DSWAP

Decision **s**upport-based approach for sustainable **w**ater reuse application in **a**gricultural **p**roduction

LAYMAN'S REPORT

Application in Spain:

Solar-driven membrane-based tertiary desalination module

CSIC Consejo Superior de Investigaciones Científicas · fluence · Technische Universität Dresden · nireas International Water Research Center · S.K. eur market LTD Water & Wastewater Engineering · APRIA Systems · Université de Lorraine · Agricultural Research Organization Volcani Center · Università degli Studi di Salerno · Universidade Católica Portuguesa

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LAYMAN´S REPORT OF SPANISH PARTNERS (APRIA and CSIC)

DSWAP Project: “Decision support-based approach for sustainable water reuse application in agricultural production”

Coordinating beneficiary: Agricultural Research Organization, Volcani Center (Israel)

Associated beneficiaries: Fluence Corp. (Israel), Technical University of Dresden (Germany), University of Cyprus, Nireas-International Water Research Center (Cyprus), S.K. Euromarket LTD (Cyprus), Spanish National Research Council, CSIC (Spain), APRIA Systems S.L. (Spain), University of Loraine (France), University of Salerno (Italy), Catholic University of Portugal (Portugal)

Total budget: 1,999,859 €

Period: July 2019 – December 2022

Introduction

The problem

Wastewater treatment (WWT) requirements for effluents used for agricultural irrigation are considerably different from those of effluents discharged to aquatic environments. For example, nitrogen and phosphorus are essential elements for plant cultivation and therefore exhaustive processes for reducing nutrients (i.e., denitrification and phosphate removal) are not imperative in wastewater reuse for irrigation. Conversely, the capacity of human pathogens and associated antibiotic resistance genes to persist in irrigated soils and to potentially colonize plant tissues, as well as evidence of the uptake of various contaminants of emerging concern (CECs) by crops makes treated wastewater irrigation a potential public health hazard because these elements can be transferred to humans and animals through the food chain. In addition, the detrimental long-term effects of effluent-derived salinity and CECs on soil structure and crop yield in treated wastewater irrigated fields (especially in clay-rich soils) suggest that salt removal may be crucial when irrigating with wastewater effluents.

> *Evidence of the uptake of CECs by crops makes treated wastewater irrigation a public health hazard*

Originality and innovative aspects of DSWAP

DSWAP adopts a circular economy approach, aiming for safe and sustainable valorization of wastewater for irrigation, with minimized ecological and agronomic impacts. The concept consists of a cost-effective, modular, de-centralized wastewater treatment/irrigation systems coupled to a decision support tool for the removal of contaminants, while retaining beneficial nutrients, whose levels can be adjusted as a function of local needs. This is achieved by the coupling/decoupling of treatment modules as a function of the wastewater source and measured quality parameters. It ensures optimal water quality for irrigation and long-term sustainability of irrigated soils. Individual modules within these networks are coupled to alternative energy sources to reduce costs and greenhouse gas emissions.

The above concept focuses on two novel decentralized secondary treatment modules, three energy-efficient advanced treatment modules for the removal of microbial and chemical contaminants, and two units designed to remove salinity.

A decision support tool is used for the application of post-treatment desalination and pathogen intervention which requires efficient data transfer, processing and harmonization from online and offline monitoring sources.

The monitoring relies on a comprehensive diagnostic toolbox, which evaluates the quality of the effluents from individual and integrated technological systems (modules), plus their impact on soil quality, ecosystem functioning and agronomic performance.

Expected impacts

DSWAP will have a major impact on the enhancement of sustainable wastewater reuse. In essence, it is expected to facilitate a paradigm shift from conventional wastewater treatment approaches that are specifically designed for effluent discharge to aquatic environments, to systems designed for wastewater reuse, with a special emphasis on agricultural irrigation. These systems will become increasingly imperative in the coming years due to dwindling freshwater resources associated with increasing world population and global climate change.

> *"DSWAP will facilitate a paradigm shift from conventional wastewater treatment to systems designed for wastewater reuse for agricultural irrigation"*

Specific impacts:

- Energy efficient wastewater treatment technologies integrated into decentralized wastewater reuse networks, customized according to specific needs.
- Safe and agronomic beneficial wastewater reuse that consider environmental, socio-economic and legal constraints.
- Reduction of soil salinization and promotion of sustainable and safe agricultural production
- Ecosystem and public health protection through the transfer of knowledge and best practice to key stakeholders.
- Recommendation for the preparation of guidelines, standards and regulations for harmonized testing of the quality of wastewater to be reused through the development of a unique decision support tool.
- Technological solutions/tools that may be commercialized by the Small and Medium-sized Enterprises (SMEs) of the consortium, contributing thus to the enhancement of their company profile, their profit margin, the expanding of their clientele and increased competitiveness for European companies.

Objectives

The main goal of DSWAP is to develop modular cost- and energy efficient wastewater treatment systems specifically designed for wastewater reuse in the human and environmental health and long-term agronomic sustainability. This goal encompasses five specific objectives:

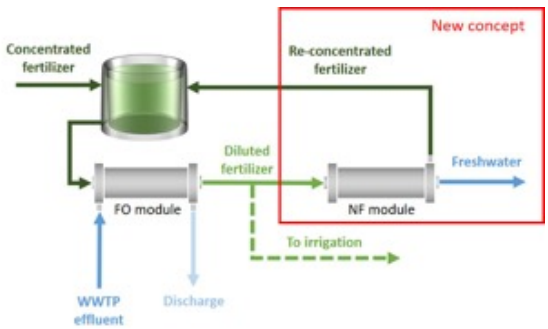
1. Optimization and evaluation of energy-efficient secondary treatment modules specifically designed for integration to decentralized wastewater reuse systems.
2. Development and evaluation of novel advanced treatment (tertiary) modules for integration into decentralized wastewater reuse systems for reduction of microbial pathogens, antibiotic resistance elements and contaminants of emerging concern (CECs).
3. Development and evaluation of modules for reduction of effluent salinity to prevent soil salinization, which over time can detrimentally impact soil quality and crop productivity.
4. Evaluation of integrated modular configurations (using the modules described above) that meet the needs and criteria of specific stakeholders based on local infrastructure, geography, influent load, installation and energy costs and maintenance availability.
5. Development and application of decision support tool that integrate and evaluate data generated by a myriad of state-of-the-art diagnosis tools for holistic evaluation of microbial, chemical, phyto-toxicological and ecosystem functioning-associated parameters in effluents and in corresponding irrigated soils.

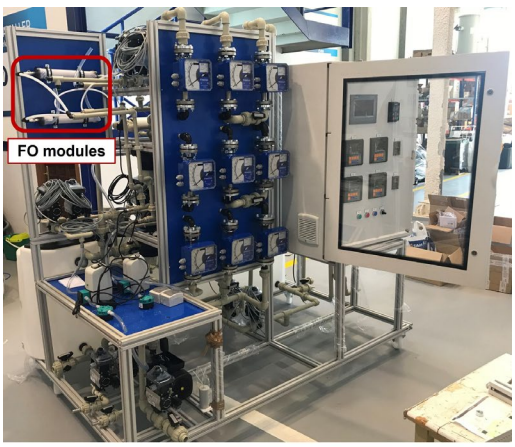
Actions and results

Solar-driven membrane-based tertiary desalination module

APRIA and CSIC carried out the design and construction of a system able to recover and reuse secondary urban wastewater treatment plant (UWTP) effluents. Forward osmosis (FO) technology was proposed, where the fertilizer was used as the draw solution. This allows the wastewater effluent recovery for irrigation purposes at the same time the concentrated fertilizer is diluted with the membrane permeate generated from wastewater effluent to be used for irrigation. However, an additional nanofiltration (NF) line was integrated with the aim of recovering the concentrated draw solution stream if required. Under continuous mode of operation, the conductivity of the permeate is still too high to be used for irrigation, and the additional NF treatment system can generate an additional freshwater stream. This new approach also allows the recovery and re-concentration of the fertilizer, closing the loop within the system. In this manner, the system operation was redefined, gaining both greater flexibility and complexity.

A PI&D and a O&M handbook were also made, including safety issues, maintenance, installation and operation protocols.





APRIA provided the pilot plant. The fertilizer drawn forward osmosis process (FDFO) was used, since it is an energy efficient method and competitive with other membrane-based technologies. A concentrated fertilizer solution is used as a draw solution, diluted by permeation with reclaimed water (RW) through a semipermeable membrane driven by the difference of osmotic pressures between the RW and the fertilizer.

The goal is to obtain a nutrient solution, free of contaminants and suitable for irrigation. The FO membrane was a biomimetic membrane (Aquaporin, HFFO2, 2x modules, total active area 4.6 m^2). A NF module (NF270, Dupont) is used to obtain deionized water to clean the FO membrane by physical cleaning.

KCl was chosen as nutrient and draw solution due to its relatively high osmotic pressure. An ancillary hydraulic system continuously feed the plant and supplied the treated water to the irrigation network, while discharged the rejected water back to the canal.

> *The approach allows the recovery and re-concentration of the fertilizer, while generating an irrigation stream and a freshwater stream*

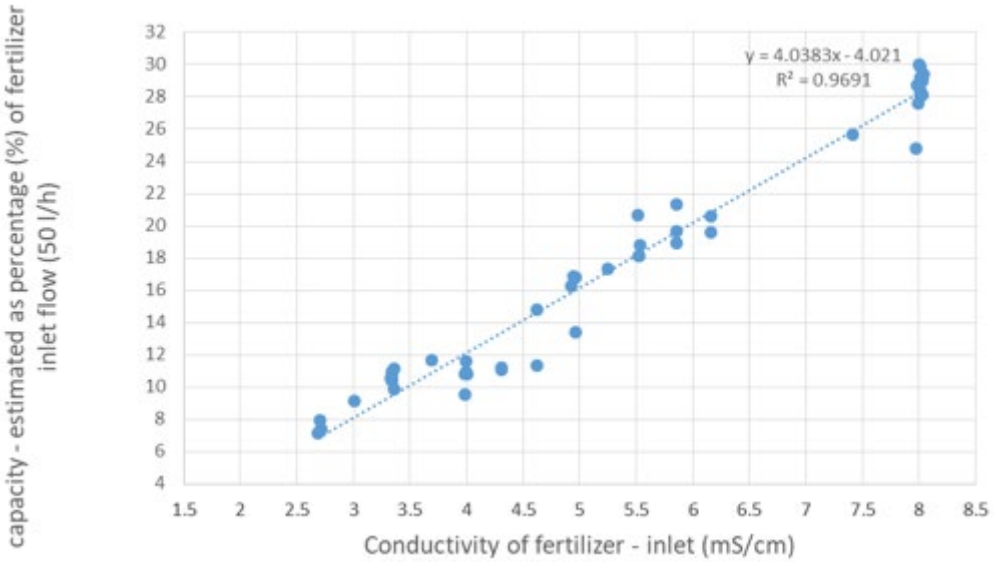
A FO optimization was carried out by APRIA and CSIC with the aim of obtaining treated water with a suitable concentration of nutrients for irrigation. The plant was operated in the continuous mode for both feed and fertilizer (KCl). Water flux was evaluated according with the fertilizer concentration.

The higher the concentration of nutrients, the higher the osmotic flow, being the highest at 0.5 M. Higher nutrient concentrations were not assayed to avoid excessive Cl^- concentration in the irrigation of irrigation water that is deleterious to crop.

Water flux was measured at different concentrations of the fertilizer. A linear relationship between the osmosis flowrate and the fertilizer conductivity (R^2=0.9691) is obtained in the evaluated range from 2.5 to 8 mS/cm.

> *The pilot plant was operated in the FDFO process and in continuous mode yielding a variable flowrate depending on the fertilizer concentration*

The main drawback in the continuous operational mode is the high conductivity of the permeate that needs an additional dilution with freshwater to be used for crop irrigation. In order to circumvent this limitation, the batch operational mode allows a substantial reduction of the conductivity below 2000 μS/cm, providing also a high removal efficiency of CECs (below the detection limit), and in 1 log in the abundance of antibiotic resistance genes (*sul*1) and integron integrase (*intI*1). However, this operational mode is limited for low water demand applications. The hybrid operational mode combining forward osmosis and nanofiltration can provide low conductivity permeate below 1000 μS/cm and much higher volumes of produced water.



KCl concentration (M)	Fertilizer inflow (L/h)	Fertilizer outflow (L/h)	Water flux (L/m²/h)	Feed inflow (L/h)
0.5	45	90	9.7	100
0.05	50	60	2.2	100
0.0125	50	52	0.4	100

Dissemination

Participation in ICOM 2020

APRIA participated in the 12th International Congress on Membranes and Membrane Processes. (7-11 December 2020). The DSWAP project was presented by APRIA Systems personnel, who laid out the main project goals and the designed technological solution.

Promotional video

CSIC prepared a promotional video that shows the main objectives of the DSWAP project. The video can be accessed through the following link: https://youtu.be/WdK8NMbKb1I

Publications of news in websites

Acciones de I+D

Kickoff meeting PRIMA-DSWAP project

29 enero, 2020 in Acciones de I+D

DSWAP (Decision support-based approach for sustainable water reuse application in agricultural production), a new challenging research project funded under PRIMA call just started with a 2 days kickoff meeting at CSIC in Barcelona.

The DSWAP project aims to provide flexible and cost-effective wastewater treatment solutions specifically designed for crop irrigation, with minimal ecological and agronomic impacts, combined to decision support tools coupled to cutting-edge analytical methodologies, consistently with the circular economy approach.

The DSWAP consortium encompasses a multi-disciplinary team of engineers, microbiologists, plant scientists, chemists, soil physicists and ecologists from academic (Technical University of Dresden, University of Cyprus, University of Loraine, University of Salerno, Catholic University of Porto) and government research (Agricultural Research Organization (coordinator), CSIC-Barcelona) laboratories and SMEs (Fluence Corp., Euromarket LTD, APRIA Systems) highly experienced in both scientific and applicative aspects of wastewater treatment and reuse.

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Proyectos actuales ES

DSWAP – PRIMA

Sistema de soporte para la toma de decisiones en la reutilización de agua residual tratada en la producción agrícola

- Financiación: Programa PRIMA
- Presupuesto: 2.000.373,75 €
- Periodo: julio 2019 – julio 2022
- Web: www.dswap-prima.eu
- Objetivo: desarrollar un sistema modular eficiente y de bajo coste para el tratamiento de aguas residuales que sean aptas para su reutilización en el contexto de la irrigación de cultivos, respetando la salud pública, la calidad del medioambiente y sus suelos y la sostenibilidad a largo plazo del sector agrícola.

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

PRIMA programme is supported by Horizon 2020, the European Union's Framework Programme for Research and Innovation.

Conferencias y ferias

Participación en el workshop organizado por el proyecto AQUAlity

9 julio, 2021 in Conferencias y ferias

APRIA Systems participó en el workshop organizado por el proyecto H2020 AQUAlity, donde hablamos sobre nuestra contribución al tratamiento y reutilización de aguas a través de tecnologías basadas en procesos de oxidación avanzada y membranas. Es destacable que durante nuestra presentación tuvimos la oportunidad de hacer difusión sobre varios de nuestros proyectos de I+D (ELOXIRAS, ELOXIRAS Dulce, LED4Future, DSWAP, LUV2Innovate y UV-Cleaning).

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