Federal Ministry of Education and Research

An Initiative of the Federal Ministry of Education and Research
WavE
Water Technologies: Reuse

Water Technologies: Reuse (WavE II)

Water is the key to sustainable development. In many regions of the world, however, water is becoming increasingly scarce, while global water demand continues to grow as a result of population growth, dramatically increased industrial and agricultural activity as well as rapid urbanization. Climate change is also causing more frequent and more extreme water events such as heatwaves and strong rainfall, resulting in water stress even in regions that were unaffected in the past. And Germany is no exception—here, too, severe dry periods in recent years have led to crop failure in some regions. To help meet the water needs of industry, agriculture, and private households as we move forward into the future, one of the main approaches will be to close water cycles by reusing treated wastewater.

In light of this, the Federal Ministry of Education and Research (BMBF) launched the funding program Water Technologies: Reuse (WavE II), which seeks to develop innovative technologies, operational concepts, and management strategies for water reuse and desalination that will sustainably increase water availability. Since early 2021, a total of 13 joint projects have been under way spanning three different thematic research areas: Water reuse by utilizing treated municipal wastewater, recycling of industrial water, and treatment of saline groundwater and surface water.

WavE II will contribute to the implementation of the UN Sustainable Development Goals (SDGs) as well as European regulations on water reuse. The funding measure is a continuation of the earlier initiative WavE (Future-oriented Technologies and Concepts to Increase Water Availability by Water Reuse and Desalination) which was completed in 2020. WavE II is part of the BMBF "Research for Sustainability" (FONA) strategy.

The joint projects will be accompanied by the networking and transfer project Trans-WavEplus, which will constitute the overarching interdisciplinary framework for the different projects both internally and externally, supporting results transfer to field applications at national, European, and international level. The primary focus of the projects is the development of application-oriented solutions for water reuse that address relevant technical challenges, economic requirements, and overall social and organizational conditions.

The R&D work is supported by a steering group comprising coordinators from within the individual projects as well as external experts from the water industry. The steering group serves as an interface between research and practice and facilitates direct exchange of knowledge and information as well as results transfer.

Water Technologies: Reuse (WavE II)

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FONA
Sustainable Water Management

WavE II: Joint Projects and Locations

(by thematic research areas)

Municipal Wastewater

1. FlexTreat
2. HypoWave+
3. Nutzwasser
4. PU2R

Industrial Water

5. FITWAS
6. Med-zeroSolvent
7. NERA
8. ReWaMem
9. RIKovery
10. WEISS_4PN

Saline Groundwater and Surface Water

11. HaSiMem
12. innovatION
13. SULFAMOS

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An Initiative of the Federal Ministry of Education and Research
WavE
Water Technologies: Reuse

FITWAS—Reuse of Filter Rinse Water from Groundwater Treatment to Secure Drinking Water Supply

Water Technologies: Reuse (WavE II)

During the uncharacteristically hot summers of 2018 to 2020, many of Germany's water treatment plants were stretched to breaking point trying to meet the dramatically increased demand for drinking water. At the same time, population growth and new commercial developments have caused the demand for water in cities and municipalities to rise to an unprecedented level—and this is unlikely to change. Consequently, many water suppliers need additional raw water to produce drinking water. However, the water rights process is long-winded and the construction of new wells costly. The partners in the joint project FITWAS are investigating an alternative: the use of backwash water produced during drinking water treatment. They will be trialing membrane filtration processes to identify the most energy-efficient and cost-effective way of recovering and reusing this water.

Identifying New Sources of Drinking Water

A total of 60 percent of Germany's drinking water is recovered from groundwater. The water is generally treated based on a natural process of filtration, to remove the iron and manganese from the raw water. This produces an iron-rich filter sludge which has to be regularly rinsed out of the filters. The resulting backwash water is collected in basins or ponds, where the sludge settles and, regardless of its composition, is either disposed of or reused. The waterworks then channels the clear water into nearby streams or rivers.

As a result, between one and four percent of groundwater that could be used for drinking water is wasted in the form of backwash water. At first glance, this does not seem much—until we consider that a medium-sized water treatment plant produces around one million cubic meters of drinking water each year Consequently, if just part of the backwash water were to be reused in drinking water production, this would amount to substantial water savings.

Settling basin for backwash water. With the water drained away, the sludge that has settled on the basin floor is clearly visible.

This is where the FITWAS project comes in. Here, the project partners aim to identify additional sources of drinking water by developing viable membrane filter processes for the reuse of filter rinse water from groundwater treatment. The project is also exploring ways of reusing filter sludge.

Which Process Works Best?

There have already been several attempts at treating filter backwash water with membrane filters. These processes used microporous ultrafiltration membranes to produce water of a microbiologically safe quality. This backwash water is suitable for drinking water production.

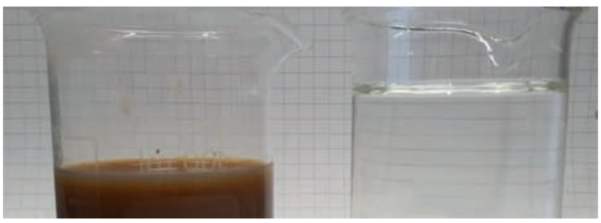
Due to the comparatively high costs, as well as technical issues, recovery of backwash water has not yet become an established practice. Given the increasing demand for untreated water and advancements in filtration technology, however, it would be well worth considering this option for use by waterworks in future. In light of this, as part of the FITWAS project, research is being conducted into what type of membrane filtration is the most cost-effective and how technical problems can be avoided.

First, the project team conducts laboratory tests on different process concepts (positive or negative pressure filtration), different membrane module shapes, and membrane materials and compares them with conventional treatment technologies such as sand filtration. In terms of materials, the project researchers are also exploring the option of ceramic membranes.

These are a more recent development and will be used for the first time in the treatment of filter backwash water. These ceramic membranes are expected to be more energy-efficient and thus also cost efficient. They are suitable for use at high water temperatures, which is an advantage when it comes to exporting to countries with warmer climates. Moreover, the project team expects these filters to have higher operational stability.
After the laboratory phase of the project, trials will be conducted in four different waterworks. Here, operational parameters and purification strategies will be developed to ensure that the membrane filtration process is both stable and energy efficient. The pilot treatment plants will serve as the basis for the construction of large-scale plants in the future. Parallel to this, FITWAS is investigating whether membrane filtration also provides advantages for the use of filter sludge—the sludge that goes through the membrane filtration process is purer than that which settles in basins or ponds. If the sludge is then treated and achieves the requisite quality, this might mean it can be used in drinking water production, agriculture and forestry, in biogas production, or in the brick-making industry, for instance.
The reuse of backwash water and recycling of filter sludge must also be supported by relevant legislation. Regarding the requisite conditions when it comes to the quality of the water—particularly from a microbiological perspective—and of the sludge—especially as regards heavy metal content—, the project partners are coordinating with the health ministries, the national and federal authorities, as well as different institutional bodies.

Advice for Waterworks

The aim is for the project findings to culminate in a set of guidelines for waterworks. These guidelines will provide information on which membrane process is most favorable for the reuse of backwash water and under what conditions. Here, requirements for use in other countries will also be taken into account with a view to promoting export opportunities for German water technology providers.



A sample of backwash water before and after membrane filtration

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Reuse of Filter Rinse Water from Groundwater Treatment to Secure Drinking Water Supply (FITWAS)

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WavE
Water Technologies: Reuse

FlexTreat—Flexible and Reliable Concepts for Sustainable Water Reuse in Agriculture

Water Technologies: Reuse (WavE II)

Drought affects countries the world over, and Germany is no exception, with regions across the country facing drought with increasing frequency. Agriculture, in particular, struggles with the impacts of climate change. When it comes to the water management approaches employed to date, therefore, a rethink is needed. There is untapped potential in municipal wastewater, for example. The goal of the joint project FlexTreat is to develop flexible technical and natural treatment systems to allow the safe recovery of purified wastewater for use in agriculture.

Safe, Clean Water for the Fields

Currently, only a very small share of the total volume of water used in Germany goes into agricultural irrigation. In regions that are particularly hard hit by drought, demand for irrigation water could, however, increase dramatically in the future. Wastewater reuse is thus becoming increasingly important in Germany. Any potential risks of reusing wastewater should be minimized through advanced treatment processes.

At the EU level, new legislation in place since December 2019 has set out the minimum requirements for reuse of wastewater. In order to meet these requirements, conventional wastewater treatment processes often simply need to be very slightly expanded and/or adjusted. The FlexTreat project aims to test the effectiveness of these novel advanced treatment methods based on a broad spectrum of physical, chemical, and microbiological water quality parameters. During this process, for reasons of groundwater protection and food safety, the project partners also consider potential for recontamination, antibiotic resistance, and what are known as trace substances, which are very low concentrations of undesirable synthetic substances dissolved in the water.

The focus of the project is on four specific process combinations used in wastewater treatment alongside the conventional sewage treatment process. At the same time, the project partners are also employing new computer-controlled process monitoring methods and developing these further. The plan is to ensure that ambitious quality targets are consistently and reliably met, e.g., ensuring that the treated wastewater is suitable for all irrigation purposes across the board.

A center pivot sprinkler being used to irrigate a field. In future, wastewater purified in advanced treatment processes can be used as alternative source of agricultural irrigation.

Flexible High and Low-Tech Solutions

The project researchers will analyze and compare the different process combinations for advanced wastewater treatment at four locations either in a pilot-scale or a large-scale project. Here, the following technologies will be investigated: ozonation, rapid filtration, UV disinfection, soil filters, activated carbon adsorption, ultrafiltration, treatment using constructed wetlands, as well as disinfection using innovative electrochlorination. The process combinations cover both high-tech applications (ozonation and activated carbon adsorption + membrane filtration) and less technically complex solutions (retention soil filters and constructed wetlands treatment systems). The latter are also suitable for use in rural regions where the infrastructure does not allow for the construction of high-tech plants.

As a result, the analysis is not only relevant for Germany but also provides knowledge and insights for potential sales markets in the Mediterranean or the Middle East.

The project researchers will also assess the transferability of the technologies to the aforementioned markets based on country case studies, including for Spain, Egypt, and Bahrain.

Digital technologies will be used to help optimize the effectiveness of the processes in respect of the broad range of quality parameters. Various new methods will be trialed, including computer-controlled process monitoring which combines online measurement techniques with modern data analysis (online simulation, machine learning, digital twin). This enables the operation of treatment plants to be successfully adapted to specific requirements when it comes to the volume and quality of water, thus producing treated water that can be safely reused.

Moreover, the project partners are working on developing an evaluation methodology to enable them to select suitable process combinations in future. Alongside the desired water quality, this also takes into account possible health risks, as well as the robustness of the systems that have been developed, and economic and environmental aspects.

Promoting the Potential for Reuse

Although the reuse of treated wastewater is something that is already happening in many places around the globe, various factors, including the lack of a clearly defined legal framework and a lack of acceptance, has prevented wastewater reuse from become standard practice in Germany so far. In light of this, the FlexTreat project partners will consolidate the results of this joint project in a compact set of guidelines that will provide practical recommendations on treatment processes and the potential of digital technologies in the reuse of wastewater, as well on risk management. In addition, the guidelines will address questions pertaining to the legal framework and the acceptance of wastewater reuse. The aim is to create the foundations for safe use of treated wastewater in agricultural irrigation in Germany and to promote the national implementation of European standards.

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Flexible and Reliable Concepts for Sustainable Water Reuse in Agriculture (FlexTreat)

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WavE
Water Technologies: Reuse

HaSiMem—Water Recovery from Stockpile Leachates Based on Membrane Distillation Processes and Coupling with Crystallization

Water Technologies: Reuse (WavE II)

All over the world, seawater is being desalinated on a massive scale for the purposes of obtaining drinking water. Other sources of saline water, in contrast—e.g., from mining—largely remain untapped. As a result, vast quantities of water are not being exploited economically, nor is the salt load they contain. The joint project HaSiMem uses an innovative membrane distillation system to treat stockpile leachates from open-pit potash mines, a process that is both economically viable and environmentally sound. The project seeks to drastically reduce the quantity of harmful salts carried into our waterways, to reuse process water, and recover the salts which are a valuable resource.

Combined Treatment Processes

More than 2.5 million cubic meters of saline leachate from mine stockpiles is currently produced in Germany. In most cases, this is being channeled into bodies of water. In mere technical terms, processes such as reverse osmosis and evaporation are well-established methods used to recover water and solids. When it comes to high salinity water, however, these methods are not economical, and the potential to use stockpile leachates as an important resource remains unexploited. Another problem is the salt contamination of our waterways. Feasible technical solutions for water and salt recovery that can be implemented at reasonable cost have the potential to change all this.

The HaSiMem project team will be testing a combined treatment process for stockpile leachates based on membrane distillation and subsequent crystallization. The desalinated water can be channeled into waterways without causing pollution or contamination or back into the water cycle for industrial process water. The production of marketable salts such as sodium chloride (NaCl) in industrial salt quality or as road salt make the process even more economically viable.

Improving Processes and Membrane Modules

Membrane distillation (MD) is a thermally driven separation process that is suitable for high salinity brine with high osmotic pressures. The hot brine releases water vapor that passes through the membrane and condenses on the opposite side—known as the permeate side. Unlike conventional membrane filtration, no high pressures are needed here. Membrane distillation is particularly promising when it comes to treating saline wastewater that is already produced at high temperatures. Up till now, however, existing processes have not been adapted to meet the requirements of stockpile leachates, nor have suitable membrane modules been developed. To obtain usable salts or brines and distilled water from stockpile leachates, the HaSiMem team have developed an integrated membrane distillation and crystallization process.

The materials that are being considered for the membrane are plastic and ceramic. Both materials will be tested during the HaSiMem project for durability and desired distillate volume and will be optimized for use with stockpile leachates. One of the main challenges for the membrane distillation modules is the high salt concentration in the solutions; here, it is important to ensure that the membranes are not damaged by uncontrolled salt crystallization. To avoid this, the salt is not crystallized until it has been removed from the membrane module, a process that is induced by deliberate oversaturation.

Tubular membranes with different geometries for filtration applications

In the case of stockpile leachates this does not happen directly, but in an intermediate step that involves mixing with the concentrated solution and lowering the temperature. The research team calculate the necessary quantities and temperatures for crystallization.

The HaSiMem team will test the new process at different locations using a mobile pilot unit with an evaporation rate of up to 30 liters of condensate an hour. The process will then be evaluated with a view to specific technical and economic aspects, the aim being to achieve a similar level of energy efficiency as in conventional processes—e.g., two-stage technical evaporation—but with lower investment and running costs. If this is a success, the researchers will transfer the results from the pilot unit to the construction and operation of a demo plant with an average minimum evaporation rate of 1,000 liters per hour.

Model Project

Practical technical solutions for the treatment of high salinity water are needed not only in Germany but all across the globe in order to combat water scarcity and improve water availability. This need opens up opportunities for German tech firms.

HaSiMem is a model project; the new membranes and processes that will be developed as part of the project can also be transferred to other locations in the chemical industry where wastewater containing sodium chloride is produced. The project plays an important role in addressing the climate and supraregional challenges of our time.

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Water Recovery from Stockpile Leachates Based on Membrane Distillation Processes and Coupling with Crystallization (HaSiMem)

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Water Technologies: Reuse

HypoWave+—Implementation of a Hydroponic System as a Sustainable Innovation for Resource-Efficient Agricultural Water Reuse

Water Technologies: Reuse (WavE II)

Around the world, agriculture is becoming increasingly dependent on irrigation. In Germany, as in other countries, heatwaves and dry soil mean that high crop yields can no longer be taken for granted. New water-saving methods of cultivation are thus becoming increasingly important. The BMBF-funded research project HypoWave has successfully developed an innovative new concept for growing vegetables using recycled municipal wastewater. The follow-up project HypoWave+ sees the method being used in practice on a large scale and under scientific supervision for the first time. Using the HypoWave concept, the aim is to devise a new, sustainable form of high-quality regional vegetable production. Particularly important here is quality management and the marketability of the method developed.

From the Lab to the Field

As part of the predecessor project HypoWave, researchers developed a water-saving concept for agriculture which uses specially treated wastewater for plant production in what are known as "hydroponic systems." In a hydroponic system, the plant roots do not grow in soil but rather in pipes, fed by a nutrient solution. The new HypoWave process provides an alternative to irrigation using drinking water or groundwater. Moreover, in this process, the plants receive essential nutrients, such as nitrogen and phosphorus, recovered from recycled water. The system has been successfully piloted in Wolfsburg-Hattorf in Lower Saxony.

The aim of HypoWave+ is to transfer the knowledge gained from this water-efficient process based on recovered water to a large-scale project, under scientific supervision. In cooperation with farmers from Lower Saxony, the project partners are planning to grow up to 700 tonnes of tomatoes and bell peppers under a glass construction built on a one-hectare plot in Weißenberge near the town of Gifhorn. The aim is to develop innovative new scientific, technical, and social practices.

Available on Supermarket Shelves

The wastewater used for the hydroponic vegetable production comes from wastewater treatment ponds. In order to produce high-quality and hygienically safe irrigation water, the project team uses various methods including the installation of an innovative activated carbon biofilter. This filter specifically removes residues of synthetic organic substances known as trace substances. Microorganisms are then removed using a combination of a sand filter and UV disinfection.

A glimpse of the HypoWave concept in its pilot phase in Wolfsburg-Hattorf

A nutrient management system that is tailored to the specific requirements for plant nutrition and uses the nutrients in the wastewater ensures accurate, needs-based fertilization. The crops thus also serve as an additional purification stage in the wastewater treatment process.

The project also employs artificial intelligence in the form of a sensor, data processing, and control system. The largely automated operation of the wastewater treatment system as well as the water supply for the hydroponic plant enables the project team to continuously collect data.

These data are then used by the self-learning control system to improve the individual process steps. This system also identifies potential problems in the wastewater treatment process immediately.

The acceptance of the new system is promoted thanks to a comprehensive quality management system developed as part of the HypoWave+ project. This encompasses all stages of the process, from wastewater treatment to food production to the sale of the vegetables, also taking into account legal instruments, such as the new EU regulation on minimum requirements for water reuse. To ascertain how marketable this system of hydroponic vegetable production is, the project partners will conduct tests in a real-world laboratory, connecting the different actors involved in the process, including those from the fields of wastewater management, crop production, logistics, retail, and consumers. Vegetables will be marketed under realistic socioeconomic conditions by a newly created agricultural start-up and will be distributed via regional grocery stores throughout the year, with just a short break for winter.

From Weißenberge to the World

The aim of the HypoWave+ project is to develop an integrated system solution for regional vegetable production which works not only in Weißenberge but also at other locations and under different conditions. Due to advancing climate change, year-round regional greenhouse vegetable cultivation, which also conserves water, could become a viable option for farmers. At the same time, retailers are also showing significant interest in vegetables such as cucumbers, tomatoes and bell peppers that are produced using regional hydroponic systems. Combined wastewater treatment and agricultural production is thus opening up a whole new business field—one which offers German companies some major opportunities, especially when it comes to exports.

Different interested parties from the field visit the HypoWave greenhouse during its pilot phase

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Implementation of a Hydroponic System as a Sustainable Innovation for Resource-Efficient Agricultural Water Reuse (HypoWave+)

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Water Technologies: Reuse

innovatION—Selective Removal of Monovalent Ions from Saline Waters for Groundwater Recharge and Drinking Water Treatment

Water Technologies: Reuse (WavE II)

While worldwide demand for freshwater is ever increasing, the quality and quantity of available resources is on the decline. Something that both groundwater and surface water are particularly affected by is salinization, which means the water has elevated concentrations of different monovalent and polyvalent ions. In order to use saline water for drinking water production or groundwater recharge, it is often completely desalinated. The joint project innovatION aims to develop a sustainable alternative using an energy-efficient technology which selectively filters out monovalent ions from saline groundwater and surface water. The method is based on membrane-supported capacitive deionization.

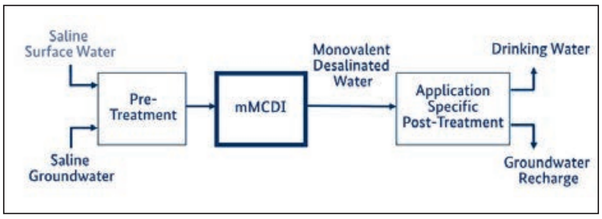
Not Everything Has to Go

The global increase in demand for water and the decline in available freshwater resources means there is growing interest around the world in developing efficient processes of desalination. Freshwater that is influenced by the sea or geogenic salt deposits (naturally occurring under the ground) has high concentrations of sodium and chloride. In addition, nitrates also end up in the groundwater, mainly through agricultural fertilizers.

Currently, the method used for desalination is based on membrane processes which are quite energy intensive. These processes tend to involve complete desalination of water and generally do not distinguish between salts that must be removed and those that can be retained. This is not, however, a particularly efficient approach. In fact, partial desalination which only removes monovalent ions in the salt, such as sodium, chloride, and nitrate, would be sufficient. The innovatION project brings together different partners from research, industry, and the field to develop a dedicated selective desalination process. The new methodology is based on an electrochemical desalination technology known as membrane-based capacitive deionization (MCDI).

Energy-Efficient Desalination Technology

For the desalination of slightly saline water, with far lower concentrations of salt than sea water, besides membrane processes, electrochemical methods such as MCDI are also suitable. In these methods, the charged salt ions are temporarily stored in electric double layers within capacitive electrodes (meaning they store electric charge) and thus removed from the water. The process requires only very low electrical voltage and so uses very little energy. Ion exchange membranes installed either directly in front of or actually on the electrodes only allow positively or negatively charged ions to migrate towards the relevant electrodes.



The principles of the mMCDI process for direct treatment of saline water

The innovatION team has developed this process further to enable selective removal of the monovalent ions only. This targeted retention of other ions is achieved using innovative electrodes and ion exchange membranes. The surface of the electrodes has more available attachment sites for monovalent ions than in the conventional MCDI process. In this process, the polyvalent ions, such as calcium and magnesium, which have to be returned to the water following the conventional complete desalination process, remain in the water. The electrodes and selective membranes needed for the monovalent MCDI (mMCDI) are being developed as part of the innovatION project and will be installed in newly constructed modules for use in laboratory and pilot facilities.

Factoring in Sustainability

The project partners will be conducting laboratory desalination tests on different qualities of water and for different treatment targets, with a view to identifying the optimal field of application for mMCDI. The development and implementation of the technology is being supported by computer-assisted modelling and simulations. Extensive automation and digital implementation make process control easier.

The knowledge acquired from the laboratory tests will be used by the project researchers to construct a pilot plant which will be trialed at two locations in Germany. The first trial, conducted on the East Frisian island of Langeoog, involves the removal of sodium and chloride from groundwater, while in the second trial in Nienburg on the Weser in Lower Saxony, nitrate is removed. In addition to the pilot trials on Langeoog, the project partners will also perform modelling and simulations with the aim of enriching the groundwater. An environmental and economic sustainability assessment will be carried out throughout the project to ensure that the UN Sustainable Development Goals (SDGs) are tied into the project's recommendations for action regarding the newly developed technology.

The aim is for the results of the innovatION project to contribute to sustainable management of water resources, helping to ensure that drinking water needs are met. The experiences acquired and the technology developed in Germany will also be internationally transferable. The aim is ultimately for the project to generate marketable products such as membranes and modules.

Selective mMCDI technology being trialed in laboratory test setups

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Selective Removal of Monovalent Ions from Saline Waters for Groundwater Recharge and Drinking Water Treatment (innovatION)

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An Initiative of the Federal Ministry of Education and Research
WavE
Water Technologies: Reuse

Med-zeroSolvent—New Insights in Medical-Technological Water Management

Water Technologies: Reuse (WavE II)

The dialysis equipment used for renal replacement therapy contains specially designed dialysis filters to purify the blood. These dialyzers contain dialysis membranes. The wastewater generated by the production process contains solvents, meaning some of this water has to be disposed of at external treatment plants. This is highly energy intensive and harmful to the environment. The joint project Med-zeroSolvent is developing a process for the environmentally sound, energy-optimized treatment of this wastewater at its point of production. The aim is to allow this treated process water to be reused in the production of the membranes.

Tackling the Problem at Source

Dialysis membranes are made mainly from synthetic polymers such as polysulfones. During the production process, nitrogen-containing solvents such as N-dimethylacetamide (DMAc) are used. A significant proportion of the solvents are recovered in-house and reused in the production process. However, wastewater containing solvents that is not suitable for recovery is still produced and therefore has to be disposed of. Diluted wastewater can be transported to municipal sewage works to be treated there. Highly concentrated wastewater, however, has to be incinerated.

Both options have their down sides. Incineration is very energy intensive. But treating the process water at a sewage plant shifts the environmentally harmful industrial chemicals and microplastics generated during production to the municipal sector. What is more, these substances can have a negative impact on sewage plant operations.

The Med-zeroSolvent project is developing a multi-stage, energy-efficient process for the on-site treatment of process water from membrane production which contains solvents. Alongside biofilm and membrane processes, adapted natural treatment processes are an essential component of the new process combination. Ultimately, the treated wastewater then re-enters the production process.

Technology and Nature Go Hand in Hand

In the first step, the wastewater is treated using a combination of biological processes. In this case, the project partners will use technical and natural biofilm processes. The aim is to remove, as far as possible, the carbonaceous compounds from the solvent DMAc in the first process step where the heavily contaminated water is treated. The nitrogen which is initially organically bound in the DMAc is first converted into inorganically bound nitrogen (ammonium). Next, the ammonium is oxidized to produce nitrate in a multi-phase natural biofilm process, and can then be denitrified, in other words converted into elemental nitrogen.Natural biofilm processes are generally referred to as constructed wetlands.

Constructed wetlands are seldom used to treat industrial wastewater. The advantage of the method, however, is that it requires very little energy compared to other biological wastewater treatment processes.

Constructed wetlands are an energy-efficient method which is being further developed for use in the treatment of industrial wastewater

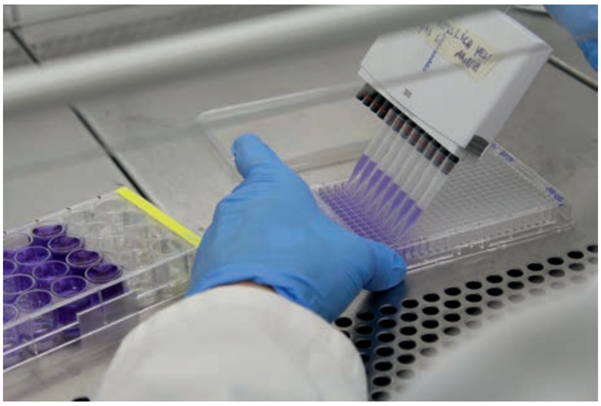
The Med-zeroSolvent project is therefore developing adapted constructed wetlands in which the waste air from the preceding high contamination treatment stage is also treated.

Before the biologically purified wastewater is returned to the production process, it is further treated with a membrane process in an ultrapure water stage. Using various monitoring methods, the substances in the process water are tested in real time to guarantee the high quality needed to manufacture the membranes. The project partners also use biotests to ensure that no critical degradation products occur during the wastewater treatment process.

Transferable Module Concept

Based on tests initially conducted on a laboratory scale, the project researchers will design a pilot plant. The aim is for this plant to demonstrate how well the whole system functions—both from a technical and from an economic perspective.
Building on this, the project partners will be developing a modular system using standardized treatment modules that can be adapted for any relevant application. This makes it possible to design the perfect solution depending on the volume of wastewater and how contaminated it is.

Provided the implementation of this process is a success, it should also be of interest to other industries producing similar solvent-containing wastewater. This has several advantages including conservation of freshwater, the ability to remove environmentally harmful substances at source, and a reduction in the CO2 emissions associated with having to dispose of the wastewater externally.



Biotests are used to check the safety of the degradation products generated by the wastewater treatment

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
New Insights in Medical-Technological Water Management (Med-zeroSolvent)

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WavE
Water Technologies: Reuse

NERA—Zero Emission Raw Water Production in the Automotive Industry

Water Technologies: Reuse (WavE II)

Wastewater produced in the metalworking industry is usually treated by adding acid, alkali, precipitation chemicals, and flocculants. The resultant treated water has elevated levels of salinity, which is why industrial process water recovery does not make economic sense. The joint project NERA takes a novel approach to wastewater treatment, developing an electrochemical treatment process for wastewater containing metal ions. The project partners seek to develop a climate-neutral process for the removal of elements contained in wastewater, such as phosphate and heavy metal ions, as well as process wastewater recovery that does not rely on chemicals or produce waste.

Closing Water Cycles

In line with the goals of its national sustainability strategy, Germany seeks to achieve resource-efficient, climate-compatible water use by 2030. Reusing treated wastewater containing heavy metals, vast quantities of which are produced in the automotive industry for example, can bring about a number of benefits. First, natural water resources are conserved; second, far lower levels of salt resulting from the chemicals used in wastewater treatment are discharged into the receiving waters. Owing to the high levels of salinity in the water, up till now there was no economical method of treating wastewater where the treated water is fed back into the water cycle as (recovered) process water.

The joint project NERA seeks to demonstrate that there are economical and climate compatible ways to recover process water from the automotive industry. The cornerstone of the project is an innovative electrochemical reactor-based wastewater treatment process with which metal ions and phosphates can be removed completely without using chemicals, leaving behind treated wastewater that can be reused. The elements that are removed from the wastewater can be reused in their entirety. Over the long term the project findings will serve as a basis for the development of integrated wastewater/raw water management concepts for a future zero emissions strategy.

Future-Oriented Water Management Concept

To implement the electrochemical wastewater treatment process, the project partners are building a pilot plant with a scalable electrochemical reactor that will be trialed at Volkswagen's Braunschweig site. The new system is based on a two-chamber reactor with rotating electrodes.

To begin with, the researchers have to develop, optimize, and evaluate new materials for the reactor electrodes as well as new processes for electrochemical recovery of heavy metals and phosphates. Here, they will be focusing on new material combinations both for the electrodes and the membranes used in the treatment process. Another important aspect is optimized resource recovery, which is why the different substances in the wastewater are recovered separately.

Current wastewater treatment plant at the Volkswagen Group's Braunschweig site treats 150,000 m3 of wastewater every year

Initially, the project researchers will validate the results of the aforementioned analyses in a pilot-scale test unit. The operational results from this will then form the basis of the pilot plant that will be built at the Volkswagen site in Braunschweig and that will treat 8,000 cubic meters of wastewater per year using the new process.

The results from the pilot plant will then be used to develop a pioneering, new and improved water management concept for the city of Braunschweig. This includes a sustainability assessment to determine the CO2 footprint of the treatment process including material and energy resource consumption. If the electricity needed for wastewater treatment/raw water production comes from renewable sources, the result is a climate-compatible solution—in fact even zero emission raw water production is feasible.

Versatile Solution for Multiple Possible Applications

The electrochemical solution developed as part of the NERA project can be transferred to the majority of applications in the metalworking industry or can even be used in broader applications such as water softening, meaning it could potentially also be used in the area of electroplating and surface technology. Once the project is complete, the partners plan to market components for electrochemical reactors in major industrial enterprises as well as a small-scale turnkey solution for smaller businesses.

Bodies of water—e.g., in the Oberharz region—can be protected by reducing industrial water demand

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Zero Emission Raw Water Production in the Automotive Industry (NERA)

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February 1, 2021 – January 31, 2024

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WavE
Water Technologies: Reuse

Nutzwasser–Generation of Reclaimed Water and Water Reuse Options for Urban and Agricultural Irrigation

Water Technologies: Reuse (WavE II)

How can we meet the increasing demand for urban and agricultural irrigation resulting from climate change? A possible solution may lie in treated municipal wastewater which can be reused in the form of what is known as non-potable water. The joint project Nutzwasser seeks to develop a solution for demand-led recovered water supply and practical flexible management strategies for safe water recycling and reuse. The desired non-potable water quality will be achieved using multi-stage treatment processes.

Conditions for Wastewater Reuse

Water recycling and reuse is becoming increasingly important worldwide. Despite this, there is a lack of concepts for the comprehensive evaluation of the quality of the recycled water as well as the risks involved in using treated wastewater in agriculture and in urban irrigation management. In light of this, the joint project Nutzwasser will put together comprehensive recommendations for the use of reclaimed (non-potable) water that define suitable legal, economic, and ecological conditions.

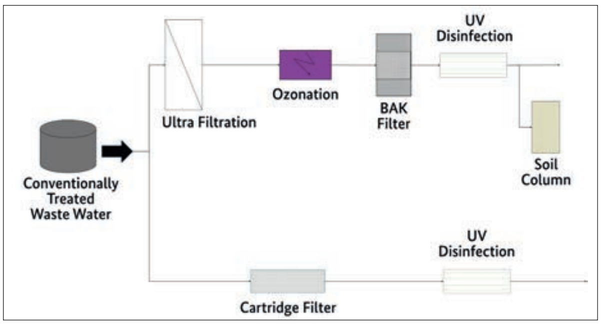
These recommendations are intended to support applicants and water management offices in the authorization process as well as to ensure that water reuse is compliant with local wastewater regulations. The result will be new, flexible, needs-based management strategies for wastewater irrigation. In addition, previous national and international approaches and experiences in the area of urban and agricultural water reuse will be summarized in the form of community of practice documentation.

Instrumental for the safe use of the non-potable water is the water quality. Thus, with the help of corresponding process monitoring, the project team will be developing a set of specific requirements tailored to the respective irrigation purpose. Potential risks will be determined quantitatively and incorporated into a risk analysis. The wastewater will be treated in a needs-based process conducted using various innovative treatment processes that the project partners will test in pilot systems.

Innovative Advanced Treatment

The test location for the project, which involves the production and reuse of non-potable water, is Schweinfurt, Bavaria, where advanced wastewater treatment units will be built at existing sewage works. The project researchers will be testing multi-stage treatment processes that can be ramped up or down at short notice, depending on the demand. The methods that will be trialed include a combination of ultrafiltration with ceramic membranes, ozone and powdered activated carbon treatment, and UV disinfection. This multi-barrier approach is designed to remove both microbiological and chemical substances. The project team is looking to identify flexible and robust advanced water treatment processes which are able to provide the desired water quality both reliably and cost efficiently.

To put this to the test, the project team is planning trial runs in a greenhouse on the premises of the sewage works as well as in open spaces in the region. The water quality achieved and the impact this has on the plants will be compared with water that has been treated in line



In the joint project Nutzwasser, multi-stage treatment processes are used to produce water of different qualities with the EU's minimum requirements for water reuse as well as with drinking water. If this proves successful, the plan is to use the non-potable water to irrigate various green spaces around the city of Schweinfurt, including the areas where the 2026 Regional Garden Show will be held, as well as sports fields and the local stadium.

A cloud-based irrigation management system automatically supplies the non-potable water in line with current demand. The system is designed for real-time data collection for any data needed for quality control purposes as well as to determine irrigation needs, i.e., regional weather data, groundwater levels, soil humidity, and groundwater extraction. What is important here is that the different uses for the treated water are both economically viable and climate compatible. To calculate how expensive this approach is compared to more common water management solutions, the project researchers will conduct a comprehensive economic and ecological analysis of the systems solutions and products developed in the course of the project. Building on this, they will devise operator solutions that allow—at the very least—for the new, complex water treatment system to break even in operation. Surveys among potential users will also help provide insight into the level of acceptance for urban and agricultural applications.

Impetus for New Concepts

In many countries around the world, wastewater is already being used as an alternative water resource. In Germany, this has seldom been the case up till now. The recommendations for action developed within the Nutzwasser project in collaboration with the relevant authorities, operators, and planners, are instrumental in the implementation of new concepts both in Germany and around the globe. In the medium to long term, this will also strengthen the position of German businesses in promising markets such as Southern and South-East Europe and Turkey.

Pilot units and greenhouse at Schweinfurt sewage works

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Generation of Reclaimed Water and Water Reuse Options for Urban and Agricultural Irrigation (Nutzwasser)

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WavE
Water Technologies: Reuse

PU²R—Point-of-Use Re-Use: Dezentralized Agricultural Reuse of Municipal Wastewaster to Reduce Competition for Water

Water Technologies: Reuse (WavE II)

Climate change is increasingly resulting in regional water shortages. This can lead to more competition for water, for example between using it for drinking water or for agricultural irrigation. One alternative is to reuse domestic wastewater. A point-of-use, demand-led wastewater treatment system could supply water for irrigation, thus taking some of the pressure off drinking water resources. It is this approach that the joint project PU2R is exploring. In Brandenburg, the project partners are using mobile equipment located directly at the recovery site to treat wastewater from drainless pits. By means of extensive chemical and microbiological laboratory analysis, they are also able to identify the potential risks pollutants or pathogens pose for humans, the environment, and irrigated crops.

Ideal Conditions for Point-of-Use Treatment

Treated wastewater is increasingly being recognized as a valuable resource, for instance for agricultural irrigation. Sewage plants are often located close to urban centers, frequently at quite some distance from the agricultural land where the treated water could be used. These long distances make wastewater reuse difficult.

The situation in Brandenburg, however, is quite different. Here, some 11 percent of the population is not connected to a centralized sewage treatment plant. Instead, their wastewater is collected in drainless pits and transported to sewage plants or disposed of locally. The joint project PU2R takes advantage of this setup. The project partners are developing a mobile point-of-use treatment process for domestic wastewater from these pits. Their aim is to produce water that meets high microbiological and chemical requirements and can thus be used to irrigate field crops. At the same time, the plan is to ensure that the quantity of nutrients required by the plants is retained in the water. Another aim of PU2R is to explore both the potential for as well as the possible risks of point-of-use wastewater reuse.

Lab and Field Tests

In order to make sure the treated water meets high standards both in terms of hygiene quality and chemical properties, the project team will use a membrane bioreactor (MBR) in their tests.

This method combines conventional biological degradation of wastewater substances with membrane filtration, which is capable of removing even very small particles such as bacteria. An ultrafiltration membrane is used for this purpose. By adding powdered activated carbon (PAC) and a precipitant, the water quality can be improved even further. A combined process such as this can even remove trace elements such as pharmaceutical residues. To increase the quantity of pathogens filtered out of the water, especially viruses, the project researchers have combined the MBR with a UV reactor that will improve disinfection efficiency. They are also investigating how the UV treatment influences the degradation of trace elements.

Within the joint project PU2R, domestic wastewater is treated in a mobile membrane bioreactor (MBR)

With high levels of UV light and the optional addition of an oxidizing agent—such as hydrogen peroxide, for instance—pollutants can be transformed into harmless substances.

In tests under laboratory conditions using specially prepared soil cores known as lysimeters, as well as in the field, the project team are investigating the effect of the treated water on plant growth and are working on optimizing this by means of adapted irrigation systems. Chemical and microbiological analyses provide information on what happens to trace elements, bacteria (including resistant strains), and viruses in water, soil, and plants. More specifically, they are looking at how these substances are bound and then released again, to what extent they biodegrade, and what matter transport processes take place. The team then uses the data they collect to create a location-independent model of the transport processes that can also be applied to other regions.

A soil core (lysimeter) planted with brewer's barley

Potential for Brandenburg and Beyond

The aim of the PU2R project is to develop mobile and thus versatile systems for the treatment of domestic wastewater that can be used almost anywhere without the need to upgrade the infrastructure. This system makes it possible to purify and disinfect the wastewater, demand-driven, at the location where it will be reused. This is a very promising option for rural agricultural locations that are not connected to the public sewage system. The tests conducted as part of PU2R will serve as an important basis for quantifying the potential of point-of-use wastewater reuse in Brandenburg and other regions.

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Point-of-Use Re-Use: Decentralized Agricultural Reuse of Domestic Wastewater to Reduce Competition for Water (PU2R)

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WavE
Water Technologies: Reuse

ReWaMem—Recycling of Laundry Wastewater for Reuse by Means of Ceramic Nanofiltration

Water Technologies: Reuse (WavE II)

Huge volumes of water are used in the laundry industry, meaning just as much wastewater is produced. How contaminated this water is depends on the use of detergent, the microfibers released during washing cycles, and the dirt contamination in the laundry. The laundry industry therefore has a vested interest in developing resource-efficient treatment processes and a method for using the treated laundry wastewater. The partners in the joint project ReWaMem are developing a new process chain with ceramic membranes where the laundry wastewater is fed back into the cleaning cycle, reducing the need for freshwater and chemicals.

Targeted Wastewater Recycling

According to data from the Federal Statistical Office of Germany (Destatis), there are around 5,000 small and medium-sized enterprises operating in the laundry and textile cleaning industry in Germany. Together, these companies use around 20 million cubic meters of freshwater each year. The joint project ReWaMem aims to significantly reduce the freshwater needs of this industry through targeted treatment of wastewater. Targeted, in this case, means customized to the level of contamination in the wastewater, which in turn depends on the textiles being washed and the water quality required to clean those textiles.

For this purpose, the project researchers are developing a process chain which will be piloted in an industrial laundry. The cornerstone of the system is a nanofiltration system based on innovative ceramic membranes that remove the majority of heavy metals and organic halogen compounds (AOX) from the wastewater as well as reduce the chemical oxygen demand. The heavily contaminated residual materials from the filtration process—known as concentrates—are also treated to enable them to bio-de-grade more easily.

Large-sized Channels and Rotating Discs

Innovative new membranes will be trialed in a pilot facility which the project team will install in a laundry for doormats, mops, and fabric towels. One of the aims here is to treat the highly discolored wastewater so that it is suitable for washing non-dyed towels. To achieve this, the first step is to analyze the wastewater and define quality requirements for the recycled water. For the treatment process, the project partners will develop two different types of ceramic nanofiltration membrane: multi-channel tubes and rotating discs. Ceramic membranes are particularly well suited for the high temperatures that typically characterize wastewater in the laundry industry. This has a positive impact on the filtration process.

The multi-channel tubular membranes comprise channels with extra-large diameters, preventing the membranes from being blocked with lint or other fabric residue, for example. The rotating disc filters developed as part of the ReWaMem project, on the other hand, are installed in a dedicated module to form a multi-disc unit. The project researchers will conduct technical laboratory tests to ascertain which of the two membrane types is the most robust and energy-efficient.

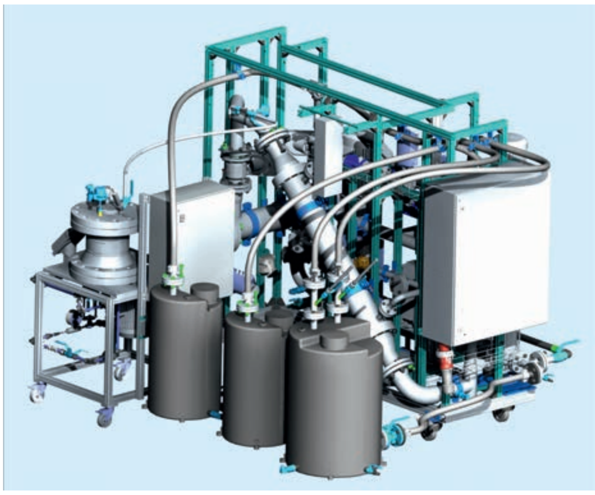


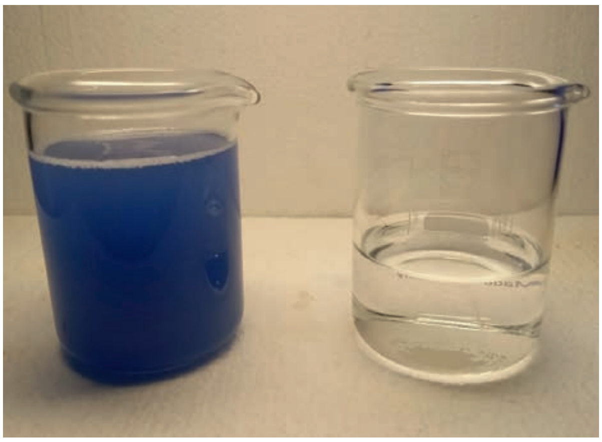
Image of the pilot system with tubular and rotating ceramic membrane components

Lastly, the project researchers will also conduct comparative analyses of different laundry processes with a focus on energy and resource needs. In future, the plan is for laundries and textile cleaning companies to be able to determine their own potential for saving energy and water as well as for recycling wastewater using an online tool. ReWaMem will also work on the improvement of a tool already being used in the industry and will make this available online at the end of the project for companies to use free of charge.

The project partners will treat the highly polluted residues resulting from the filter process using an advanced oxidation process. This oxidizes all the harmful substances in the wastewater using highly reactive oxygenated chemical molecules, converting them to substances that biodegrade more easily. This makes it easier and more cost effective to dispose of the concentrates, for example via the sewage system.

Transferable Solutions

The laundry wastewater recycling solutions developed as part of the ReWaMem project are not only suitable for the laundry and textile cleaning sector, but also for other branches of industry where large volumes of organic and saline wastewater are produced. This might include dairy processing, the health sector, industrial kitchens, and slaughterhouses. For businesses this translates to cost savings resulting from reduced outlay for freshwater and wastewater disposal, while the environment benefits from less contamination of our lakes and rivers.



Blue-colored wastewater from laundering towels, compared with a wastewater sample after ceramic membrane filtration

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Recycling of Laundry Waste Water for Reuse by Means of Ceramic Nanofiltration (ReWaMem)

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WavE
Water Technologies: Reuse

RIKovery—Recycling of Industrial Saline Water by Ion Separation, Concentration and Intelligent Monitoring

Water Technologies: Reuse (WavE II)

Many industrial processes produce vast quantities of wastewater with high concentrations of saline that can pollute our waterways. In Germany alone, more than six million tons of chloride enter our rivers and lakes through wastewater discharge each year—primarily from the chemical and mineral processing industry. This includes process wastewater and sub-streams from treatment processes as well as saline wastewater from mining dumps or saline groundwater. The joint project RIKovery addresses the question of how to make optimal use of saline industrial wastewater to lessen the burden on our natural resources.

Economically and Ecologically Viable Recycling

The salts and mixtures of different salts found in saline industrial wastewater is often in such low concentrations that they cannot be reused directly. Instead, different treatment processes have to be used in combination—something that is technically complex and uses a lot of energy at the same time. In the joint project RIKovery, partners from industry and research seek to develop an economically and ecologically viable recycling process for high salinity brine. Their aim is to assess the potential of different innovative technologies when it comes to recovering high purity, concentrated salts in the quality required for specific applications. Drawing on this analysis, the project researchers will develop a sound decision-making basis for the implementation of salt and water recovery processes on a production scale.

New Treatment Process for Saline Water

To obtain meaningful, broadly transferrable results, the project consortium identified industrially relevant applications from the chemical industry (polymers and specialty chemicals) and potash mining. Given the huge differences in wastewater composition and recycling requirements in these areas, they can be seen to represent a large share of industrial saline discharges, e.g., process water from plastic production and catalytic converter production or from dumps or saline groundwater. Customized, production site-specific process water recovery processes will be tested in the different areas of application.

The success (or failure) of a recycling concept is determined by two factors. First, the salts have to be separated or have a certain composition. Second, they have to be concentrated to a suitable level using more energy-efficient processes than have been used to date. For high salt concentrations, in particular, there has been a lack of suitable technology up till now. The project partners are thus working on the development of transferable treatment processes that have been adapted to these conditions.

Given that no single technology can cover all the areas of application, RIKovery examines the potential of four innovative processes: osmotically assisted reverse osmosis (OARO), high-pressure nanofiltration (HPNF), pressure based forward osmosis, and flow-electrode capacitive deionization (FCDI).

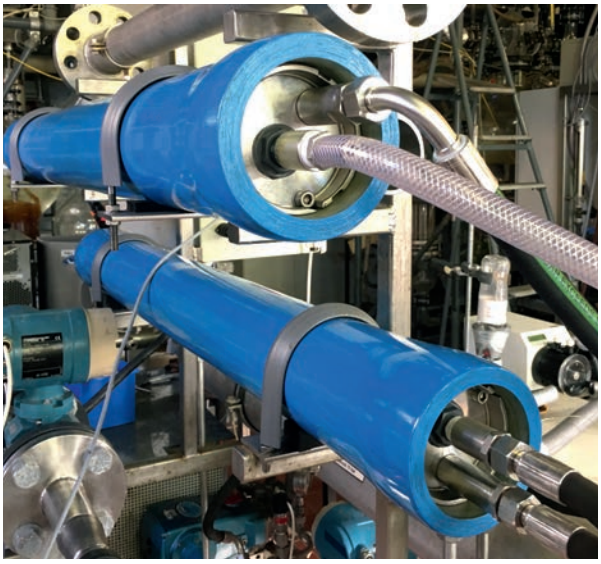
With the help of dedicated technologies, saline industrial water flows can be almost fully recycled, conserving natural resources

The technologies that, according to current knowledge, are deemed most promising for each industrial application will then be tested in pilot plants operated by the project partners.

For the treated wastewater to be able to be used for downstream processes, it has to meet with specific quality criteria. The RIKovery consortium is thus developing innovative process monitoring and quality assurance for previously unknown constituents in the water.

The Bigger Picture

Drawing on the results from the pilot plants as well as evaluation data on energy efficiency, cost efficiency, and potential environmental impacts, the project researchers are able to determine which processes can be implemented successfully in practice. This opens up new prospects for wastewater recycling and the reuse of the recovered constituents across multiple branches of industry. Closed water cycles also help ensure that fewer harmful substances get into our surface water. Another added benefit is the reduced consumption of valuable freshwater resources and other raw materials for production processes in industrial applications.



High-pressure membrane module

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Recycling of Industrial Saline Water by Ion Separation, Concentration and Intelligent Monitoring (RIKovery)

Duration
February 1, 2021 – January 31, 2024

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WavE
Water Technologies: Reuse

SULFAMOS—Sulfate Removal by Forward Osmosis and Hollow Fiber Immersion Modules

Water Technologies: Reuse (WavE II)

One of the long-term effects of lignite mining in Germany is the widespread iron and sulfate contamination of groundwater and surface water. At the same time, however, the upcoming coal phase-out will mean the disappearance of gypsum, an important raw material for the construction industry that up till now has been produced in flue gas desulfurization systems in power plants. Those involved in the joint project SULFAMOS will develop a combined process that is designed to solve both problems. Once the sulfate has been removed from the contaminated water, it can be used as drinking and non-potable water once again. Moreover, the residue can also be used to make gypsum.

Coal Phase-Out and the Challenges it Brings

The rivers, lakes, and groundwater in the lignite mining region of Lusatia are contaminated with high concentrations of sulfate, oftentimes even iron as well. The rising groundwater level in former open-pit mines is transporting even larger quantities of these substances into our waterways, resulting in ever higher sulfate contamination. This then impacts other regions such as Frankfurt/Oder and Berlin, whose water supply companies source water from the river Spree.

High sulfate and iron concentrations damage water supply and distribution systems due to corrosion and deposits. These substances also discolor the water and negatively impact its taste. For this reason, the contaminated groundwater and surface water can often no longer be used as a source of drinking or non-potable water or have to undergo expensive treatment processes.

While the iron contamination can be substantially reduced using water purification systems and other measures, to date no large-scale solutions have been developed to address the sulfate problem. A number of sulfate removal processes do exist; they are, however, either too costly or they produce large quantities of sludge or take up too much space.

Coal phase-out also impacts the building materials industry. Gypsum—a vital raw material in this industry that is in high demand and that is largely produced in the fluegas desulfurization systems found in lignite-fired power plants—could become very scarce as a result.

The project partners in the SULFAMOS project will be developing a process that not only removes sulfate from contaminated water but also produces gypsum for the building materials industry. To do so, they will combine forward osmosis membrane technology with chemical precipitation.

Clean Water and Reusable Material

Forward osmosis, a molecular separation process based on membrane technology, uses the natural process of osmosis to separate water from dissolved solutes. Unlike the widely used process of reverse osmosis, in this process no external pressure is applied. Instead, the osmotic pressure itself transports the water through the semi-permeable membrane. Forward osmosis is thus more energy saving and less susceptible to fouling in the membrane pores and resultant blockages.

Sulfate caught in a conventional hollow fiber membrane module

For the membrane stage, the SULFAMOS team is using a hollow fiber immersion module with an innovative coating. The module draws water out of the solution being treated, creating a concentrated solution of the constituents in the process. The solution is flushed over the outside of the immersion module, making it easier to clean and resulting in a longer service life than conventional hollow fiber immersion modules where the solution being treated is passed through the inside of the membrane. In the next treatment stage, the concentrated sulfate is precipitated as gypsum, i.e., the dissolved sulfate is converted to gypsum by adding a precipitating agent. The gypsum is separated, cleaned if needed, and dried. It can then be used as a raw material in the construction industry, making it a sustainable alternative to the gypsum produced in the fluegas scrubbing process in lignite-fired power plants.

Flexible Technology for Various Locations

The researchers will test the combined forward osmosis/ chemical precipitation process in a mobile pilot plant at different locations. Field tests will also be carried out at the Tzschelln mine water treatment plant, Burgneudorf modular water treatment plant, as well as at Kitzscher waterworks and other water extraction sites, with a view to demonstrating the flexibility this combined process offers for both highly contaminated mine water and groundwater with far lower levels of contamination. The results of the various tests can be used as a decision-making aid for the selection of other potential locations, making them very useful for operators of water management systems with sulfate problems.

Field tests with the demo equipment are carried out at various water extraction sites and other test sites

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Sulfate Removal by Forward Osmosis and Hollow Fiber Immersion Modules (SULFAMOS)

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May 1, 2021 – October 31, 2023

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WavE
Water Technologies: Reuse

WEISS_4PN—Integrative Application of Innovations and Digital Cooling Capacity Management to Reduce the Amount of Water Required in Steel Production

Water Technologies: Reuse (WavE II)

In industry, water is used primarily for cooling purposes. In steel production, for example, as much as 75 percent of the water used is required for cooling operations. At any one location, up to 1,000 cubic meters of water per hour are needed to replace the evaporated water and the concentrated wastewater in the huge cooling circuits. The joint project WEISS_4PN seeks to reduce the amount of freshwater used as much as possible. To help achieve this, the project partners will be testing various innovative approaches to desalinating and recycling wastewater produced at the production sites.

Reuse it, Don't Waste it

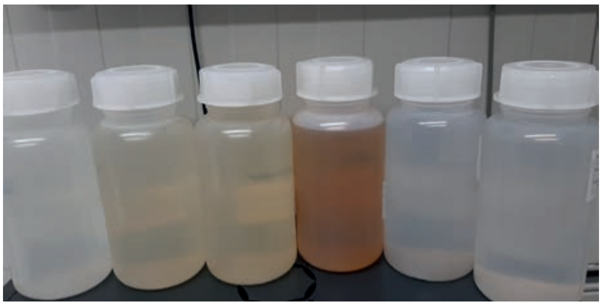
Today, excess heat from production processes is usually transferred to open cooling towers where it evaporates and is emitted into the atmosphere. However, only the water evaporates, leaving concentrated salts behind in the cooling circuit water. To prevent salts and, in particular, limescale, precipitating in the cooling towers, the salt concentrations in the cooling circuits have to be retained at a level that ensures that reliable operations can be maintained. If the maximum concentration is reached, what is known as cooling tower blowdown is discharged and replaced by low-salinity freshwater. In steelworks, other wastewater flows are added to the blowdown to be purified before being introduced into watercourses.

This is where the WEISS_4PN project comes in, which seeks to recover water from these wastewater flows and use this as an alternative to freshwater. By separating steel production from water availability, the project partners are hoping to reduce the competitive pressure for water at arid production sites. This will result in more water for agricultural and drinking water purposes, while ensuring reliable steel production at the same time

Combined Desalination and Digital Tools

The researchers will compare two desalination processes based on membrane technology. These processes are particularly well suited to differences in wastewater composition and chemical additives used in wastewater treatment. They are also energy-efficient and low maintenance. On the one hand, the project partners will be looking at conventional reverse osmosis membranes with a special coating that prevents the accumulation of organic substances or microorganisms on the membrane surface or pores—a process known as fouling where the deposits have to be removed at regular intervals using aggressive chemical agents. The benefit of this coating is longer membrane cleaning intervals and a reduction in the consumption of wastewater and chemicals.

On the other hand, the project partners will be testing an innovative membrane technology known as membrane-based capacitive deionization (mCDI). In this energy-saving process, voltage is applied to the solution, removing the salts which are then stored on the surface of porous electrodes. The voltage is then reversed, releasing the salts as concentrate. This process entails very little pre-treatment.



In the WEISS_4PN project various desalination processes are being tested; left to right: samples from the inflow (1), concentrates (2-3), super-concentrate (4) and purified blowdown (5-6)

For the reverse osmosis process, on the other hand, the researchers are testing different pre-treatment methods.

In particular, an ultrafiltration process adapted precisely to the specific requirements under laboratory conditions, ensures reliable operation.

The concentrates are desalinated a second time in the high-pressure reverse osmosis unit. With a water yield of 95 percent or more, this process can be considered wastewater-free. The small amount of residual saline brine—known as the super-concentrate—is then treated by nanofiltration and evaporation, turning the highly contaminated residue into a reusable raw material. The aim is to separate monovalent ions from divalent ions to obtain usable salts from the salt mixture. Any residue can simply be disposed of.

Digital tools can help optimize the management of available water for cooling circuits. In WEISS_4PN, a dedicated software tool will be developed to predict water supply and demand to ensure that supply bottlenecks are quickly identified. The resulting new digital cooling capacity management system adapts the heat load produced during production to the installed cooling capacity, factoring in the current climate conditions and available freshwater quality and quantity. The results of the joint project are tested in a mobile pilot plant.

Benefits for Industrial Water Use

The desalination process, concentrate treatment, and digital tools can be adapted to any given blowdown as well as other slightly saline wastewater from various industries, resulting in potential water savings across all industrial sectors. The result is reliable production, even in the event of bottlenecks in water supply, as well as reduced chemical consumption and lower environmental impact.

The processes developed are tested in a mobile pilot plant

Funding Measure
Water Technologies: Reuse (WavE II)

Project Title
Integrative Application of Innovations and Digital Cooling Capacity Management to Reduce the Amount of Water Required in Steel Production (WEISS_4PN)

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April 1, 2021 – March 31, 2024

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