PROSPECTIVE BRINE MANAGEMENT STRATEGIES FOR SUSTAINABLE DESALINATION IN THE GCC COUNTRIES

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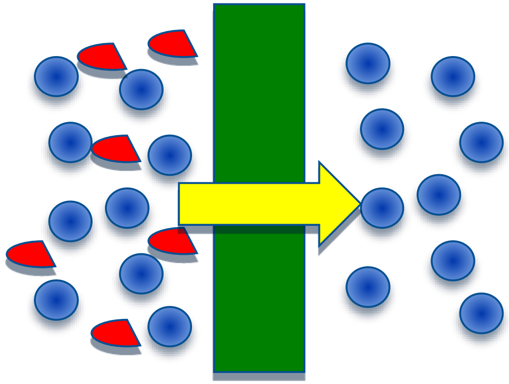
Background

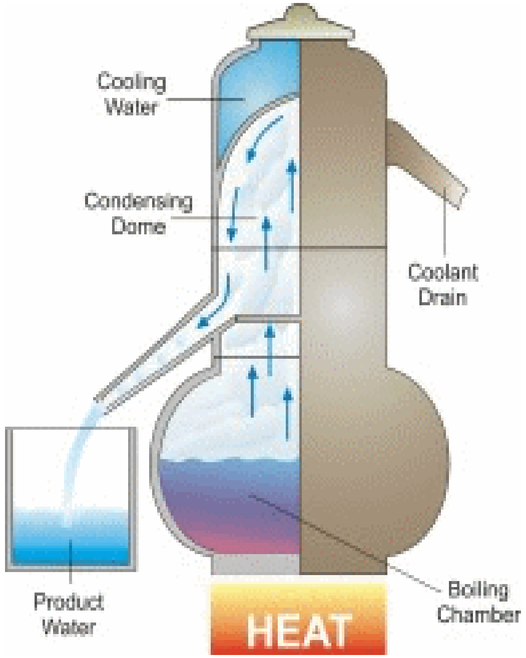
- Gulf Cooperation Council (GCC) has 50% of global desalination capacity using mainly thermal and membrane-based technologies.
- Majority of GCC countries are shifting to reverse osmosis (RO) process technology.
- Brine disposal is a significant issue in the Arabian Gulf, with 40% of feed water being drinkable and 60% being brine discharge.
- Brine can contain hazardous chemicals, heavy metals, and organics, requiring economical and viable brine management systems.
- Study includes analysis of emerging technologies for brine treatment, including greenhouse desalination, pressure retarded osmosis, and electro-dialysis-based hybrid systems.

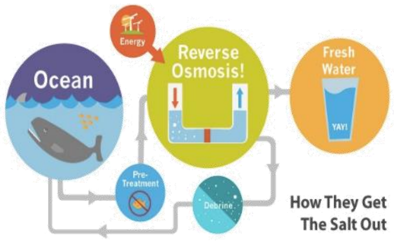
Seawater Desalination Technology

Main water desalination technologies used worldwide are as follows

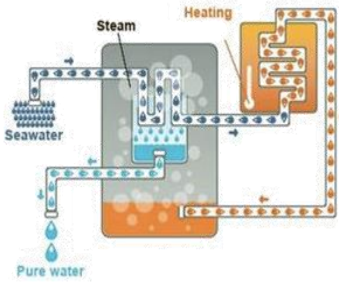
1. Thermal Desalination Processes
   - MSF and MED
2. Membrane based Process
   - Reverse osmosis technology





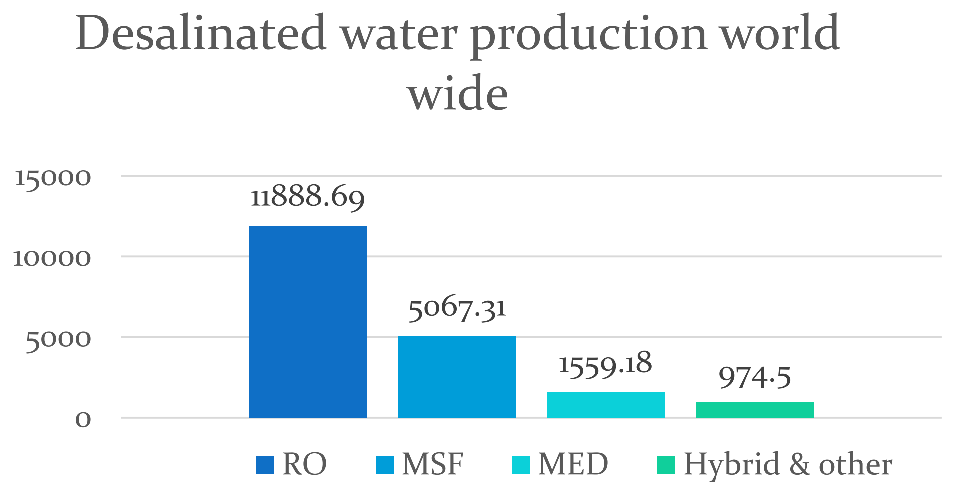


MEMBRANE

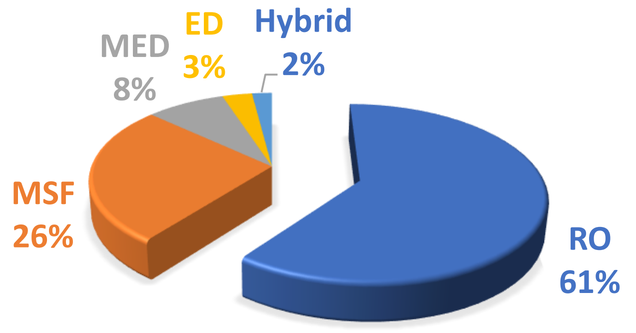


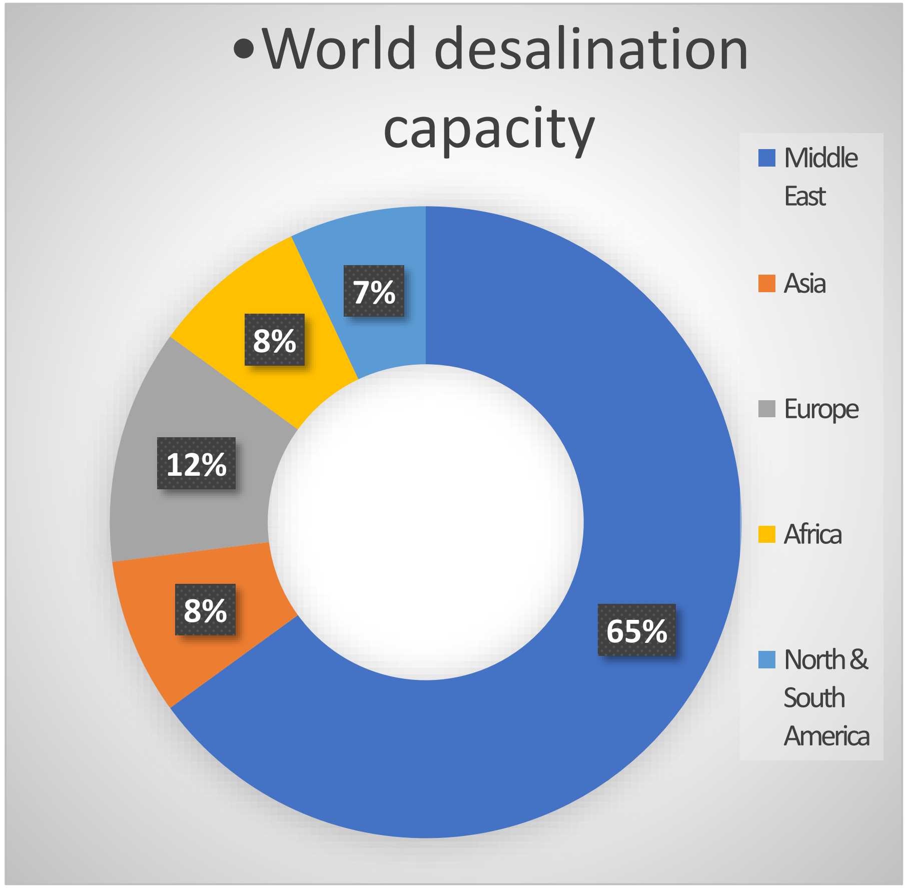
DISTILLATION

Desalination is the answer to global water scarcity with the help of emerging technology As earth has enough water in the form of sea which can be made potable using desalination



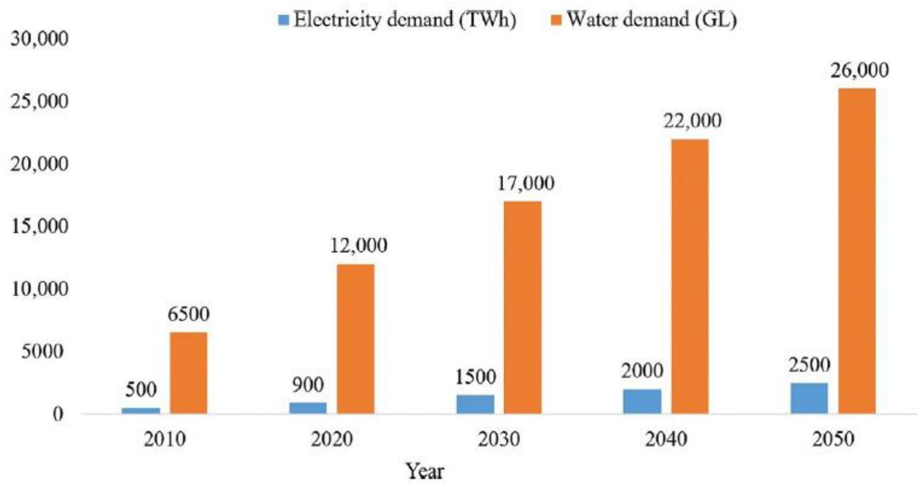
Technology used

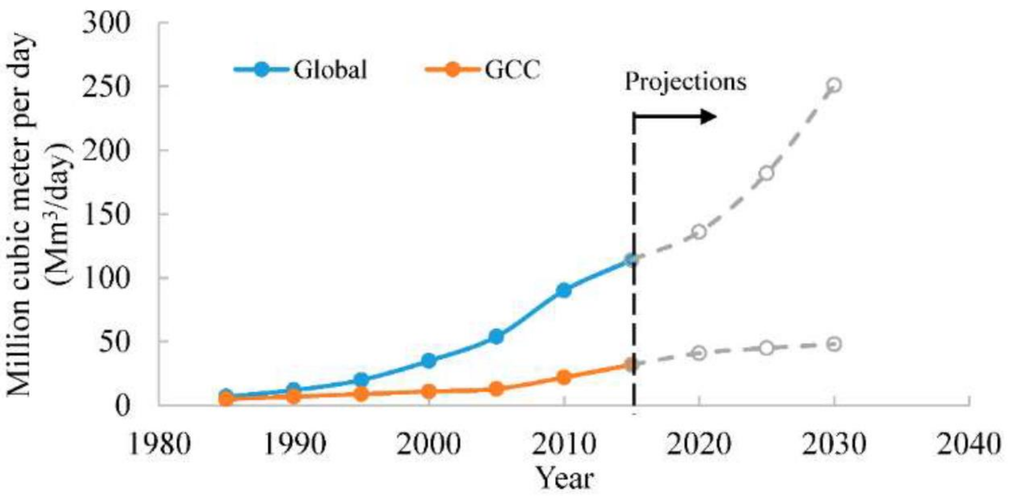




GCC-based Desalination plants capacity and population

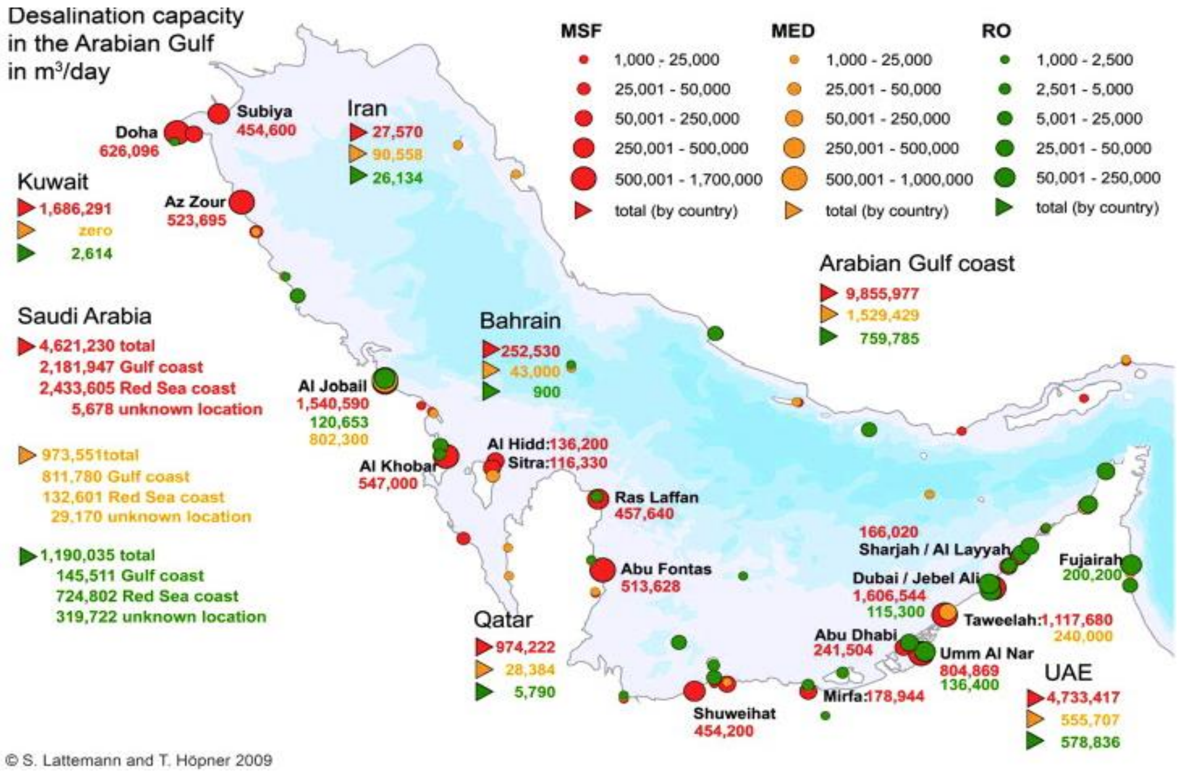
- Population growth rates and water stress in the GCC
- Increasing industrial growth rate
- Depleting natural water resources
- High concertation of desalination plant in the GCC
    - 17346 total plant /7499 plants in the GCC
- Expected doubling of power requirement and plants by 2030 compared to 2020

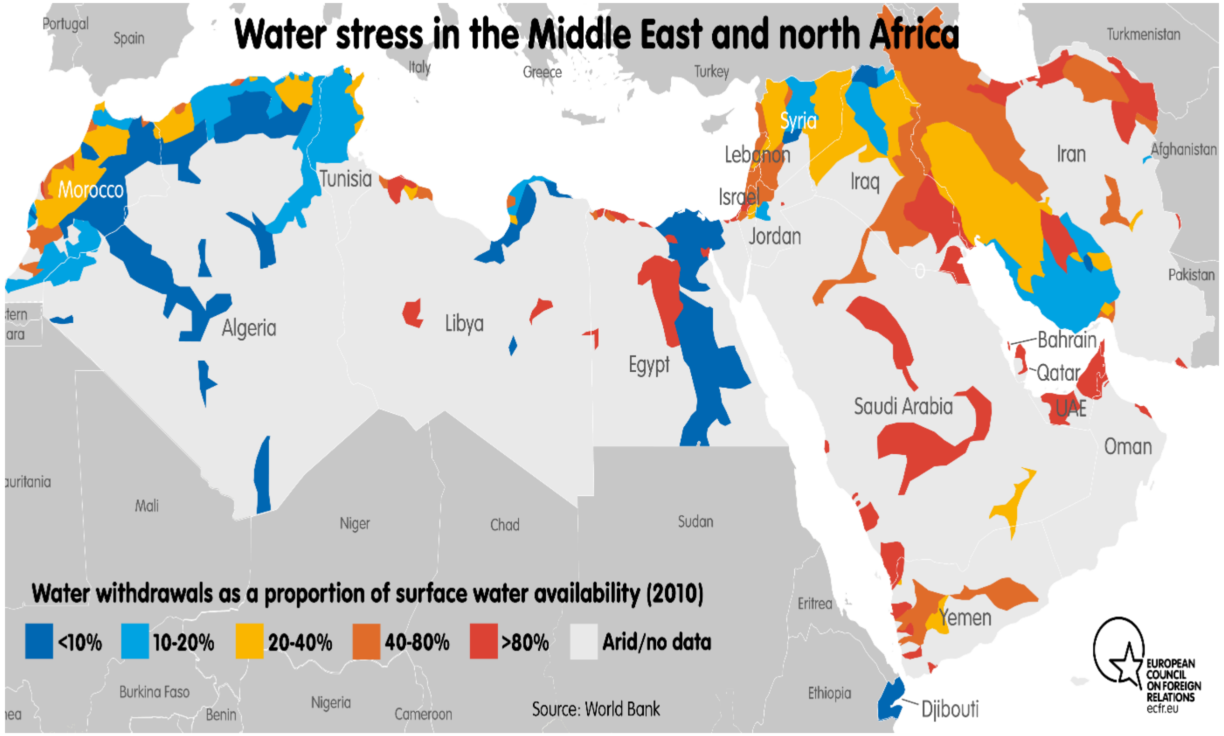


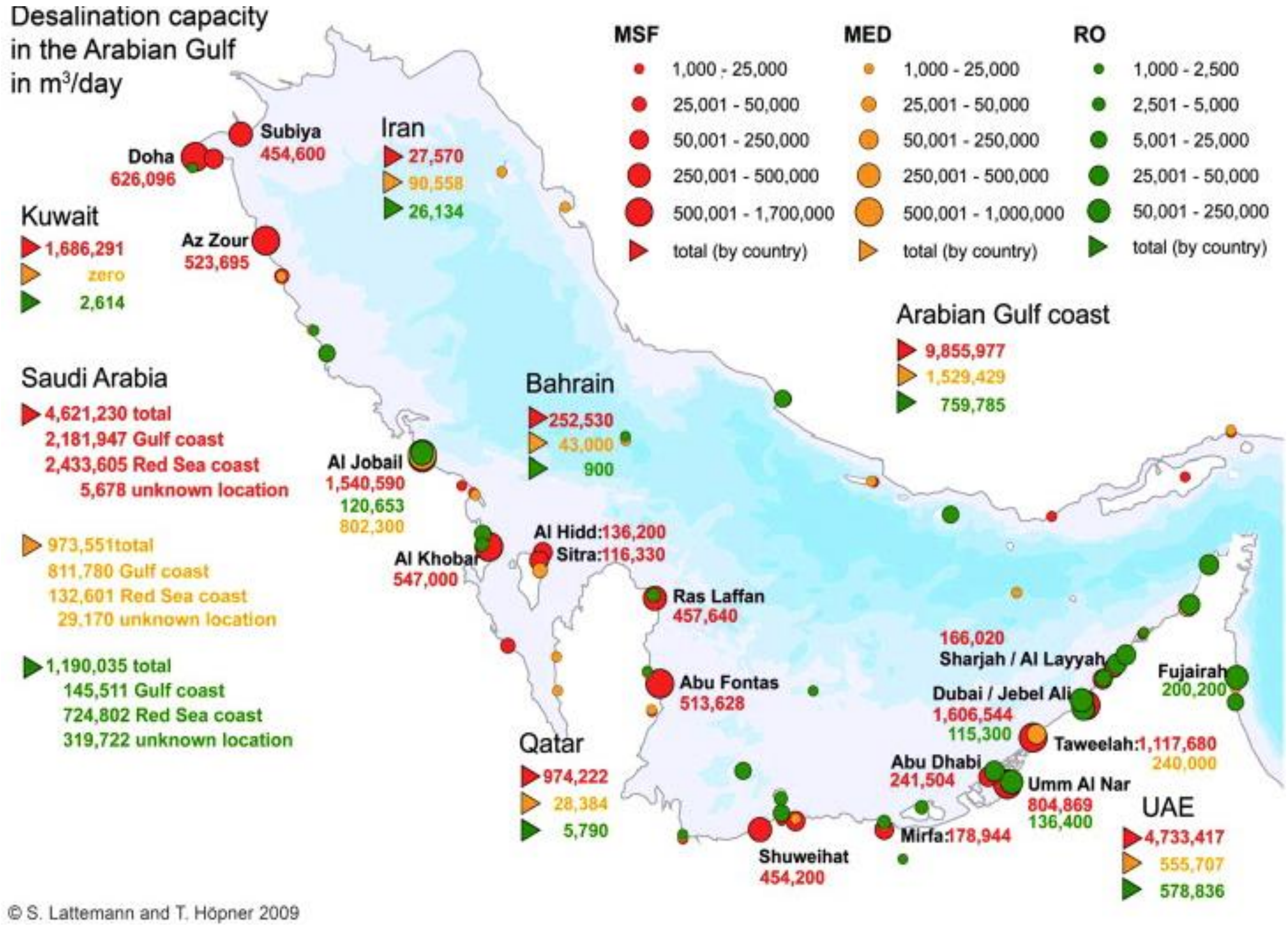


Water Quality of the Arabian gulf

- Desalination plants of the Arabian gulf region are in close vicinity to each other.
- Base overall concentration is increasing over the years due to brine and industrial discharge the ground aquifers also get salt intrusion near the seashore
- High sea transport and oil tanker traffic in the Arabian gulf






Desalination capacity in the Arabian Gulf in m³/day
MSF
MED
RO
1,000 - 25,000
25,001 - 50,000
50,001 - 250,000
250,001 - 500,000
500,001 - 1,700,000
total (by country)
1,000 - 25,000
25,001 - 50,000
50,001 - 250,000
250,001 - 500,000
500,001 - 1,000,000
total (by country)
1,000 - 2,500
2,501 - 5,000
5,001 - 25,000
25,001 - 50,000
50,001 - 250,000
total (by country)
Subiya 454,600
Doha 626,096
Kuwait
1,686,291
zero
2,614
Az Zour 523,695
Iran
27,570
90,558
26,134
Arabian Gulf coast
9,855,977
1,529,429
759,785
Saudi Arabia
4,621,230 total
2,181,947 Gulf coast
2,433,605 Red Sea coast
5,678 unknown location
973,551total
811,780 Gulf coast
132,601 Red Sea coast
29,170 unknown location
1,190,035 total
145,511 Gulf coast
724,802 Red Sea coast
319,722 unknown location
Bahrain
252,530
43,000
900
Al Jobail 1,540,590 120,653 802,300
Al Khobar 547,000
Al Hidd:136,200
Sitra:116,330
Ras Laffan 457,640
Abu Fontas 513,628
Qatar
974,222
28,384
5,790
166,020
Sharjah / Al Layyah
Dubai / Jebel Ali 1,606,544 115,300
Fujairah 200,200
Taweelah:1,117,680 240,000
Abu Dhabi 241,504
Umm Al Nar 804,869 136,400
Mirfa:178,944
Shuweihat 454,200
UAE
4,733,417
555,707
578,836
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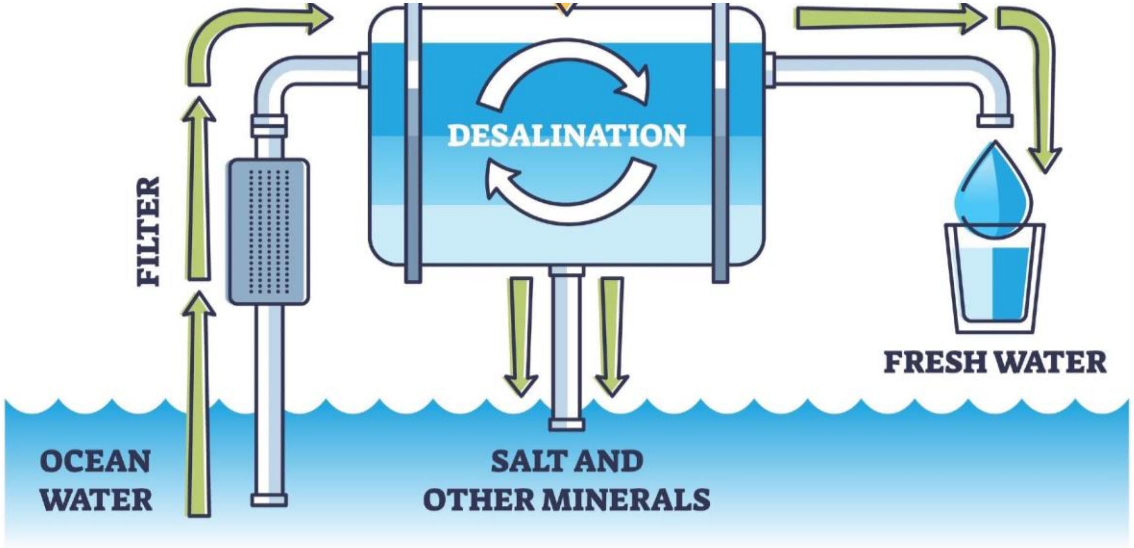
Approximately 15,906 desalination plants worldwide producing almost 95.37 million cubic m^3/day of desalinated water

Brine, also known as concentrate, is the by-product of the desalination process that has an adverse impact on the environment due to its high salinity.



(BRINE DISCHARGE)

Brine Production from Desalination

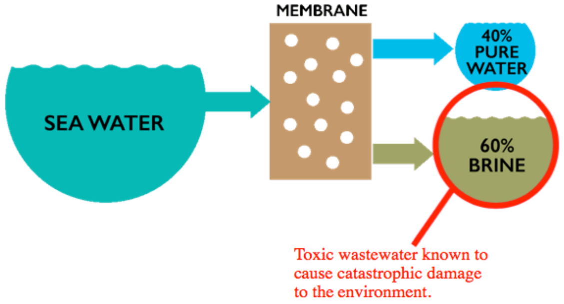
Brine salinity produced by membrane-based technologies, mainly seawater reverse osmosis (SWRO), ranges from 60 g/L TDS to 85 g/L TDS

Brine salinity produced by thermal technologies (i.e., MSF and MED) ranges from 55 g/L TDS to 65 g/L TDS, respectively

Compared to thermal-based plants, this differentiation can be attributed to the higher recovery rates (40–45%) present in commercial and well-established RO plants.

Recovery ratio of different feedwater-technology combinations producing desalinated water.

Feedwater type	Technology							
	RO	MSF	MED	NF	ED	EDI	EDR	Other
Seawater (SW)	0.42	0.22	0.25	0.69	0.86	0.90		0.40
Brackish (BW)	0.65	0.33	0.34	0.83	0.90	0.97	0.90	0.60
River (RW)	0.81		0.35	0.86	0.90	0.97	0.96	0.60
Pure (PW)[a]	0.86	0.35		0.89	0.90	0.97	0.96	0.60
Brine (BR)	0.19	0.09	0.12		0.85			0.40
Wastewater (WW)[b]	0.65	0.33	0.34	0.83	0.90	0.97		0.60



Global Brine Production

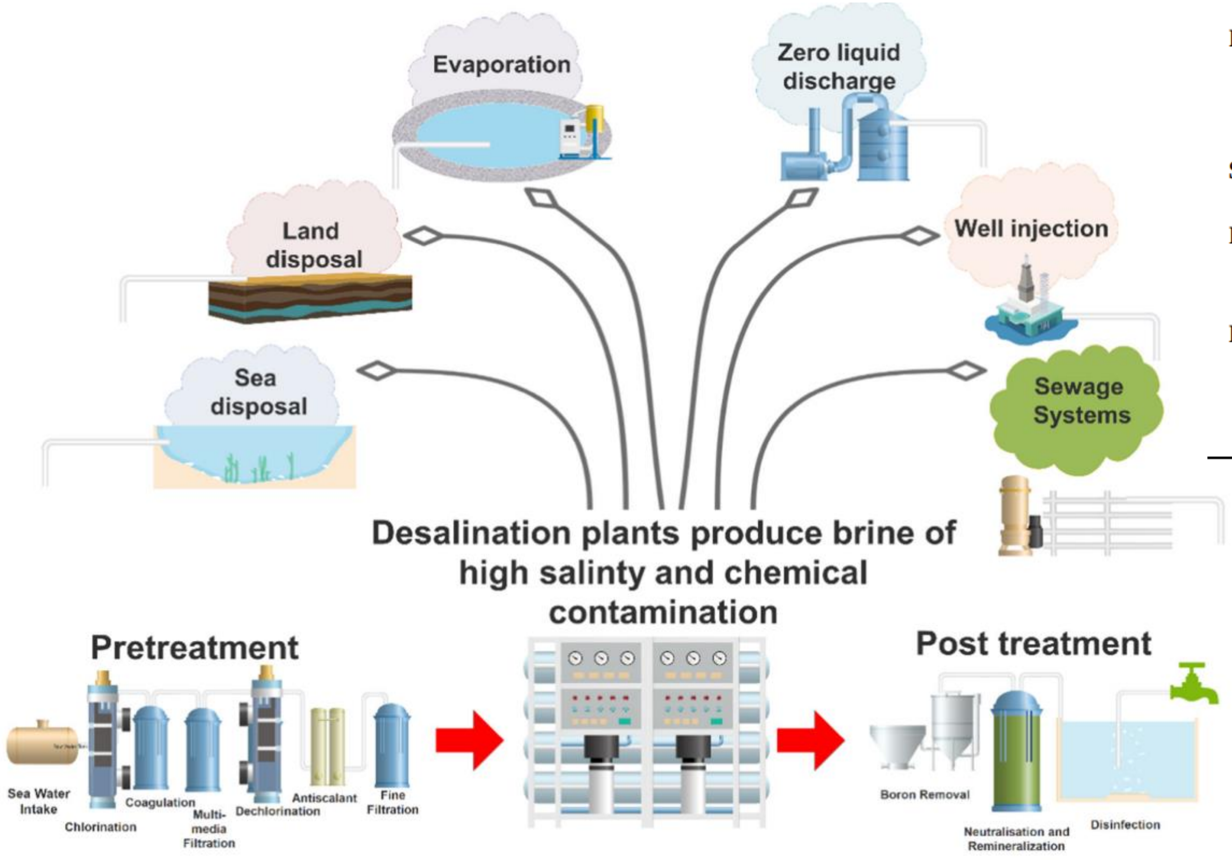
Current global brine production stands at 141.5 million m^3/day, totaling 51.7 billion m^3/year

Brine production and share of global total by region, income level and sector use.

Global brine production is concentrated in the Middle East and North Africa, which produces almost 100 million m^3/day of brine, accounting for 70.3% of global brine production.

	Brine production	
	(million m^3/day)	(%)
Global	141.5	100
Geographic region		
Middle East & North Africa	99.4	70.3
East Asia & Pacific	14.9	10.5
North America	5.6	3.9
Western Europe	8.4	5.9
Latin America & Caribbean	5.6	3.9
Southern Asia	3.7	2.6
Eastern Europe & Central Asia	2.5	1.8
Sub-Saharan Africa	1.5	1.0
Income level		
High	110.2	77.9
Upper middle	20.7	14.6
Lower middle	10.5	7.4
Low	0.03	0.0
Sector use		
Municipal	106.5	75.2
Industry	27.4	19.3
Power stations	5.8	4.1
Irrigation	1.1	0.8
Military	0.5	0.3
Other	0.3	0.2

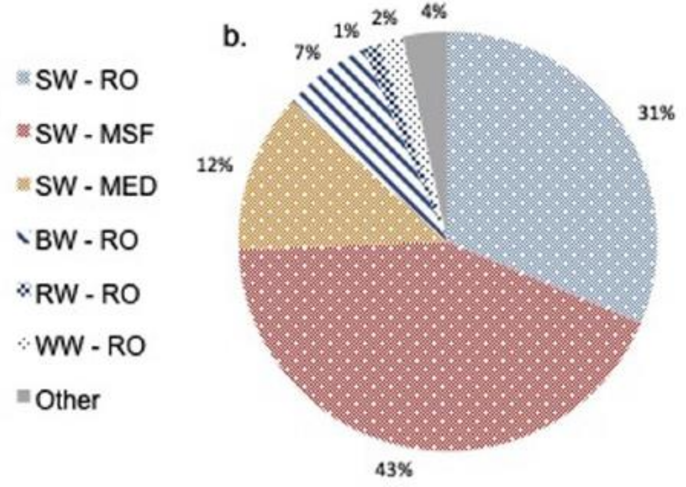
Brine disposal methods currently practiced worldwide



Method	Principle	Cost (US $/m^3$_{brine\ rejected}$)	Environmental challenges
Sewer discharge	Brine is rejected in a sewage collection system	0.32–0.66	Inhibition of bacterial growth in the wastewater treatment plant
Evaporation pond	Brine is evaporated in a pond and the residual salts are gathered	3.28–10.04	Groundwater pollution and soil salinization
Surface water discharge	Brine is rejected into the surface water	0.05–0.30	Marine environment pollution
Deep-well injection	Brine is injected into porous subsurface rock formations	0.54–2.65	Groundwater pollution and soil salinization
Land application	Brine is used in irrigation of salt-tolerant crops and grasses	0.74–1.95	Soil salinization

Factors Affecting Brine Management Approaches

1. Type of water:
2. Level of salinity
3. Cost
4. Regulatory requirements
5. Availability of resources



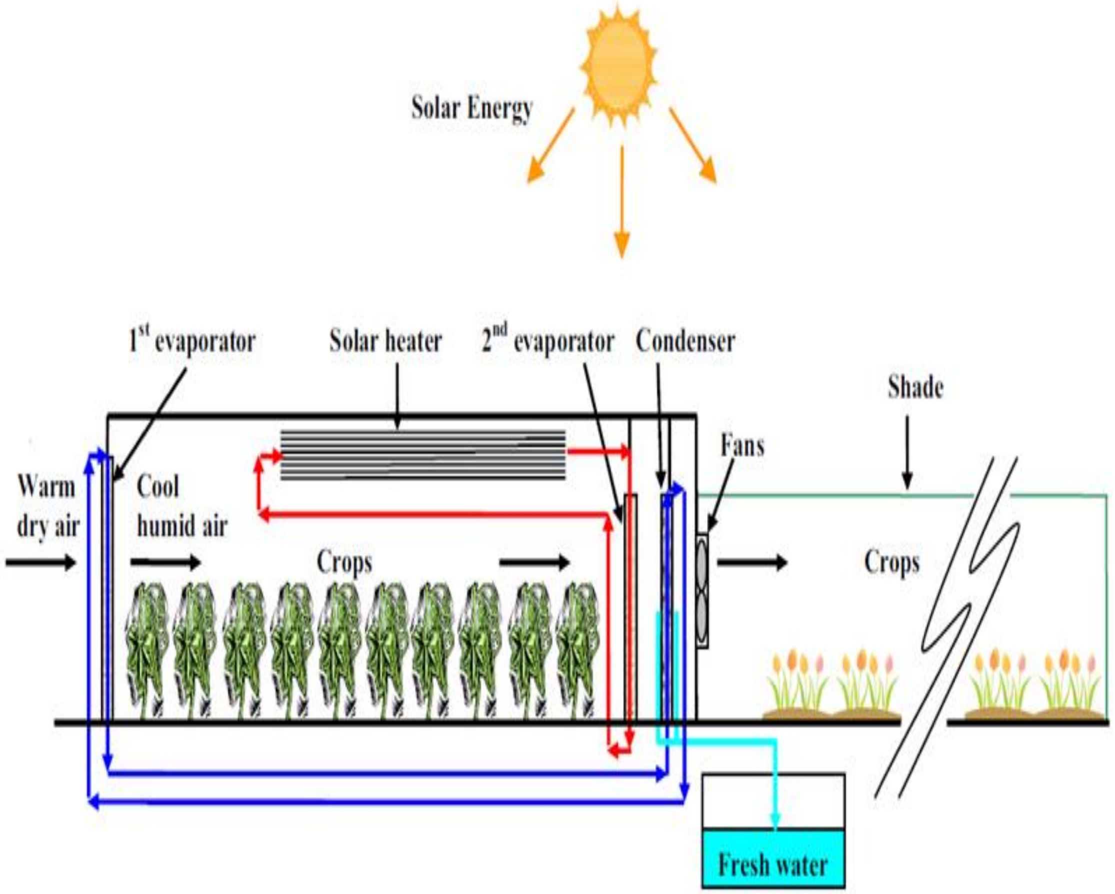
Emerging Technologies for Brine treatment:

- New and developing technologies for the brine management being tested and incorporated with existing plant which show a potential to have a future with better brine management are as follows .
- **Greenhouse Desalination**
- **Pressure Retarred osmosis**
- **Hybrid system**
  - Electrodialysis-based Hybrid Systems
  - Reverse electrodialysis-based Hybrid Systems

Emerging Technologies for Brine treatment: Green House Desalination

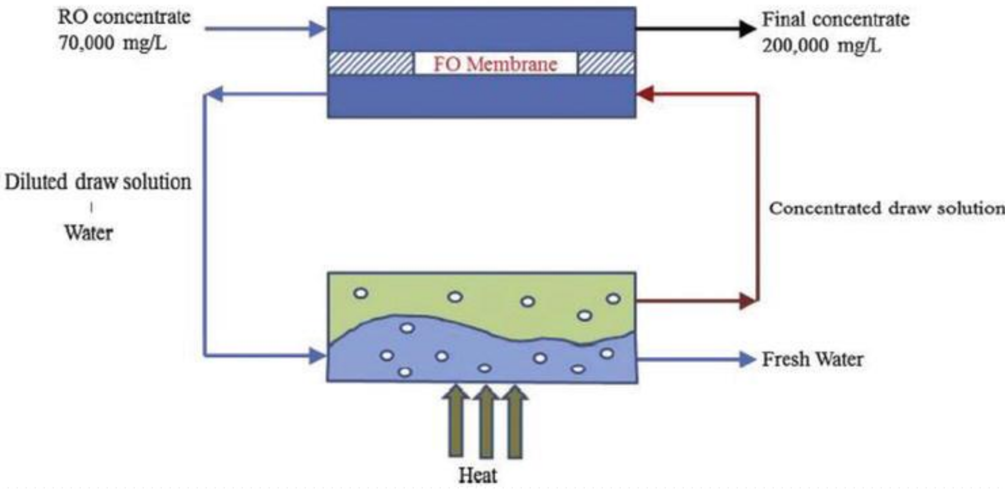
Green House Desalination

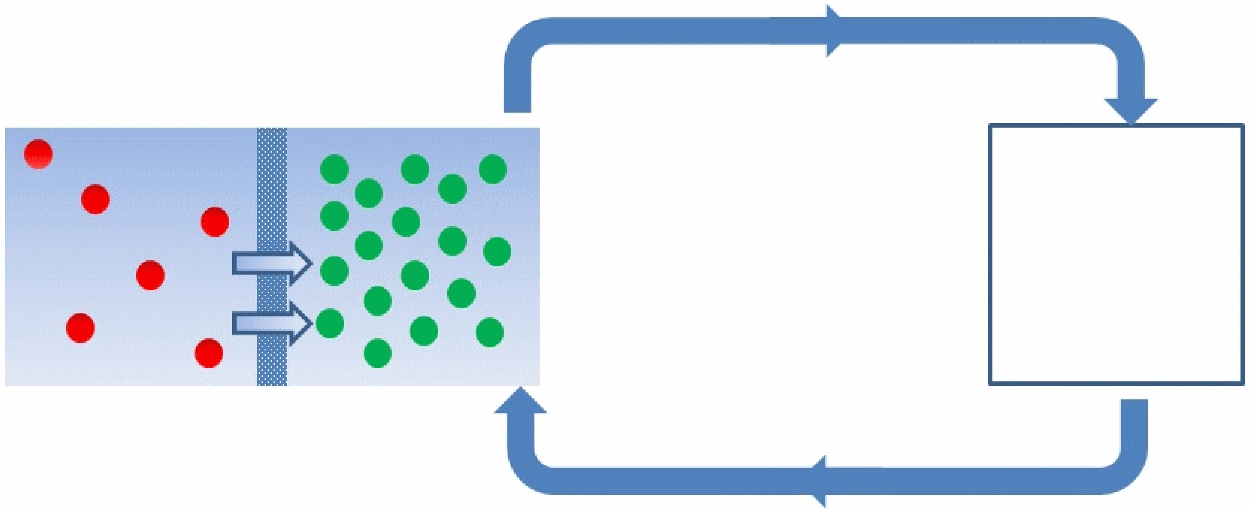
- Seawater greenhouse technology provides a source of clean water for irrigation
- Decreasing brine volumes possible using evaporative coolers in seawater greenhouses
- High-value crop cultivation and sea salt production facilitated
- Technology recreates the hydrologic cycle through evaporation and condensation of saline water sources
- Renewable energy based technology
- Multiple stages of development with favorable practical results in regions with fresh water shortage
- Ecomic value goes in dehumidification
- Reduce water consumption by 60 %
- Almost zero salinity in the water produces



Emerging Technologies for Brine treatment: Forward Osmosis

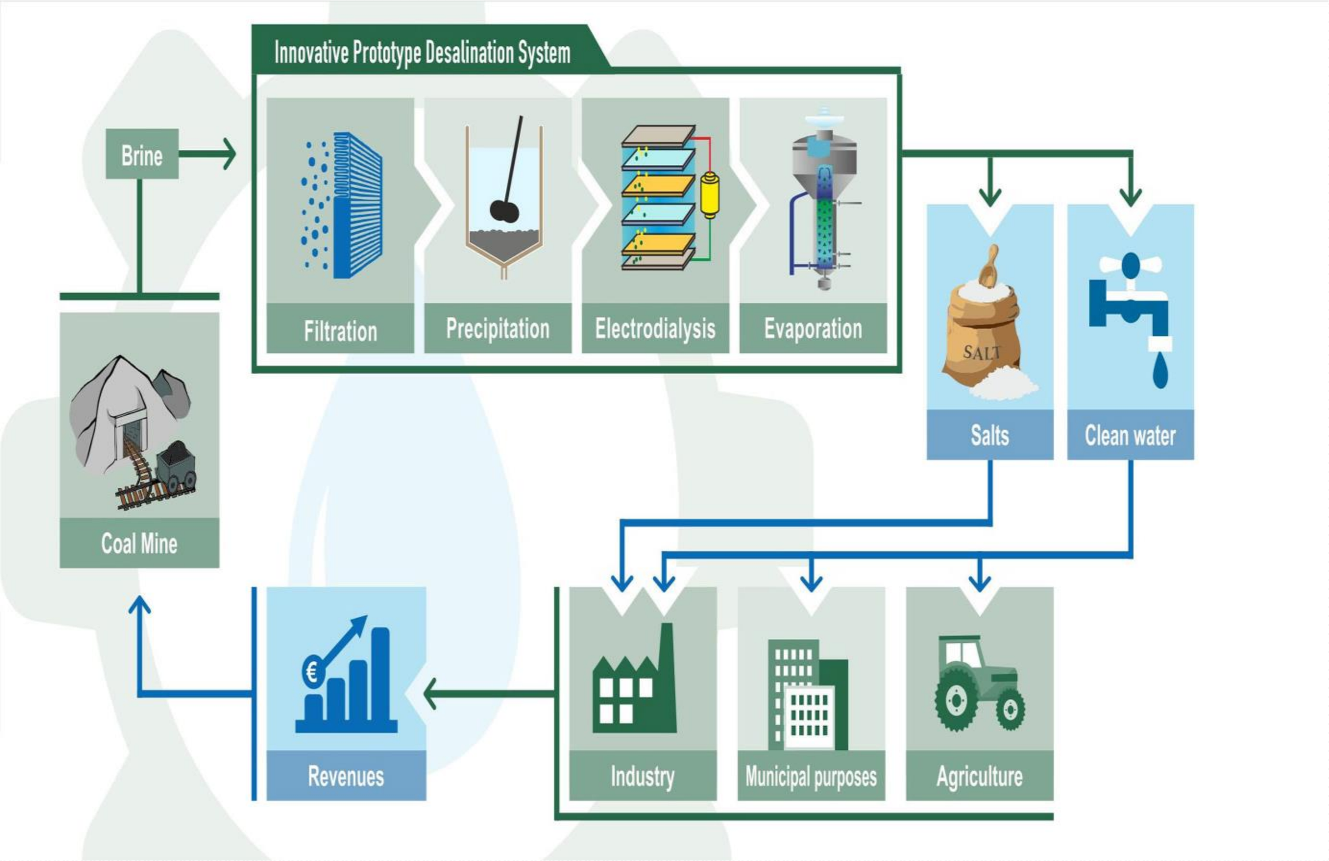
- **Forward Osmosis**
- FO uses osmotic pressure difference to drive water transport across a semi-permeable membrane
- The membrane allows only water molecules to pass through, rejecting dissolved solids and contaminants .
- FO concentrates brine by extracting water, reducing volume and increasing dissolved solids concentration .





Emerging Technologies for Brine treatment: Brine Mining and Mineral Recovery

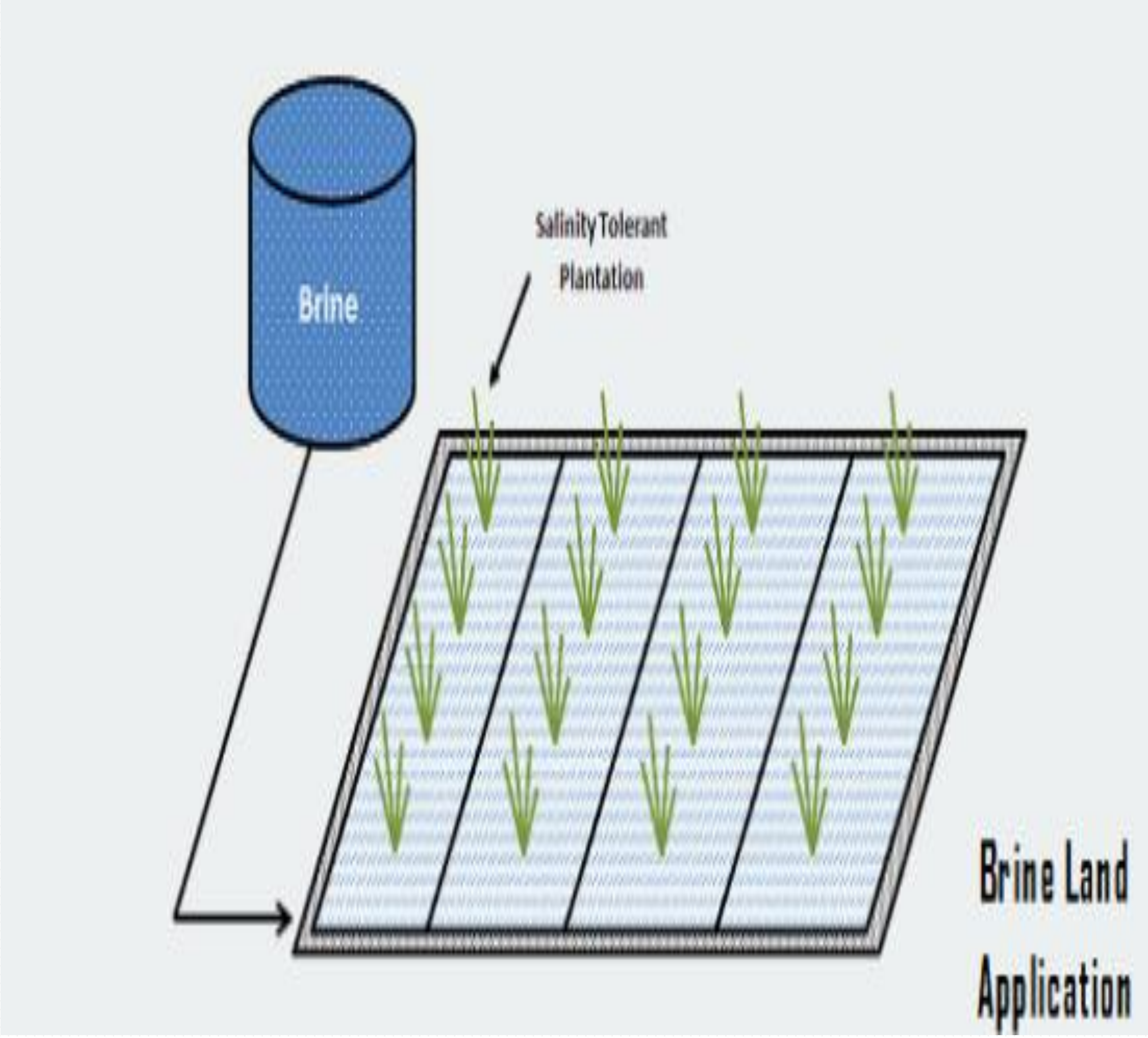
- Extraction of valuable resources
  - Selective separation techniques extract minerals/metals from brine
  - Lithium recovered for batteries via adsorption, ion exchange, solvent extraction
  - Magnesium compounds ($Mg(OH)_2$, $MgCl_2$) precipitated for pharmaceuticals, refractories
  - Bromine extracted for flame retardants, drilling fluids via stripping, oxidation



Emerging Technologies for Brine treatment:

Brine Utilization in Agriculture

- Irrigation of salt-tolerant crops (halophytes)
  - Halophytes like Salicornia, Atriplex, Distichlis thrive in high salinity
  - Can be irrigated with brine, reducing freshwater demand
  - Provides biomass for biofuels, animal feed, food products
  - Integrating halophytes with brine management creates sustainable solution for water-scarce regions

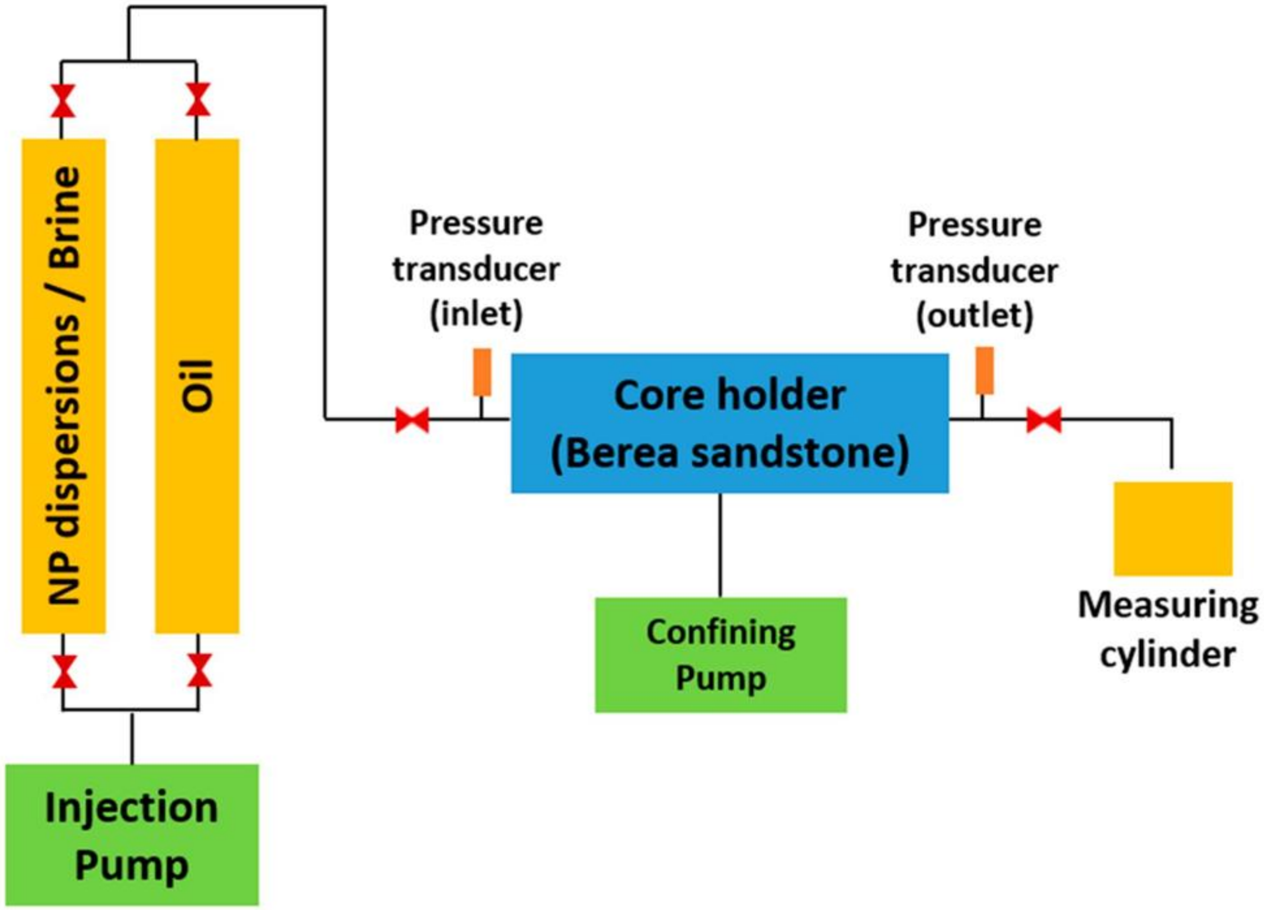


Emerging Technologies for Brine treatment:

Brine Injection for Enhanced Oil Recovery

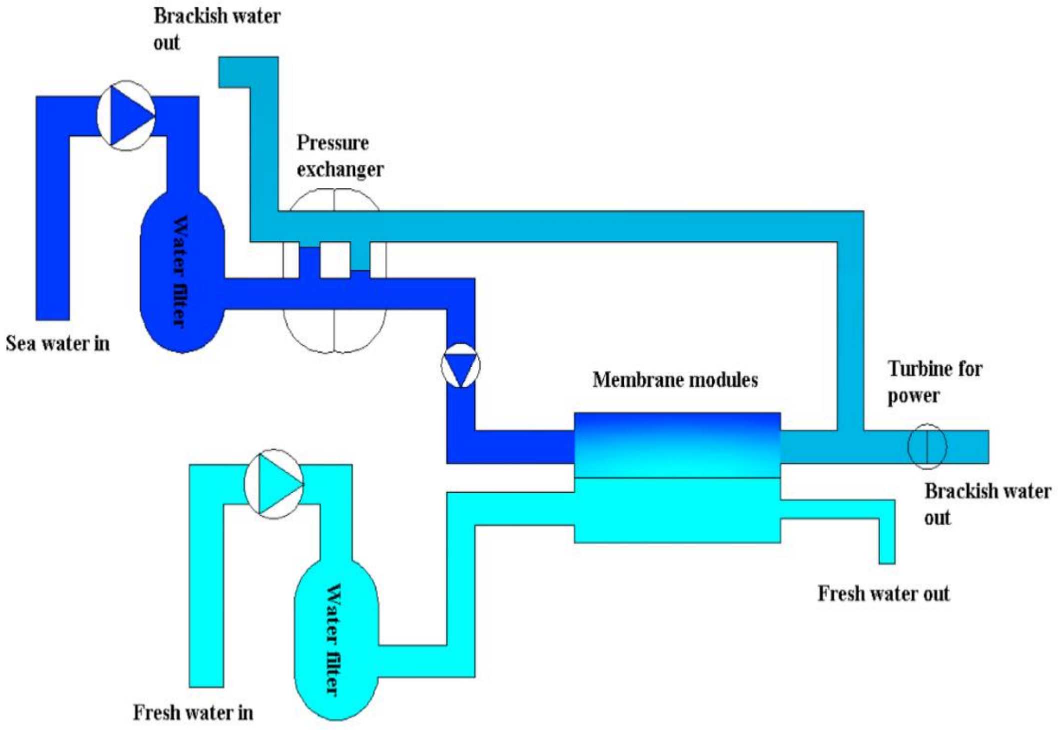
Brine for Enhanced Oil Recovery (EOR):

- Brine injection maintains reservoir pressure and displaces residual oil
- Improves oil recovery efficiency, especially in mature/declining fields
- Extends life of oil reservoirs and maximizes resource extraction
- Widely used EOR technique in the oil and gas industry



Emerging Technologies for Brine treatment: Pressure Retarded osmosis

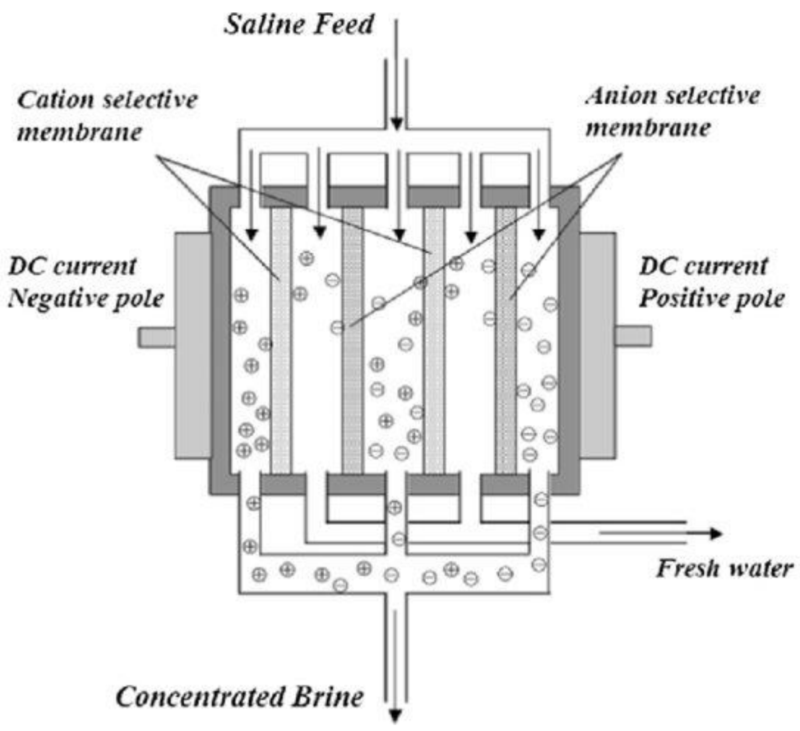
- Utilizes osmotic pressure difference between two solutions to generate energy
- One solution is saltwater, and the other is fresh water
- Saltwater solution is separated from fresh water by a semi-permeable membrane
- The osmotic pressure drives water from the freshwater side to the saltwater side
- Energy is generated as the water flows through a turbine to generate electricity
- Can provide a sustainable and renewable energy source in regions with abundant fresh water and saltwater sources
- Currently, PRO is at a research and development stage and its potential for large-scale implementation is still being studied.



Emerging Technologies for Brine treatment: Hybrid System

Electrodialysis-based Hybrid Systems

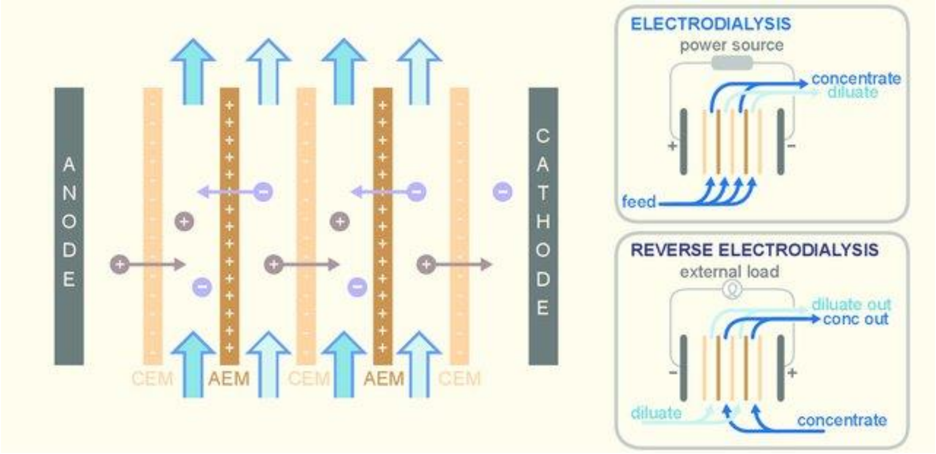
- Ions are transported through a Membrane under a influence of current(DC Voltage)
- This can treat extremely high saline water
- Reduced reverso osmosis brine effluent volume
- Used along with RO to produce 120G NaCL per Kg of water
- Concentrate taken to distillation to where recovery of salt is 80%

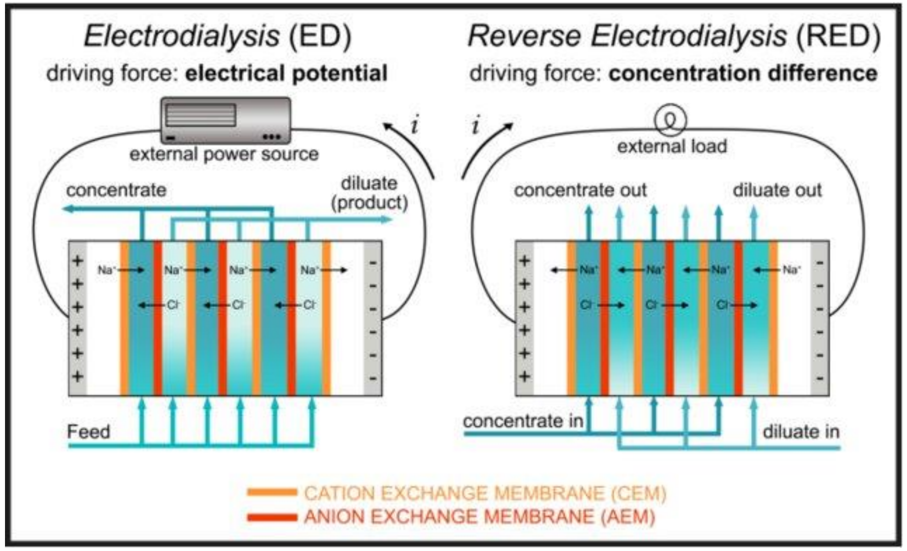


Emerging Technologies for Brine treatment: Hybrid System

Reverse electrodialysis-based Hybrid Systems

- Reverse electrodialysis is a developing membrane-based technology that generates electrical power from salinity differences between two solutions
- Constituent ions in the solutions are driven by an ion-exchange membrane and a salinity gradient
- RO brine can be used as a higher salt concentration feed solution for reverse electrodialysis to increase power density
- Reverse electrodialysis reduces environmental impact of RO brine by decreasing salt concentration of discharged brine
- It also reduce energy usage of RO by pretreating feed solution





Conclusion and Recommendations

- Brine production is influenced by feed water type and purification technology used
- Renewable energy sources, such as wind and solar, needed for future desalination in GCC nations
- Emerging technologies promising for brine volume reduction but still at lab/pilot scale more research and development is required
- Concentrated brine solution can reduce environmental impact and produce energy output
- Electrodialysis-based and reverse electrodialysis-based systems ideal for brine management
- efficiency and sustainability of these technologies need to be studied
- High salinity pressure retarded osmosis requires further investigation for practical application
- Proper organization and laws needed for effective implementation of desalination processes and Brine Management

Future Directions and Research Needs

- Collaborative Efforts among Stakeholders
  - Multi-stakeholder partnerships and knowledge sharing
  - Roles of industry, academia, and government
- Technological Advancements in Brine Treatment and Resource Recovery
  - Emerging technologies and process intensification
  - Research and development priorities

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THANK YOU

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