European Twinning for research in Solar energy to (2) water (H2O) production and treatment technologies
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SoI2H2O

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Fast Track School #2

Beyond State of the Art in Solar-driven Water production & Treatment technologies and brine treatment processes

ITC Instituto Tecnológico de Canarias, Pozo Izquierdo, 25..09.2024

Sol2H2O

UNIVERSIDADE DE ÉVORA

Solar-driven wastewater treatment - Pilot plant installed within the Sol2H2O project

ITC Instituto Tecnológico de Canarias, Pozo Izquierdo, 25.09.2023

Outline

Reactor Design and Construction

Assessment of solar-driven wastewater treatment processes

Assessment of the SoI2H2O photoreactor

WP2 Solar driven wastewater treatment

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The two main research lines **(JRA)** that will be tackled in coordination with the widening partner are:

- ➔ Improvement and optimization of photoreactors, like the absorber tube diameter of the CPC or the agitation mechanism in raceway pond reactors (RPR), to better fit the AOP to be applied, the raw characteristics of the wastewater to be treated and the water quality required depending on final reuse purposes;
- ➔ combination with PV systems for renewable energy supply to the electrical parts of the solar photoreactors.

Solar Concentrators Testing Platform

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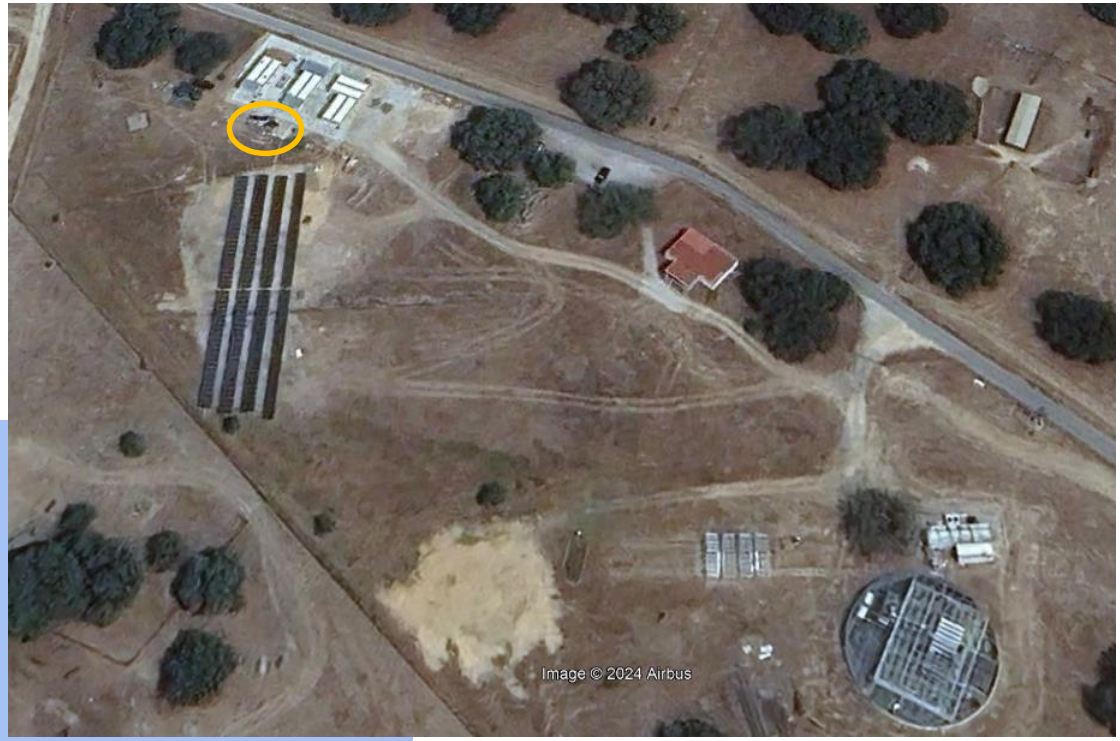






- Tubular photoreactor with high pathlength
- Inclination: 40◦ / South-facing (east-west mounting)
- **150 L total volume**; **62.32 L** illuminated volume (ratio: 0,42)
- Operating in batch mode with water recirculation (flow rate: 25 – 130L/min)

One-Sun Compound Parabolic Collectors (CPC)

simplified design for low cost production (“big tunnel”), Osório et al. (2019)

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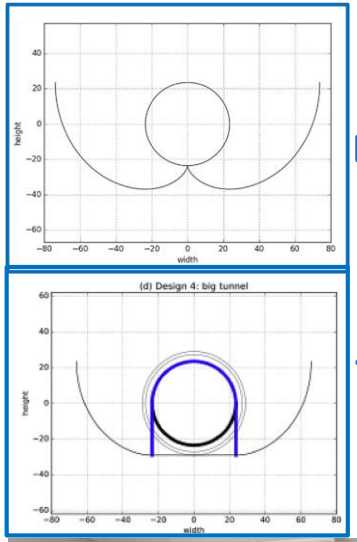
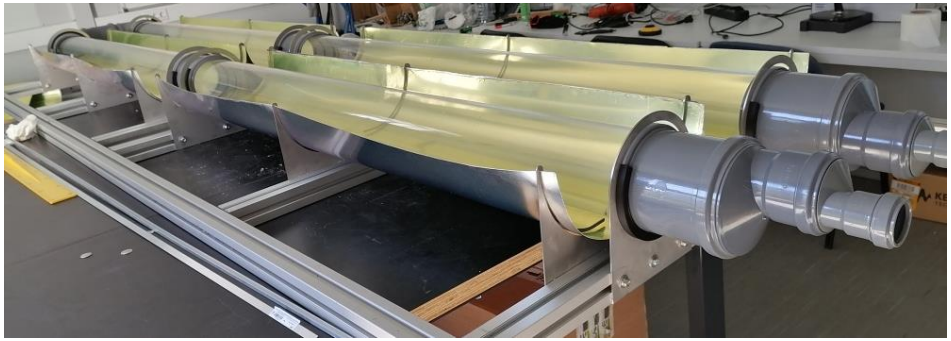


Solar collector was obtained by molding the CPC-type profile over the receiver length



Electro-brightened pre-coated mirror finished aluminium (SWR686)

- ≥84% Total solar reflectance
- ≥87% Total solar reflectance

“visible range”

- <3% Diffuse reflectance
- ≥80% Specular reflectance

Dimensions:

- Aa = 305.64 mm^2
- Perimeter = 453.23 mm
- Aperture area = 1.83 m^2

Tubular horizontal receivers connected in series

4 tubes

- borosilicate glass 3.3 DURAN®
- 125 mm outer diameter
- 5 mm wall thickness
- 1.5 m length
- with tubes and valves made of HDPE

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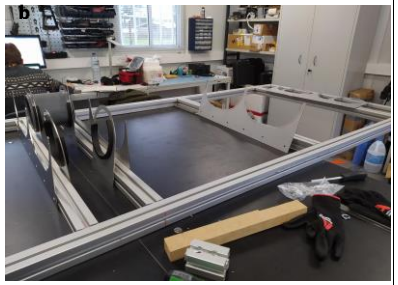

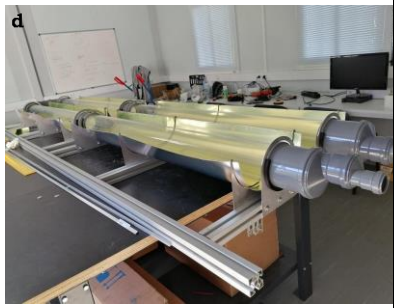

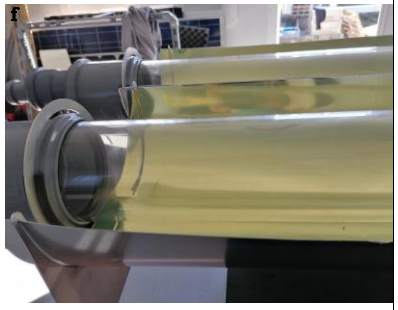

Assessment of solar-driven wastewater treatment processes

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- **wastewater characterization**
  - chemical contaminants, mineral and organic matter concentrations
  - physico-chemical parameters as pH, EC, turbidity
  - microbial characterization

- **reactor design and operation**
  - type and configuration of the collector
  - reflector design and material
  - optical efficiency
  - geometrical concentration factor
  - receiver geometry, dimensions and material
  - the operating mode
  - tilt
  - flow rate
  - oxidant loading method, reactor capacity
  - the ratio between the illuminated volume/total volume

Assessment of solar-driven wastewater treatment processes

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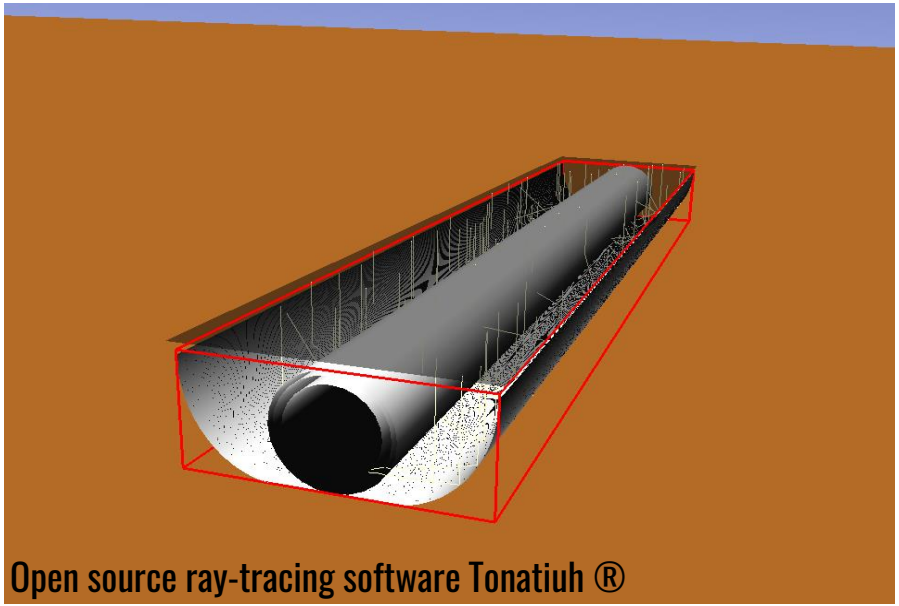
- **characterization of the Advanced Oxidation Process (AOP)**
  - type of Advanced Oxidation Process
  - oxidant agent and concentration
  - catalyst type and concentration
- **overall assessment of the photoreactor efficiency**
  - degradation time,
  - TOC and chemical contaminants removal,
  - toxicity of degradation products,
  - microbial inactivation
  - energy consumption per volume of treated water
- **economic assessment**
  - reactor cost CAPEX
  - treatment cost OPEX
  - specific treatment cost along system lifetime

Assessment of the Sol2H2O photoreactor

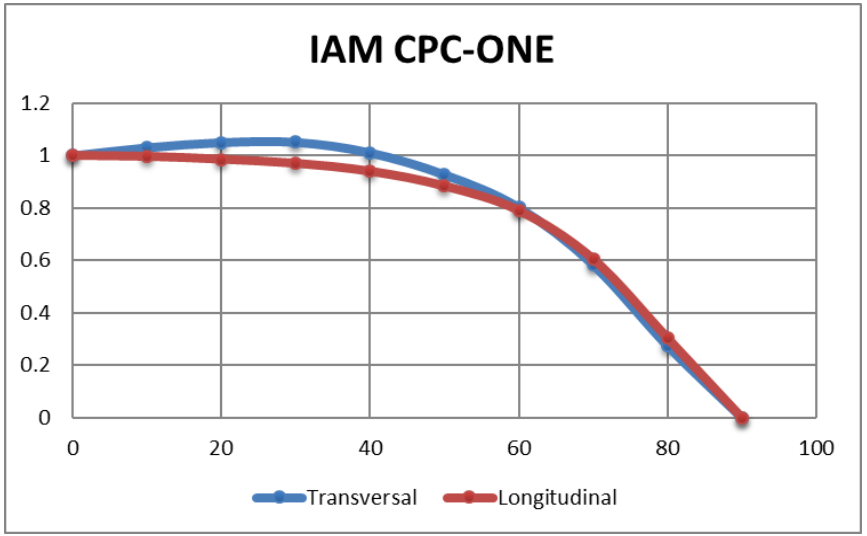
- **Optical efficiency**



Enables the calculation of the expected optical performance of the collector, through the ratio between the total amount of power absorbed by the receiver and the total amount of power hitting the entrance of the collector

Incidence Angle Modifier Curves (IAM)

variation of the optical efficiency of the collector as a function of the incidence angle of the sunlight, both on the longitudinal and transversal plane of the collector



The ideal optical efficiency is **0.9** (Osório et al. 2019)
Real optical efficiency of the collector **0.6**

Assessment of the Sol2H2O photoreactor

- **Solar irradiance measurements**
- **Flow rate**

Microflow sensor for magnetic flow meters MS600 ISOMAG, with a Flow rate of 0 to 12.500 l/h with a converter MV110 ISOMAG

Data on **Direct Normal Irradiance (DNI)**, **Global horizontal irradiation (Ghi)** and **Diffuse horizontal irradiation (Dhi)** are acquired at a nearby (~100 m) meteo station (CMP11, CHP1, Kipp & Zonen)

SUV-A Kipp & Zonen UV **Radiometer** (315-400 nm) and a CMP11 Kipp & Zonen **pyranometer** (285 to 2800 nm) to gather data on the Global iradiation on the plane (Gplane_i)

Assessment of the Sol2H2O photoreactor

- **Electrical consumption**

- Average 0,6 KWh per hour

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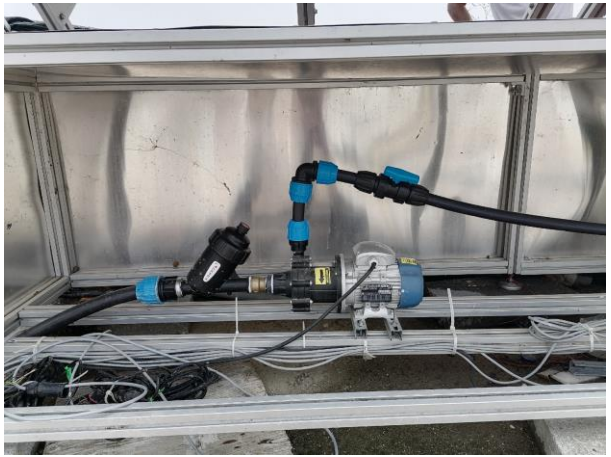

Magnetic drive pump ADM 10, delivery rates up to 13 m^3/h, with a motor of 0.75HP and 2800 RPM

Microflow sensor for magnetic flow meters MS600 ISOMAG, with a Flow rate of 0 to 12.500 l/h

Assessment of the Sol2H2O photoreactor

- **Phenol**

Heterogeneous photocatalysis with TiO_2

Phenol (10 mg L^{-1}); 120 L/min

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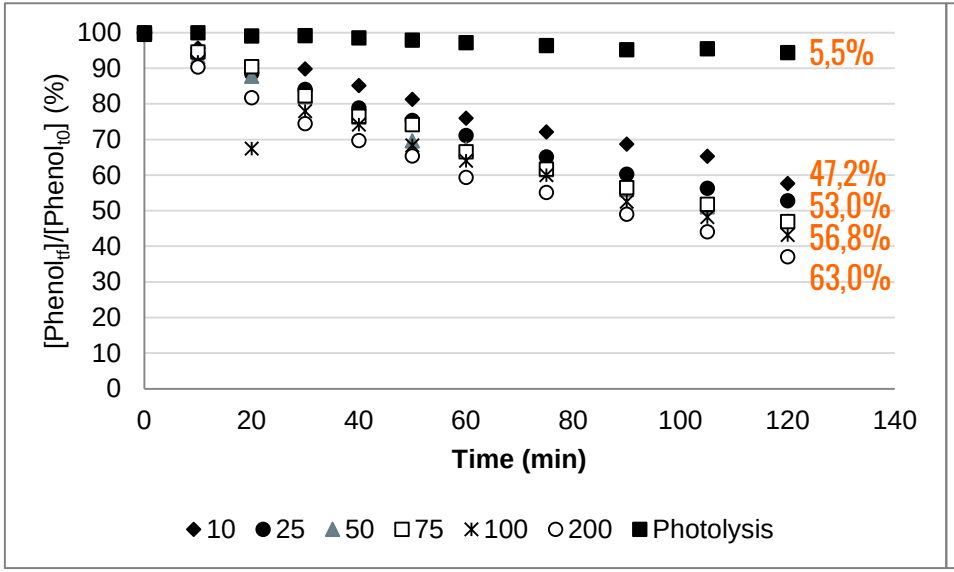
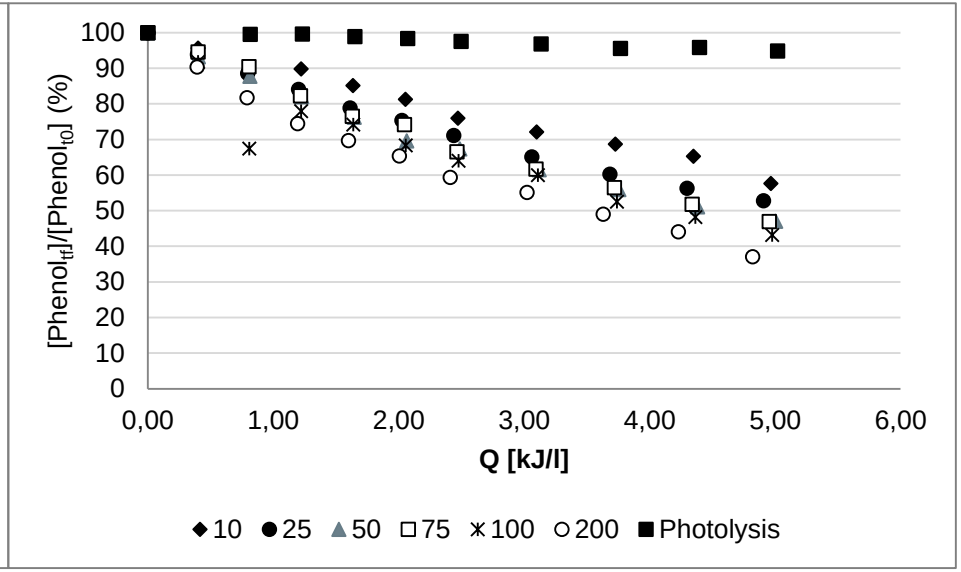




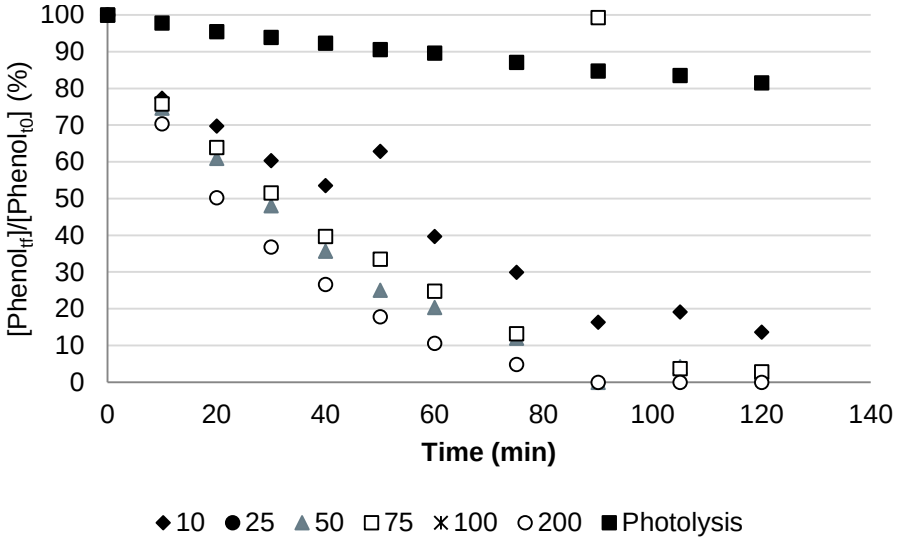
Mineralization rate

Photolysis	10 mg/l TiO_2	25 mg/l TiO_2	50 mg/l TiO_2	75 mg/l TiO_2	100 mg/l TiO_2	200 mg/l TiO_2
3%	18%	10%	24%	28%	31%	35%

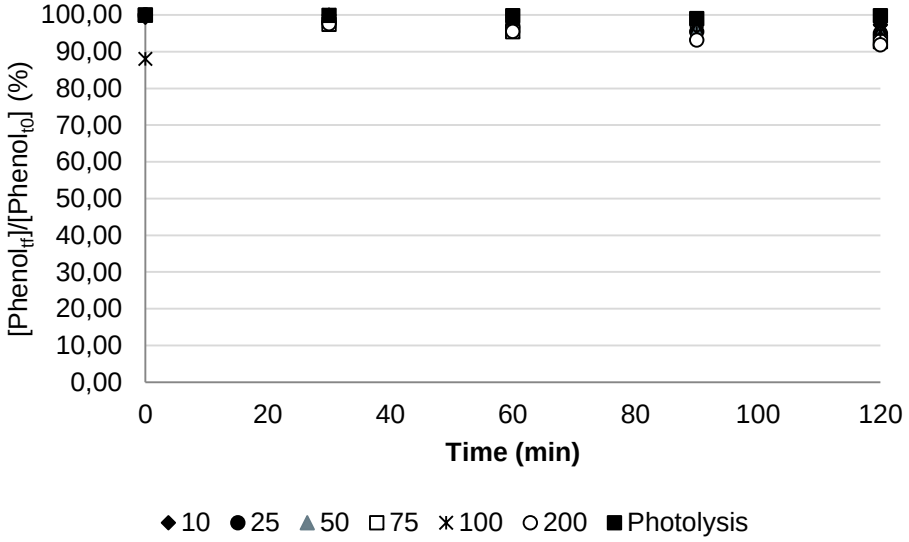
Heterogeneous photocatalysis with TiO_2

Phenol (10 mg L^{-1})

Illuminated Control



Control in the dark



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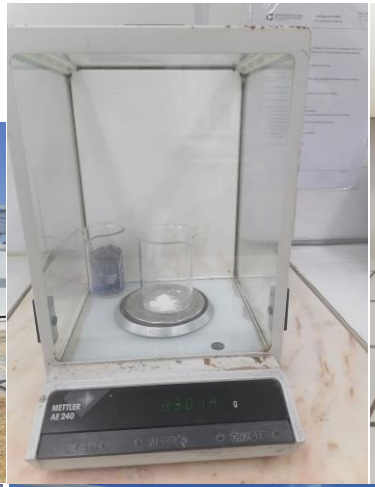
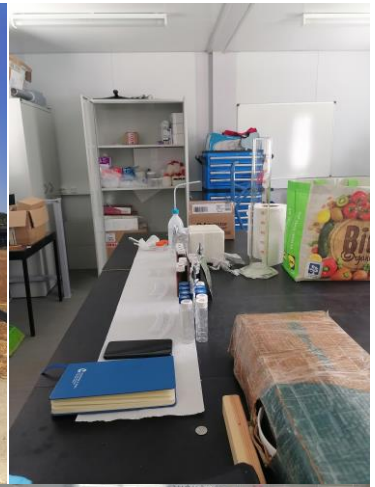
Assessment of the Sol2H2O photoreactor

- **Sulfamethoxazole**







Assessment of the Sol2H2O photoreactor

Heterogeneous photocatalysis with TiO_2

Sulfamethoxazole (10 mg L^{-1})

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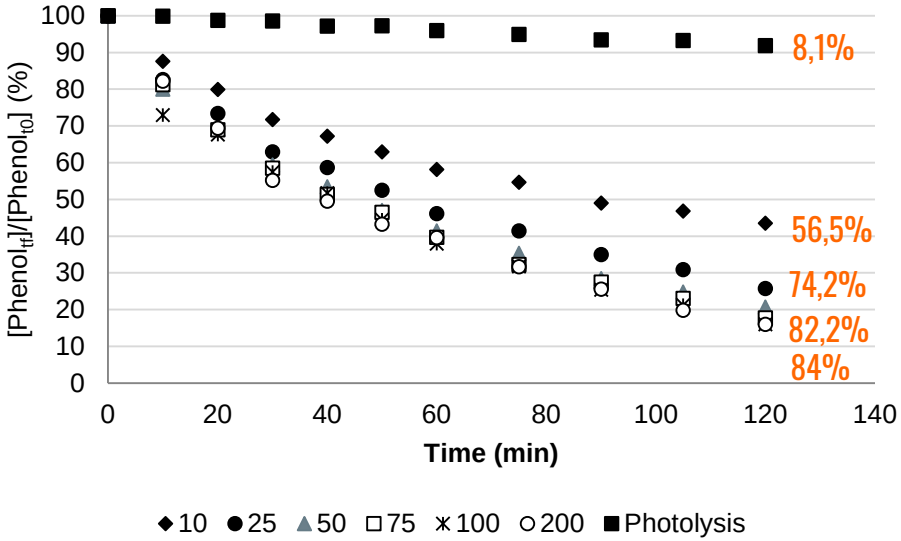
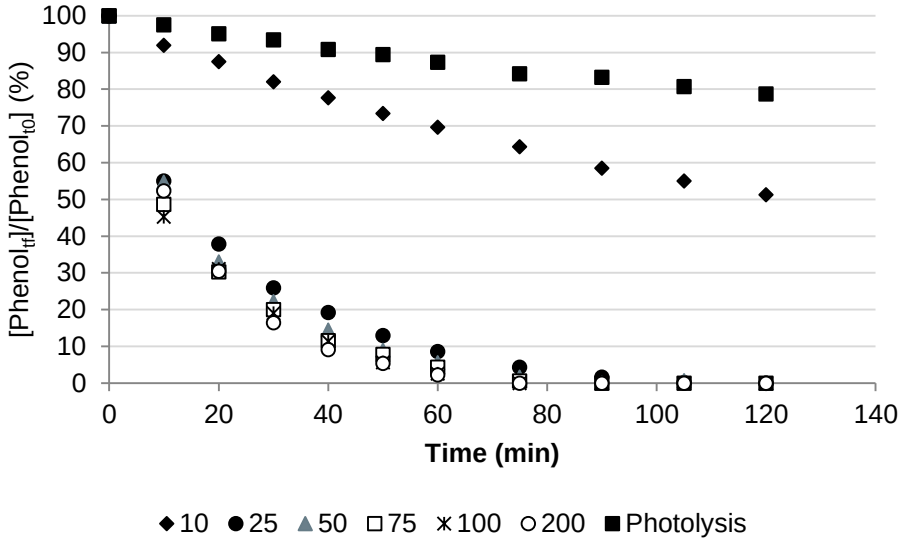


Illuminated Control



Mineralization rate

10 mg/l TiO_2	25 mg/l TiO_2
54%	59%

Assessment of the Sol2H2O photoreactor

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- **Economic assessment**

Reactor components	Costs (€)
Control and operation equipment	4 195,00 €
Reactor structure	2 182,17 €
Tubing accessories	485,23 €
Reflector	4 341,60 €
Personnel	1 500,00 €
Estimated costs for 1 m^3	**11,858.40 €**

OPEX - Maintenance and operation costs will be also calculated at the end of the project

Team

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RENEWABLE ENERGIES CHAIR

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