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CORDIS Results Pack on water innovation

A thematic collection of EU-funded research innovation results

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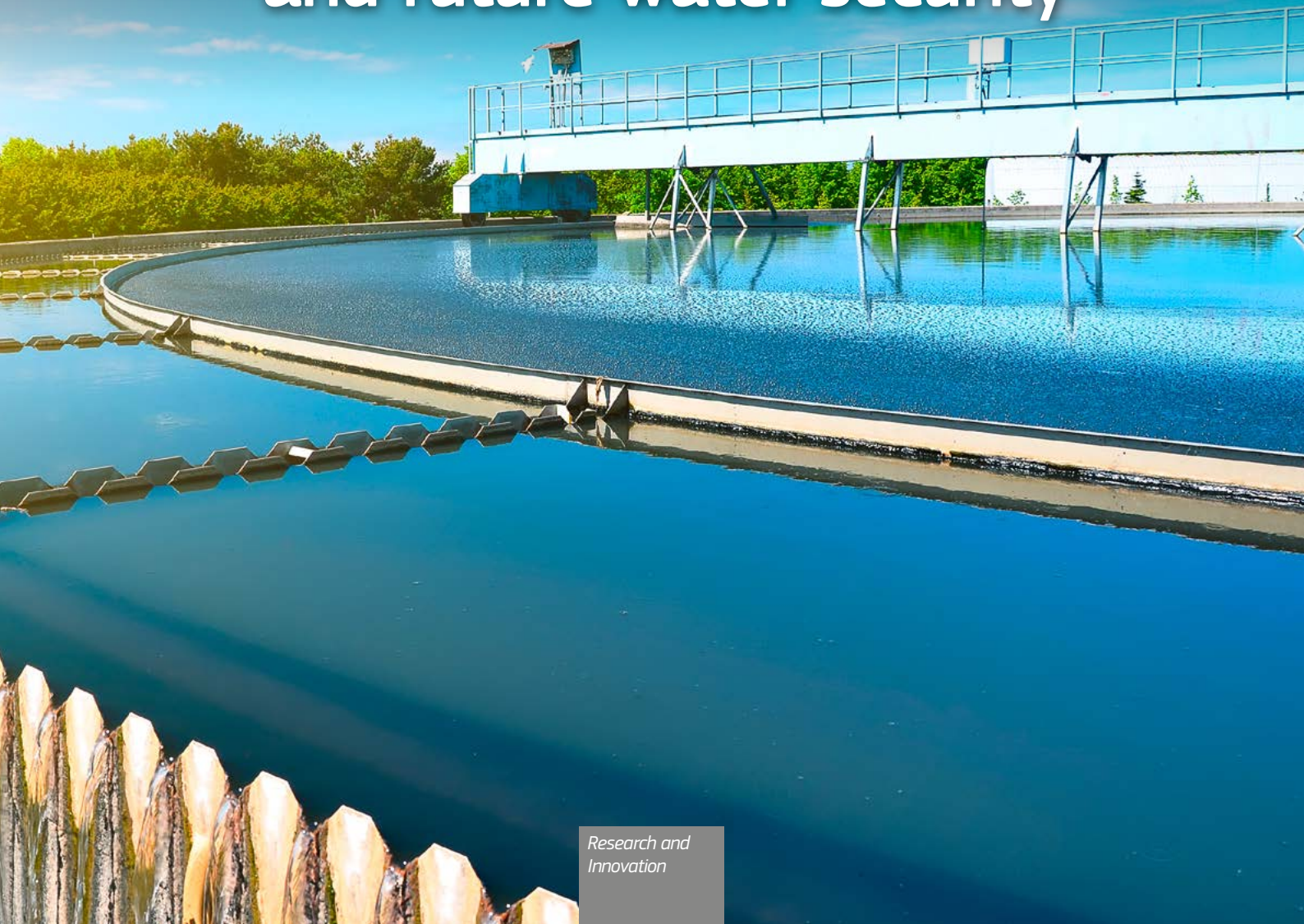
Innovative technological solutions for ensuring Europe's present and future water security



Research and Innovation

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Innovative technological solutions for ensuring Europe's present and future water security

Water is the essence of life and its abundance is a crucial ingredient in a healthy environment. With climate change threatening water resources across the globe, maintaining a stable supply of water for both human consumption and the ecosystem as a whole is a major concern, and thus new technological solutions need to be developed and quickly put into action. This CORDIS Results Pack focuses on 10 EU-funded projects that are doing just that.

Water is a precondition for human, animal and plant life as well as an indispensable resource for the economy. Water also plays a fundamental role in the climate regulation cycle. However, with the threat of ever-hotter and drier summers due to climate change, there are genuinely growing fears over how sustainable the water supply is and how easily it can be replenished. Whilst scarcity is a problem in some areas, climate change can also cause floods that can heavily damage the urban and rural environment.

Coordinated EU action

The European institutions are committed to ensuring Europe's future water security. This is a challenge that truly transcends national borders and cannot be solved by one country alone. Thus, a coordinated effort is necessary to guarantee effective protection of the EU's water sources.

From a legislative perspective, the keystone of the EU's water protection policy is the EU Water Framework Directive, which committed all Member States to protecting and enhancing freshwater resources with the aim of achieving a good status for EU waters. Its scope extends beyond lakes, rivers and groundwater to transitional and coastal waters. The main tools for implementing the Directive are the River Basin Management Plans (RBMPs) and the Programmes of Measures, which are prepared in 6-year cycles.

The EU's water legislation underwent evaluation in 2019. An evaluation for the Water Framework Directive, its associated directives and the Floods Directive, and one for the Urban Waste Water Treatment Directive were completed. Research and innovation supports the implementation of the directives.

Spurring water innovation through technological progress

However, political action, whilst extremely important, is not enough. Europe must look towards innovation to develop new and pioneering methods to ensure its water security and an adequate supply for all. This Results Pack covers 10 such EU-funded projects, with each project contributing far-reaching solutions and innovative ideas.

These projects are supporting the reduction of water stress and pollution, improving water efficiency and reducing greenhouse gas emissions (GHG) in the water sector, and promoting water and resource reuse. Their objectives are also much in line with the strategy and priorities put forward by the new European Commission President, Ursula von der Leyen, for the European Green Deal, the New Circular Economy Action Plan and the zero pollution ambition.

Adaptable, scalable and cost effective local solution to urban flooding prevention

Efforts to prevent urban flooding have often resulted in costly and complex systems based on rainfall forecasts which are often inaccurate. A new approach offers more agility, at a fraction of the investment.

There are several Real-Time Control (RTC) sewerage systems in European cities. These systems comprise networks of sensors and control hardware. Control decisions are centralised, driven by network models and rainfall radar data. The systems have high capital cost and demand high levels of expertise for operation.

The EU-funded CENTAUR (Cost Effective Neural Technique for Alleviation of Urban Flood Risk) project developed a market-ready, decentralised, autonomous system. CENTAUR has shown that it is possible to get additional urban flood protection from existing piped networks.

Introducing intelligent data driven controls

The CENTAUR system works by installing a flow control device (FCD) upstream of a flooding location in a section of the piped

drainage network which would have spare capacity if the downstream network was flooding. The FCD is fitted directly into an existing manhole and uses wireless based communications to dynamically respond to water level measurements in the local drainage system.

The water level monitoring system identifies high water levels in a flood prone site and available capacity upstream. The operating algorithm can then take the decision to close the FCD and store water, reducing flow and so water levels at the flood prone location – minimising the likelihood of flooding.

As the communication system is solar powered and can be attached to nearby infrastructure, such as lamp posts, it is very agile and so quickly deployable. Crucially, the CENTAUR system can be operational without the need for structural changes to the existing drainage and sewer system.

As Prof. Simon Tait, project coordinator, explains, "Urban areas can benefit from additional flood protection without the need to build expensive new structures, such as storage tanks. Focusing locally means that interventions can be implemented with more limited finances and quickly, without waiting to obtain the large capital sums and for the permissions necessary for new construction."

Another major advantage of the technology is that its autonomous design means that it can be scaled to cover increasing flood prone locations in a network. As each system works autonomously, they do not depend on each other; in contrast to existing RTC approaches which frequently optimise whole system performance.

"As CENTAUR is data-driven, flow control decisions are made based on actual measurements of water levels at the flood prone site and at locations upstream of the flow control device and not based on uncertain model predictions, as in previous large scale RTC systems," says Prof. Tait.

Both the pilot in Coimbra (Portugal) and the demonstrator in Toulouse (France) have proven that the technology works. In the Coimbra pilot over 60 storms were controlled, with the downstream flow rate and depth reduced by up to 37% and 19% respectively. The Toulouse demonstrator is still collecting data and its performance is being evaluated.

As CENTAUR is data-driven, flow control decisions are made based on actual measurements of water levels at the flood prone site and at locations upstream of the flow control device and not based on uncertain model predictions, as in previous large scale RTC systems.

Flexibility for wide implementation

CENTAUR contributes directly to meeting the requirements of the EU's Floods Directive, and the system's web-enabled visualisation dashboard offers water utilities the opportunity to display how the system is protecting citizens and property.

Additionally, in the future the local dynamic control of sewer networks offers the potential to control intermittent discharges from combined sewer overflows into watercourses, supporting the implementation of the Urban Wastewater Treatment Directive and the Water Framework Directive.

"Often in urban areas when drainage and sewer systems fail, the same properties get repeatedly flooded. The rapid, cost effective CENTAUR solution means that effective flood protection can now be offered to locations that see flooding in only a small number of properties," Prof. Tait adds.

CENTAUR's SME partners have started marketing the system at the project target price of under EUR 100 000, compared to a small centralised RTC system in excess of EUR 1 million. The team are currently looking to investigate the use of the CENTAUR system at multiple locations in a sewer or drainage network for flexible, adaptable control over a wide area. They are also exploring usage of CENTAUR for better management of combined sewer overflows to reduce the impact on receiving waters, and also to see if manipulating sewer network flows can reduce pumping and treatment costs (energy and chemicals) within wastewater treatment plants.

PROJECT
CENTAUR – Cost Effective Neural Technique for Alleviation of Urban Flood Risk

COORDINATED BY
University of Sheffield in the United Kingdom

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
sheffield.ac.uk/centaur

Rapid, flexible water analysis creates industry stir

The EU-funded CYTO-WATER project has developed an innovative onsite analytical system capable of rapidly detecting different microorganisms in water.

© CYTO-WATER

The analytical process, which takes no more than two hours, was validated for the detection of the microorganisms *Legionella* and *Escherichia coli* but can easily be adapted to detect other microorganisms. Rapid detection means that decisive action can be taken; a crucial element in ensuring that any potential disease outbreak is contained.

"Infectious diseases caused by microorganisms are the most common and widespread health risk associated with water, drinking and bathing," says the technical director of the project, Dr Vicente Catalan, from Labaqua in Spain.

"Reducing the risk of waterborne diseases will improve the reputation and competitiveness of businesses such as water distribution companies, hotels, food and beverage industries and chemical plants."

Rapid results

The new platform works by automatically concentrating a water sample, labelling each microorganism under investigation automatically as well. Using a fluorescence image cytometer, each specific labelled microorganism in the sample is detected and counted. "This imaging cytometer is like a kind of microscope without a lens that identifies the presence of a microorganism based on the fluorescence being emitted," explains Dr Catalan.

One of the main advantages of the system is that it can be implemented onsite, avoiding the need for sending samples to the lab and having to wait days for the results. In the case of *Legionella*, traditional methods based on culture isolation can take up to 12 days, whereas the CYTO-WATER (Integrated and portable image cytometer for rapid response to Legionella and Escherichia coli in industrial and environmental waters) platform provides conclusive results in just two hours. "This is a disruptive advantage in the rapid diagnosis of quality threats to environmental and industrial waters," says Dr Catalan.

Another advantage is that each of the three modules involved in sampling, labelling and counting pathogens can be sold individually, opening up a potentially far wider market. The automatic labelling module for example could be adapted to the workflow of laboratories of different sectors such as hospitals and universities.

"CYTO-WATER is a universal platform with applications for any waterborne microorganism," underlines Dr Catalan. There is huge potential here, from monitoring *Pseudomonas* and *Mycobacterium* in hospital facilities to spoilage and pathogen detection in food and beverage plants."

High specifications

To get to this point, the CYTO-WATER project team had to successfully overcome a number of key technical challenges. For example, water samples must be concentrated in order to improve the detection of pathogens, and the imaging cytometer has to be sensitive and robust enough to meet stringent regulatory standards. Different modules of the platform were adapted and validated individually to make sure they met with market specifications. "Another challenge was integrating the technologies involved in the concentration, labelling and detection of pathogens within a miniaturised analytical system," adds Dr Catalan.

Operational performance under real conditions was then evaluated. An environmental and economic comparison with traditional spot sampling indicated that CYTO-WATER was more environmentally efficient for *Legionella* detection, and is less costly due to the need for less personnel and transportation.

The results we achieved in detecting Legionella and E. coli demonstrate the technical capabilities of the system.

Following official completion of the project in May 2018, new business and exploitation plans are being drawn up to consider how manufacturing costs can be further refined. Commercial analyses will also be conducted to determine the level of customer demand for the platform and its individual modules.

"The results we achieved in detecting *Legionella* and *E. coli* demonstrate the technical capabilities of the system," says Dr Catalan. "However, market studies for other applications still need to be conducted, to fully assess the business potential."

PROJECT
CYTO-WATER – Integrated and portable image cytometer for rapid response to Legionella and Escherichia coli in industrial and environmental waters

COORDINATED BY
Labaqua in Spain

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
cytowater.eu

Designing a full recycling solution for the textile industry's waste water

Solutions which efficiently recycle industrial wastewater support an age of sustainable development innovations. The EColoRO concept scaled up within the ECWRTI project, which is low cost and environmentally friendly, offers a proposition which looks set to fit the bill.

Competing demands for fresh water across several sectors are rendering it an increasingly scarce resource. To counter this within industry, measures are currently being explored to increase the efficiency of water use.

The EColoRO concept scaled up within the ECWRTI (ECOLORO: Reuse of Waste Water from the Textile Industry) project has demonstrated the use of electro-coagulation (EC), combined with flotation, to efficiently remove pollutants, colorants and chemicals from textile industry waste water.

This innovation is followed by ultrafiltration and reverse osmosis (RO) membrane processes downstream. The approach has shown that the EColoRO concept could re-use waste water more cost-effectively than using fresh water and then discharging the waste.

The EColoRO concept

ECWRTI has worked to bring a new technological concept to the market that separates the water, organometallics and salty brine

in wastewater, to produce clean water that can be fully reused in the textile industry.

The innovation works by first treating wastewater effluent using electro coagulation, a technology well known in the galvanic industry, whereby Fe^{3+} ions are released from an iron source through electrolytic action from low voltage Direct Currents. The Fe^{3+} directly coagulates with the impurities present in the textile waste water, resulting in round shaped flocs which can be removed from the water by settling.

EColoRO offers new water management and distribution approaches for industrial parks and factories; and with comparable solutions not yet available on this scale, the proposition is unique.

After coagulation and flotation/sedimentation the water is passed through membrane processes, the resulting sludge is dewatered in a conventional chamber filter press, with the extracted water recycled for reuse as fresh water supply. As Mr Eric van Sonsbeek, co-owner of the EColoRO company elaborates, "The traditional recycling rate for wastewater is about 70 %. Using the ECWRTI technology, if the RO brine can be concentrated and crystallised on a commercial scale, recovery rates are predicted to reach above 95 %."

One of the key differences of the EColoRO concept compared to conventional technology is the intensity of the process, avoiding expensive technologies often applied in waste water treatment, such as advanced oxidation – due to the effective decolouring of the electro coagulation process.

Additionally, unlike biological treatments, in electro coagulation and physical/chemical treatment, the dosing requirement for pH correction is lower. This is possible due to the lower sensitivity of these processes for low and high pH, as no bacteria are involved in the process.

As Mr van Sonsbeek summarises, "Compared to conventional processes, the EColoRO concept is the most flexible, scalable and modular set-up currently available, and comes with a low footprint. It is also suitable for retro-fit, brownfield or greenfield applications."

Towards a healthy, sustainable and competitive industry

The long-term availability of affordable clean water is a key European Union priority, with Framework Directive 2000/60/EC specifically concerned with the prevention and reduction of pollution to protect the environment and aquatic ecosystems. Doing so also supports the sustainable use of water, while reducing the effects of flooding or drought.

As Dr Ir. Andreas ten Cate, Director International Business Development at the Institute for Sustainable Process Technology, adds, "To find new solutions, services and technologies, innovation for sustainable water use in society and industry gets significant attention from the EU, as witnessed by the activities of the European Innovation Partnership (EIP) on Water. EColoRO offers new water management and distribution approaches for industrial parks and factories; and with comparable solutions not yet available on this scale, the proposition is unique."

Working on the pilot scale of the technology allowed the project to determine the final design parameters for a demonstrator.

PROJECT
ECWRTI – ECOLORO: Reuse of Waste Water from the Textile Industry

COORDINATED BY
Institute for Sustainable Process Technology in the Netherlands

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
ecwrti.eu

Treating sewage with Microbial Electrochemical Technologies to produce clean water

Industrial symbiosis in the circular economy turns an output from one process into an input for another. The iMETland project has demonstrated that urban wastewater can be sustainably cleaned, and be suitable for irrigation, at no energy cost, using bacteria which make an electrical current from pollutants.

To help close the gap between innovative water solutions and marketplace replication, the iMETland (A new generation of Microbial Electrochemical Wetland for effective decentralized wastewater treatment) project developed a full-scale application of an eco-friendly technology which treats urban sewage produced by small communities, with zero-energy costs. The technique combines constructed wetland biofilters with Microbial Electrochemical Technologies (MET).

© iMETland

Combining electroactive bacteria with electroconductive material has resulted in depuration rates that are 10 times higher than with traditional techniques. Additionally, as the result is very low biomass, it avoids clogging the biofilters with sediment (colmatation).

Crucially, the process removes pollutants from the wastewater and, after electro-oxidative treatment, produces water which is pathogen-free and suitable for irrigation. Having already passed the research and pilot phases of development, EU-funded support has allowed iMETland to progress to a full-scale demonstration to accelerate market uptake.

Tapping the living cell social network

The iMETland technique of bacteria induced pollutant reduction essentially uses the same method for harvesting energy as we use for food. As project coordinator Dr Abraham Esteve-Núñez, explains, "We extract electrons from food, which are in turn consumed by the oxygen we breath. The electroconductive material used in our system shows an unlimited capacity to accept electrons and so bacteria can keep eating pollutants at a higher rate."

We extract electrons from food, which are in turn consumed by the oxygen we breath. The electroconductive material used in our system shows an unlimited capacity to accept electrons and so bacteria can keep eating pollutants at a higher rate.

The electrons running through the iMETland electroconductive biofilter material create an electrical current which allows the microbial communities to interact with each other, at distance. Optimising this 'electro-talking' amongst the microbial community enhances the efficiency of clean-up efforts.

Once the water is free of chemical contaminants, iMETland can generate bleach from the chloride naturally present in the water, which kills bacteria creating water safe for irrigation purposes.

What makes the technology especially innovative is the intensity of the ability of the electroactive bacteria's metabolism to convert pollution into electricity, which is proportional to the quantity of pollutant removal. The more they eat, the more electricity is harvested, and by measuring the electricity generated, operators can monitor the efficacy of the bacteria in removing contaminants through specially designed smart tools.

"The main challenge of iMETland was coping with real conditions such as unexpected seasonal changes, so we tested for cold Northern Europe winters and hot Mediterranean summers," Dr Esteve-Núñez reflects. He goes on to add that, "A nice surprise was the dominance of the electroactive Geobacter bug in the presence of oxygen, increasing the technique's performance. This bacterium has always previously been cultured away from oxygen, so our finding reminds us that natural adaptation is stronger than scientific prejudgment."

Contributing to water and wastewater priorities

The multidisciplinary nature of iMETland aligns well with the water and wastewater treatment priorities of the EU's EIP Water initiative. It specifically addresses the ambition of creating water treatment innovation hubs in regions currently lacking appropriate sewer treatment systems and sanitation facilities. As it offers a system that reduces the amount of energy needed to treat wastewater, so it decreases municipalities' costs and CO_2 emissions.

Currently, iMETland units that have already been tested can be integrated within small communities to irrigate gardens or green areas, with the plant-based solution increasing the visual appeal of facilities. An additional target for adoption of the solution is public buildings. Towards this end it has already been implemented at IMDEA Water.

"Metland is already a registered brand and the concept is ready to reach the market through a start-up SME called METfilter, founded for this purpose," summarises Dr Esteve-Núñez.

PROJECT
iMETland – A new generation of Microbial Electrochemical Wetland for effective decentralized wastewater treatment

COORDINATED BY
IMDEA Water in Spain

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
imetland.eu

Zero energy, low water consumption irrigation for agriculture

An EU-funded consortium developed large-scale photovoltaic irrigation systems that are completely powered by renewable energy and have been shown to reduce water consumption by around 30 %.

© MASLOWATEN

Developed and trialled through the EU-funded MASLOWATEN (MArket uptake of an innovative irrigation Solution based on LOW WATer-ENergy consumption) project, the technology has since been transferred to 27 European SMEs, which are currently in the process of commercialising and installing the systems for farmers. "These photovoltaic irrigation systems do not belong to the future," says project coordinator Dr Luis Narvarte from the Polytechnic University of Madrid in Spain. "They belong to the present, and we expect fast market growth."

A pressing issue

Irrigation is of vital importance for food security, employment and economic development. While irrigated agriculture takes up just 20 % of the cultivated surface of the earth, it produces more than 40 % of the world's food. In areas where precipitation is subject to high inter-annual and seasonal variability, irrigation is essential in supporting crop diversification, assuring yield and quality and stabilising food supplies.

This reliance on irrigation however is coming under increasing pressure. Despite water scarcity concerns, land is all too often irrigated without efficient devices or controls on the volume of water needed. "Also, modernised irrigation is based on sprinklers, pivots and drip systems that require pressure to work," notes Dr Narvarte. "These consume electricity produced with conventional sources resulting in CO_2 emissions."

This has become a major concern. Dr Narvarte estimates that the Mediterranean area as a whole may face an increase in gross irrigation requirements of between 4 and 18 % due to climate change alone if irrigation systems are not improved.

Sustainable, marketable solutions

The MASLOWATEN project therefore sought to speed up the commercialisation of smart renewable energy-powered irrigation systems within the agricultural sector in order to give farmers the tools to achieve sustainable high-yield production. This was achieved in part by removing the technical barriers to large-scale photovoltaic irrigation systems.

"Some of the problems we overcame were related to power intermittences due to, for example, passing clouds, and matching PV electricity production to water needs," explains Dr Narvarte. "We were able to evaluate the operation of the demonstrators over two years."

During the project, five full-scale demonstrators were implemented across regions of Spain, Portugal, Italy and Morocco. Each pilot covered the different needs of farmers, co-operatives, irrigator communities and agro-industries, and were monitored for two years to demonstrate their technical reliability, economic feasibility and environmental friendliness. "These end users then communicated their experiences and, believe me, they are now recommending large-power irrigation systems to other colleagues."

The demonstrators also showed impressive economy, allowing farmers to irrigate with renewable electricity and achieve energy cost savings of between 60 % and 80 %. Water consumption reductions were estimated at between 22 % and 34 %. "We put the payback period for energy and CO_2 emissions at between two years and nine years; that is to say, it should take between two and nine years to pay back the energy and CO_2 emissions that were put into their manufacturing. The operational life of the technology should be more than 25 years."

The project team developed tools to smooth the market uptake of large-power PV irrigation systems, such as: technical specifications assuring their quality and design; simulation models; environmental accreditations; and business plans for their commercialisation.

We have estimated the potential market for this technology to be at around 16 GW for the south of Europe alone.

Dr Narvarte is positive that sustainable solutions to some of the world's pressing issues are now being realised. "The ultimate goal of MASLOWATEN has been to ensure market uptake of this solution, and to have a real impact on the European economy and environment," he says. "We have estimated the potential market for this technology to be at around 16 GW for the south of Europe alone. This would represent potential business of some EUR 24 billion, more than 290 000 new jobs and more than 16 million tons of CO_2 emissions reduced every year."

PROJECT
MASLOWATEN – MArket uptake of an innovative irrigation Solution based on LOW WATer-ENergy consumption

COORDINATED BY
Technical University of Madrid in Spain

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
maslowaten.eu

Satellite data ensures smooth flow of water resources

The MOSES platform puts earth observation data from satellites and cutting-edge forecasting technology at the fingertips of water authorities and agencies, helping them to make informed decisions on procuring and managing supplies.

This gives water authority managers, research institutions and the like the knowledge to minimise drought risks, reduce unnecessary water consumption and supply farmers with exactly what they need for their crops; a hugely important task given that agriculture is one of the largest water-consuming sectors.

"The project came about partly in response to the challenges posed by climate change," explains the EU-funded MOSES (Managing crOp water Saving with Enterprise Services) project coordinator Dr Alessandro di Felice from ESRI in Italy. "Everyone involved in agriculture is aware that this phenomenon exists; for example, we've recently seen droughts in Italy and floods in Romania. We wanted to develop a support tool that addresses these kinds of problems that increasingly arise seasonally."

Better water management

The online platform brings together mapping and geographic information system (GIS) technologies as well as seasonal and in-season weather forecasts, which deliver strategic information both before the irrigation season – in March and April – and during the irrigation season. Being able to better plan water procurement and allocation before the start of the irrigation

© MOSES

season would help to mitigate against water shortages, while continuous in-season monitoring of crop water requirements would enable suppliers to adjust their allocation plans throughout the growing season.

After the irrigation season the system's forecasts can be compared to what actually occurred, together with an analysis of water and cost savings made. This can help in planning water procurement and allocation before the next irrigation season and provide advice to farmers about water shortage risks.

"Procurement and distribution agencies have typically distributed constant volumes of water with little variability," notes project partner Dr Giulia Villani from Agromet in Italy. "Climate change however has had dramatic effect, with huge variabilities in precipitation and temperature. In Northern Italy in 2014 for example we had a very wet summer and thus a decrease in irrigation volumes, while 2017 was extremely dry. This platform makes available valuable information on whether certain areas will need more or less water than average."

The platform makes available valuable information on whether certain areas will need more or less water than average.

Avoiding crises

During the project, four demonstration areas were set up in Italy, Spain, Romania and Morocco. Different water procurement and distribution scenarios were considered along with user needs and the possible incorporation of existing local services. In the Italian test case for example, water is delivered either through pressurised irrigation systems or through channels. The tool enabled authorities to estimate irrigation water needs at the district level by providing drought indicators and weather information, and highlighting potential technical issues such as black-out risks.

The tool was shown to effectively support agriculture water use efficiency, water resource monitoring and flood and drought risk management. "Another positive result was that the end users involved asked for the pilot projects to be expanded," says project partner Dr Maria Gabriella Scarpino from SERCO in Italy. "This shows that the system has been seen to be useful. Although it is a little early to say, we think that, in the areas where we have been working, approaches to irrigation water use will have to change."

While project partners are continuing to use the prototype platform, there are plans to expand operations through a third party. "This would be an expert in the water management sector, who would provide the service to end users such as water management agencies, reclamation consortia and farming associations through a web app," explains Dr di Felice.

The online platform has been designed to be flexible and adaptable, and is capable of including new features and GIS products related to Copernicus, the EU's earth observation satellite system. These might include more high-resolution optical imagery for land agriculture or more accurate land-surface temperature measurements. Europe must make better use of its water resources if it is to achieve its sustainable development goals, and the MOSES platform offers a practical tool to help meet these targets.

PROJECT
MOSES – Managing crOp water Saving with Enterprise Services

COORDINATED BY
ESRI in Italy

FUNDED UNDER
H2020-ENVIRONMENT

Towards net energy wastewater treatment using current technology

Municipal wastewater treatment in Europe consumes the energy equivalent of around two power stations per year – but could actually be generating the energy of 12. The EU-funded POWERSTEP project demonstrates how to make this more than a pipe dream.

Whilst much of the European wastewater treatment industry, with incremental energy efficiencies, is looking to achieve energy neutrality – where treatment generates the same amount of energy as it consumes – research indicates that the level of ambition could be much higher.

Studies point to the fact that processing sewage at treatment plants could already offer a new source of renewable energy, without compromising performance. In fact, it has been calculated that the potential chemical energy contained within European municipal wastewater is about 87 500 GWh per year.

The EU-funded POWERSTEP (Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration) project set out to show just how it is possible to achieve energy-positive wastewater treatment plants without any other external renewable energy sources, by only using the power of sludge.

The overall POWERSTEP concept could be achieved, drawing on lessons from six full-scale case studies, spread across four countries, of each essential process step. Benefiting from the involvement of industry partners, the project was able to move to large scale demonstrations, paving the way to quick market roll-out and supporting the business plans of participating technology providers.

Integrating technologies

POWERSTEP was set up to integrate the various individual technology assessments developed in the case studies pre-dating the project. This enabled the researchers to streamline whole processes such as treatment scheme modelling and design, global energy and heat management, carbon foot printing and integrated design options.

The key first stage of the POWERSTEP wastewater treatment plant concept for enabling energy-neutrality, or even energy-positivity, is carbon extraction. The extraction of carbon rich sludge (with an 80 % extraction rate possible using POWERSTEP technology) allows a strong increase in biogas production.

© POWERSTEP

In terms of improved treatment methods towards this end, the team investigated enhanced carbon extraction (pre-filtration), innovative nitrogen removal processes (such as advanced control, main-stream deammonification, duckweed reactor), power-to-gas (biogas upgrades) with a smart grid approach, heat-to-power concepts (thermoelectric recovery in combined heat and power units, steam rankine cycle, heat storage concepts) and innovative process water treatment (nitritation, membrane ammonia stripping).

Energy-neutral wastewater treatment is not illusionary anymore, we have shown that it is absolutely possible now with commercially available state-of-the-art technologies.

As Dr Christian Loderer explains, "Across the EU, wastewater energy self-supply – that is biogas production for electricity production – is at very different levels. In some countries such as the Netherlands and Germany, self-supply is high but not reaching the energy-neutrality of 100 % (except in very few cases). Other countries, especially in Eastern Europe, have very low self-supply, missing 50-80 % of the energy-potential of their wastewater."

This highlights the fact that there are a number of barriers to be overcome. One is that biogas from water treatment is currently not yet accepted as a quality renewable energy, in comparison with biogas from energy crops. This is despite the negative side-effects of biogas from crops such as the creation of corn monocultures, excessive fertiliser application and nutrient release into the aquatic environment. Conversely, biogas from sewage sludge does not have these negative side-effects.

Contributing to the circular economy

POWERSTEP, with its practical examples of how to best produce renewable energy from wastewater, significantly contributes to EU efforts towards transitioning to the circular economy, guided by ambitions for sustainability across society, the economy and the environment. This fact was recently underlined by the Director-General of the European Commission's DG Energy, Dominique Ristori, who described POWERSTEP as, "extremely well placed when considering the priorities of the Energy Union."

Furthermore, with the electricity to run treatment plants costing around EUR 2 billion per year, the savings could be pronounced. Dr Loderer contends that if municipalities were to follow the POWERSTEP approach, EU citizens would also directly benefit with reduced energy bills.

"Energy-neutral wastewater treatment is not illusionary anymore, we have shown that it is absolutely possible now with commercially available state-of-the-art technologies," as Dr Loderer says. And with the Altenrhein Waste Water Treatment Plant in Switzerland now equipped with a full-scale Nitrogen-recovery unit, which had been studied in detail by the POWERSTEP partner EAWAG, momentum is literally building.

Looking to the future Dr Loderer adds that, "Energy-positive treatment, up to 140-170 %, is also possible but still requires more work on technology reliability and economic viability, for full-scale systems to be rolled out."

In the immediate term, as a proof of concept showing that the technology works for the small as well as large scale, the team is in discussions with key industrial partners from the project on how to establish a network of small wastewater treatment plants which will partly implement POWERSTEP approaches.

PROJECT
POWERSTEP – Full scale demonstration of energy positive sewage treatment plant concepts towards market penetration

COORDINATED BY
Berlin Centre of Competence for Water in Germany

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
powerstep.eu

Reducing water scarcity by restoring contaminated groundwater aquifers

The fight against water scarcity is becoming one of the main 21st century challenges, with securing a clean supply key to efforts. The REGROUND project has developed a novel, green groundwater innovation and is ready to introduce it to European markets.

Municipal, agricultural and industrial demand for water is growing worldwide. At the same time, water resources are increasingly being degraded, due to infrastructure erosion and pollution.

Toxic metals contaminating groundwater sites, drinking wells or river bank filtration sites, present the most common threat; with numerous methods available for their removal or immobilisation. However, these frequently require a prohibitively high financial and technical investment, making them unavailable to many regions.

To combat this situation, the EU-funded REGROUND (Colloidal Iron Oxide Nanoparticles for the REclamation of Toxic Metal Contaminated GROUNDwater Aquifers, Drinking Water Wells, and River Bank Filtrations) project has developed low cost nano-geotechnology for the immobilisation of toxic contaminants. The project applied the groundwater remediation technology at real-scale, with three pilots and two large-scale barriers installed within industrially-polluted sites, observing the reduction in dissolved toxic heavy metal in groundwater.

An adsorptive *in situ* barrier

Prior to the REGROUND project, the team had already had a few years' experience developing technology which injected iron oxide nanoparticles (NPs) into groundwater contaminant plumes. The feasibility of this approach was successfully tested in lab experiments and in the field.

Outlining REGROUND, the project coordinator Dr Sadjad Mohammadian says, "Our consortium has worked on several projects using nanotechnology for environmental applications. Different aspects of the proposed technology, including distribution of particles in the underground, synthesis of new particles, reactivity and environmental toxicity, have been developed by our members. In REGROUND we consolidated this knowledge to upscale and bring it to the market."

The REGROUND's barrier method works by injecting the high-tech iron oxide NPs into sediments, using simple wells in aquifers. The NPs travel pre-determined distances and then precipitate on the aquifer material, without blocking pores.

By bringing our cost-effective technology to the market, we will help stimulate innovation in the water sector, facilitating public and private efforts to improve European, and global, groundwater recovery.

For Dr Mohammadian this stage represented the biggest challenge to the project, "We had to produce meta-stable NPs; that is, that remain in suspension, not precipitate or sediment during synthesis, production, transport and injection, only starting to precipitate after injection." As Dr Mohammadian goes on to explain, "This required us to develop an innovative synthesis, easily adaptable to the properties of each aquifer."

The contaminated groundwater then flows through this NP zone, where the dissolved toxic heavy metals are adsorbed to the NPs, with metal-free water then released downstream. As it is easy to apply and does not require large-infrastructure and soil removal, cleaning costs are significantly reduced.

The approach specifically targets arsenic, barium, cadmium, chromium, copper, lead, mercury and zinc, all identified as major groundwater contaminants.

After two pilot applications, REGROUND adopted the innovation for two contaminated aquifers in industrial locations, in Spain and Portugal. The project's post-injection monitoring results indicate that heavy metals were successfully removed at the levels targeted in the remediation plan. These results indicate that the technology is market-ready.

The project further approved the applicability of the technology via two additional pilot tests. In an industrial park in Germany, a zinc contamination was treated while normal daily actions on the site were carried out. Additionally, a drinking water well in Iran contaminated with geo-genic arsenic was cleaned using REGROUND technology. These cases showed that the technology can be applied in a wide range of locations, regardless of the source and size of contamination.

As Dr Mohammadian summarises, "The technology's near-market replication and subsequent commercialisation efforts are an integral part of REGROUND. This will enable immobilisation of toxic metal contaminations at sites which have been left untreated so far due to technical or economic reasons."

Stimulating water sector innovation

The ambition of REGROUND aligns with the scope of the EU's water policy, specifically Directive 2013/39/EU, which seeks to bring new water cleaning technologies to the market.

To further advance the work more immediately, the project team is now entering the market of groundwater reclamation by creating a spin-off company. This company, ColFerrox GmbH, offers its products and technology to treat heavy metals and other contaminations, such as cyanide and polycyclic aromatic hydrocarbons (PAHs).

Expanding on this, Dr Mohammadian says, "By bringing our cost-effective technology to the market, we will help stimulate innovation in the water sector, facilitating public and private efforts to improve European, and global, groundwater recovery."

PROJECT
REGROUND – Colloidal Iron Oxide Nanoparticles for the REclamation of Toxic Metal Contaminated GROUNDwater Aquifers, Drinking Water Wells, and River Bank Filtrations

COORDINATED BY
University of Duisburg-Essen in Germany

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
reground-project.eu

Ceramic solution opens recycled wastewater possibilities

Ceramic membranes manufactured from recycled locally-sourced materials could facilitate the cost-effective recycling of treated wastewater and help address water shortages.

© REMEB

Trials of the membranes developed through the EU-funded REMEB (Eco-Friendly Ceramic Membrane Bioreactor (MBR) based on Recycled Agricultural and Industrial Wastes for Waste Water Reuse) project, have demonstrated how municipal facilities can cost-effectively filter and recycle wastewater for a range of uses, including street cleaning and even agricultural irrigation. The innovation could also enable industries to recycle their own wastewater and in doing so cut costs and reduce their environmental footprint.

"We tested the membranes at the Aledo municipal wastewater treatment plant in Murcia, Spain," says REMEB project coordinator Elena Zuriaga from FACSA in Spain. "Following the success of this, our plan is to continue working on improving the

ceramic membranes and bring the solution into the industrial environment."

Reusing resources

Wastewater treatment through the use of a filtering MBR has been recognised as one possible solution to increasing the amount of recycled water in circulation. These MBRs however – which often feature inexpensive polymeric membranes – tend to have low thermal, mechanical and chemical resistance, which limits their efficacy. In addition, not all countries are comfortable with using recycled wastewater, a mentality that Zuriaga and her team hope to change.

We need to be innovative and be openminded to find solutions for water reuse.

"We have to find new ways of reusing water," she says. "At present only 2.4% of treated wastewater in Europe is reused, and we have to work at increasing this number. We need to be innovative and be openminded to find solutions for water reuse."

Water scarcity is a critical issue and wastewater recycling less of a taboo, with water used for street cleaning subject to less restrictive recycling requirements. In such instances, ceramic membranes could provide municipal facilities with an economical means of delivering recycled wastewater for such purposes. For end uses such as agricultural irrigation where higher standards must be met, different ceramic membrane standards apply specific selective layers (in other words, decreasing the pore sizes).

Recycled materials

Another important element of the REMEB project was that it set out to develop these membranes by using raw material and waste found in the region, reducing the landfill disposal. In this way, the project planned to create potential new revenue streams for local industrial waste.

"In the neighbouring Spanish region of Castellón (Comunidad Valenciana) where we sourced raw materials, this meant manufacturing ceramic membranes from waste collected from the local ceramic tile industry, as well as using olive oil solid wastes and marble powder wastes," says Zuriaga. "We even trialled rice harvest waste, given that the Valencia region is the home of paella!"

Other raw materials trialled in Spain as well by project partners in Italy and Turkey included coffee, almond and hazelnut shells. Organic matter burnt at high temperatures is used to create the pores that allow water to flow through. After development, the membranes were trialled at the municipal wastewater plant of Aledo in Murcia. This region was selected for validation since it promotes the reuse of reclaimed water for agricultural purposes.

"One of the challenges was scaling up from the lab to the industrial level, where processes are far harder to control," says Zuriaga. "We experienced cracked ceramics at the beginning, but found that we were able to solve this by modifying the temperatures during the sintering process and adjusting the composition."

Production of the optimised membranes was then replicated at the pilot scale with partners in Turkey and Italy, where again, regional recycled materials and waste products were used. "I am very proud that we have been able to manufacture membranes from agricultural and industrial waste, which will contribute positively to the circular economy," says Zuriaga.

PROJECT
REMEB – Eco-Friendly Ceramic Membrane Bioreactor (MBR) based on Recycled Agricultural and Industrial Wastes for Waste Water Reuse

COORDINATED BY
FACSA in Spain

FUNDED UNDER
H2020-ENVIRONMENT

PROJECT WEBSITE
remeb-h2020.com

Subsurface Water Solutions for stressed coastal regions

Securing freshwater for drinking water, industry and agriculture requires radical changes to the way we manage our water resources. SUBSOL does just that: opening up, restoring and managing underground aquifers to solve water challenges worldwide.

Worldwide, coastal regions are amongst the most economically productive and the most populated regions. The high demand this exerts on food supplies, as well as freshwater resources and ecosystems, puts these areas at risk of problems like seasonal water shortage, saltwater intrusion, and wetlands disappearance. And this situation is predicted to get even more pronounced in the decades to come, necessitating a step-change in water management and use, especially in freshwater storage and water reuse.

SUBSOL (bringing coastal SUBsurface water SOLutions to the market), an EU-funded project, has successfully demonstrated the technical capacity of the subsurface to temporarily store and preserve freshwater to secure additional water supply during periods of shortages. The project developed a range of practical approaches to water storage and management (so-called Subsurface Water Solutions) that can be applied to resolve local and regional freshwater challenges.

© SUBSOL

Developing a Subsurface Water Solution toolbox

Subsurface Water Solutions (SWS) make use of the subsurface's potential to store water. Water storage in the subsurface has been applied for many decades using Managed Aquifer Recharge (MAR) and Aquifer Storage Recovery (ASR) techniques. For example, to supply drinking water in the western part of the Netherlands, riverine water is temporarily stored in the dunes.

The SUBSOL team focused on the development and demonstration of different technical concepts to store freshwater in coastal settings, where saline and brackish aquifers currently prevail. As project coordinator Dr Gerard van den Berg explains, "Recovery of previously stored freshwater is particularly challenging in coastal aquifers because freshwater and saline water will mix to a certain extent. Also groundwater flow may hamper recovery of previously stored water."

For this reason, not all aquifers are suitable for storing water and so SUBSOL developed concepts, based on the use of vertical or horizontal wells, and systems with single or multiple screens, which could maximise water storage and recovery rates.

Testing various methods, SUBSOL scaled-up existing reference sites where concepts for water storage had already been successfully applied. As Dr Van den Berg elaborates, "Building on experiences from these reference sites, a number of replication sites were developed. Subsurface water solutions were tested under a variety of geological conditions, and purposes, for example for agricultural, drinking water, ecological and industrial applications, as well as water reuse."

The project in effect created an SWS design toolbox, offering details on the technical feasibility of different options, including: the ASR-Coastal (vertical wells with multiple screens); Freshmaker (based on horizontal wells with simultaneous extraction of freshwater and brackish water); and Freshkeeper (based on vertical wells with simultaneous extraction of freshwater and brackish water). As Dr Van den Berg says, "The toolkit is designed to help water managers design the best SWS system to meet their needs."

In terms of ensuring market acceptance of the solutions, SUBSOL collaborated right from the start with engineering companies as well as end users, such as members of the water industry or drinking water utilities. Additionally, besides testing subsurface water solutions under natural conditions, market studies were also carried out into worldwide opportunities. These have shown clear potential for the application of SWS not only in Northwest Europe and the Mediterranean region, but also in the Gulf of Mexico, Brazil, China, Singapore and the Gulf region.

Pressing water problems call for radical solutions

Water reuse is one of the most widely accepted approaches used to tackle the lack of freshwater for domestic use and irrigation. However, successful practices strongly depend on supply and demand, in terms of not only volumes, but also timing and quality. The subsurface provides an almost endless capacity for temporary storage and has the potential to protect the injected water from quality deterioration.

SUBSOL has demonstrated the successful application of Subsurface Water Solutions thanks to innovations in pre-treatment, water well designs, groundwater modelling and management, control and decision support systems.

"SUBSOL has demonstrated the successful application of Subsurface Water Solutions thanks to innovations in pre-treatment, water well designs and groundwater modelling and management," Dr Van den Berg reflects.

Follow up research and implementation will focus on the scaling up of SWS from small sized (2-30 ha) to intermediate sized systems (of approximately 250 ha in commercial systems already in construction) and on to regional scale water solutions (> 1 000 ha). This work is undertaken through public private partnerships, with research organisations and consultancy companies jointly developing SWS applications.

In the meantime, SUBSOL leaves behind a knowledge base of data, information and experiences that it has made available to interested parties.

PROJECT
SUBSOL – bringing coastal SUBsurface water SOLutions to the market

COORDINATED BY
KWR Water B.V. in the Netherlands

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RESULTS PACK ON THE CIRCULAR ECONOMY

This Results Pack focuses on how the Circular Economy can help reduce Europe's waste problem. Innovative solutions are being researched through the EU Horizon 2020 funding programme and this interdisciplinary CORDIS Results Pack highlights some of the most exciting projects that are busy promoting waste reduction and improved resource efficiency in the textile, construction, photovoltaic, steel industry, bulky and urban waste sectors.

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