Sustainable Electrochemical Reduction of Contaminants of Emerging Concern and Pathogens in WWTP Effluent for Irrigation of Crops (SERPIC)

SERPIC for Crops Irrigation

Sustainable Treatment of Wastewater for Safe Crop Irrigation and Environmental Health

A Solution for Water Scarcity

SERPIC has developed an integral technology based on a multi-barrier approach that uses a combination of **membrane filtration** and the **electrochemical production of powerful oxidants** to treat the effluents of municipal wastewater treatment plants (WWTPs) and maximise the removal of contaminants of emerging concern (CECs).

High Reliability and Flexibility

This process will be used to degrade CECs and resulting in a limited formation of hazardous by-products.

Food Production and Alternative Water Source

SERPIC's aim is to investigate and minimise the spread of CECs and antibiotic resistant bacteria/antibiotic resistance genes (ARB/ARG) within the water cycle from households and industries to WWTP effluents to the environment. After application of the SERPIC technology, the treated wastewater is directed to agricultural irrigation (Figure 1, Route A), or flows into surface water bodies (Figure 1, Route B).

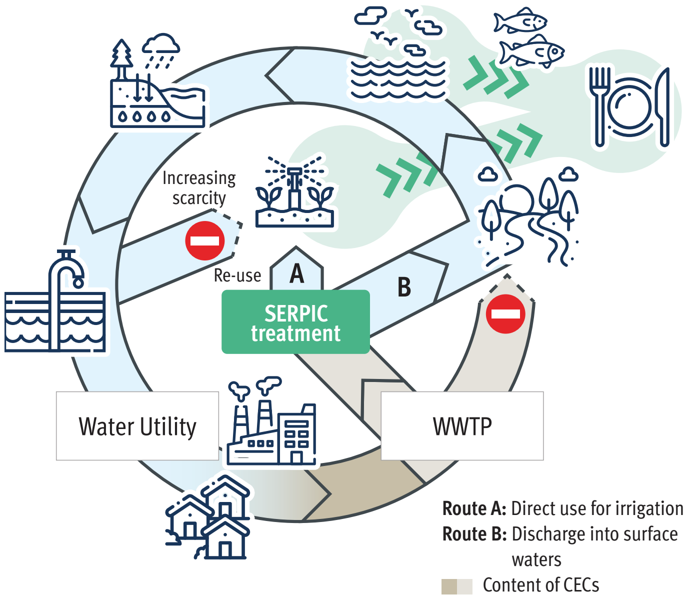

Figure 1. SERPIC removes CECs from the WWTPs effluent (or water discharged from WWTPs) and makes it available for irrigation.

Progressively Achieving the Targets for CEC Reduction

A membrane nanofiltration (NF) technology was used to reduce CECs in the permeate stream by at least 90 %. A disinfection step that uses **ozone gas** produced electrochemically was added to the stream used for crops irrigation (**Route A**). The CECs in the polluted concentrate (retentate) stream were reduced by **light-driven electrochemical oxidation**. When discharged into the aquatic system (**Route B**), the treated stream will contribute to the quality improvement of the surface water body (Figure 2).

How do we Evaluate the Removal Efficacy of CECs in a New Treatment Technology for Water Reuse? By identifying target compounds, considered to be representative of a wide group of diverse substances in terms of occurrence, bioaccumulation, ecotoxicity, and persistence in their degradation and removal, irrespective to the class of usage they belong to.

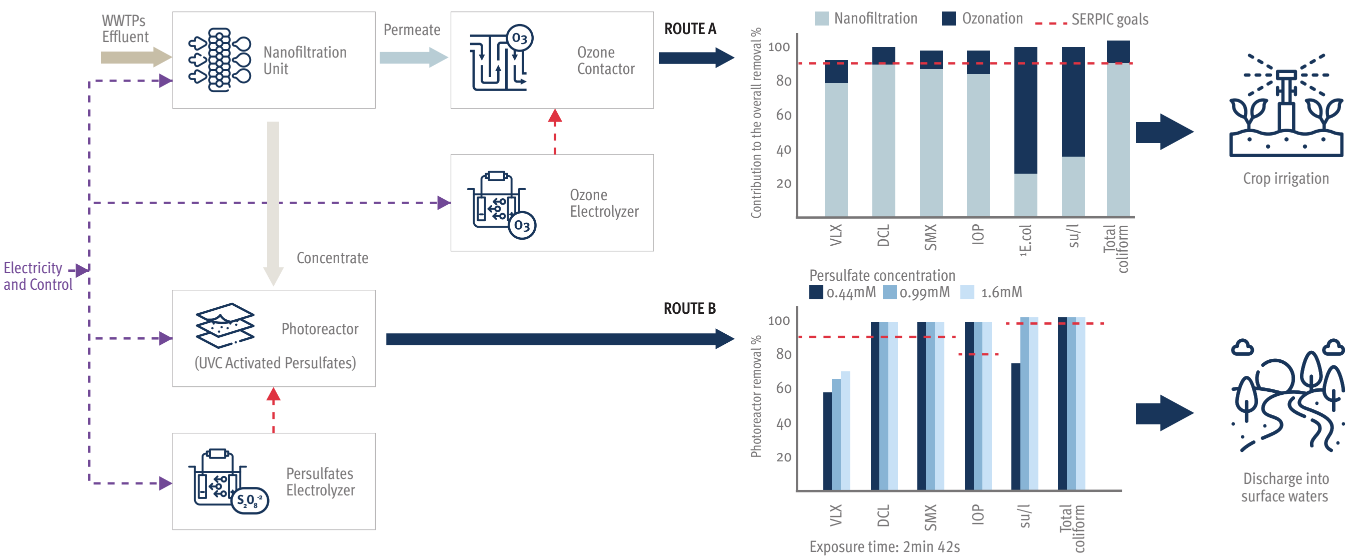

Figure 2: Membrane Nanofiltration for Contaminant Reduction: Dual Routes for Environmental Sustainability. The overall removal efficiencies (on average) for the selected CECs achieved by Route A (effluent used for irrigation) and Route B (effluent released into the environment). Route A considers the contributions of the two steps: nanofiltration and ozonation (VLX: venlafaxine, DCL: diclofenac, SMX: sulfamethoxazole, IOP: iopromide, [1]E. coli < 10 MPN/100 mL). Route B considers the contributions of the photoreactor with UVC-activated persulfates.

Aquatic Pollutants

Sustainable Electrochemical Reduction of Contaminants of Emerging Concern and Pathogens in WWTP Effluent for Irrigation of Crops (SERPIC)

Ozone was generated with two boron-doped diamond electrodes (BDD) used as anode, assembled with a proton exchange membrane and inserted in a 3D-printed casing. Operated at 12V in batch mode, it produces 36 mg/h of ozone for disinfection, utilizing innovative gas evacuation design to prevent ozone decomposition reactions.

Parameters Varied/ %	Effect on Ozone Production	
Temperature decrease/ 40%	▲	+
pH alkaline medium	▼	−
Electrolite concentration increase/ 1000%	▼	−
Current density increase/ 40%	▲	−
Current density decrease/ 70 %	▼	+

Persulfate generation improves at high current densities, temperatures below 25 °C and with the use of acid electrolyte. When operated in continuous mode higher persulfates amounts are produced, which makes it possible to use in industrial application.

Parameters Varied/ %	Effect on Persulfate Conc.	
Temperature decrease/ 40%	▲	+
pH alkaline medium	▼	−
Current density decrease/ 50%	■	+
Current density decrease/ 75%	▼	−

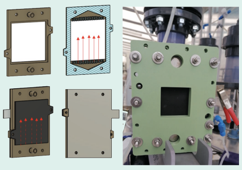

Figure 3. Top) SERPIC used a commercially available membrane electrode assembly (MEA) (CONDIAS GmbH, Germany) and a tailored PEM cell (UCLM, Spain) to electrogenerate ozone. Bottom) Fraunhofer IST created persulfate electrodes for the photoreactor. In both cases different parameters were tested and optimized for their pilot-scale use (arrows indicate increase/decrease of concentration, plus/minus indicate positive or negative effect on concentration).

SERPIC at Your Service

The technologies we are developing aim at providing efficient treatment of WWTP effluent. We are able to achieve high removals of a wide spectrum of organic and microbial CECs. This results in compliance with EU standards for water reuse in agriculture and a higher protection of the receiving water bodies. Finally, our technologies enable the future use of reclaimed water for industrial purposes, aliviating the pressure on strained water systems.

Adequate Protection of the Environment, Human and Animal Health

- **Regulation EU 2020/741** = No specific quality standards have been set for CECs in water reuse. Annex II defined additional requirements for water quality and monitoring
- **Directive 2008/105/EC** = EU watch list concerned with CECs
- **Recast of Directive 91/271/EEC (UWWTD)** = regular monitoring of CECs, quaternary treatment for removal of a broad spectrum of CECs, and monitoring of antimicrobial resistance at the WWTP inlet and outlet (will be required)

Diamond in Our Treatment Trains

To produce ozone and persulfates, which are two different oxidants, we designed and tested (BDD) and a proton exchange membrane (PEM) cell . The massive generation of these chemical species is favored at the surface of these electrodes. An extra benefit is that they also present higher chemical and electrochemical stability than other electrode materials.

ROUTE A

O_3 : Ozone is a strong oxidant widely used in water advanced oxidation processes and disinfection.

ROUTE B

$S_2O_8^{-2}$: Persulfates are oxidants with longer lifetime, but they need to be activated by UVC light in a photoreactor.

The design of the electrochemical reactor plays a major role in the efficiency of the process for O_3 and $S_2O_8^{-2}$ electrogeneration, directly affecting energy consumption, oxidant decomposition and hydrodynamic behavior. Electrochemical parameters are key in achieving maximum efficiency (Figure 3).

The results of the treatment technology will be transferred to other regions, especially in low- and middle-income countries.

A Solution For Water Scarcity

A prototype treatment plant is being tested in Ciudad Real at the Universidad de Castilla - La Mancha (UCLM Spain). Here, we are comparing the irrigation of potatoes and carrots with three different water qualities (Figure 4). SERPIC water is produced by treating a municipal WWTP effluent with our novel technologies. This water undergoes investigations of different organic and microbial CECs and other water quality parameters.

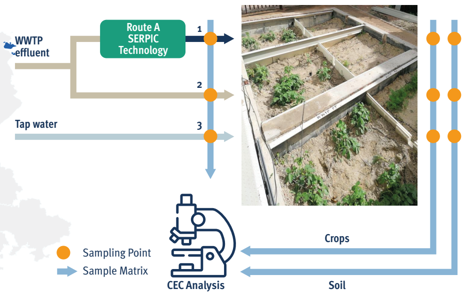

Figure 4. Right) In Route A, SERPIC's field test in Spain uses 3 water qualities for irrigation – 1) SERPIC effluent, 2) WWTP (secondary) effluent and 3) tap water – to irrigate potatoes and carrots. Left) SERPIC partners are located in Italy, Spain, Germany, South Africa, Norway and Portugal.

Collaboration

This factsheet was developed by AquaticPollutantsTransNet in collaboration with the SERPIC project as part of the AquaticPollutants Cross-Cutting Issue #3 on "Mitigation Technologies for CECs and AMR".

aquatic-pollutants.eu

serpic-project.eu

SERPIC Partners

1. Fraunhofer-Gesellschaft e.V., Germany (coordinator)
   a) Fraunhofer Institute for Surface Engineering and Thin Films IST
   b) Fraunhofer Institute for Solar Energy Systems ISE
2. SolarSpring GmbH (SSP), Germany
3. Università degli Studi di Ferrara UNIFE, Italy
4. Universidad de Castilla-La Mancha UCLM, Spain
5. Universidade do Porto UP, Portugal
6. AdP VALOR, Serviços Ambientais, SA, Portugal
7. Norwegian Institute for Water Research NIVA, Norway
8. Stellenbosch University SU, South Africa

Funding

The AquaticPollutantsTransNet partners have received funding from the BMBF, the ANR and the SRC as part of the 2020 Transfer Project Call, which will be implemented as part of the ERA-NET Cofund AquaticPollutants of the Joint Programming Initiatives (JPIs) on Water, Oceans and Antimicrobial Resistance (AMR)