warrior
Low-emissions water reuse for irrigation

Innovative and sustainable production of reclaimed water for agricultural irrigation

LAYMAN'S REPORT

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www.life-warrior.eu

Contents

Full title
Innovative cost-effective water reuse approach in compliance with the new European regulatory framework for agricultural irrigation (WAter Reuse adaptation RegulatIOn agRo)

Acronym
LIFE WARRIOR

Funding
LIFE programme, the European Union's funding instrument for the environment and climate action

Budget
€1,954,879 (EU contribution: €1,172,927 (60%))

Duration
42 months (October 2022 to March 2026)

Coordinator
Cetaqua – Water Technology Centre

Consortium
Veolia and Aguas de Murcia (EMUASA)

Pilot plant
Nueva Sucina (Murcia, Spain)

Website
https://www.life-warrior.eu/

Reclaimed water for agricultural irrigation: a bit of context

Climate change is intensifying the frequency, duration and severity of droughts, particularly in semi-arid Mediterranean regions. These periods of drought, combined with growing demand for water, are increasing the pressure on available resources and the need for efficient water management.

According to the Intergovernmental Panel on Climate Change (IPCC), **approximately 50% of the world's population suffers from severe water scarcity for at least part of the year**. At the European level, the European Environment Agency (EEA) notes that around 30% of countries experience seasonal water stress.

One of the most affected areas in Europe in this context is **the Region of Murcia.** Its intensive agricultural activity, a key driver of its economy, generates a demand for water that exceeds available water resources, making it essential to adopt sustainable solutions that guarantee long-term supply. Faced with this scenario, **the reuse of reclaimed water for agricultural irrigation is emerging as one of the most effective alternatives** from both an environmental and economic perspective, compared to options such as desalination or water imports.

Although **Murcia is a pioneering region in the use of reclaimed water** (according to ESAMUR, in 2024, a total of 99.7 hm^3 was reused for agriculture, equivalent to 89% of the total treated water), **the large-scale implementation of reclamation systems in other regions still faces technical, economic and regulatory barriers**.

In terms of regulation, the European Commission adopted Regulation (EU) 2020/741 to promote the highest safety standards for reclaimed water used for agricultural irrigation. This Regulation sets out minimum requirements for quality, control and management, which were implemented in Spain through Royal Decree 1085/2024, establishing quality standards for reclaimed water that are more stringent than those previously in force.

This new regulatory framework poses significant technical and operational challenges, where conventional treatments in wastewater treatment plants (WWTPs) and water reclamation plants (WRPs) may prove insufficient or excessively energy-intensive.

It is in this context that LIFE WARRIOR emerged, a project aimed at **developing and validating an innovative scheme for the reclamation of Class A+ water, the highest quality for agricultural irrigation.** This approach is aligned with European sustainability policies and the Sustainable Development Goals (SDGs), promoting solutions that integrate environmental protection, resource efficiency and adaptation to climate change.

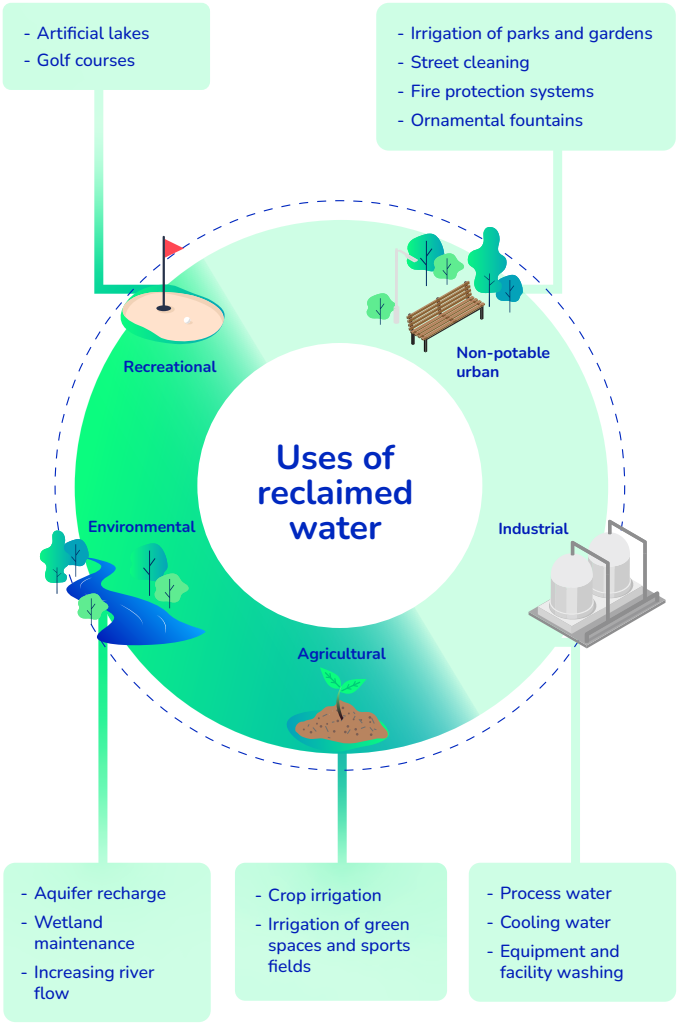

Figure 1. Uses of reclaimed water in the Region of Murcia.

LIFE WARRIOR: innovative and sustainable production of reclaimed water for agricultural irrigation

The LIFE WARRIOR project has developed and demonstrated an innovative solution for reclaiming Class A+ water for agricultural irrigation, in line with Royal Decree 1085/2024 on water reuse. The solution has been tested at the Nueva Sucina urban WWTP in the Region of Murcia (Spain), a region where water reuse already plays a central role in agricultural activity.

Its approach is based on an **advanced treatment system that integrates two technologies**. First, **the project reuses ultrafiltration (UF) membranes from drinking water treatment plants (DWTPs).** Although these membranes no longer meet the necessary requirements for producing drinking water, they are still suitable in water reclamation processes for agricultural use, allowing LIFE WARRIOR to give existing resources a second life.

Second, it incorporates a **disinfection system using ultraviolet (UV)-LED lamps**, which eliminates pathogenic microorganisms without the need for chemicals and with a lower environmental impact compared to the mercury lamps commonly used.

This treatment process is complemented by a **digital tool**, comprising a **decision support system** (DSS) and a **sanitation safety plan** (SSP) that includes a monitoring system using sensors and alarms**.** Its aim is to help estimate and extend the service life of UF membranes and to facilitate risk management through digitalised health safety plans.

Finally, to promote a circular economy model in the UF membrane sector, the project has developed the Re-UF Marketplace Service, a **digital marketplace** that puts used membrane suppliers – primarily water operators or authorities that run treatment plants – in touch with potential end users. This encourages the reuse of materials, reduces costs and promotes a more efficient use of resources.

Thus, by implementing reused membranes, **LIFE WARRIOR manages to add value to a product, reduce its carbon footprint and produce Class A+ water for use in agricultural irrigation.** Furthermore, this technology can be replicated in other regions facing similar challenges and aligns with the SDGs and the European Union's guidelines on water reuse.

Image 1. LIFE WARRIOR pilot plant. On the left, the shed housing the UV-LED disinfection system and the digital tool, and on the right, the system of reused UF membranes.

Main objectives of the LIFE WARRIOR project

Demonstrate an innovative system for reclaiming top-quality water for agricultural irrigation in the Region of Murcia, in compliance with Royal Decree 1085/2024.

Promote a circular economy model through the use of reused UF membranes from DWTPs, extending their service life and promoting their reuse via the Re-UF Marketplace Service platform.

Implement a disinfection process using UV-LED technology, which is chemical-free and consumes less energy than conventional solutions.

Develop a digital tool to optimise plant operation and maintenance, as well as improve risk management.

Improve the sustainability of the reclaimed water production process, reducing its environmental, economic and social impact.

Raise public awareness of the uses of reclaimed water.

Assess the replicability and transferability of the pilot project to other parts of Europe suffering from water scarcity.

Technological solution

Reclaimed water is a non-conventional water resource that is increasingly widespread globally and can serve as a powerful ally against the effects of climate change and the scarcity of natural resources. Reclaimed water is **water from the secondary treatment of WWTPs that has undergone additional** (tertiary) treatment, allowing it to be used for **various activities** (such as irrigation, cleaning, or aquifer recharge) that do not yet include direct human consumption. The use of this non-conventional water source reduces the consumption of natural water resources, thereby alleviating the water stress faced by many countries such as Spain and other regions of the Mediterranean.

The LIFE WARRIOR project presents an innovative and sustainable solution for the production of reclaimed water for agricultural irrigation through the construction of a pilot plant in the Sucina region of Murcia, Spain. There are **three main elements that set the pilot plant apart from other conventional WRPs:** the **use of reused UF membranes**, the **implementation of a UV disinfection system using LED lamps** and the **development of a digital tool to improve risk management and process optimisation**, which helps to estimate and extend the membranes' service life. In addition, the LIFE WARRIOR project has developed a **marketplace for reused UF membranes** in the form of a free digital platform, to provide a tool that puts used membrane suppliers (water companies or authorities operating DWTPs) in contact with end users.

For a **virtual tour of the pilot** project at the Nueva Sucina WWTP (Murcia), go to:

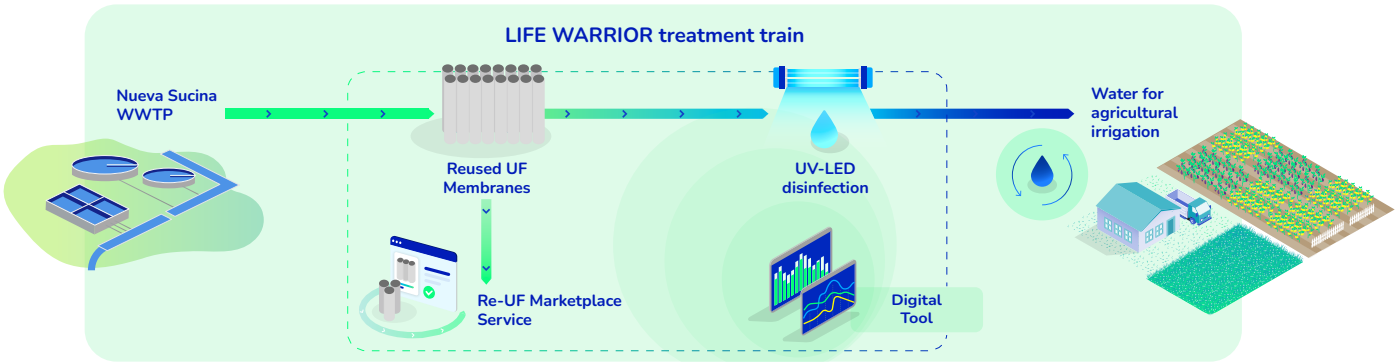

Figure 2. Process followed in the LIFE WARRIOR treatment line.

Reused UF membranes

The UF process consists of a filtration process that uses **semipermeable membranes with very fine pores** to separate, with the aid of a pump, water from suspended solids, microparticles and high-molecular-weight substances. This technology **is usually employed as a pre-treatment** in wastewater treatment, seawater desalination or freshwater purification. However, **it can also be used as the main treatment in the production of reclaimed water, as is the case with LIFE WARRIOR**.

Among the various innovations developed in this project is the **reuse of UF membranes previously used in drinking water treatment processes**, specifically at the Sant Joan Despí DWTP (Barcelona, Spain), one of the largest membrane-based water treatment facilities in the country and operated by Aigües de Barcelona. The project's initial hypothesis is that UF membranes used in DWTPs are discarded when they can no longer guarantee water quality suitable for drinking; however, given that drinking water quality standards are higher, the membranes could still be useful for water reclamation processes, thereby extending the life of these products.

UV-LED lamps

There are **two main types of water disinfection: chemical** (by adding chemical compounds) and **physical** (using UV radiation from lamps). In both cases, the aim of disinfection is to eliminate or inactivate pathogenic microorganisms present in the water. The LIFE WARRIOR project opted for UV technology, but unlike conventional mercury lamps, a **more innovative solution was chosen: UV-LED lamps.**

The main advantage of UV-LED lamps over conventional ones is the reduction in environmental impacts

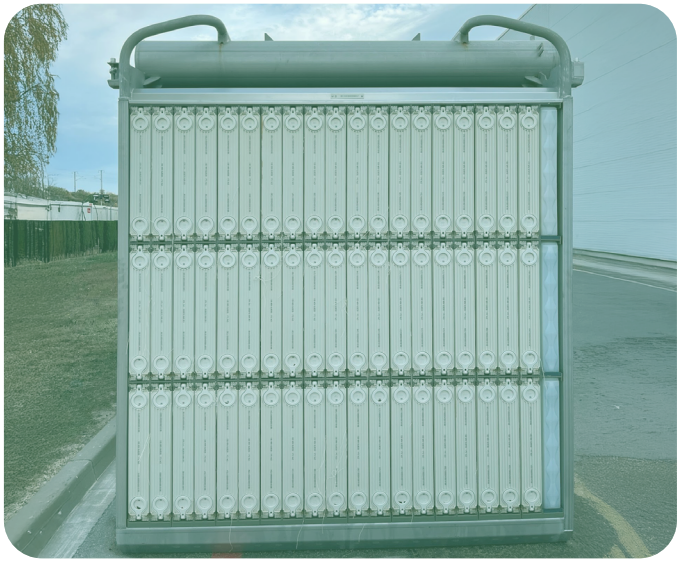

Image 2. Reused UF membranes from the Sant Joan Despí DWTP.

associated with mercury, the residue of which is toxic. Furthermore, LED lamps allow for more efficient operation thanks to their ability to be switched on and off as required without damaging them or reducing their lifespan, unlike mercury lamps.

Digital tool

The WARRIOR Digital Tool consists of two main components: a **decision support system** (DSS) and a **digitalised sanitation safety plan** (SSP).

The **DSS** is a digital resource that **analyses operational data to calculate, identify and report in real time on the correct or incorrect functioning of the UF plant,** providing water operators with valuable information. This system monitors permeability reduction and predicts extreme fouling events, enabling adjustments to membrane cleaning procedures, optimising the process and thereby estimating its service life.

Meanwhile, the **SSP** includes **a system performance sensor** that allows the **membrane's condition to be tested automatically every 24 hours**, thereby monitoring its effectiveness as a physical barrier and facilitating the design of health risk management plans.

Re-UF Marketplace Service

The Re-UF Marketplace Service is a **free digital platform designed to connect used membrane suppliers with end users**. On this platform, DWTP operators can report on the availability and condition of their used membranes and find interested customers directly, without intermediaries. This reduces delivery times, a critical factor in preventing the membranes from losing the necessary moisture and compromising their structural integrity prior to reuse.

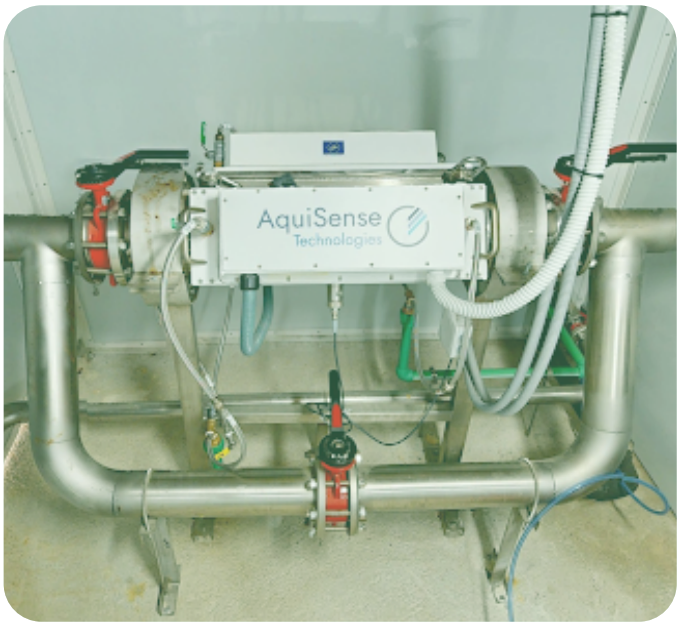

Image 3. UV lamp used in the LIFE WARRIOR pilot plant.

Image 4. The WARRIOR Digital Tool interface, where users can view various parameters relating to the performance of the UF membranes and water quality in real time.

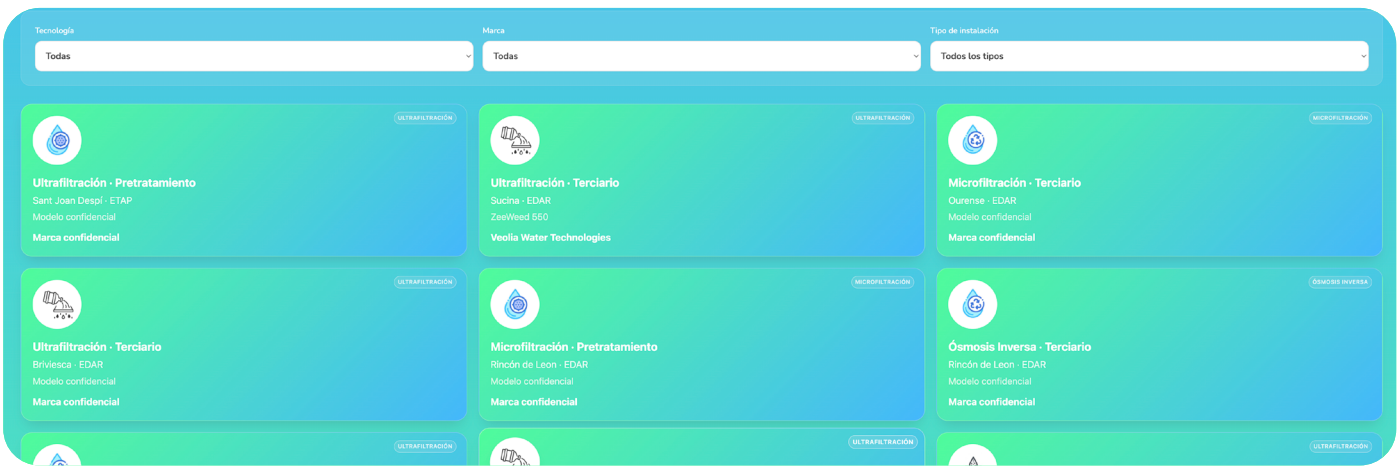

Image 5. Screenshot of the Re-UF Marketplace Service showing available membranes to new end users.

What are LIFE WARRIOR's achievements?

Demonstration and validation of a scheme based on the use of reused UF membranes and disinfection using UV-LED lamps as a feasible solution for producing high-quality reclaimed water at an urban WWTP for agricultural use.

Actual production of 80,059 m^3/year of Class A+ reclaimed water, the highest grade for agricultural use.

Development and implementation of a digital tool combined with sensors and alarms to monitor the process, as well as to facilitate communication and information transfer between members of the chain, minimising the health risks associated with reclaimed water production.

Development and implementation of a DSS that allows us to predict membrane fouling events, thereby optimising their cleaning and extending their service life.

Reduction in capital (CAPEX) and operating (OPEX) costs for reclaimed water to €0.608/m^3.

Reduction in CO_2 emissions by 41% compared to the conventional scenario (new UF membranes + UV disinfection with a mercury lamp).

Reduction in energy and chemical costs: €0.07/m^3 compared to the cost of conventional treatment, €0.17/m^3.

Creation of the first public marketplace for UF membranes, the Re-UF Marketplace Service, to put people interested in buying or selling reused membranes in touch.

Development of a replication plan, including five case studies.

Creation of a business model aimed at WWTP operators in areas affected by water scarcity who need a sustainable and cost-effective way to produce reclaimed water.

Dissemination of the project results.

Image 6. Details of the reused UF membrane system of the LIFE WARRIOR pilot plant.

Watch the video here:

Benefits and impacts of the LIFE WARRIOR project

The LIFE WARRIOR project has carried out a **life cycle analysis to assess the long-term environmental, economic and social sustainability of the project**, in a 5-year post-project scenario. The following outlines the improvements in sustainability, mainly due to the following elements and factors of the project:

- **The reuse of UF membranes**, which extends their service life and avoids the impacts associated with the production of new membranes.
- **The replacement of mercury lamps for disinfection with UV-LED lamps**, which contain no toxic elements.
- **The optimisation of chemical consumption and pilot plant operation**, which extends the life of the reused membranes, thanks to the use of the WARRIOR Digital Tool platform.
- The development of the **Re-UF Marketplace Service**, which promotes the reuse of UF membranes in other treatment plants.

Environmental impacts

We have compared the following **environmental benefits** generated by the LIFE WARRIOR project **with a conventional scenario** where, instead of using LIFE WARRIOR's innovative technologies (reused membranes, UV-LED disinfection, the WARRIOR Digital Tool and the Re-UF Marketplace Service), new UF membranes and a mercury disinfection lamp are used.

- A **41% reduction in CO_2 equivalent** emissions per cubic metre of water produced compared to the conventional scenario, contributing to reduced impacts in the climate change category.
- A **47% reduction in water consumption (water footprint)** per cubic metre of reclaimed water produced by the project compared to the conventional scenario.
- An **80.7% reduction in the consumption of resources, minerals and metals** per cubic metre of reclaimed water compared to the conventional scenario.
- **100% reduction in toxic waste (mercury)** generated by conventional treatment.

Economic impacts

To calculate the economic benefits of the project, we also used the comparative life cycle analysis methodology in relation to the conventional scenario mentioned above. The main result of this study was the **reduction in CAPEX + OPEX costs** in the LIFE WARRIOR post-project scenario, with a value of **€0.608** per cubic metre of reclaimed water produced, compared to €0.621/m³ in the conventional scenario.

Image 7. Reclaimed water after the treatment process.

Social impacts

To assess the social benefits of the LIFE WARRIOR project, we carried out an analysis based on **interviews with different groups of people** involved in the project or subject area: research and academia, industry and the value chain, workers and end users of reclaimed water. The main results are shown below:

- **Higher level of acceptance and trust** in reclaimed water.
- **Support for the agricultural industry** by offering a sustainable alternative water resource.
- **Improved process safety** in reclaimed water production thanks to digital innovation.
- **Increased knowledge transfer and participation in decision-making** by promoting the creation of an integrated risk management plan.
- **Better business opportunities** thanks to the development of the Re-UF Marketplace Service.

Business model

The LIFE WARRIOR project business model consists of a **business-to-business (B2B)** model aimed at **WWTP operators located in areas suffering from water scarcity** and who urgently need to adapt to the requirements imposed by the new European Regulation on reclaimed water (Regulation (EU) 2020/741). Therefore, this business model must ensure that **technologies for reclaimed water production provide resilience and profitability directly in areas with higher agricultural demand and lower availability of conventional water resources**.

The LIFE WARRIOR project developed a **10-year financial plan,** setting out a conservative and realistic economic roadmap designed to assess the long-term viability of a business model based on the circular economy and digitalisation.

The **profitability of the model is based on the diversification of its revenue**: **direct sales derived from the execution of the engineering project and the sale of membranes,** and the **vital generation of recurring revenue through annual licences (SaaS model) to use the digital tool**.

However, the success of this proposal is subject to a fundamental structural risk: the potential shortage of reused UF membrane cartridges from DWTPs. To ensure the company's survival and growth, it is essential to actively promote its Re-UF Marketplace Service platform and forge strong strategic partnerships that guarantee a steady supply of this essential raw material.

In summary, the 10-year financial forecast demonstrates that, despite initial logistical constraints, the strategy of diversifying revenue streams guarantees the long-term economic sustainability of the LIFE WARRIOR project's activities.

Image 8. Technical staff during the monitoring of the LIFE WARRIOR water reclamation and reuse facilities.

Next steps: continuation of the project

Although the project concluded in March 2026, the plant will remain operational, supplying Class A+ reclaimed water to irrigation communities in the Region of Murcia.

In addition, work will focus on transferring the plant's technology to other WWTPs and identifying new replication studies in different geographical and operational contexts to improve the sustainability of reclaimed water production processes. Given the great interest generated by the LIFE WARRIOR project, work will also continue on refining the business plan proposed within the project framework and promoting the search for new membrane suppliers to incorporate into the Re-UF Marketplace Service, as well as studying other alternative models in collaboration with stakeholders from different sectors and regions of the EU.

Conclusions

Water scarcity represents one of the greatest challenges facing European agriculture, particularly in semi-arid regions such as the Region of Murcia. In this context, wastewater reuse is gaining ground as a sustainable, safe alternative to ensure the availability of water resources. Despite its advantages, water reclamation is far from reaching its full potential in other regions.

LIFE WARRIOR addresses this challenge with an innovative solution that demonstrates it is possible to produce Class A+ reclaimed water for agricultural irrigation using reused UF membranes and a disinfection process employing UV-LED technology, thereby reducing energy consumption, the use of chemicals and operating costs. This project is aligned with the European Commission's regulatory framework (Regulation (EU) 2020/741), which sets out minimum quality requirements for reclaimed water for agricultural irrigation, as well as its incorporation into Royal Decree 1085/2024, which establishes more stringent quality standards for reclaimed water.

The exchange of membranes between suppliers and end users can be carried out via the Re-UF Marketplace Service platform, created within the framework of the project. By giving a second life to membranes from DWTPs, LIFE WARRIOR turns waste into a valuable resource, extending its useful life and reducing its environmental impact.

Image 9. Water reuse and efficient water management will be key to ensuring the sustainability of agriculture in semi-arid regions.

LIFE WARRIOR, a shared challenge between...

CETAQUA
WATER TECHNOLOGY CENTRE

Cetaqua – Water Technology Centre is a network of water technology centres based on a unique public-private partnership model. We work to provide innovative solutions that ensure the complete water cycle is sustainable and efficient at every stage, and we do so through an ecosystem comprising four independent centres in Barcelona, Andalusia, Galicia and Chile, and a branch in the Valencian Community. They all work in close collaboration with one another and with relevant public and private stakeholders.

Role in the project: Cetaqua coordinated the project's management and technical implementation throughout its 42 months of operation. It also led communication and dissemination, provided the technical expertise required to design and construct the treatment train, and assessed and monitored LIFE WARRIOR's impact.

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AGUAS DE MURCIA

Aguas de Murcia (EMUASA) is a public-private partnership in which the Murcia City Council holds a 51% stake and Veolia a 49% stake. EMUASA manages the water cycle in the municipality of Murcia, serving around 469,177 people spread across the urban centre, the surrounding rural areas and 55 districts.

Role in the project: EMUASA led the operational management of the prototype, starting with obtaining permits for its installation, supervising its design, construction and integration into the existing infrastructure, and ensuring its operation and optimisation, to promote sustainable water management.

aguas@emuasa.es https://www.emuasa.es/

VEOLIA

Veolia aims to become the leading company in the green transition. With operations all over the world and 215,000 employees, Veolia designs and implements useful and practical solutions for water, waste and energy management that contribute to a radical change in the current situation. Through its three complementary business lines, the company helps to facilitate access to resources, preserve their availability and renew them.

Role in the project: Veolia acted as a bridge between innovation and the market, ensuring that the products and tools validated within the project move beyond the demonstration phase and achieve effective market launch.

comunicacion.spain@veolia.com https://www.veolia.es/

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