Federal Ministry
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and Research

MEWAC
Middle East Regional Water
Research Cooperation Program

EXALT—Coupling Thermal Desalination and Extraction of Dewatered Salt with Hydroponic Greenhouse Cultivation via Heat Pumps

Middle East Regional Water Research Cooperation Program (MEWAC)

In arid regions of the Middle East, desalinated brackish water is increasingly being used in plant production. Water-saving cultivation methods, such as hydroponic greenhouses where plants grow in special nutrient solutions without soil, are helping to reduce the burden on water resources. In order to keep water losses in the greenhouses to a minimum and ensure that the desalination process is as efficient as possible, the joint German-Israeli-Jordanian project EXALT is developing a new combined process that, with the help of heat pumps, extracts heat from the greenhouse in order to keep it cool; this heat is then used in the desalination process. At the same time, the condensation water produced in the cooling and desalination process can be recovered and used for irrigation.

Sustainable Plant Production Despite Water Shortages

In the countries of the Middle East, some of which are strongly impacted by extreme drought, agriculture is the biggest consumer of water. To secure food production for future generations, sustainable cultivation methods based on efficient water use are pivotal. Hydroponic greenhouse systems, for example, are especially well suited to arid regions. In these systems, plants grow in special nutrient solutions rather than in soil as is usually the case, meaning they need far less water. With the help of desalination, more and more naturally existing saline water in the region can be used for plant cultivation. And of course, solar power, the regenerative energy source used for the desalination process, is in plentiful supply in these regions.

To develop an optimum process combining water-efficient plant production using saline groundwater and surface water with climate-friendly desalination, researchers from Germany, Israel, and Jordan have joined forces as part of the collaborative project EXALT. What the project partners are seeking to do is facilitate plant cultivation in arid regions all year round using a minimum of water and energy.

Closed Loop Cooling Process

At the heart of the combined process developed as part of the EXALT project is a closed loop cooling process which achieves the perfect balance between humidity and temperature in the greenhouse, ensuring the best possible conditions for plant growth. Instead of controlling these parameters using an air exchange system, as is usually the case, a heat pump actively extracts heat from the greenhouse. Thanks to the lower temperatures, the water that evaporates via the plant leaves can condense, be recovered, and reused for irrigation

Test setup to investigate the optimum growth conditions depending on nutrient solution salt concentration levels at the Hohenheim University Phytotechnical Center

Ministry of Innovation, Science & Technology

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Sustainable Water Management

The remaining water needed for consistently high plant production can be covered with salt and brackish water desalination. The energy for this process comes, among other sources, from the thermal energy extracted from the greenhouses, reducing the solar power needs. Plus, the product of this process is dehydrated salt that can be disposed of in a more environmentally friendly manner than the brine produced in conventional desalination processes. The concept developed as part of EXALT does not rely on fertile soil and low-salt water, enabling plant production with a minimum of water and energy, even in areas that are otherwise unsuitable for agricultural production.

To begin with, baseline studies on the latest methods of hydroponic greenhouse farming are conducted in the target countries Jordan and Israel; the locations selected have varying levels of water availability and salinity. The results of these studies are combined with data on the climate and quality of the available irrigation water. Based on the local conditions, the project researchers investigate the optimum temperature, humidity, and light conditions for plant cultivation and energy efficiency in relation to the salt content of the nutrient solution for selected plants. The researchers use the findings to define greenhouse cooling and dehumidification requirements and develop those combined cooling and desalination systems that appear most promising, the aim being to create holistic concepts for desalination and plant production for a total of six case study locations. These concepts are then evaluated and compared and serve as blueprints for later implementation in practice

Global Solution for Arid Regions

Regions that are affected by drought account for some 15 percent of the earth's surface and are home to more than 14 percent of the global population. Even the slightest change in the quantity and distribution of annual precipitation can have catastrophic consequences for the food security of the global population, most of whom are reliant on rainfed agriculture. By developing an innovative method for combining water-efficient greenhouse farming and climate-friendly desalination, EXALT offers a solution for all-year-round plant production in semiarid regions the world over.

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Coupling Thermal Desalination and Extraction of Dewatered Salt with Hydroponic Greenhouse Cultivation via Heat Pumps (EXALT)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1608A-B

Grant Volume
Federal Ministry for Education and Research (BMBF):
EUR 780,052
Ministry of Innovation, Science & Technology (MOST):
EUR 210,000

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Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O'Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credit
Theresa Detering

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Federal Ministry of Education and Research

MEWAC
Middle East Regional Water Research Cooperation Program

FEMAR—Feasibility of MAR for Safe and Sustainable Water Supply

Middle East Regional Water Research Cooperation Program (MEWAC)

In many Middle Eastern countries where the climate is arid or very arid, the increase in water demand resulting from high population growth is putting even more pressure on the already very scarce water resources in these regions. This has a negative impact on the region's aquifers, which are then overused, causing a decrease in the groundwater level, saltwater intrusion, as well as land subsidence. Researchers from Germany, Iran, Jordan, Lebanon, and Syria are seeking to develop artificial groundwater recharge methods to help combat these problems. As part of the joint research project FEMAR, researchers will be introducing groundwater recharge methods in the participating Middle Eastern partner countries, with the aim of ensuring safe water supply and conserving groundwater resources.

Data and Models

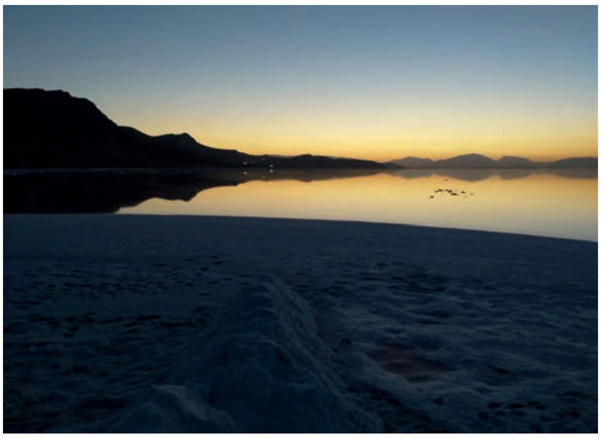
The population of the countries of the Middle East is currently some 430 million and rising. One of the most serious problems facing the region is an ever-increasing shortage of freshwater supply. Since 1950, annual water availability has fallen from 4,000 to just short of 1,100 cubic meters. According to projections, this figure will fall by a further 50 percent by the year 2050. For the countries affected, this means changes in their water management strategies are urgently needed, in both urban and rural areas.

Developing new water resources, such as treated wastewater, will play an important role in this context. Artificial groundwater recharge methods help improve the quality of these resources thanks to natural purification processes in the subsoil, while increasing the amount of groundwater available at the same time. This can be done, for instance, using infiltration methods where treated wastewater or pretreated surface water seeps into basins or pits. Another possibility is riverbank filtration where water from rivers or lakes penetrates into the groundwater, where it is purified as a result of natural filtration and degradation processes and is then removed from wells located near to the source.

To identify suitable technologies and locations for artificial groundwater recharge in Iran, Jordan, Lebanon, and Syria, the researchers involved in the FEMAR project will create integrated hydrological models based on existing data. These models transcend national borders, covering every aspect of the water cycle on a regional scale. With such integrated model systems, the impact of individual measures can be determined, weighted, and optimized in the field. The models are created using what is known as open-source software that all the project participants can access. In this way, groundwater recharge models that are already in place in Germany and the rest of Europe can be adapted to the respective conditions in the target regions, and, as a result, can help improve water supply.

Adapting Tried and Tested Methods to New Locations

The FEMAR project participants investigate potentially suitable groundwater recharge methods such as riverbank filtration and treated wastewater and pretreated surface water infiltration with a view to employing them in the locations in the four target countries determined using the models.



Maharloo Lake near Shiraz, Iran—one of the potential locations for an artificial groundwater recharge pilot project

Results from field tests are used to fine tune the model systems so that they factor in karstification in the subsoil or calculate the transport of dissolved substances, for example.

Over the course of the project, the groundwater recharge concepts adapted to the specific location are to be translated into pilot projects. To help make this possible, the researchers will be carrying out accompanying lab and field work to determine the hydrogeological and hydrogeochemical conditions in the target regions as well as the impact of temperature on material degradation. In addition to this, technical aspects will also be examined, such as the availability of filter gravel and other design materials required for the different systems such as pipes and filters.

Another key focus of the project is training for those involved in the project, with doctoral students or graduates from the target regions paying visits to German universities, for instance. The partner institutions will be organizing workshops on modelling and planning for groundwater recharge systems. To support this, an online program will also be put together which, in combination with local courses, will provide training for local specialists—employees from water supply companies and government departments—who will support and continue the initiative and the pilot projects beyond the end of the funding period.

Long-Term Prospects

The joint project FEMAR takes innovative simulation tools and combines them with artificial groundwater recharge methods that have been extensively tried and tested in Germany and the rest of Europe. The aim is for the results from the pilot projects to be transferred to other locations and actors in Iran, Jordan, Lebanon, and Syria. The FEMAR project has a wide reach within the target regions, benefiting actors from the fields of science and research, water supply, and public administration, and facilitating collaboration on multiple levels. The project is designed for longer term implementation. The German universities involved offer international master's courses in the field of water management and environmental engineering, the aim being to continue the activities beyond the end of the project and expand on the initial cooperation.

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Feasibility of MAR for Safe and Sustainable Water Supply (FEMAR)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1612A-C

Grant Volume
EUR 942,006

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Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

February 2023

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O'Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credit
TU Dresden

bmbf.de

Federal Ministry of Education and Research

MEWAC
Middle East Regional Water Research Cooperation Program

GRaCCE—Groundwater Recharge and Climate Change Effects

Middle East Regional Water Research Cooperation Program (MEWAC)

For the countries of the Mediterranean and in the Middle East, in particular, groundwater systems play a significant role in water supply. Climate change, however, is altering the formation of new groundwater, which is exacerbating the water scarcity in these regions. What is needed are state-of-the-art methods that will enable droughts to be detected early and modified water management strategies to be developed. The project participants in the international joint project GRaCCE will be developing a drought early warning system based on the temporal and spatial analysis of groundwater recharge. The new system will factor in the specific conditions in what is known as the unsaturated zone between the earth's surface and the groundwater table. This is crucial in terms of both the quality and the amount of groundwater generated.

Developing Additional Water Resources

The area of focus in the German-Israeli-Palestinian joint project GRaCCE includes the State of Israel, Jordan, and the Palestinian areas of the West Bank. The entire region suffers from a shortage of water. Irregular precipitation and substantial water loss on the earth's surface due to evaporation mean that water from rivers, lakes, and springs are often not available in the quantities needed, meaning groundwater resources are being heavily overused.

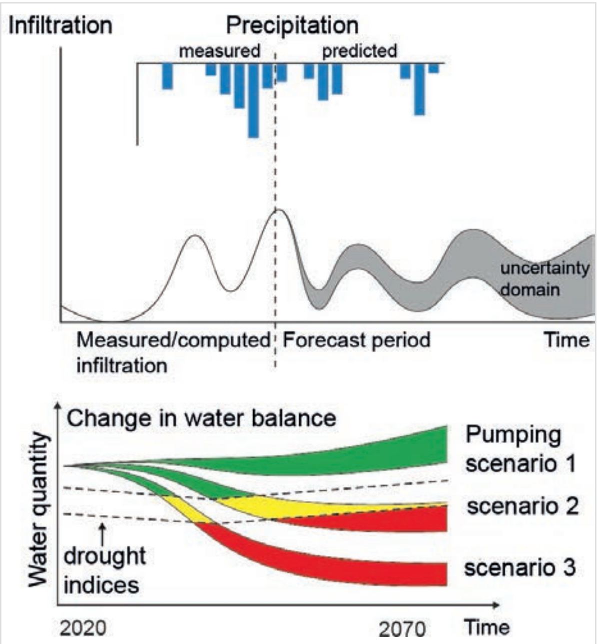
To find out how fast groundwater can regenerate and to create water management strategies based on this information, those involved in the GRaCCE joint project will be developing a new, integrated process for the temporal and spatial analysis of groundwater recharge. A fundamental aspect here is the complex groundwater movements and storage processes in what is referred to as the unsaturated or vadose zone, i.e., the layers of soil and rock between the earth's surface and the ground-water table. Given their importance for storing water, these layers must be factored into water management strategies.

Groundwater Recharge in Complex Rock Formations

Sedimentary rock such as sandstone and limestone are often marked by disturbed rock structures such as joints and faults and possess a porous structure that can store large quantities of water. The groundwater in these rock formations often lie very deep. This means it can take years for groundwater to be renewed through the penetration of rainwater from the surface. Joints and faults, however, allow a certain amount of water to flow through the layers of rock far more quickly, even within just a few hours. This sometimes makes it extremely hard to predict when groundwater recharge will occur. Earlier investigations also show that, in the region under investigation, the rock formations between the groundwater table and the surface of the earth are important in the area of water management because they serve as longterm water storage media, meaning they can be factored into water management considerations for periods of drought.

Rock formations with joints and faults can store water

To describe the process known as rainwater infiltration and groundwater recharge, the researchers in the GRaCCE project will be examining various hydrogeological, geophysical, and hydrogeochemical methods, as well as new modelling approaches. In doing so, they aim to identify the available water resources at monthly time steps. Information from the daily climate models depicting the general development of precipitation and evaporation are also factored into the long-term forecasting models for the period 2020–2070. These results serve as a quantitative basis for predicting water deficits in aquifer resources on the basis of drought indicators, i.e., factors that can be derived from the complex range of processes and can indicate the risk of drought. The groundwater recharge prediction process developed in the project is tested at various sites in Israel and in the Palestinian autonomous territories. Other sites in Germany and Switzerland will be used to validate the processes and models in a controlled environment.



Drought early warning system based on groundwater infiltration and development of adapted water management strategies

Web-Based Toolbox

At the end of the GRaCCE project, the plan is to set up a type of web-based toolbox that includes a drought early warning system and dedicated pumping and storage strategies. The purpose of this is to enable water consumers and local authorities to better prepare their regions for extreme climate events, in doing so reducing water stress. Beyond the Middle East and its aquifer resources, the project findings can be transferred to other hydrogeological and hydrological conditions in other countries.

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Groundwater Recharge and Climate Change Effects (GRaC-CE)

Duration
July 1, 2020 – June 30, 2024

Grant Number
02WME1609A

Grant Volume
Federal Ministry for Education and Research (BMBF):
EUR 934,883
Ministry of Innovation, Science & Technology (MOST):
EUR 200,000

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mewac-gracce.de

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htw-dresden.de/femar

Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O'Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credits
Front and back: Dr. J. Kordilla

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Federal Ministry of Education and Research

MEWAC
Middle East Regional Water Research Cooperation Program

HighRec—Intensification of the Recovery Ratio of Brackish Water Desalination Systems for Agriculture

Middle East Regional Water Research Cooperation Program (MEWAC)

In many parts of the Middle East, including non-coastal areas, well water is typically more saline, making these countries increasingly reliant on the use of brackish water as a resource. In some areas, brackish water is already being treated for use in agriculture and industry. Owing to the complex chemical makeup of brackish water, however, the amount of usable water recovered has been moderate to date. The joint project HighRec seeks to produce far greater quantities of usable water in brackish desalination plants and reduce the negative impacts on the environment. To make this possible, researchers from Germany, Qatar, and Iran will be joining forces to develop a new, sustainable desalination system that will be tested at two locations in Qatar and Iran.

The Problem with Brackish Water

More than 95 million cubic meters of desalinated drinking water is obtained from coastal areas around the world every day. In many areas, however, desalination of water from inland water wells is also becoming increasingly important in meeting water needs. Various factors—e.g., overuse, declining groundwater levels, or seawater penetration—causes an increase in the salinity of water in wells, resulting in brackish water that is not suitable for direct use as drinking water or in industry or agriculture.

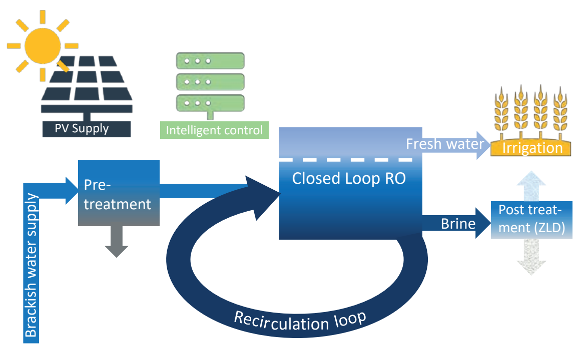
A general problem in conventional desalination processes is the high energy requirements. Another problem is the desalination waste, which is made up of concentrated residues. Technically speaking, brackish water, in particular, causes bigger problems in desalination than seawater: it contains a large number of dissolved minerals whose composition is complex from a geochemical perspective and varies strongly over time. This increases risk of scaling, which can cause damage to the system, especially if the pretreatment process cannot react flexibly enough to variations in the raw water composition. At the same time, the poor solubility of some minerals means that the recovery rate is somewhat limited.

This is where the development work of the joint project HighRec comes into play. The project researchers aim to create a flexible, solar-power desalination system including pretreatment. The new system is expected to deliver a high recovery rate and allow for dynamic adaptation to ever changing raw water composition.

The project researchers have chosen a desalination method known as closed loop reverse osmosis (CLRO). This method will be further developed during the HighRec project.

Closed Circuit System

In CLRO, the brine solution continually passes through the membranes in the reverse osmosis module, causing the salt concentration to increase to a defined threshold. The brine is not drained until this maximum level is reached. Throughout this process, the operating pressure changes continually. These systems can thus adapt to a wide range of feed water compositions and offer high water recovery rates at the same time. The energy needs are lower than in conventional reverse osmosis systems, since the pressure is low at the start of each cycle.



Closed loop reverse osmosis process developed in the HighRec project

The project researchers will test various chemical-free pretreatment technologies and resin-based ion exchangers that are installed upstream of the CLRO system; the purpose of this is to prevent deposits building up on the membrane, in doing so ensuring reliable system operation. Energy is supplied from a solar PV system with minimal battery storage. To make sure the different system components are in perfectly equilibrium, the researchers will be developing intelligent measurement and control engineering for overall system control based on defined parameters including predictive detection of threshold exceedance and errors. Additionally, the researchers are looking for ways to achieve a level of brine residue concentration that allows the salts obtained to be reused cost effectively.

All of the technical options explored as part of the joint project are evaluated on the basis of a series of technical, economic, ecological, and other criteria—for example governance. The researchers will be looking specifically at the local conditions, as well as the requirements of different sectors in the potential regions where the technology can be used.

Solution for Agriculture and Industry

The brackish desalination method developed as part of the HighRec project will be tested at a demonstration plant in two different locations in the region. The plan is for the plant to produce irrigation water for agriculture in Qatar and Iran. The experience gained here will serve as the basis for the development of a new system that is ready to go into series production in collaboration with local firms. Other sectors and markets in the MENA region besides agriculture will also be looked at—process water treatment for industrial applications, for instance.

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Intensification of the Recovery Ratio of Brackish Water Desalination Systems for Agriculture (HighRec)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1610A

Grant Volume
EUR 1,349,844

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Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O‘Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credit
Fraunhofer ISE

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Federal Ministry
of Education
and Research

MEWAC
Middle East Regional Water
Research Cooperation Program

HydroDeSal—Forward Osmosis Desalination by Thermo-Responsive Hydrogels

Middle East Regional Water Research Cooperation Program (MEWAC)

More than 96 percent of the Earth's water is found in our oceans and seas. With the right technologies, the potential to produce vast quantities of freshwater and help tackle the global water crisis is huge. Existing desalination processes, however, have a number of drawbacks. They consume too much energy, for instance, and are costly and high maintenance. The joint project HydroDeSal seeks to optimize the desalination process. To this end, the project researchers will be using innovative polymer gels that respond to the ambient temperature. With the help of these thermoresponsive hydrogels, the aim is to supply small settlements in the Persian Gulf with water without the need for external energy sources.

Changeable Gels

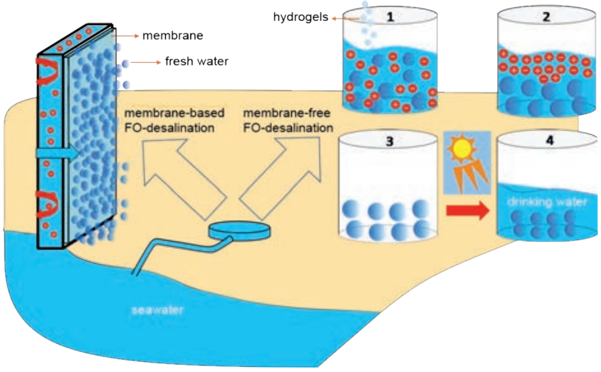
In arid countries that have access to seawater or substantial quantities of brackish water, desalination plays an important role in water supply. The desalination processes used at the moment, however—be it thermal processes such as multistage flash distillation or membrane-based processes such as reverse osmosis—are not without their drawbacks. They need huge, expensive equipment that is not economical to run unless supplying larger regions with water. Despite having been continually developed and refined over the years, reverse osmosis is still a very energy-intensive technology. Another issue is that the membranes used become easily clogged up, meaning the process consumes even more energy, which in turn negatively impacts the efficiency.

An alternative to reverse osmosis is forward osmosis. This process needs no external pressure. Instead, the water is transported by natural osmotic pressure differences. Forward osmosis is thus more energy efficient and causes fewer deposits on the membranes. Up till now, however, this process has seldom been used in water desalination. To refine this technology and increase its market readiness, the key components in this process have to be optimized. This very task is what researchers from Germany, Iran, and Iraq will be working on as part of the HydroDeSal project. A cornerstone of the developments will be special gels that are able to change their form in response to temperature, enabling them to absorb water.

Refining a Promising Idea

The process of forward osmosis can work on two different principles, i.e., with or without membranes. In the more common membrane-based version, contaminated or saline water (known as the feed solution) flows across a membrane. This membrane is only permeable to water molecules. By placing a suitable material on the other side of the membrane (known as the draw agent), pressure is produced and some of the water can pass through the semipermeable membrane. The water that is separated from the draw solution is clean drinking water.

Thermoresponsive hydrogels have proven to be very promising candidates for use as the draw agent. Below a given critical temperature (approx. 30°C), these gels will swell up in water, causing them to absorb the water. Above this temperature (from around 35–40 °C), the material loses this ability again; the particles shrink and



Membrane-based (left) and membrane-free (right) forward osmosis using thermoresponsive hydrogels release the water they have absorbed. In the HydroDeSal project, these properties are used to develop innovative draw agents and separation agents. In the next stage of the project, the plan is to use these materials in membrane-free forward osmosis as both a separation and draw agent at the same time. Since no membrane is used here, the process costs for this type of forward osmosis can be expected to be even lower. Here, the HydroDeSal project team will be taking existing hydrogels and adapting them for use as a separation or draw agent in forward osmosis

The water can be released again from the hydrogels using waste heat from industrial processes, for example. In warm regions like the Persian Gulf, heat from natural sources could be used for this. Temperature differences at different times of day mean that the gels swell up and absorb water at night, shrinking again and releasing the water when exposed to the sun during the day. As a result, this process incurs lower overall energy costs. In cooperation with our project partner in Iran, the potential of the method explored in the HydroDeSal project will be put to the test under real-life conditions in a lab-scale desalination plant.

Small Plant, Huge Opportunities

New desalination methods that are ideal for use in compact systems are perfect for smaller towns and areas with a low population density. This enables them to supply their own drinking water in an energy-efficient system that has relatively low initial investment, running, and maintenance costs. For the German water industry, this also means they have the opportunity to tap into new markets in counties that suffer from water scarcity.

Persian Gulf University campus where the lab demo plant of the desalination plant is being tested under real-life conditions

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Forward Osmosis Desalination by Thermo-Responsive Hydrogels (HydroDeSal)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1613

Grant Volume
EUR 598,290

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Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O‘Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credits
Front: Amir Jangizehi
Back: Seyed Abdollatif Hashemifard

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Federal Ministry of Education and Research

MEWAC Middle East Regional Water Research Cooperation Program

MiningWater—Mining Water Recovery Using Innovative Technologies for Saving Fresh Water

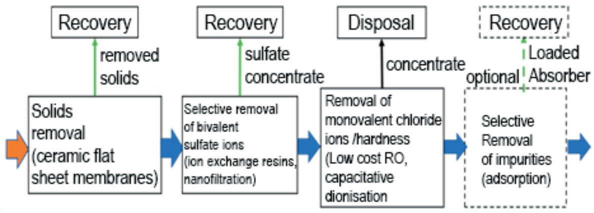
Middle East Regional Water Research Cooperation Program (MEWAC)

Permanent water stress in the Middle East leads to conflict over water use between the supply of drinking water and water for agricultural and industrial purposes. At the same time, there is often a lack of suitable methods for circular use of water and the valuable materials it contains, methods that can help conserve our water resources. For example, in phosphate mining, an important industry for the region, water and phosphate are often lost because wastewater is generally collected in open basins. This hitherto untapped potential is to be unlocked by researchers from Germany, Egypt, and Jordan, who will be developing and testing an innovative combined process at a phosphate mine in Jordan as part of the MiningWater joint research project. The new process uses ceramic flatsheet membranes to filter solid substances from the wastewater, which is then desalinated using robust and inexpensive technologies. The aim is to separate phosphate production and fresh water use as much as possible, and increase the value added by reusing the concentrates produced.

Filter, Desalinate, Reuse

During the washing and separating stages of phosphate rock processing, the wastewater produced contains solid matter. Owing to its composition, the wastewater is collected in open basins known as tailing ponds. This results in annual water losses of three million cubic meters per mine. Due to the high concentration of solid substances (that make up a mass of 15 percent) and the presence of substances that cause limescale formation, mining wastewater cannot be treated using conventional filtration methods, as this would cause clogging of the filtration materials and membrane modules. Plus, the high salt content prevents the wastewater from being reused directly.

The complex, ever-changing composition of wastewater from phosphate mining calls for simple and robust treatment processes that enable untapped water and raw material potential to be unlocked. This is where the MiningWater research project comes in. This project uses an innovative modular approach based on combined processes that can be adapted to any plant size as well as to the specific local conditions and wastewater composition. The aim is to filter phosphate-containing solids out of the wastewater, remove the sulfate and chloride in separate processes, and remove heavy metals such as chromium which are problematic for water recycling. The sulfate and filtered phosphate-containing solids can be reused, increasing the overall value of the process even further.



Combined process for the recovery of water and valuable substances from phosphate mining wastewater

From Test Lab to Implementation in Practice

In the first stage of the new combined process, the researchers test the ceramic flat-sheet membranes that are designed to filter solid matter from the mining wastewater. The membranes are energy efficient and temperature resistant and can resist harsh media such as concentrated or aggressive solvents and cleaning agents. The water can then be desalinated. This will see the project partners test for the first time how well suitable resins and selective nanofiltration membranes are for removing multivalent ions such as sulfate. The researchers also plan to develop affordable polymer membranes that will be used to reduce the chloride content in the wastewater. An alternative method being explored is an electrostatic process known as membrane capacitive deionization (MCDI) where salt ions are drawn out of the water by applying a voltage in an energy-efficient process and then stored. The voltage is then reversed and the salts can be recovered as salt concentrate.

FONA
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Using an innovative adsorber, any heavy metals present in the mining wastewater (e.g., chromium) will be removed in the final step. In this process, the metal (in this case chromium) forms a thin film on the ferrous material used as the adsorption agent. This can then potentially be used as a substitute for ore in furnaces, meaning no additional waste would be produced.

The different process technologies are tested by the project researchers in lab and pilot tests at a phosphate mine in Jordan. The results are then used to develop a dedicated method for treating phosphate mining wastewater that is directly transferrable to actual operation in the field. The new concept will also include an economic and environmental assessment.

Huge Potential Savings

The largerst phosphate rock reserves in the world can be found, among other places, in six Middle Eastern countries and in North Africa. The combined phosphate and water recovery processes developed and field tested as part of the MiningWater project, as well as the recycled concentrates that are the by-products of these processes open up hitherto untapped potential in these countries. Based on the three million cubic meters of water that these processes can help save at a single phosphate miner, the potential overall savings could be 40 times as high.

Containers used for lab tests and field trials at the pilot site

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Mining Water Recovery Using Innovative Technologies for Saving Fresh Water (MiningWater)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1611

Grant Volume
EUR 323,837

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Website
bfi.de/de/projekte/miningwater-einsatz-innovativer-techniken-zur-senkung-des-frischwasserbedarfs-durch-wasserrueckgewinnung-aus-bergbauabwaessern/

Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O‘Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credits
Front and back: VDEh-Betriebsforschungsinstitut GmbH

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Federal Ministry
of Education
and Research

MEWAC
Middle East Regional Water
Research Cooperation Program

TransFresh—Transboundary Freshwater Resource Real-Time Monitoring and Management

Middle East Regional Water Research Cooperation Program (MEWAC)

The Yarmouk River is the biggest tributary to the Jordan River and the groundwater resources in its drainage basin are important transboundary freshwater resources that provides drinking and irrigation water in Syria, Jordan, Israel, and, indirectly, Palestinian territories, too. These resources are extremely important for water management in this region. To date, however, the impact that climate change and increased water abstraction has on water resources remains largely unknown. In an attempt to gain a better understanding of the complexities of the water resource system in the area of the Yarmouk River, the partners in the joint TransFresh project will use data from a transboundary monitoring system to model the resources both above and below the ground and set out relevant recommendations for sustainable management.

Collecting Data to Understand the Complex System

The Yarmouk River is the main tributary of the River Jordan and at the same time an important strategic drinking water resource for Syria, Jordan, and Israel. Owing to the relatively heavy rainfall in the Yarmouk drainage basin, this area is crucial for the ecology of the entire Lower Jordan Valley and the Dead Sea. It is vital for farmland irrigation in the region and since 2020 has been supplying some ten percent of the population of Jordan with water through the Wadi Al Arab System II water conveyance project. Surface water runoff, however, is strictly controlled by upstream dam structures. The only thing keeping the river alive is the groundwater that flows from the Ajloun area of Jordan.

Artesian Mukeihbeh well field (Jordan). In this artesian aquifer, water flows to the ground surface under natural pressure.

At the same time, this groundwater is urgently needed to supply water to the north of Jordan, an area where water resources are under additional pressure owing to the influx of refugees. In some places, this has caused groundwater levels to drop by as much as 120 meters and has left groundwater resources at risk of salination.

The search for solutions for optimized management of the scarce water resources has been further complicated by the political situation in the region. Both the groundwater and surface water resources span Syria, Jordan, and Israel. This makes it difficult to conduct systematic analyses on the complex interplay between the individual systems.

This is where the TransFresh project comes into play. This joint research project uses a custom-developed monitoring system comprising a comprehensive network of monitoring stations along the Yarmouk River and at groundwater bodies in the river's drainage basin. These stations will deliver data on a number of variables: the discharge rate and groundwater movements, the natural interaction between rivers and groundwater bodies, as well as anthropogenic impacts. This concept is the first of its kind to combine groundwater dating tools, i.e., tools that determine the age of the groundwater, and flow path analysis with transboundary online monitoring. The data generated will be used to model the status quo of water resources, enabling recommendations for future water management strategies to be made.

Modeling and Future Projections

To meet their aims, the researchers will be combining a variety of measurement technologies, including methods to estimate the groundwater residence times in the individual groundwater bodies in the Yarmouk Gorge. This will allow them to draw conclusions on groundwater recharge points, transfer times in the aquifers, and mixing of different groundwater components. Given the strong differences in residence times, the researchers will be using what is known as a multitracer approach where different marking substances are used to trace the hydro-geochemical processes in the groundwater. By analyzing the Yarmouk for the presence of certain isotopes, i.e., atoms of an element that have the same chemical properties but different atomic masses, conclusions can be drawn on how the river is impacted by the inflow of groundwater.

All of this data goes into flow models that simulate the temporal and spatial water movements both above and below the ground in high resolution, as well as showing future developments. The researchers involved in the TransFresh project will use this to optimize the management of dams and groundwater resources. This will potentially help secure the availability of freshwater in the region for many years to come.

Improving Water Supply and Relations

TransFresh will play an important role in achieving a stable water supply from the Yarmouk basin over the long term, improving relations between the riparian countries at the same time. Stakeholders and decision-makers will be involved throughout the entire project development process; this will help deliver practical results that are transferable to real-life scenarios. In fact, the key concept behind this project sees the methods developed being transferred to other regions with transboundary water resources.

View of the Yarmouk Gorge

Funding Measure
Middle East Regional Water Research Cooperation Program (MEWAC)

Project Title
Transboundary Freshwater Resource Real-Time Monitoring and Management (TransFresh)

Duration
July 1, 2021 – June 30, 2024

Grant Number
02WME1608

Grant Volume
Federal Ministry for Education and Research (BMBF):
EUR 164,324
Ministry of Innovation, Science & Technology (MOST):
EUR 125,925

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Website
h3-i.de/transfresh

Published by
Federal Ministry of Education and Research (BMBF)
Department of Resources, Circular Economy; Geosciences
53170 Bonn

October 2022

Edited by
Project Management Agency Karlsruhe (PTKA)

Translated by
Christine O'Donnell

Layout
Project Management Agency Karlsruhe (PTKA)

Printed by
BMBF

Photo Credits
Front and back: Dr. Christian Siebert

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