wide range of applications: drinking water, water re-use, etc.

Acknowledgements

*FITOSOL project, AGL2006-12791-C02.
Spanish Ministry of Education and Science*



Thanks for your attention

inmaculada.polo@psa.es