

WASTE WATER REUSE AND DESALINATION AS STRATEGIC RESOURCE FOR AGRICULTURE: EXPERIENCES FROM AROUND THE WORLD.

MARCO ARCIERI – ICID PRESIDENT



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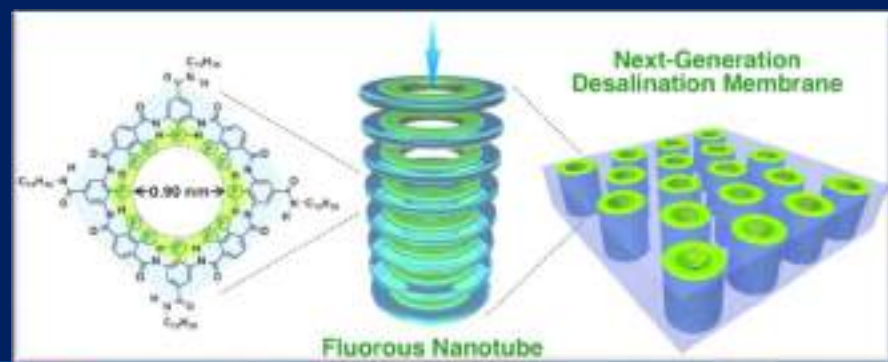
Wastewater reuse in agriculture: from liability to resource

Wastewater reuse and sea water desalination have, in time, become increasingly suitable, sustainable solutions to global water scarcity, providing to be reliable alternatives to traditional water sources.



Wastewater reuse in agriculture: from liability to resource

As of today, these technologies are transmuting from "last-resort" options into crucial components of global water security, driven by innovations in membrane and process technologies, artificial intelligence (AI), and renewable, low cost energy integration.



DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

In the agricultural sector, the use of non-conventional or poor-quality water resources as an additional source for irrigation is one of the exploitable solutions.



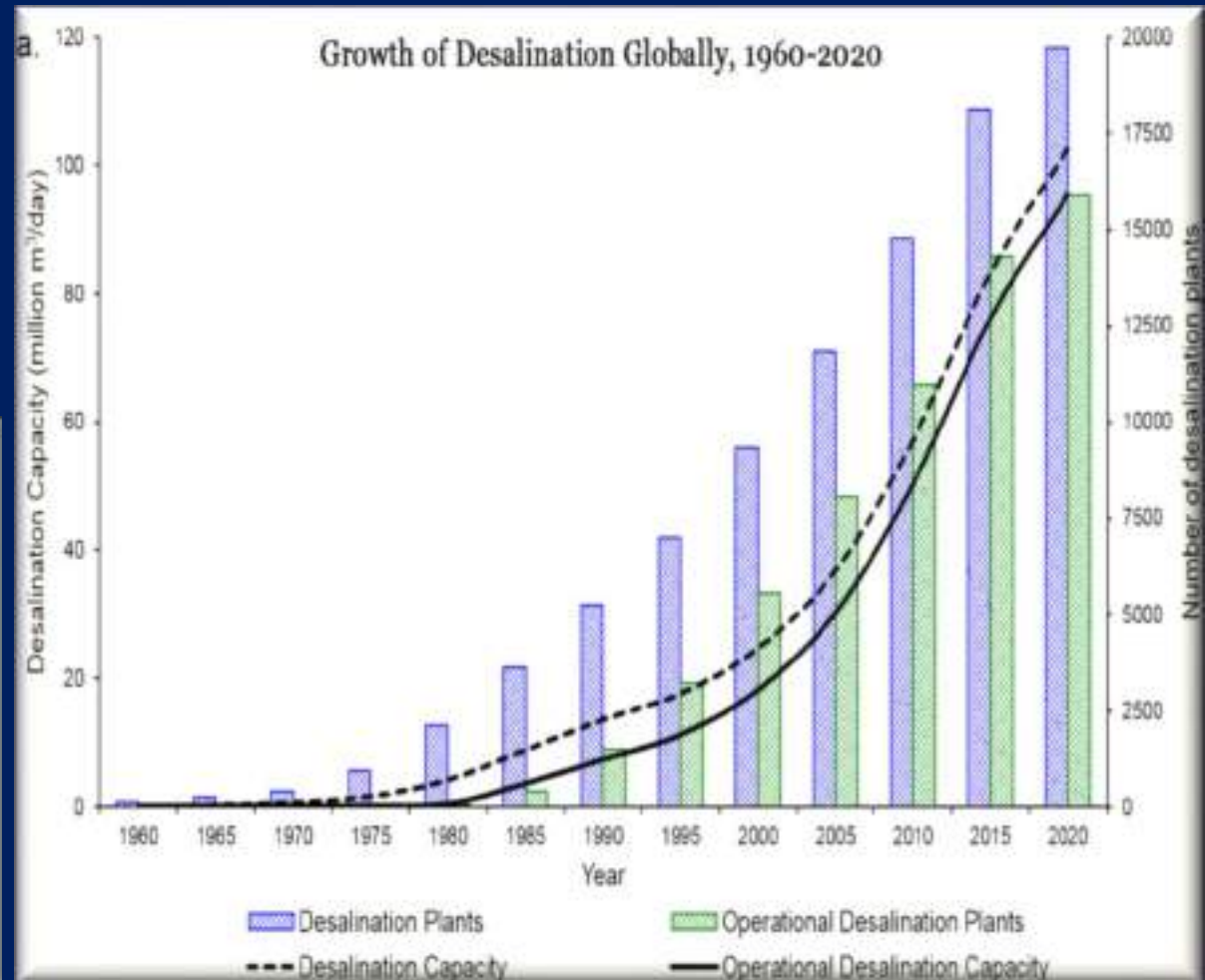
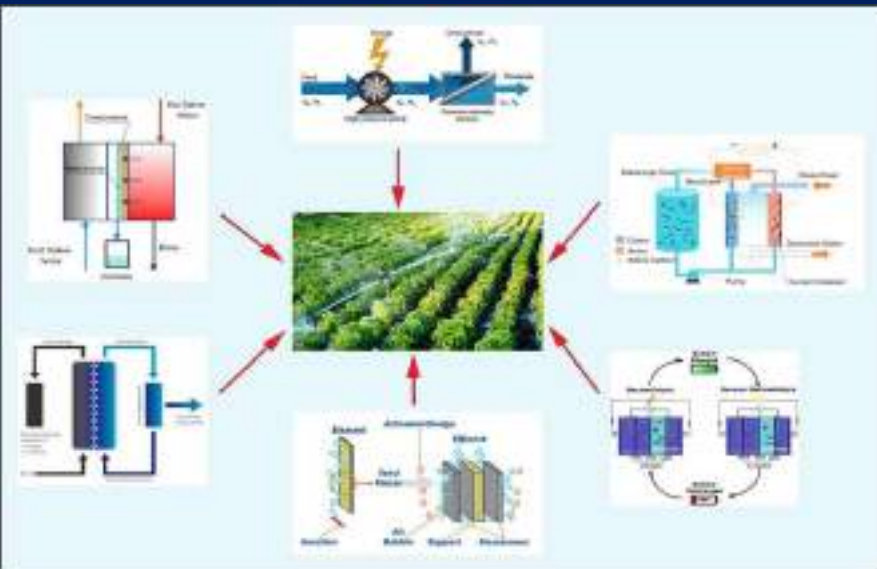
DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

In recent years, the use of desalinated seawater seems to be consolidating as an alternative solution for irrigation of cash crops, in countries such as Spain and Israel. Hence, large-scale supply with DSW has emerged as a substitute water resource for agricultural production, especially in coastal regions facing recurrent water scarcity, as well as in islands lacking freshwater resources.



DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

Consequently, its adoption is nowadays considered as a possible, technically feasible solution in order to guarantee adequate water supply for irrigation of high-income crops. And this trend is expected to intensify in the near future.

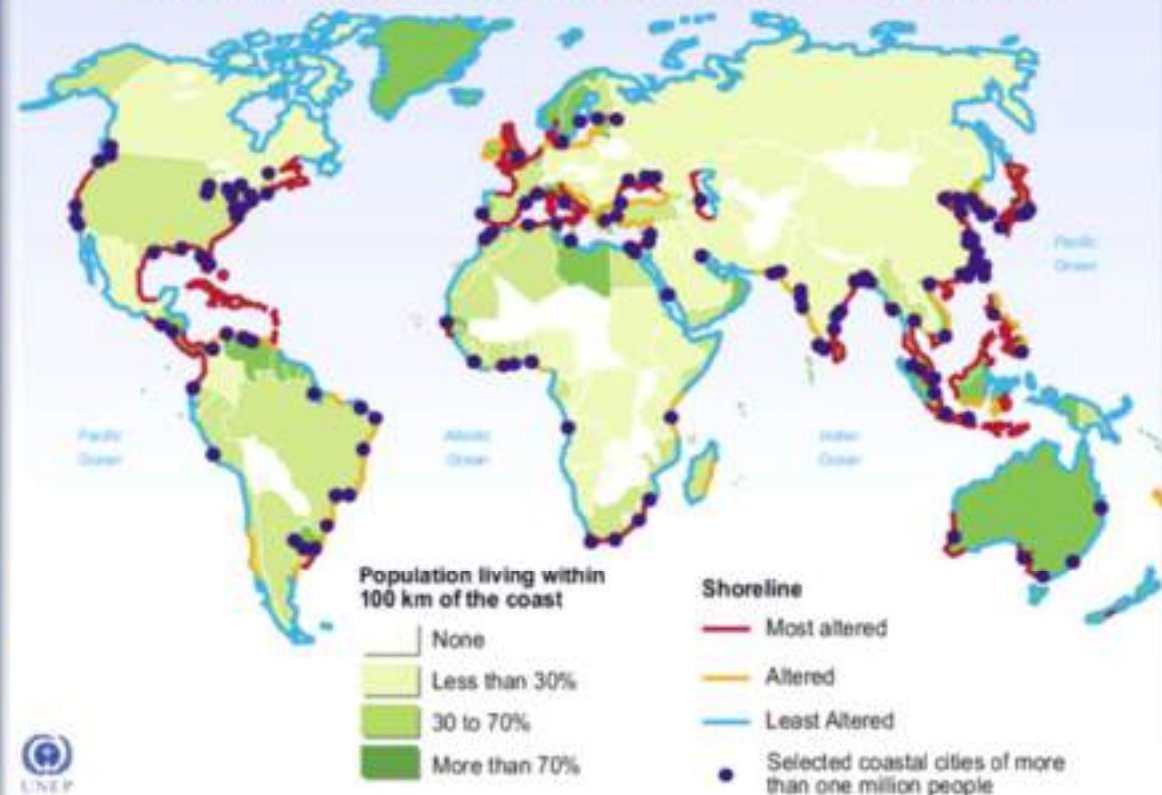


DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

All demographic data show that in the last decades population growth dynamics have been particularly significant along the coasts, all over the world. Areas where a very strong and sometimes harsh competition between domestic (tourism) and agricultural uses usually takes place, especially during the growing season.



Coastal Populations and Shoreline Degradation

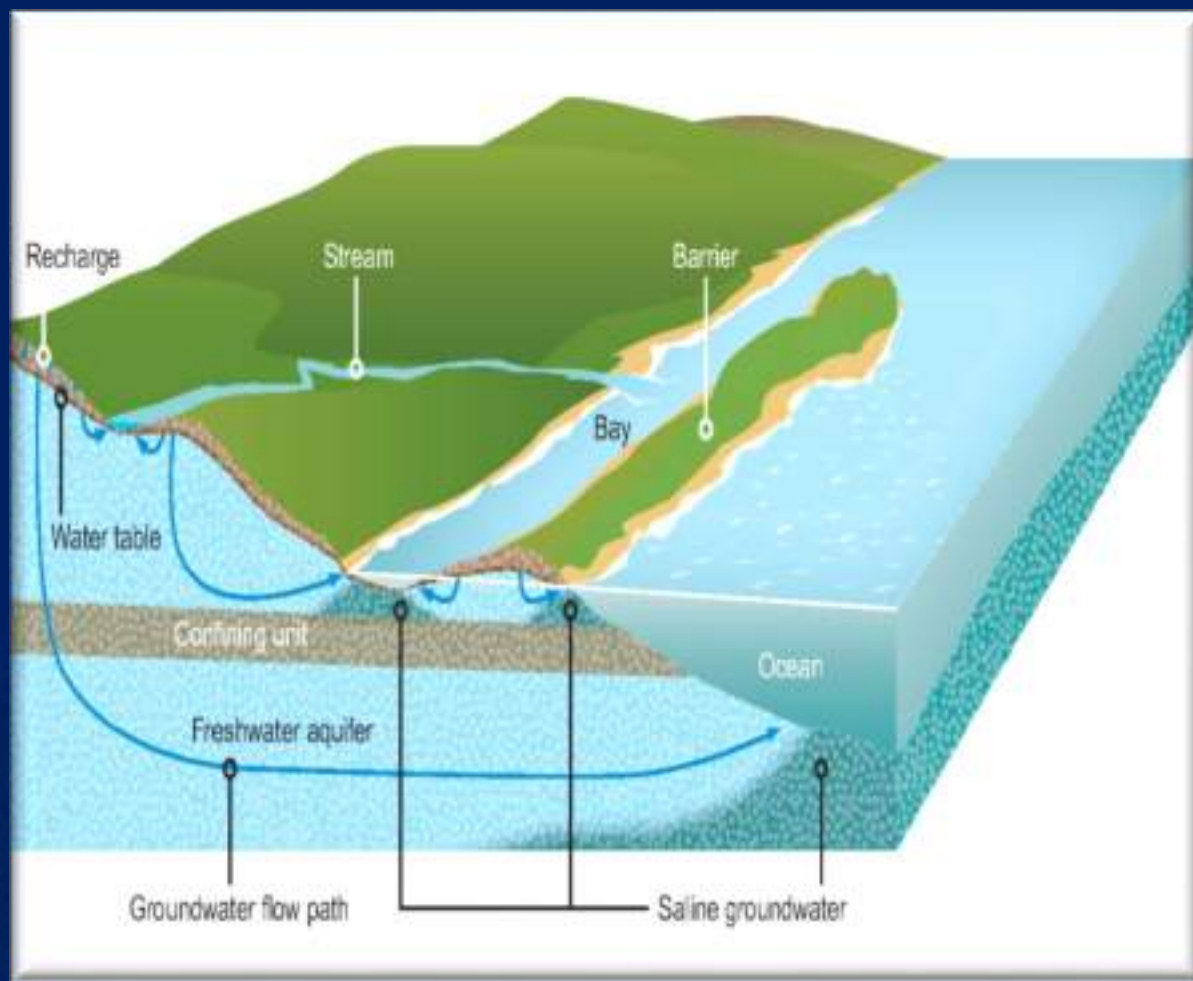


Source: Burke et al., World Resources Institute, Washington DC, 2001; Paul Harrison and Fred Pearce, AAAS Atlas of Population and Environment 2001, American Association for the Advancement of Science, University of California Press, Berkeley.



DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

Paradoxically, with more than 40 percent of the world's population presently living within 100 km of an ocean, many areas affected by freshwater scarcity are close to the sea. These are the areas where DSW can alleviate human pressure on coastal ecosystems, reducing groundwater extraction and seawater intrusion into the aquifers.



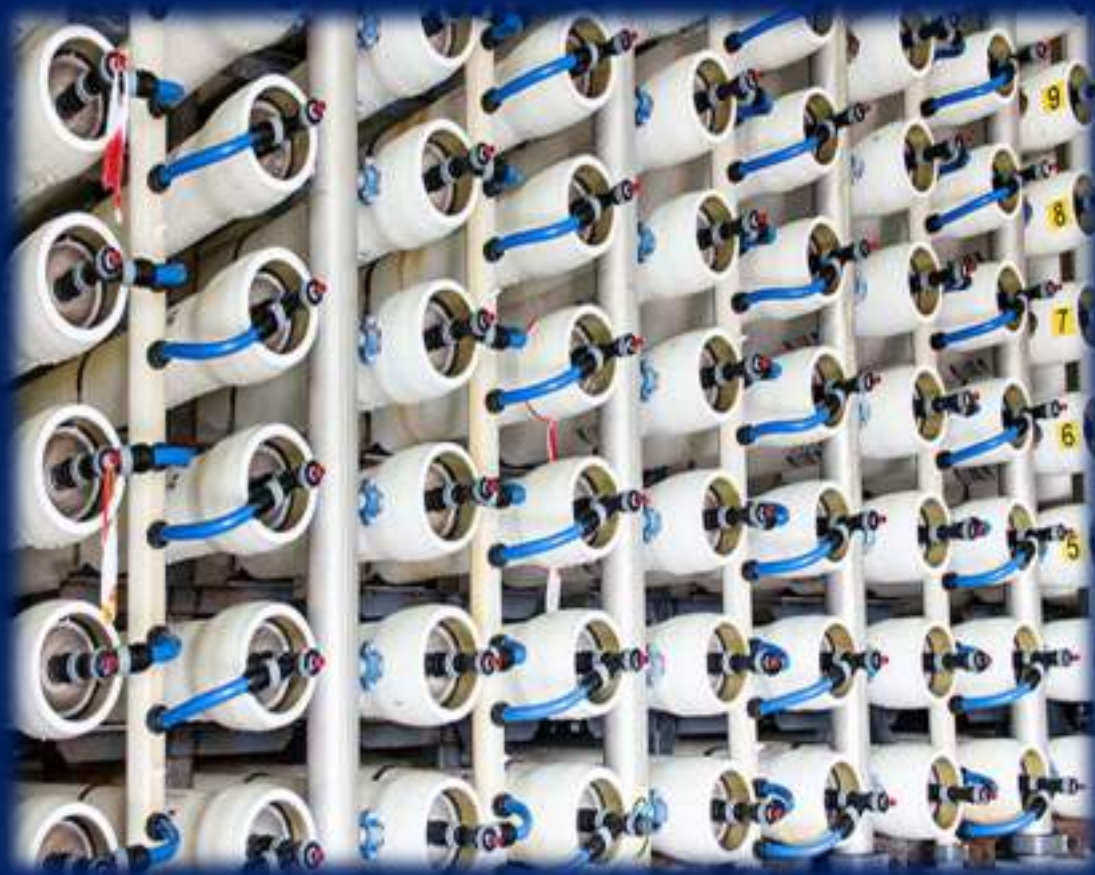
DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

This is why desalinated water is currently being used for irrigation purposes in many coastal areas around the world, thereby justifying DSW as an integral part of the globe's response to water scarcity. This is especially significant in the present scenario of climate change, where we are all withstanding the dramatic awareness of increasing water scarcity.



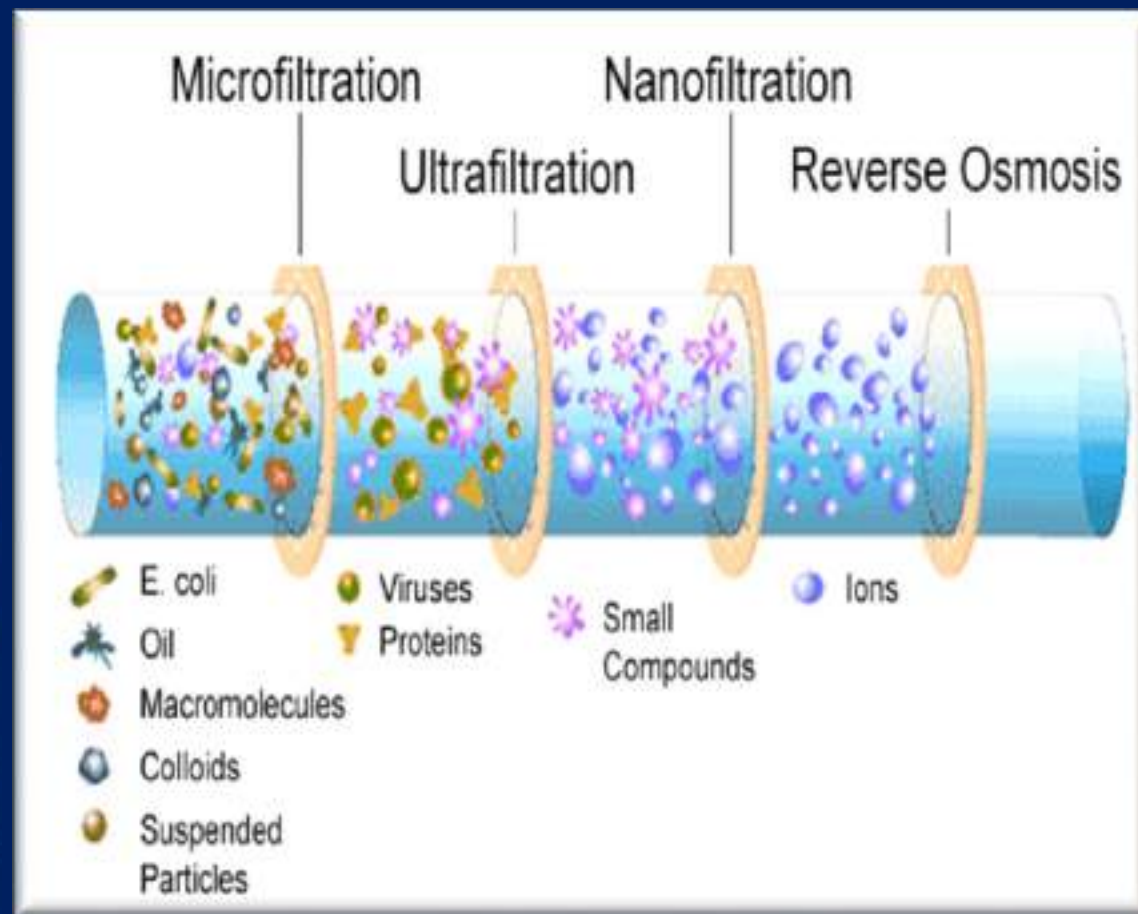
DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

As desalination technologies have developed and improved, the cost to build desalination plants has progressively declined. This decrease in cost has been one of the primary factors for the acceptance, growth and success of desalination. Since the 1960s, the cost for Multi-Stage Flash Distillation (MSF) to desalinate water has decreased approximately by a factor of 10, with approximate unit costs of US\$ 10.00/m³ to less than US\$ 1.00/m³ in 2020.



DESALINATION: THE NEW FRONTIER FOR IRRIGATION?

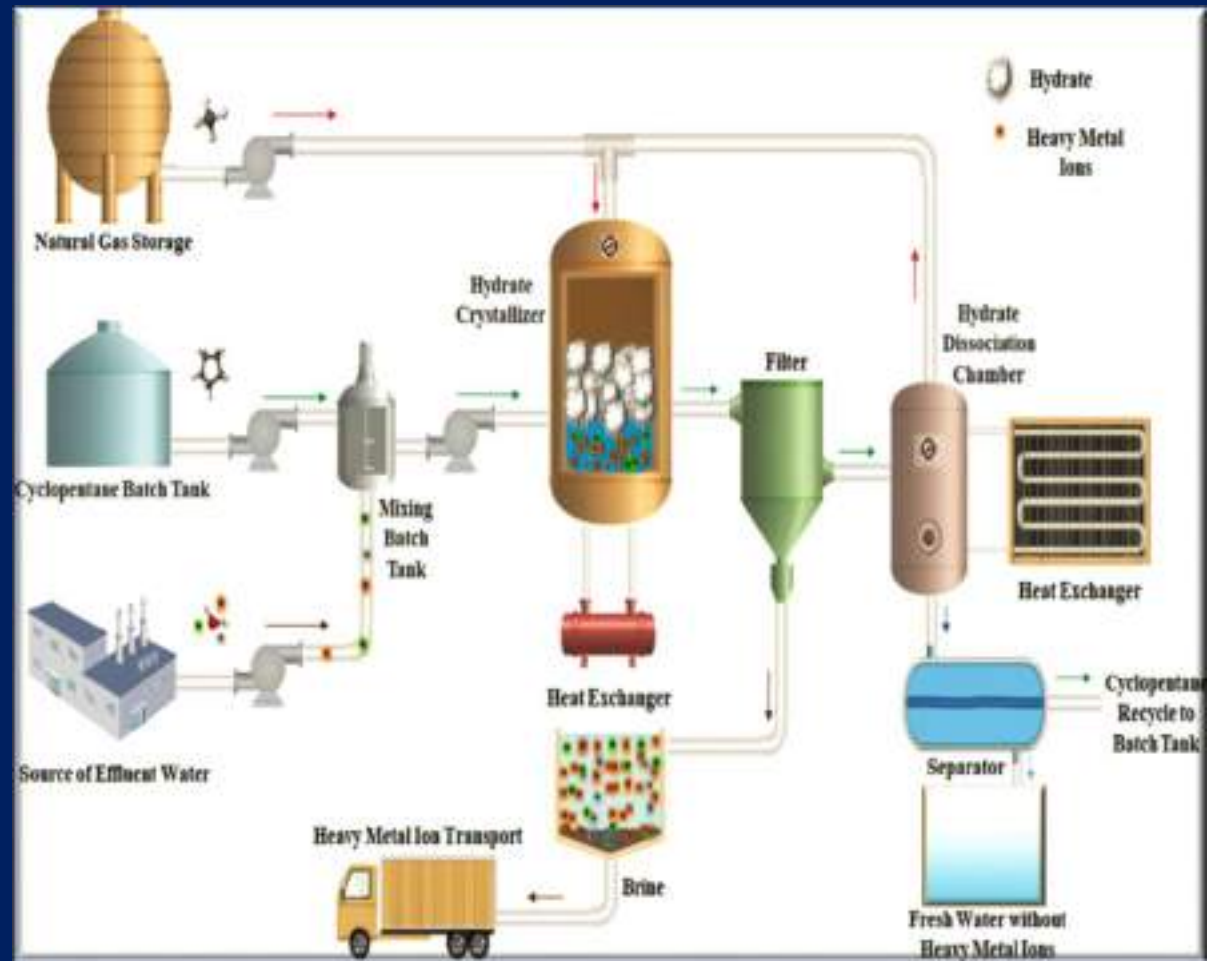
Thanks to the improved technical and innovative solutions recently introduced and showing the way forward (new membranes, innovation of desalination processes), DSW can indeed represent a possible solution to guarantee new sources of water for irrigation.



DESALINATION METHODS

GAS HYDRATE FORMATION

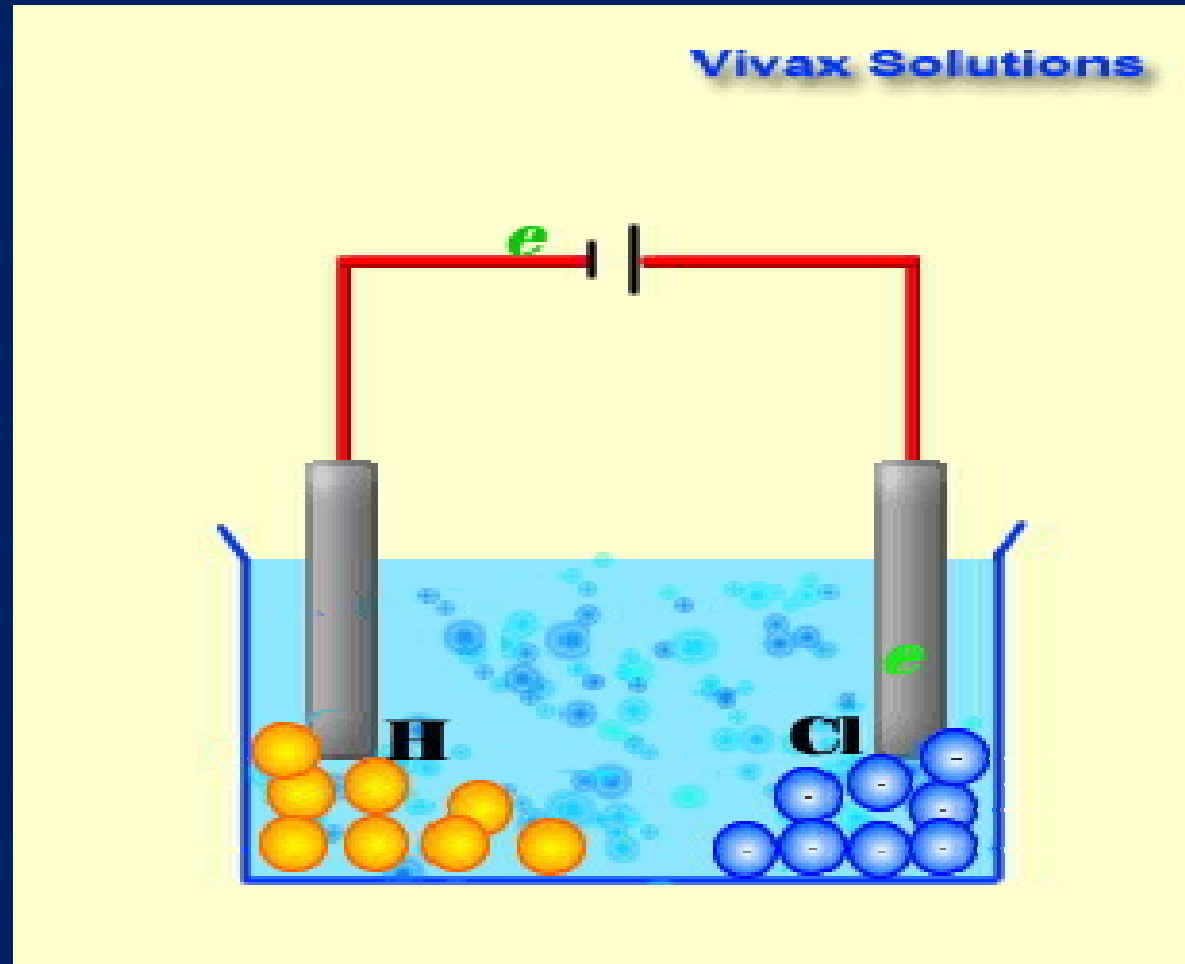
Gas hydrates are solid crystals that are formed by combining water with a gas, such as propane, at high pressure and at low temperature. During the process, all the salts and impurities present in the water disappear and as the temperature increases the gas can be recovered leaving fresh water.



DESALINATION METHODS

ELECTRODIALYSIS

The salt water moves through electrically charged membranes that trap the salt ions dissolved in the water, allowing fresh water to be extracted. There are diverse variants of electrodialysis, such as conventional and reverse.



DESALINATION METHODS

REVERSE OSMOSIS

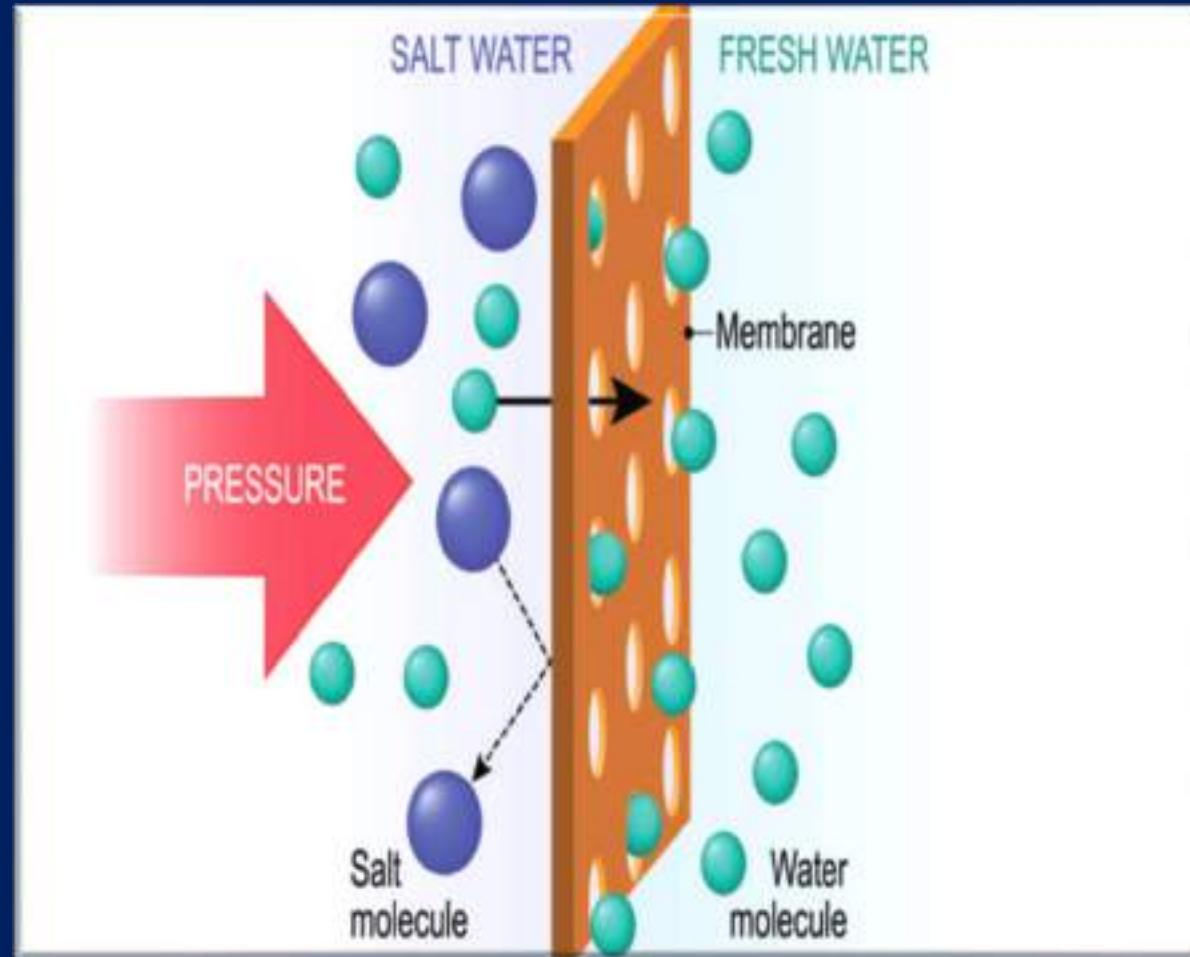
It's the most used process and consumes less energy than the rest, as it is based on the use of semipermeable membranes that allow water to pass, but not salt. These membranes are made of ultra-thin polyamide, which can become contaminated with bacteria so the water must be treated.



DESALINATION METHODS

REVERSE OSMOSIS

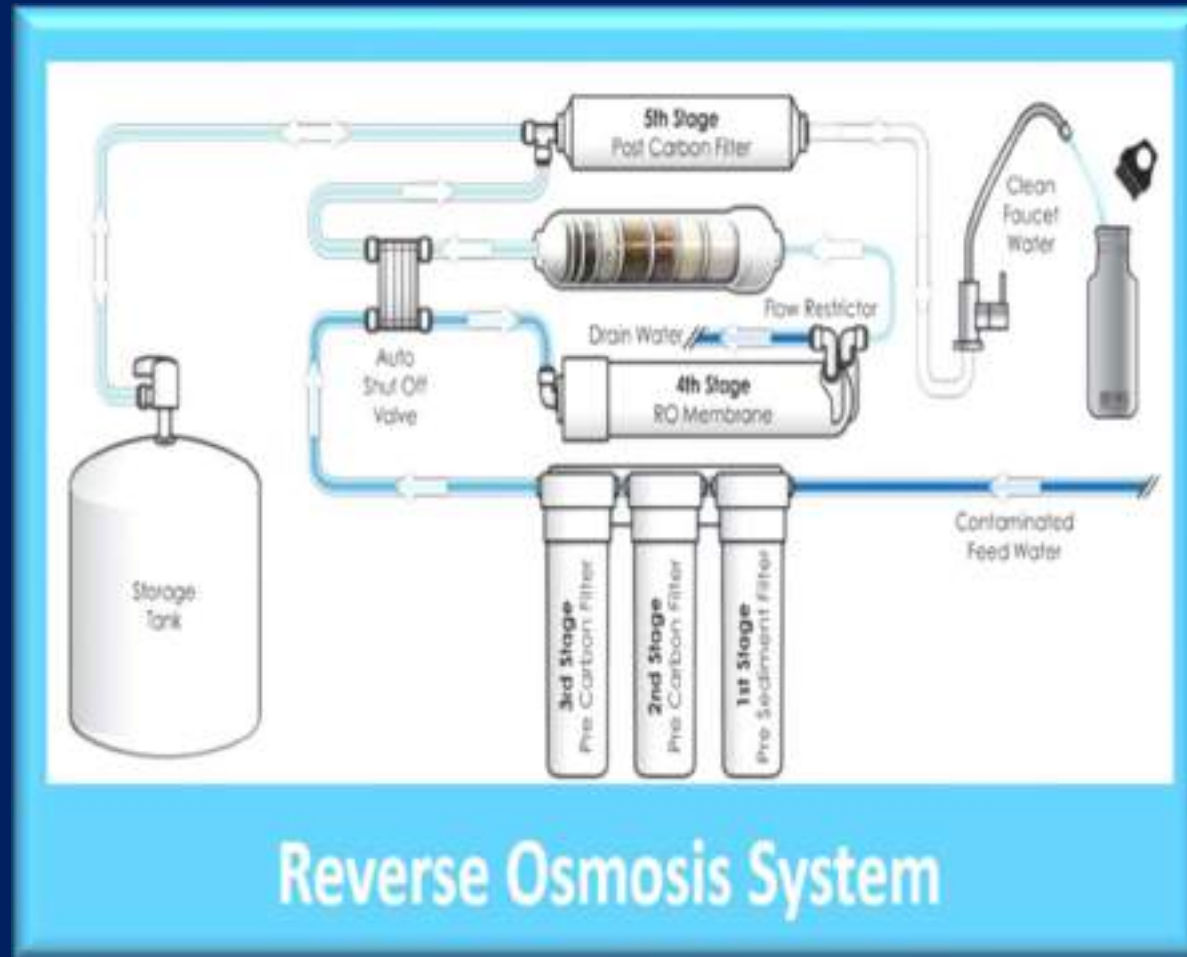
In reverse osmosis, water is pushed through semi-permeable membranes, by means of pressure. The salts do not pass through the membrane, while water molecules do. Although there is some selectivity to specific ions, desalination with reverse osmosis removes most salts from the water.



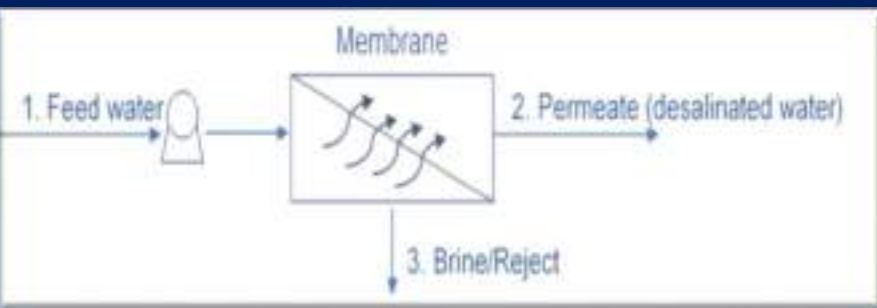
DESALINATION METHODS

REVERSE OSMOSIS

The quantity of salts removed mostly depends on the pressure exerted and on the ratio between the amount of desalinated water produced and the amount of brine water rejected and discharged as waste. Higher rejected brine volume results in better quality of the desalinated water and vice versa.



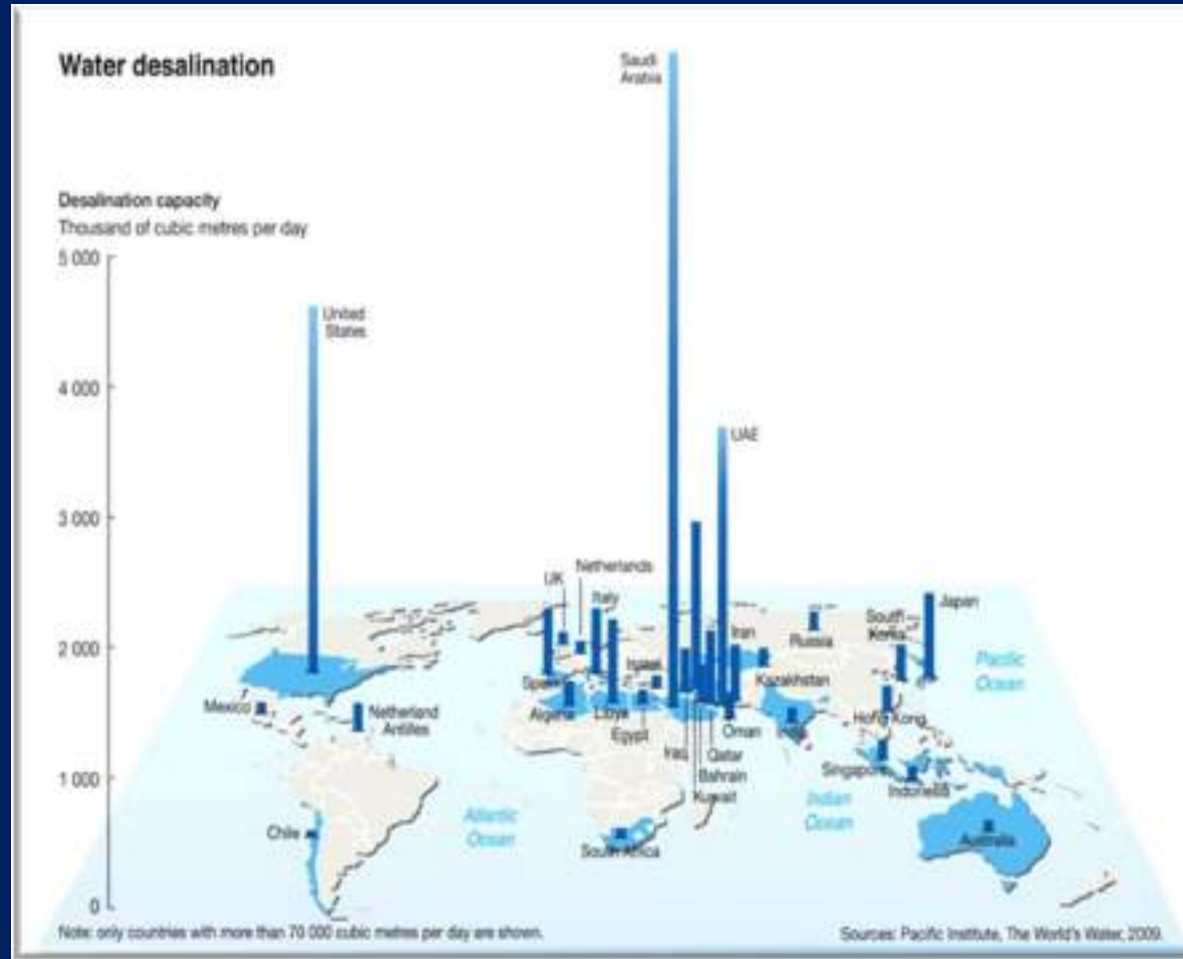
Reverse Osmosis System



DISTRIBUTION IN THE WORLD

PRODUCTION CAPACITY

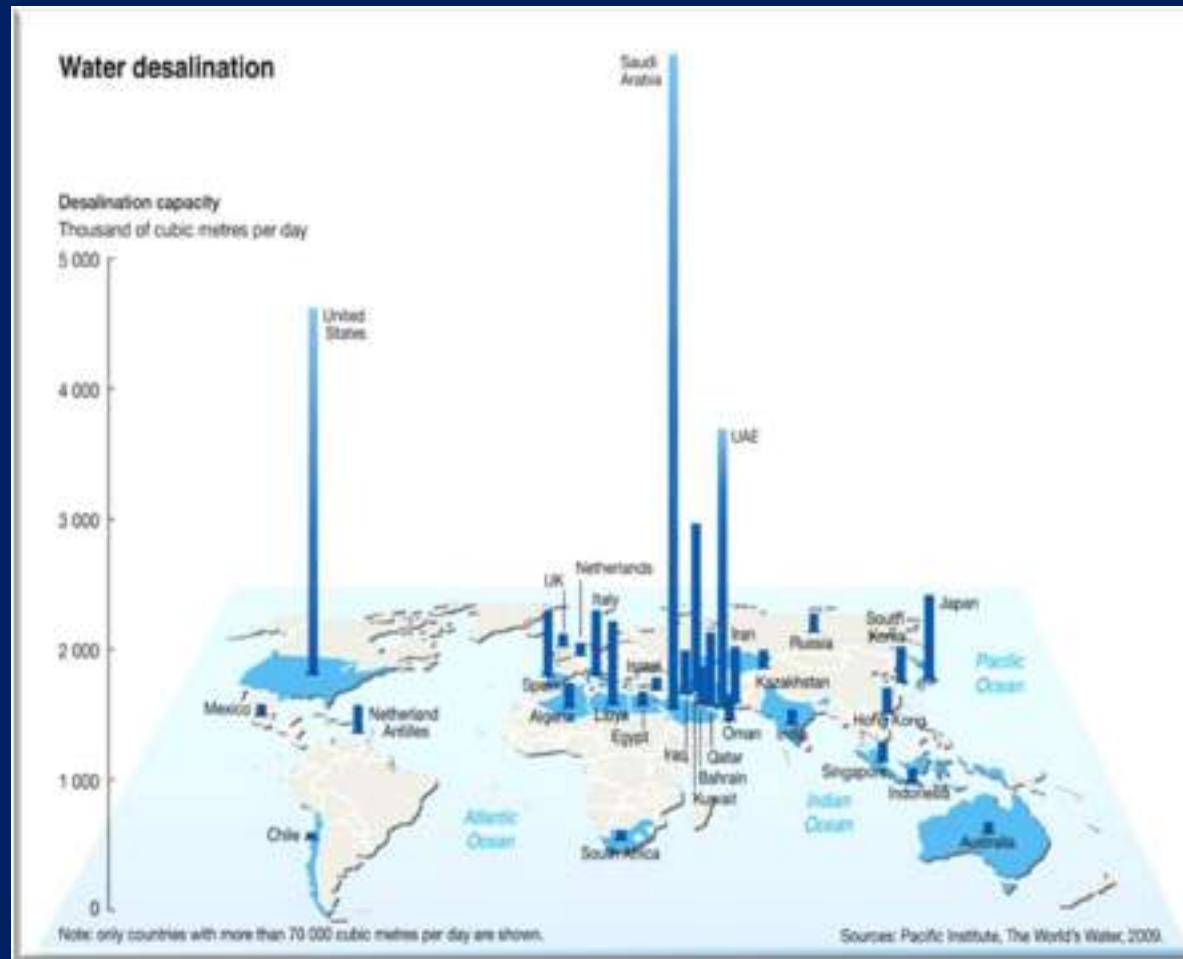
The largest production capacity by location is in the Middle East, due to the lack of freshwater sources and abundant energy resources of the area. The largest desalination user by capacity is the Kingdom of Saudi Arabia, followed by the United States, UAE, Australia, Japan, Kuwait, and Israel.



DISTRIBUTION IN THE WORLD

VOLUME CAPACITY

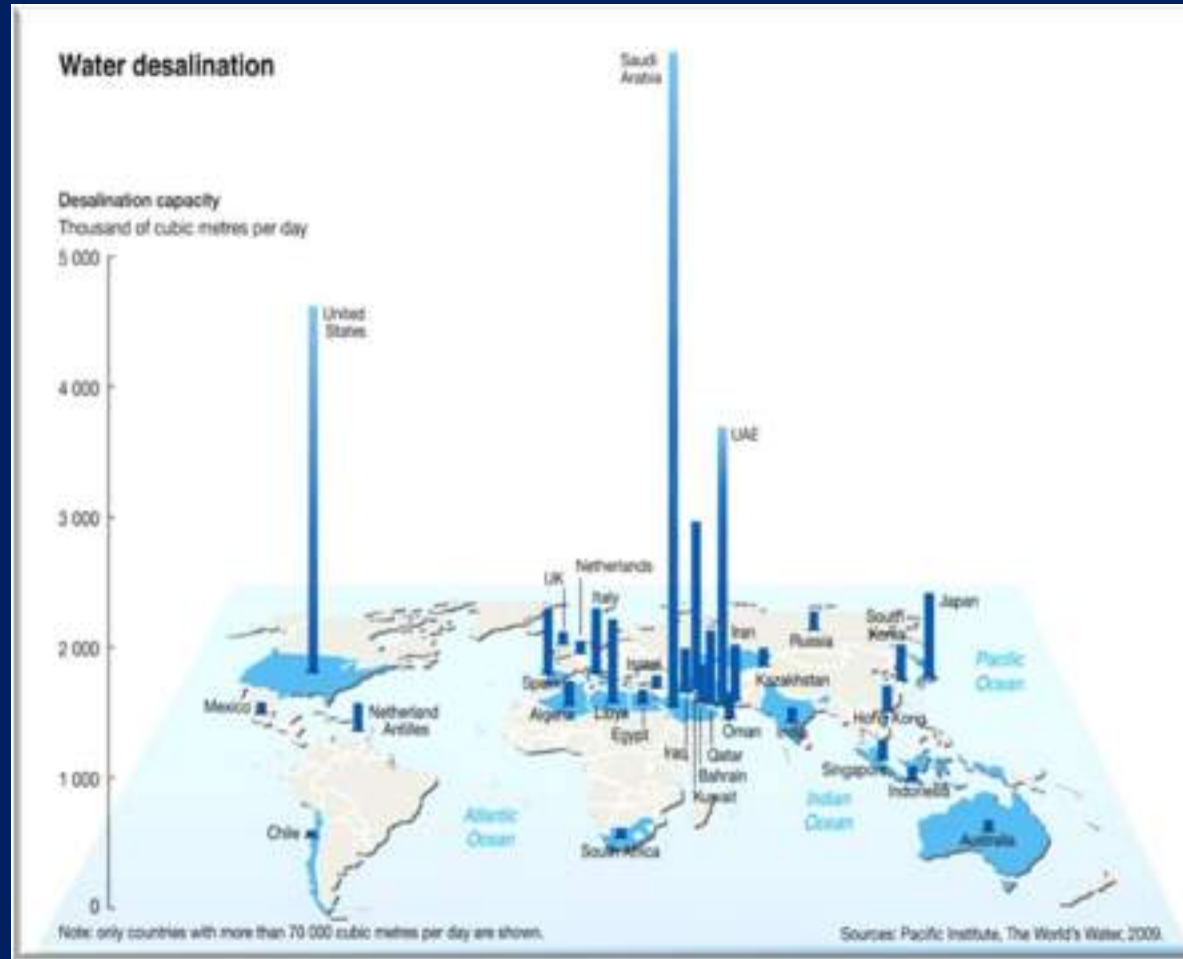
Saudi Arabia is the leading desalination country by volume, followed by the United Arab Emirates, both desert countries and highly dependent on this process. Other countries in the Middle East, such as Kuwait and Qatar, have also opted for this technique.



DISTRIBUTION IN THE WORLD

VOLUME CAPACITY

In the United States, desalination micro-plants are close to almost all the natural gas facilities, to exploit the residual heat. Spain is fourth, given the contribution of the Canary Islands and the Alicante and Murcia coast, where old thermal power plants are being replaced by desalination. Today, Spain hosts 5,7% of the world's desalination capacity, and more than 30% of its irrigation is provided by SWD.



COSTS OF DESALINATION

ECONOMIC ASPECTS

The cost of developing, constructing, and operating desalination plants depends on the location of the facility, the raw water nature and quality, type of intake and outfall, the desalination technology and energy recovery systems used, the cost of electrical power, any required post-treatment and storage, distribution costs, and the environmental regulations.



COSTS OF DESALINATION

These differences can make a large plant built in one region of the world more expensive than a smaller plant built in another region of the world, and result in significant differences in OPEX.



COSTS OF DESALINATION

USA



UAE



AUS



Region:	USA	Arabian Gulf	Australia
Project name:	Carlsbad Desalination Project	Fujairah F1 Extension SWRO	Gold Coast Desalination Plant
Plant location:	Carlsbad, CA, USA	Fujairah, UAE	Tugin, Australia
Plant construction date:	2014	2013	2009
Plant capacity m ³ /d (MGD):	189,000 (50)	136,000 (30)	133,000 (35.1)
Plant recovery:	45-50%	45-50%	45%
Raw water salinity (ppm):	36,000	45,000	38,000
Product water quality (ppm):	200	500 (WHO standard)	200
Intake type:	Open intake, co-location	Open intake	Open intake, drum screens, intake/outfall tunnel
Pre-treatment type:	Dual media filtration	Dissolved gas flotation + filtration	Dual media filtration
Desalination technology:	2 Pass SWRO	2 Pass SWRO	2 Pass SWRO
Energy recovery type:	ERI	ERI	DWEER ERD
Post-treatment:	CO2 and lime addition, chlorination, fluoridation	CO2 and lime addition, chlorination	CO2 and lime addition, chlorination, fluoridation
Storage and distribution:	3.4 MG + 10 miles conveyance pipeline and pumping	NA	8 MG + 16 miles pipeline + pumping
Brine discharge:	Direct to sea with power plant	Direct to sea	300 meters into sea, diffusers
Environmental regulations:	Very stringent	Moderate	Stringent
Specific energy (kwh/ m ³):	N/A	3.7 – 4.0	3.40
TIC cost (US\$):	\$692,000,000 (529 MM + 163 MM conv. pipeline) + \$213 MM finance costs (\$904 MM total)	\$200,000,000	\$943,000,000 (745 MM plant + 198 MM tunnels)
Projected lifetime, years:	20	20	20
Simple annualized CAPEX, US\$/year:	N/A	N/A	\$47,150,000
OPEX (US\$/year):	\$53,100,000	\$26,900,000*2	\$32,000,000
Unit production cost US\$/m ³ -day:	\$1.86	< \$0.60	\$1.63

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ICID – International Commission on Irrigation and Drainage

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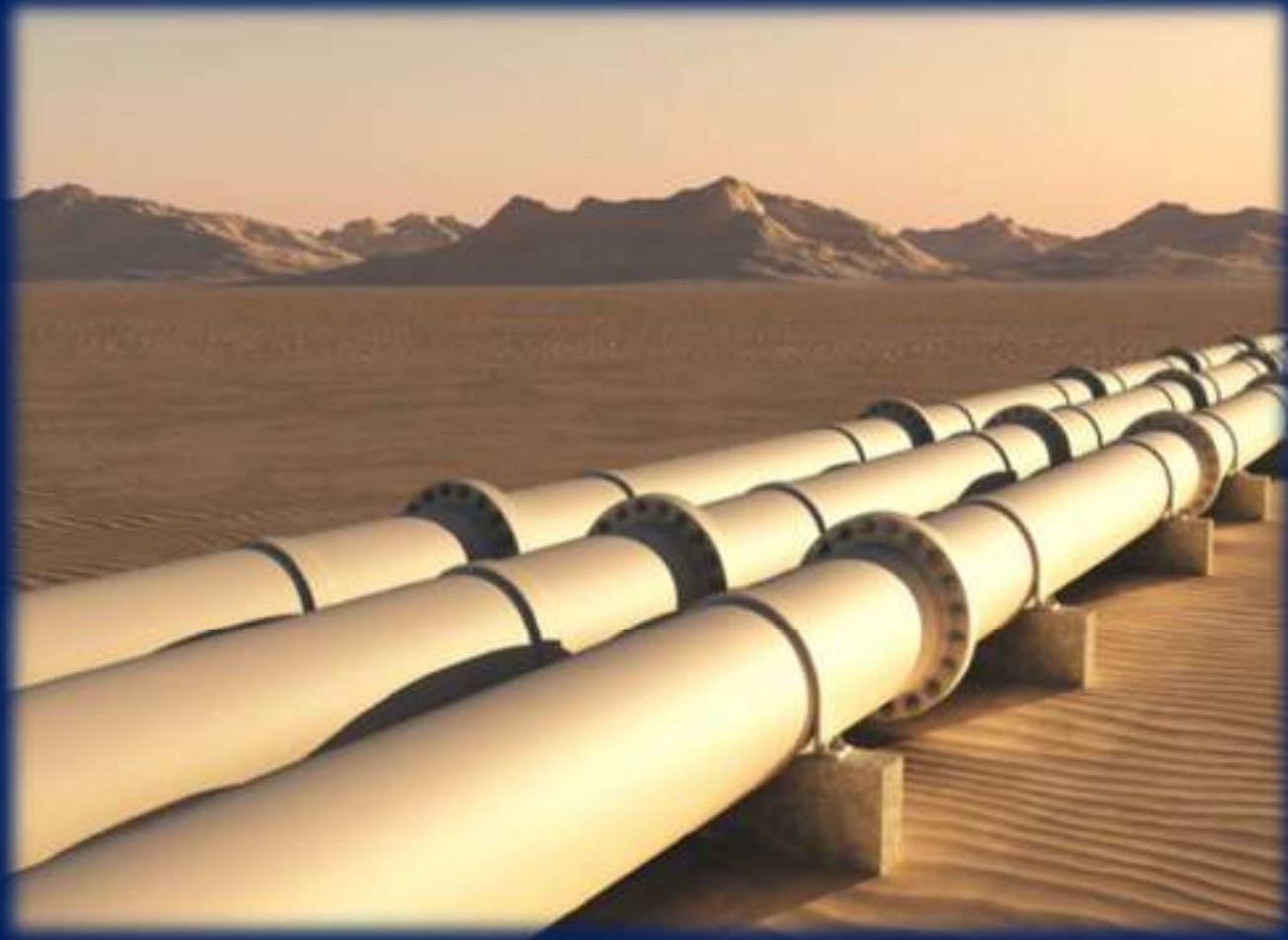
SEAWATER DESALINATION: BRINE MINING

About 18,200 desalination plants operate worldwide with a global cumulative capacity near 90 million m³/day. This capacity is expected to grow at an increasingly rapid pace in the near future, because of the water shortage crisis around the world and of the increasing water demand.



FUTURE OPTIONS FOR DESALINATION

As successfully proven in several countries (i.e. Saudi Arabia) water can be piped towards inland cities, thus desalination is not only limited to coastal cities, but can be implemented in many ocean bordering regions.



Wastewater reuse in agriculture: from liability to resource

Agricultural water reuse plants treat wastewater from municipal, industrial, or on-farm sources to irrigate crops and provide nutrients, reducing freshwater reliance.



Wastewater reuse in agriculture: from liability to resource

These plants typically use secondary, tertiary, or advanced treatment to remove pathogens, ensuring compliance with strict safety guidelines for food and non-food crops.



Wastewater reuse in agriculture: from liability to resource



Key benefits include increased drought resilience, reduced fertilizer demand, and sustainable nutrient management.



Wastewater reuse in Türkiye



In Türkiye, water scarcity forced the Ministry of Environment to initiate an important project in 2017.



Water scarcity in Türkiye

Wastewater reuse in Türkiye

The country faces the huge challenge of providing enough water to meet the growing needs of an increasing population.



The Galata Tower & the Süleymaniye Mosque.
Istanbul, Türkiye

Wastewater reuse in Türkiye

But although there are 1,015 existing WWTPs, only 15 of them realize waste water reuse.



Waste Water reuse Plants in Türkiye



[illegible]

As of 2017, the total volume of wastewater treated and reused in Türkiye amounted to 29.6 million m³/year, accounting for 0.78% of the treated urban wastewater.



Wastewater recycling in Türkiye : the Atakoy Plant

Challenged with this perspective, the MoE has been developing projects to reuse water, setting the target of 5% of reused water for agricultural irrigation, groundwater supply and urban purposes.



Akhisar Wastewater Reuse Plant – Türkiye.

Wastewater recycling in Türkiye : the Atakoy Plant

An excellent example is the Atakoy Reuse Plant in Istanbul, located in the southwest of Istanbul, near the Atatürk International Airport.



Atakoy Wastewater Reuse Plant – Istanbul, Türkiye.

Wastewater recycling in Türkiye : the Atakoy Plant

Rather than releasing into the nearby sea, the Atakoy Plant provides part of the wastewater an extra round of treatment, so it can be reused for purposes such as irrigation.



Atakoy Wastewater Reuse Plant – Istanbul, Türkiye.



Wastewater recycling in Türkiye : the Atakoy Plant

It has adopted the latest innovations to recycle part of the wastewater it treats, by means of a technology called Membrane Bio-Reactor, also known as MBR.



Atakoy Wastewater Reuse Plant – Istanbul, Türkiye.

Wastewater recycling in Türkiye : the Atakoy Plant

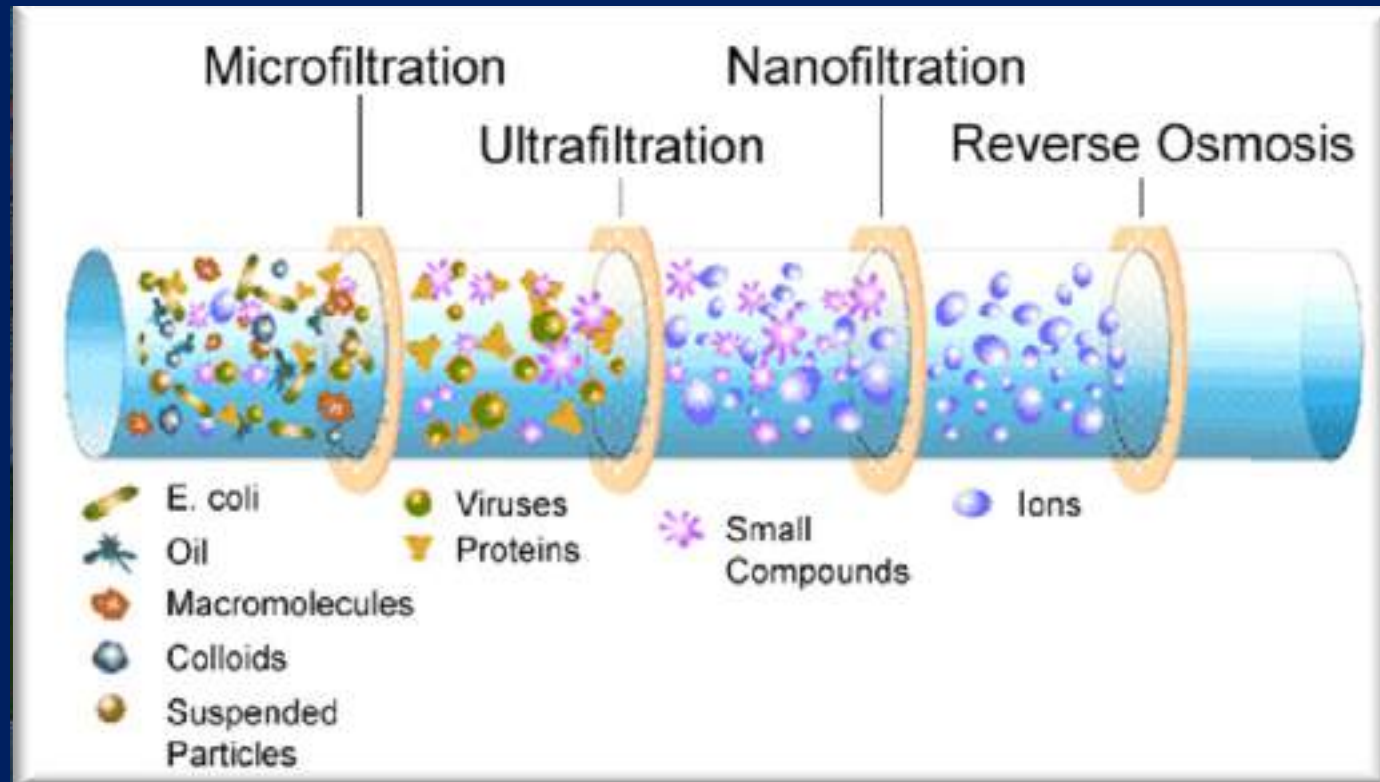
The conventional way of treating wastewater is to separate the sludge into solids and liquids, by what is called an activated sludge model.



Atakoy Wastewater Reuse Plant – Istanbul, Türkiye.

Wastewater recycling in Türkiye : the Atakoy Plant

With MBR, a further step is added with the use of membranes characterized by very tiny pores, enabling a second round of filtering for the liquids. In this way, the water comes out cleaner.



Atakoy Wastewater Reuse Plant – İstanbul, Türkiye.

Wastewater recycling in Türkiye : the Atakoy Plant

Recently put into operation, the Atakoy plant can treat 20,000 m³ per day of wastewater to be recycled. At a later stage, its capacity will increase by another 10,000 m³, for a total amount of 30,000 m³.



Atakoy Wastewater reuse Plant - Aeration Tanks II Stage

Wastewater recycling in Türkiye : the Atakoy Plant

The importance of the plant: its capacity will be 10% of the combined 5.8 million cubic meters of wastewater treated every day by all of the plants in the province.



Atakoy Wastewater reuse Plant - Aeration Tanks II Stage



Wastewater reuse in Egypt



Egypt is leading significant efforts to cope with climate change in order to ensure food security, trying to move agriculture away from the overcrowded Nile Valley.



The Delta of the Nile River–Egypt

Wastewater reuse in Egypt

The New Delta Project is a modern land reclamation initiative developed in the Western Desert, designed to transform over 9,240 square kilometers of barren desert into productive farmland.



New Delta Artificial River-Egypt



Wastewater reuse in Egypt

In order to achieve these goals, Egypt is investing heavily in wastewater treatment plants to mitigate water scarcity, focusing on reusing treated water for agricultural expansion and irrigation.

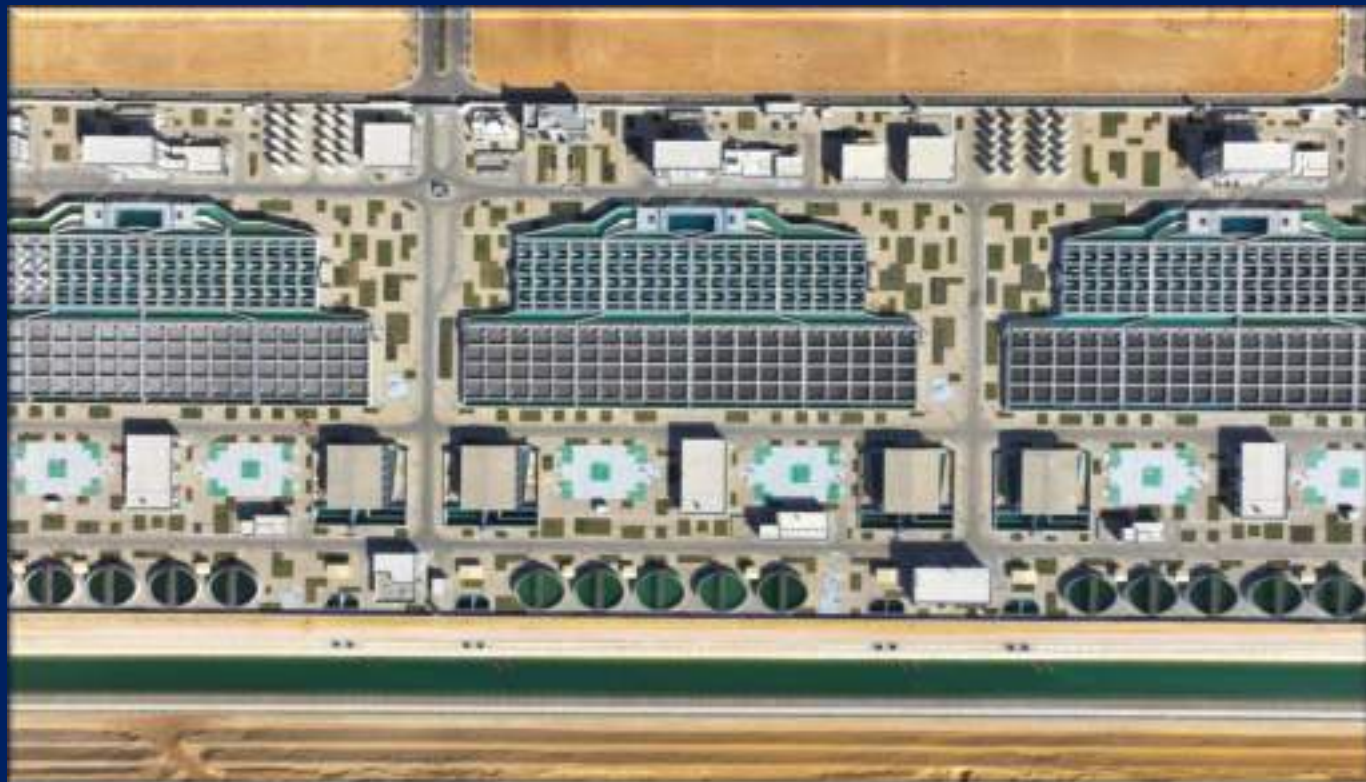


Wastewater Reuse Plant in Egypt.



Wastewater reuse in Egypt

As a matter of fact, today Egypt is the leading country in the world in terms of new, massive irrigation wastewater reuse projects.



Wastewater Reuse Plant in Egypt.



Wastewater reuse in Egypt

Most significant plants are:

- El Hamam (2021): today the largest wastewater treatment plant in the world, it treats 7.5 million m³/day.



El Hamam Wastewater Reuse Plant–Egypt.



Wastewater reuse in Egypt

Most significant plants are:

- El Hamam (2021): today the largest wastewater treatment plant in the world, it treats 7.5 million m³/day.
- Bahr Al-Baqar (2019): treats 5.6 million m³/day, handling a mix of agricultural, industrial, and domestic water.



Bahr Al-Baqar Wastewater Reuse Plant-Egypt.



Wastewater reuse in Egypt: the El Hamam plant

The El Hamam Water Treatment Plant, located in Marsa Matruh, is the largest in the world, carrying the highest sludge treatment capacity globally.



El Hamam Wastewater Reuse Plant – Marsa Matruh, Egypt.



Wastewater reuse in Egypt: the El Hamam plant

The plant has a production capacity of 7.5 million m³/day using agricultural drainage water, serving more than 900,000 ha in the western Delta region. Water is transported through a 120-kilometer-long canal.



El Hamam Wastewater Reuse Plant – Marsa Matruh, Egypt.



Wastewater reuse in Egypt: the El Hamam plant

Spanning over an area of 320,000 m², the plant operates with the capacity of 86.8 m³/second, ensuring a capability in sludge treatment of 670.01 kg/s.



El Hamam Wastewater Reuse Plant – Marsa Matruh, Egypt.



Wastewater reuse in Egypt: the El Hamam plant

The plant is expected to provide irrigation for about 485,000 hectares of land west of the Nile Delta and circa 917,000 hectares in the western region.



El Hamam Wastewater Reuse Plant – Marsa Matruh, Egypt.



Wastewater reuse in Spain



Spain is the leading country for wastewater reuse in the Mediterranean area. More than 70% of its recycled water is today used for agriculture...



Wastewater Reuse Plant in Almeria, Spain.

Wastewater reuse in Spain



...And more than 30% of its irrigation is provided by waste water reuse and sea water desalination plants.



Seawater Desalination Plant of Torrevieja (Alicante), Spain.



Wastewater reuse in Spain

The most important ones are

- El Prat de Llobregat Wastewater Treatment Plant (Barcelona)



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*



Wastewater reuse in Spain

The most important ones are

- El Prat de Llobregat Wastewater Treatment Plant (Barcelona)
- The Pinedo Wastewater Treatment Plant (Valencia)



Pinedo Wastewater Reuse Plant – Valencia, Spain.

Wastewater reuse in Spain

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- El Prat de Llobregat Wastewater Treatment Plant (Barcelona)
- The Pinedo Wastewater Treatment Plant (Valencia)
- Rincón de León Wastewater Treatment Plant (Alicante)



Rincón de León Wastewater Reuse Plant. Alicante, Spain.

Wastewater reuse in Spain

The most important ones are

- El Prat de Llobregat Wastewater Treatment Plant (Barcelona)
- The Pinedo Wastewater Treatment Plant (Valencia)
- Rincón de León Wastewater Treatment Plant (Alicante)
- Tarragona Industrial Complex (AITASA) Project.



Terragona Wastewater Reuse Plant. Tarragona, Spain.



Wastewater reuse in Spain

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- The Pinedo Wastewater Treatment Plant (Valencia)
- Rincón de León Wastewater Treatment Plant (Alicante)
- Tarragona Industrial Complex (AITASA) Project.
- Adeje-Arona Wastewater Treatment Plant (Tenerife).



Adeje-Arona Wastewater Reuse Plant. Tenerife, Spain.



Wastewater reuse in Spain: the El Prat de Llobregat Plant

One of the most important in the world is the El Prat de Llobregat plant (Barcelona), which includes a Water Regeneration Reuse Plant that produces 50,000,000 m³ per year.



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*



Wastewater reuse in Spain: the El Prat de Llobregat Plant

It utilizes advanced technologies like reverse osmosis and an innovative ultraviolet disinfection for environmental, agricultural, and industrial purposes.



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*



Wastewater reuse in Spain: the El Prat de Llobregat Plant

It treats approximately 420,000 m³ per day, being specialized in advanced water reuse for agricultural and industrial uses, as well as environmental needs.



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*

Wastewater reuse in Spain: the El Prat de Llobregat Plant

The reclamation plant has a peak flow capacity of 3.5 m³/s and a design flow of 12,500 m³/h, with around 0.75 m³/s specifically assigned for agricultural crops irrigation.



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*

Wastewater reuse in Spain: the El Prat de Llobregat Plant

The plant is expected to provide irrigation to an area ranging between 3,000 and 4,000 hectares of land, depending on the agro ecological conditions of the area, the specific crops' water requirements and the efficiency of the irrigation system.



*El Prat de Llobregat Wastewater Reuse Plant.
Barcelona, Spain.*



Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

The EDAR (Estación Depuradora de Aguas Residuales) Viveros de la Villa is one of the major wastewater treatment and regeneration plants, situated in northern Madrid.



The EDAR Villa Wastewater and Regeneration Plant.
Madrid, Spain.

Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

It has an authorized water treatment capacity of about 200,000 m³ per day, consistently handling average daily flows of 100,000 m³, its maximum water flow being 2.63 m³/second or 9,468 m³ per hour.



*The EDAR Villa Wastewater and Regeneration Plant.
Madrid, Spain.*

Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

It processes urban wastewater for roughly 700,000 residents (with a design capacity of over one million equivalent inhabitants) to protect the Manzanares River.



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Madrid, Spain.

Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

Contains complementary facilities that transform treated wastewater into high-quality reclaimed water for the city's network, primarily used for watering urban parks and green spaces.



The EDAR Villa Wastewater and Regeneration Plant.
Madrid, Spain.



Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

It employs anaerobic digestion and sludge dehydration by means of centrifuges. It also utilizes high-efficiency cogeneration systems (like MWM gas gensets) that convert biogas produced during the treatment process into electrical energy.



*The EDAR Villa Wastewater and Regeneration Plant.
Madrid, Spain.*



Wastewater reuse in Spain: the EDAR Viveros de la Villa in Madrid.

It features cutting-edge sanitization processes consisting of textile mesh microfiltration, use of ozonation, hydrogen peroxide treating, and ultraviolet (UV) lamp disinfection to eliminate microcontaminants and pathogens.



*The EDAR Villa Wastewater and Regeneration Plant.
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PROs and **CONs** of Wastewater Reuse for food security

PROs

- **Reliable Water Supply:** provides a constant, climate-resilient source of water, reducing vulnerability to droughts and erratic weather.



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- **Nutrient Enrichment:** treated wastewater is often rich in nitrogen and phosphorus, reducing the need for synthetic fertilizers.
- **Freshwater Conservation:** relieves pressure on depleting freshwater aquifers and rivers, preserving them for municipal and drinking purposes.



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- **Salinity buildup:** high levels of dissolved salts in wastewater can accumulate over time, degrading the soil structure.



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- **Emerging contaminants:** conventional treatment may not remove all micropollutants like pharmaceuticals, heavy metals, or PFAS, which can accumulate in the food chain over the long term.



FUTURE OPTIONS FOR DESALINATION

As technology will continue to produce new methods and better solutions, there can be a whole new water resource for more and more countries, currently dealing with water scarcity.



FUTURE OPTIONS FOR DESALINATION

Relying increasingly in SWD means that for many people struggling every day to survive or to maintain a decent level of existence there would be a chance, at least, to live in a better way.



ICID – International Commission on Irrigation and Drainage



THANK YOU