Federal Ministry
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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.

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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.

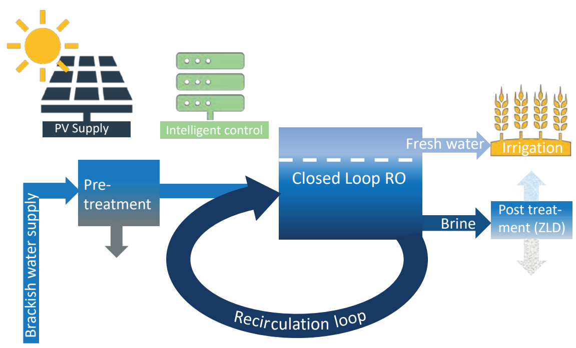
A general problem in conventional desalination processes is the high energy requirements. Another problem is the desalination waste, which is made up of concentrated residues. Technically speaking, brackish water, in particular, causes bigger problems in desalination than seawater: it contains a large 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.

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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

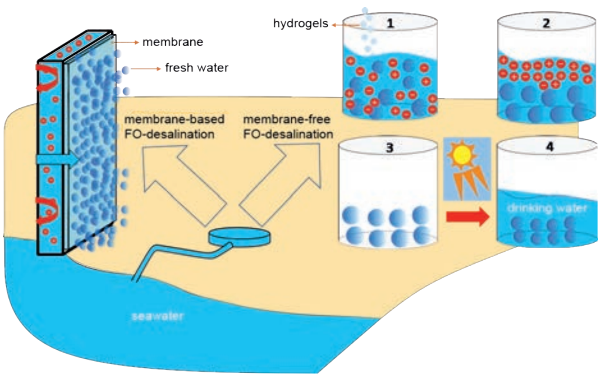
In arid countries that have access to seawater or substantial quantities of brackish water, desalination plays an important role in water supply. The desalination processes used at the moment, however—be it thermal processes such as multistage flash distillation or membrane-based processes such as reverse 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 co-operation 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

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MEWAC
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Research Cooperation Program

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

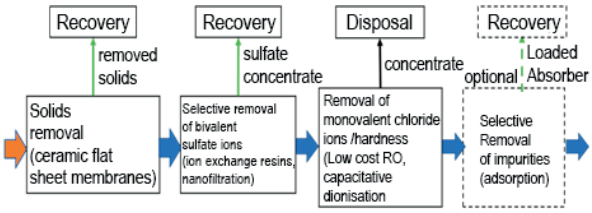
Middle East Regional Water Research Cooperation Program (MEWAC)

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
Sustainable Water Management

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

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