Desalination as a Source of Fresh Water

Desalination 101

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Presentation Overview

- Source water requiring desalination
- Properties of water and their impact on desalination
- Desalination technologies
- Water recovery and cost of desalination
- Issues associated with desalination
  - Pre-treatment of source water
  - Energy demand and energy recovery
  - Concentrate management
- Future technologies

Desalination of Impaired Water

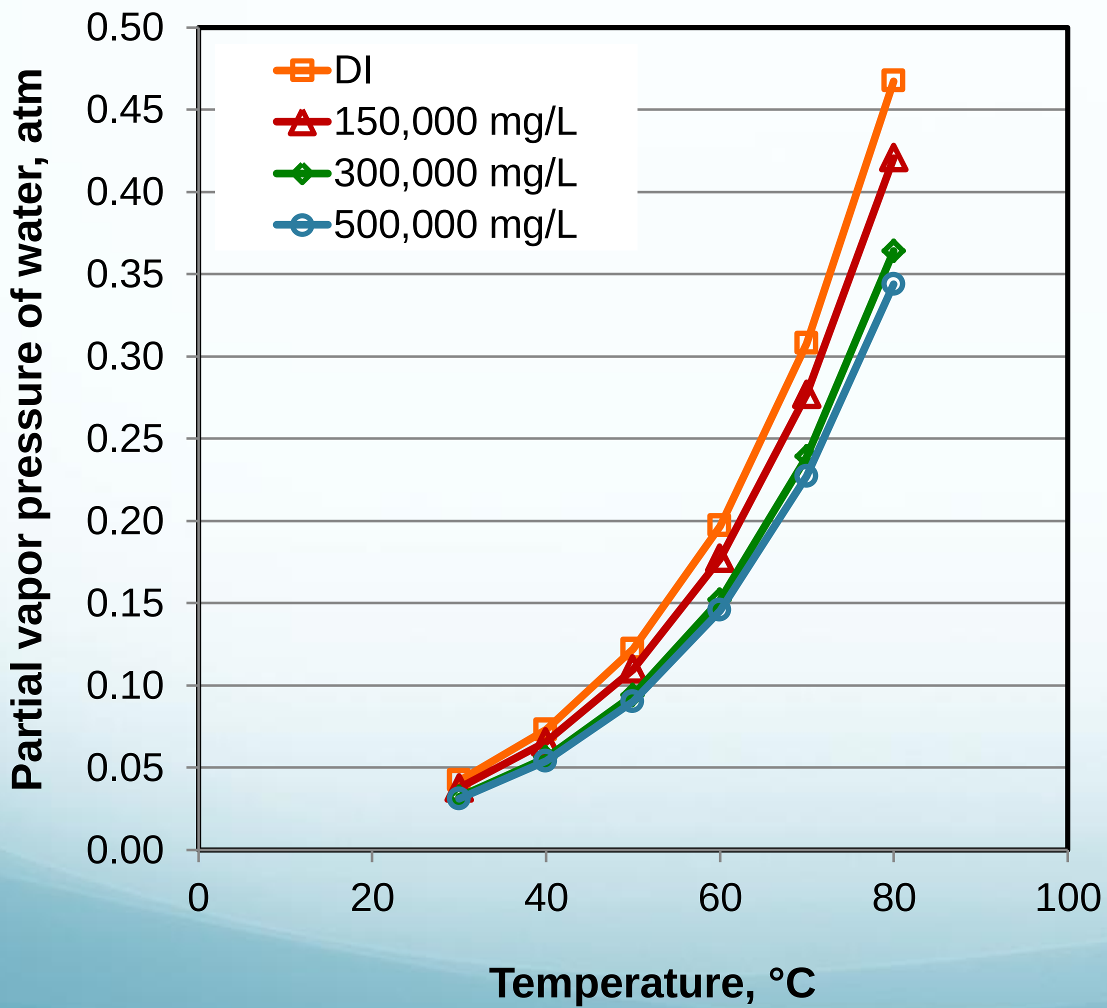
- Common water sources requiring desalination
  - Seawater
  - Brackish groundwater
  - Industrial water (high purity)
  - Domestic and industrial wastewater for advanced reuse
  - Surface water containing specific dissolved solids

- Constituents requiring removal by desalination
  - Dissolved solids, simple salts/ions, heavy metals, nutrients, hardness, organic contaminant of emerging concern, etc.

Colligative Properties of Ionic Solutions

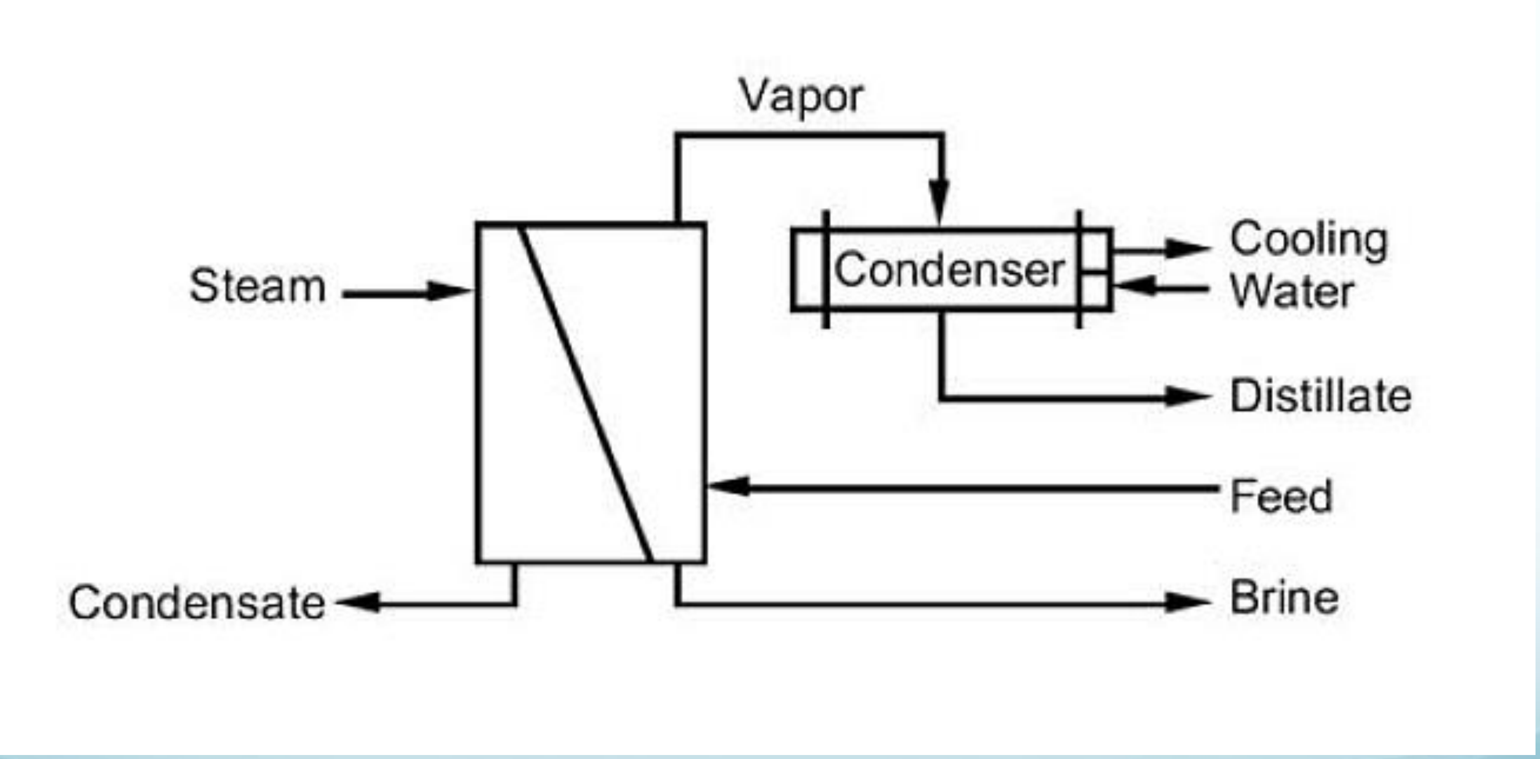
- Properties of solution that depend on the number of solute molecules present, but not on the nature of the solute
- Osmotic pressure, vapor pressure, freezing point depression, and boiling point elevation are examples of colligative properties
- Osmotic pressure and vapor pressure are two properties of solution that play a major role in desalination

Vapor Pressure of Water

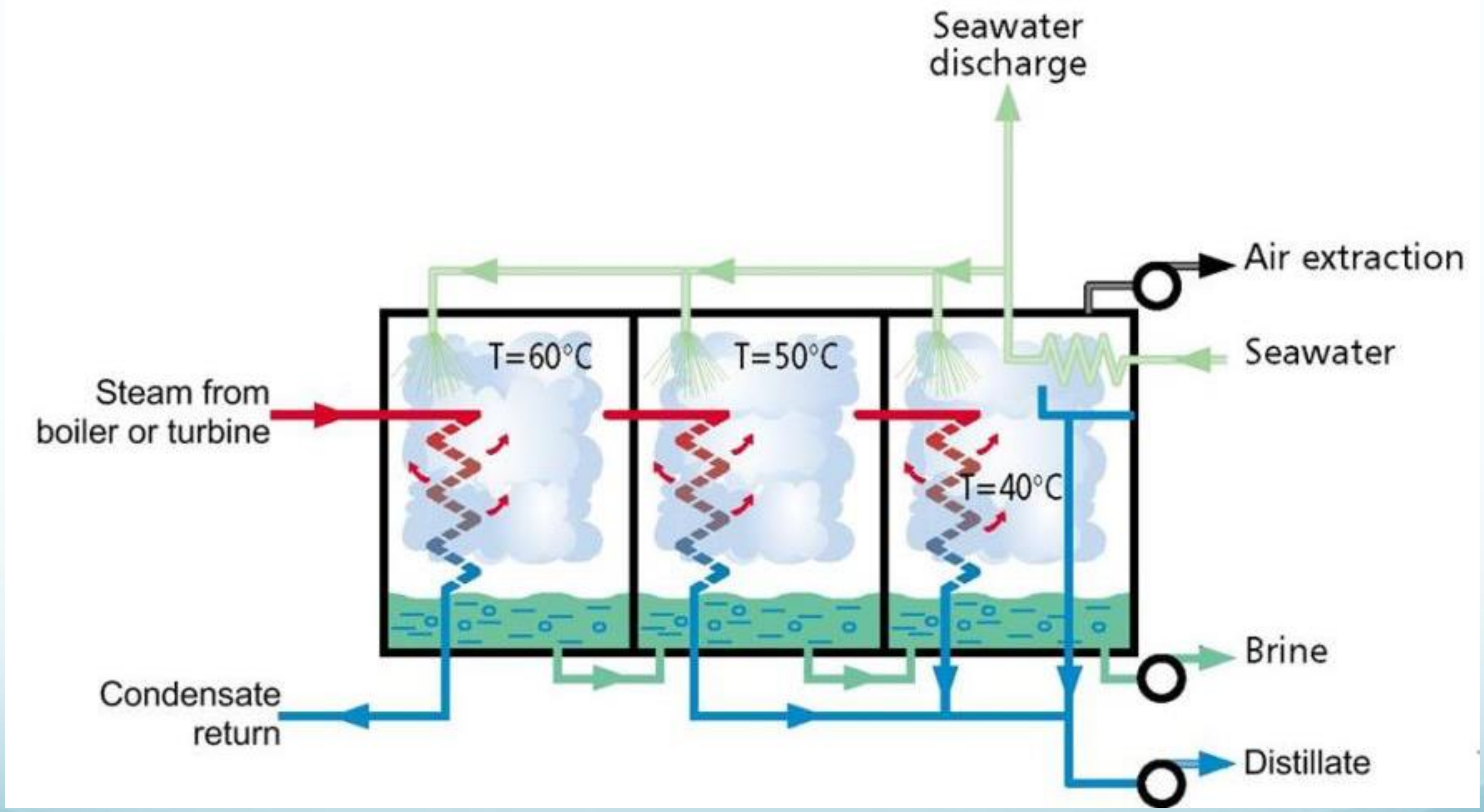


- Increases with increasing temperature
- Minimally decreases with increasing concentration

Single-effect Evaporator

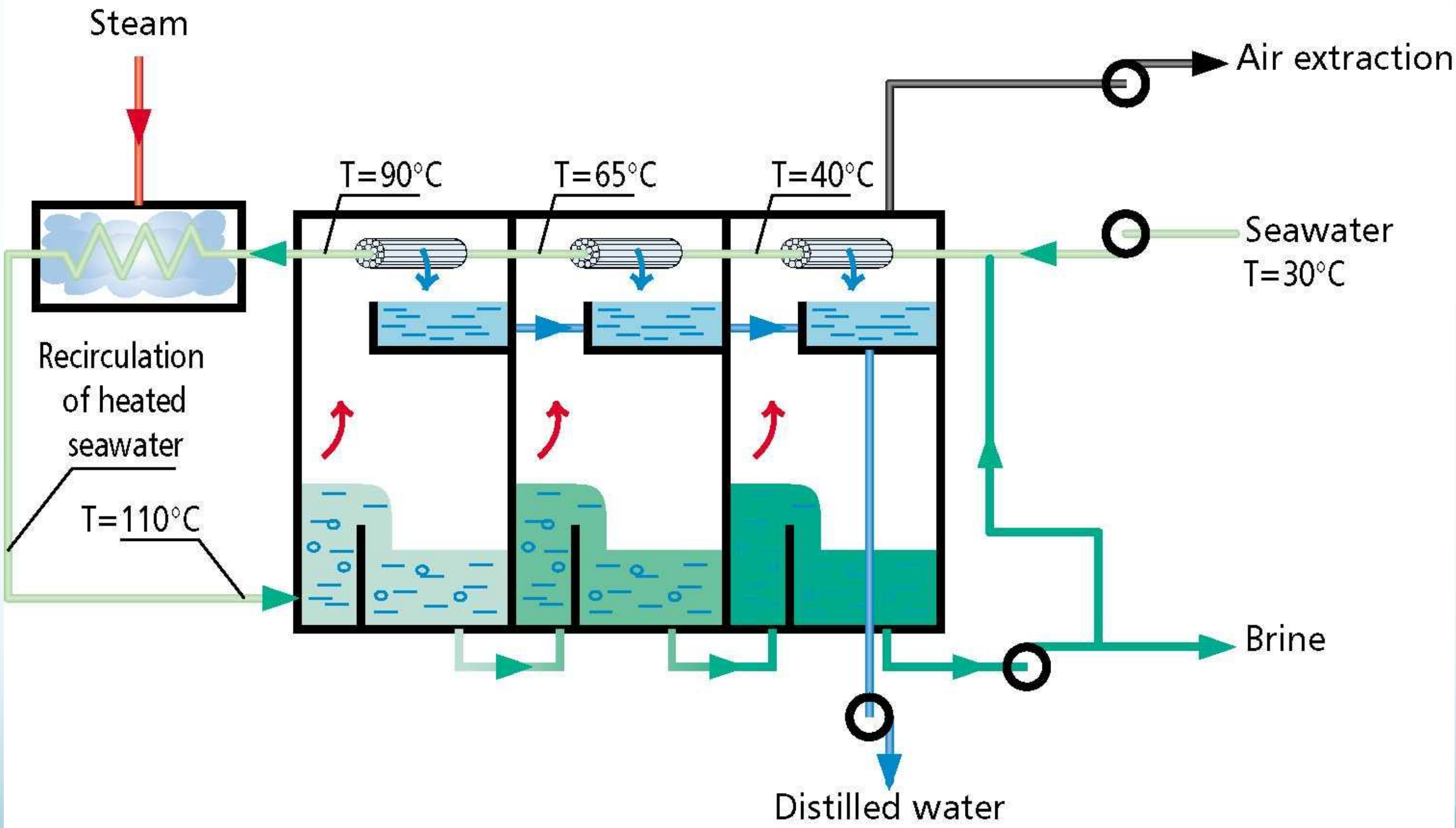


Multiple-effect Evaporator (MED)



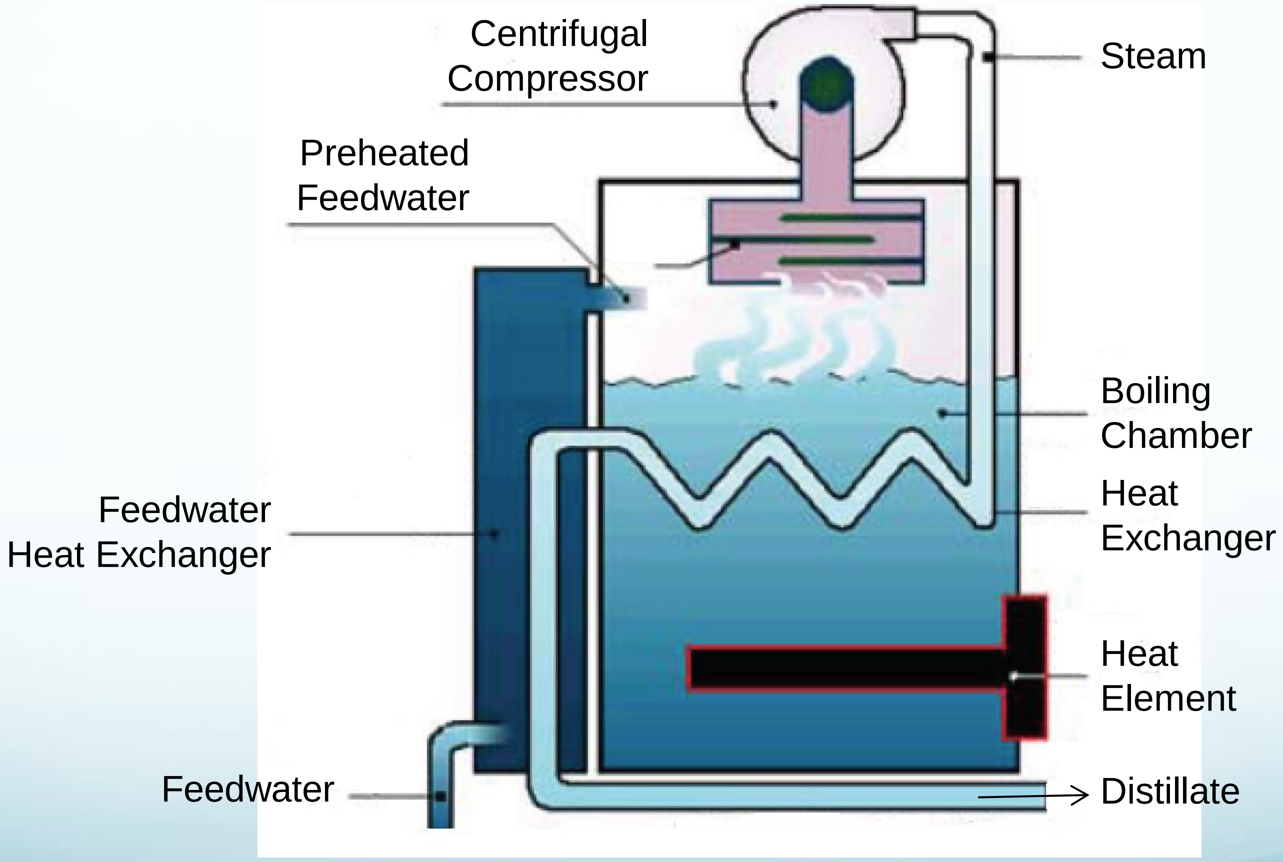
Courtesy of Tom Pankratz, tp@globalwaterintel.com

Multistage Flash Evaporation (MSF)



Courtesy of Tom Pankratz, tp@globalwaterintel.com

Vapour Compression Brine Concentrator



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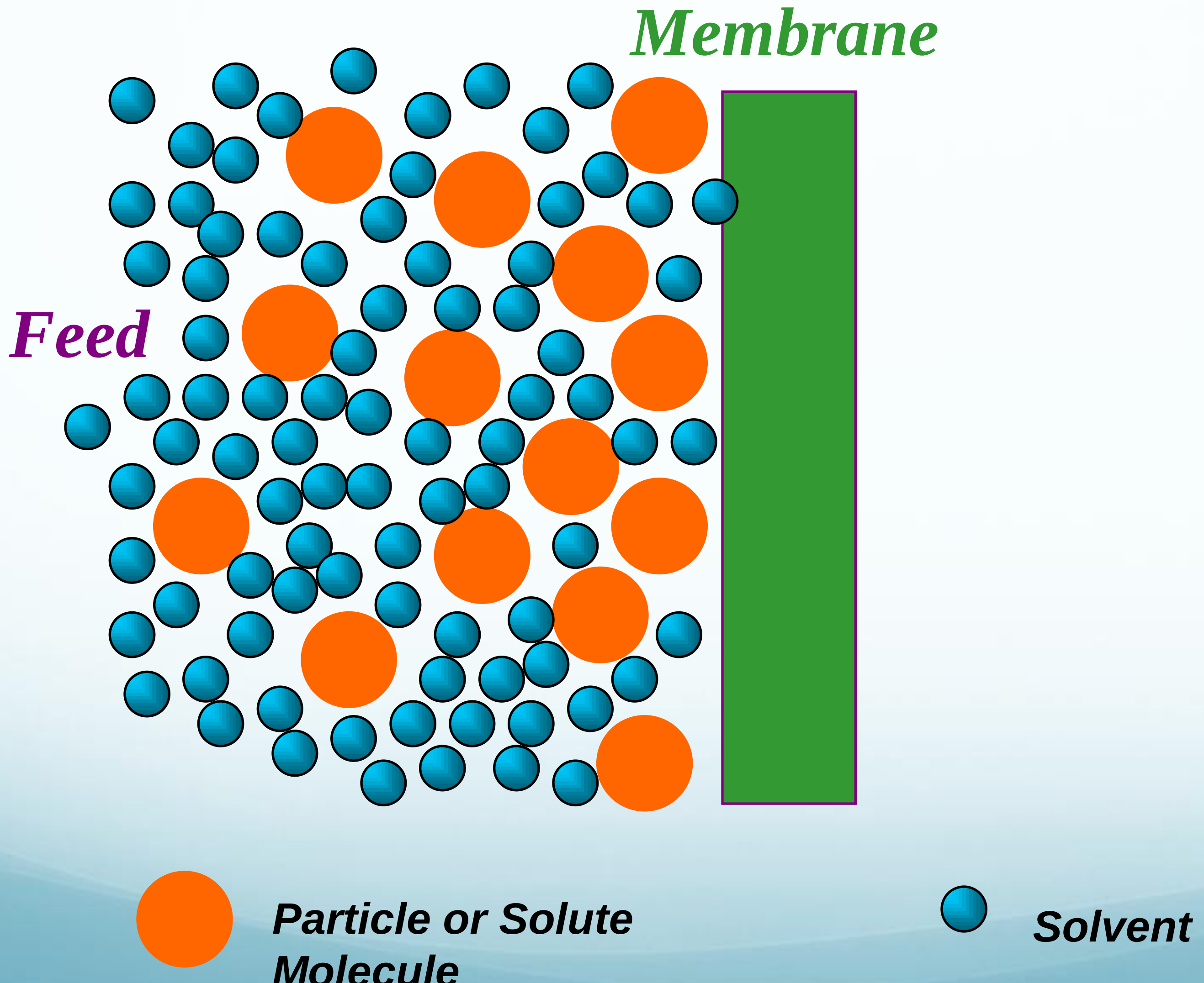
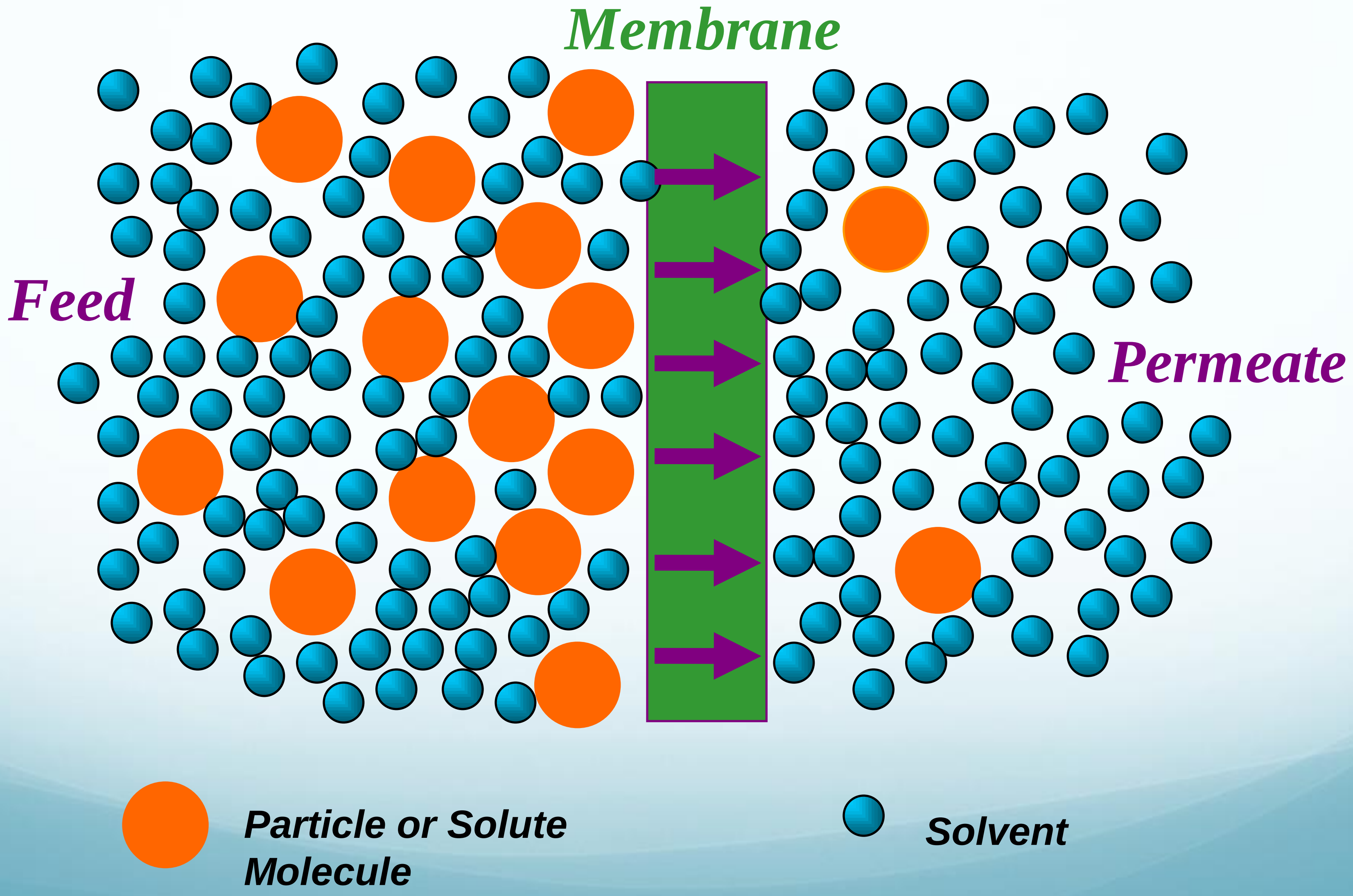
Membrane Separation

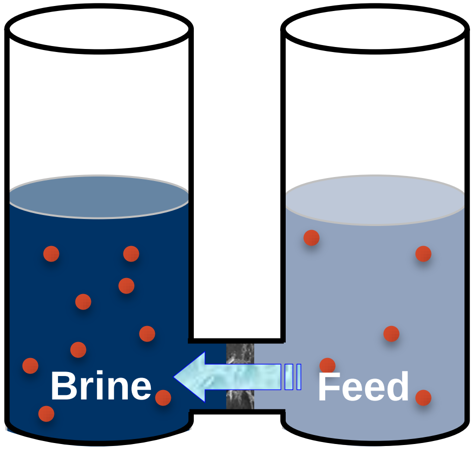


Membrane Separation



Osmotic Pressure of Solution

- Increases with increasing solute concentration
- Increases with increasing temperature



Osmosis

Osmotic Pressure of Solution

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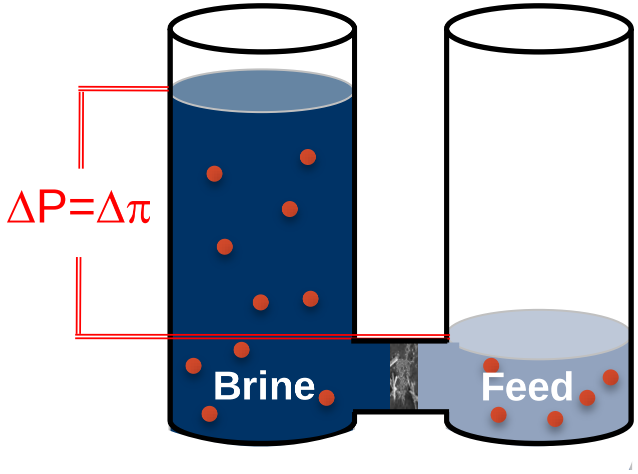
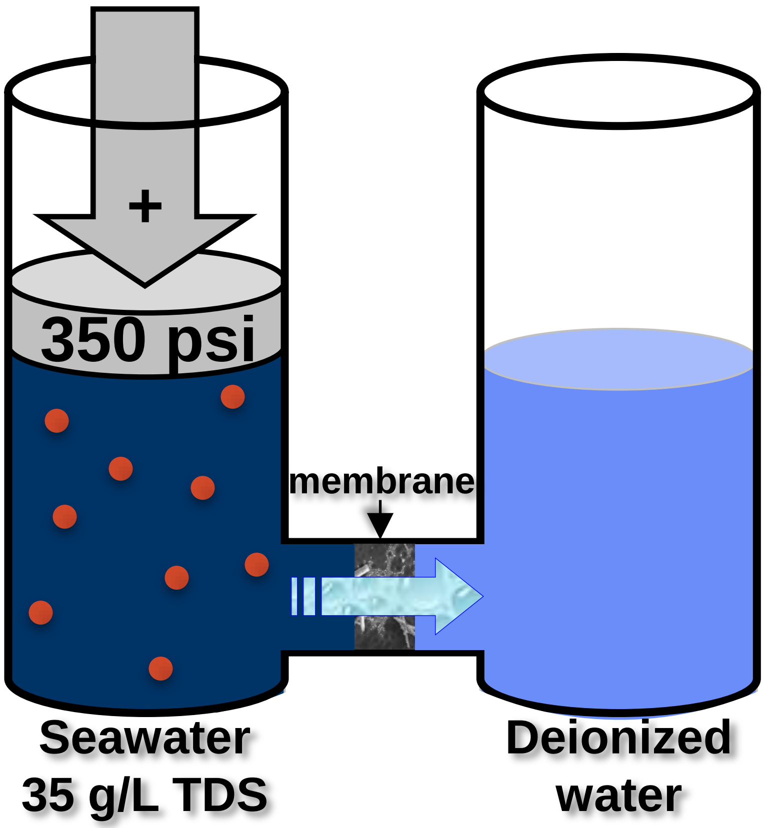
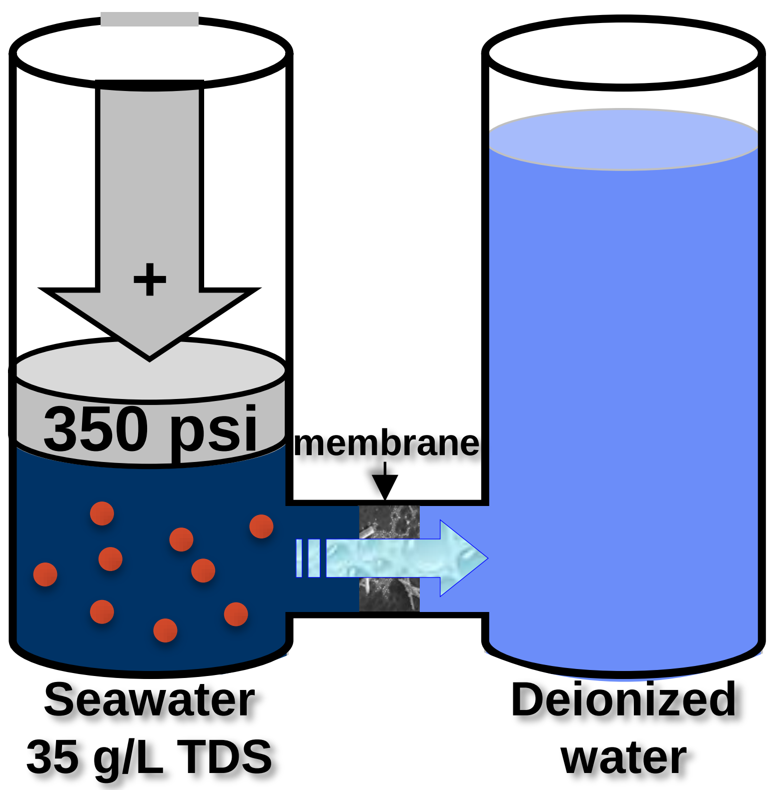


Osmosis

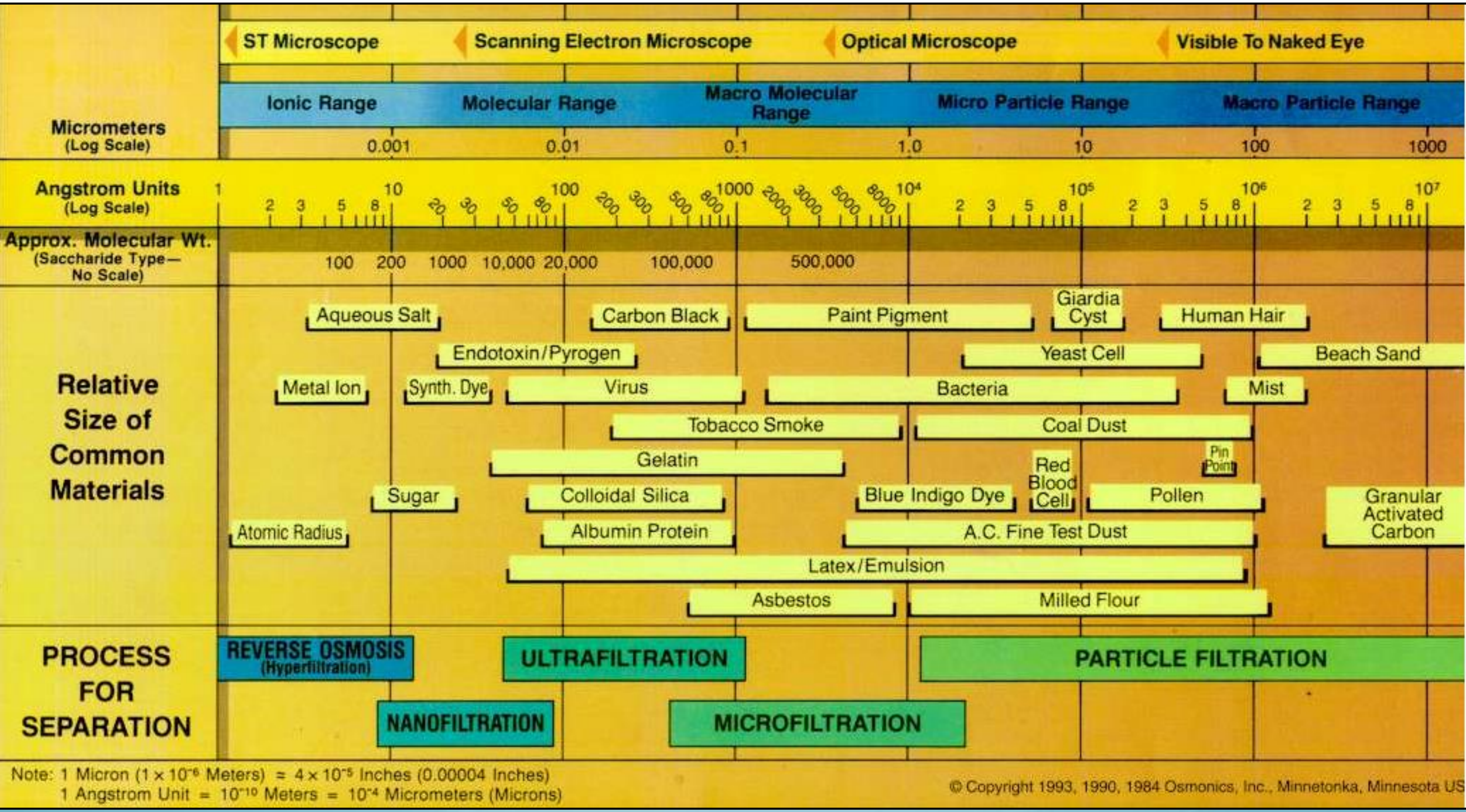
Overcoming Osmotic Pressure



Overcoming Osmotic Pressure



Domains of Filtration

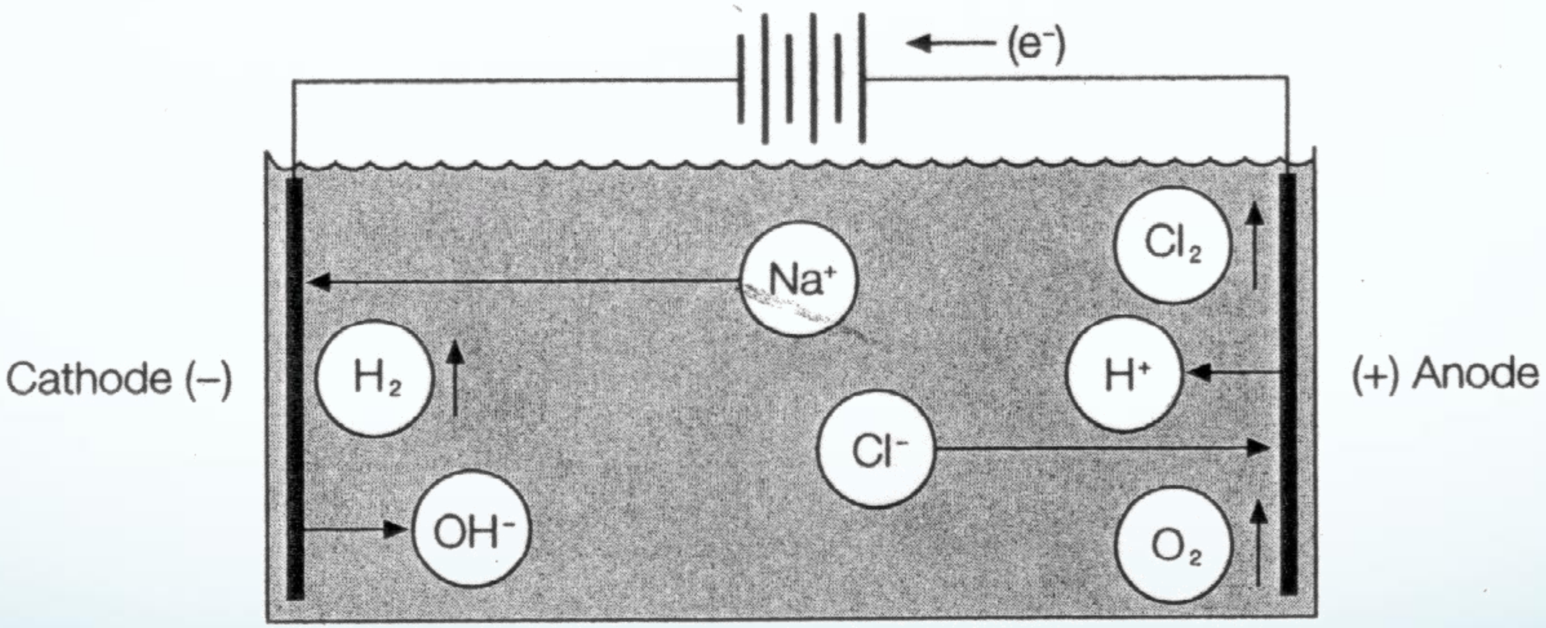


Ranges of Pressure and Flux

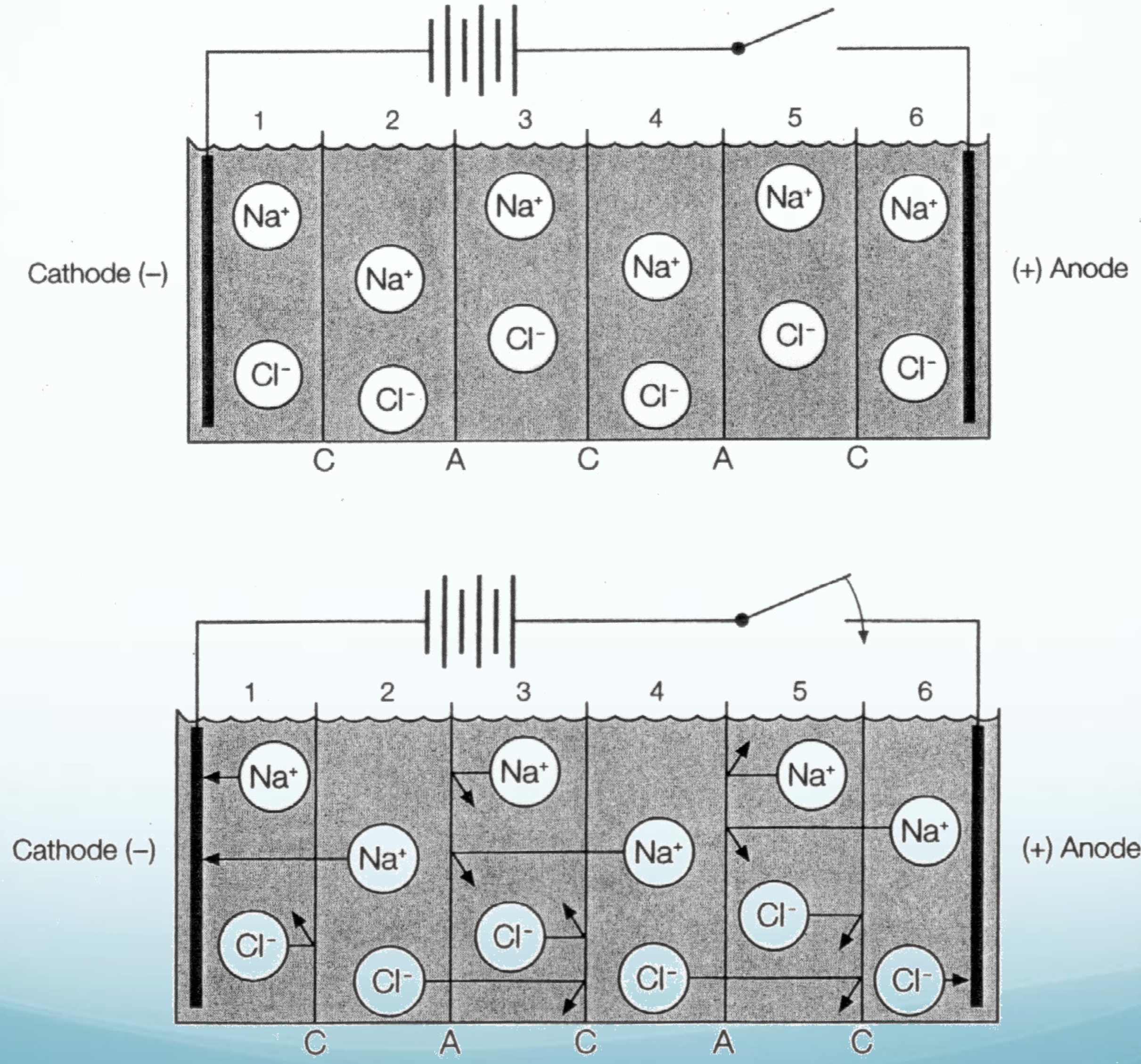
Process	Pressure		Water Flux	
	PSI	kPa	$gal/ft^2/day$ (GFD)	$L/m^2/hr$ (LMH)
Nanofiltration	100 – 400	700 – 2800	15 – 30	20 – 50
Reverse Osmosis	200 – 1000	1400 – 7000	15 – 30	20 – 50

GFD = LMH x 1.7

Electrochemistry



Principles of Electrodialysis



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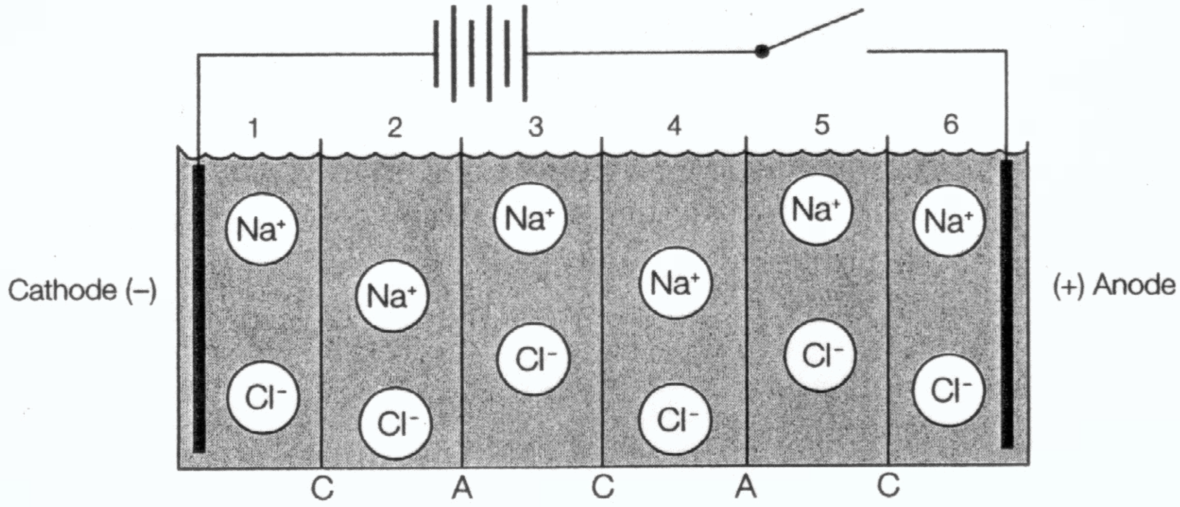

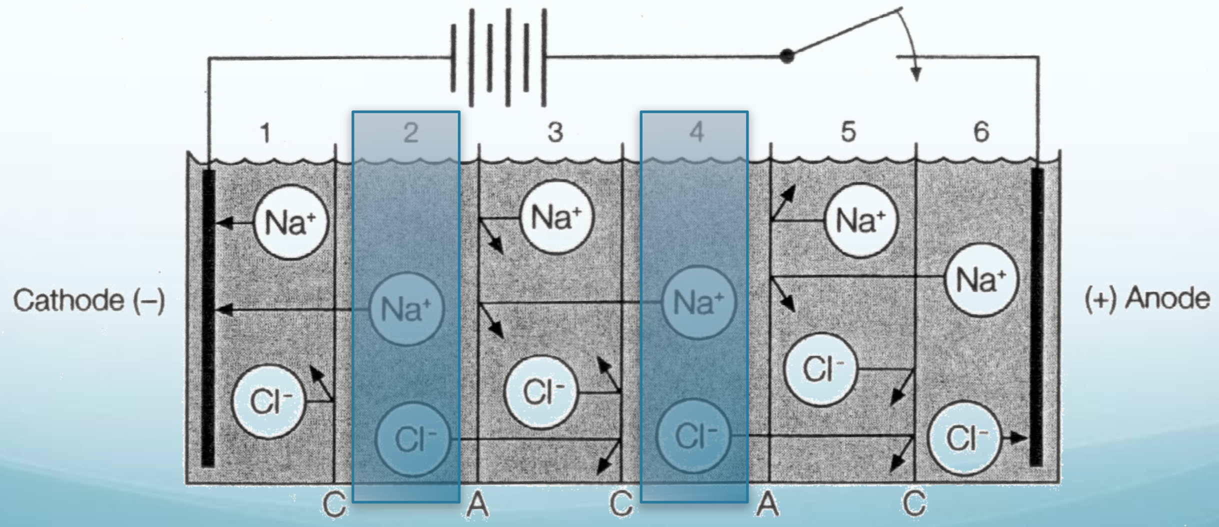

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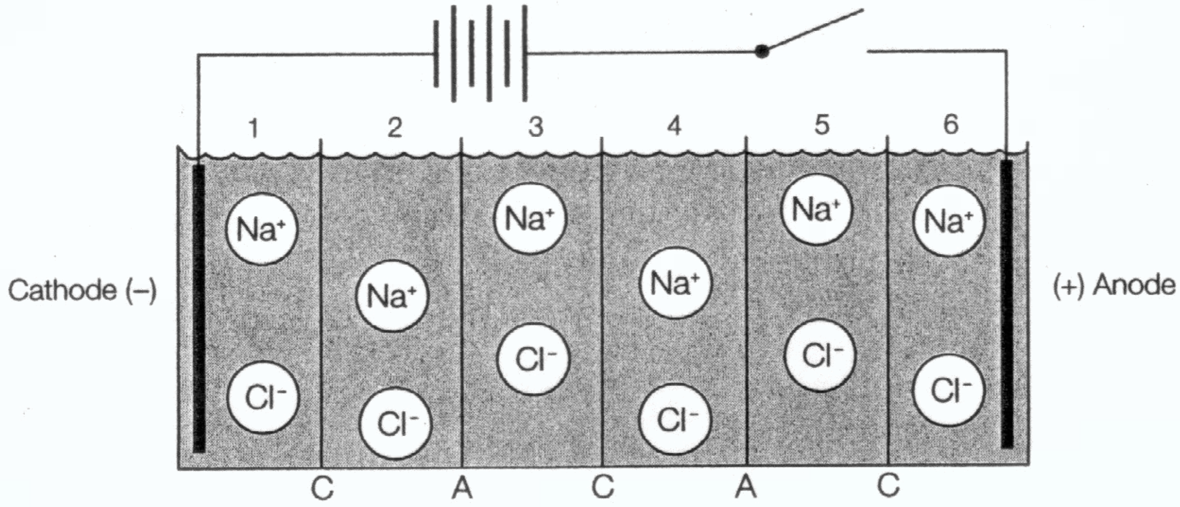
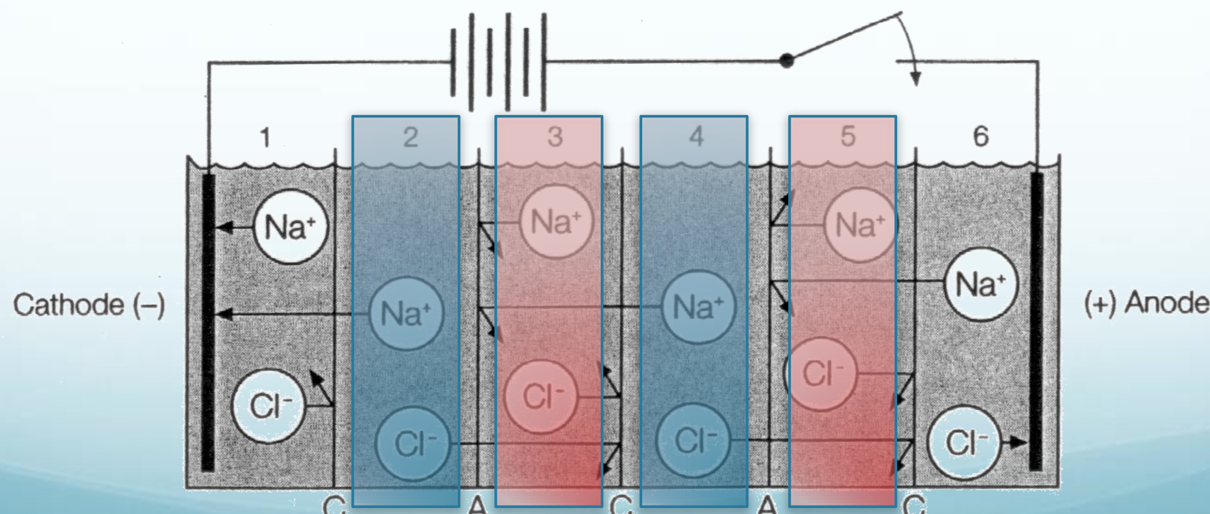
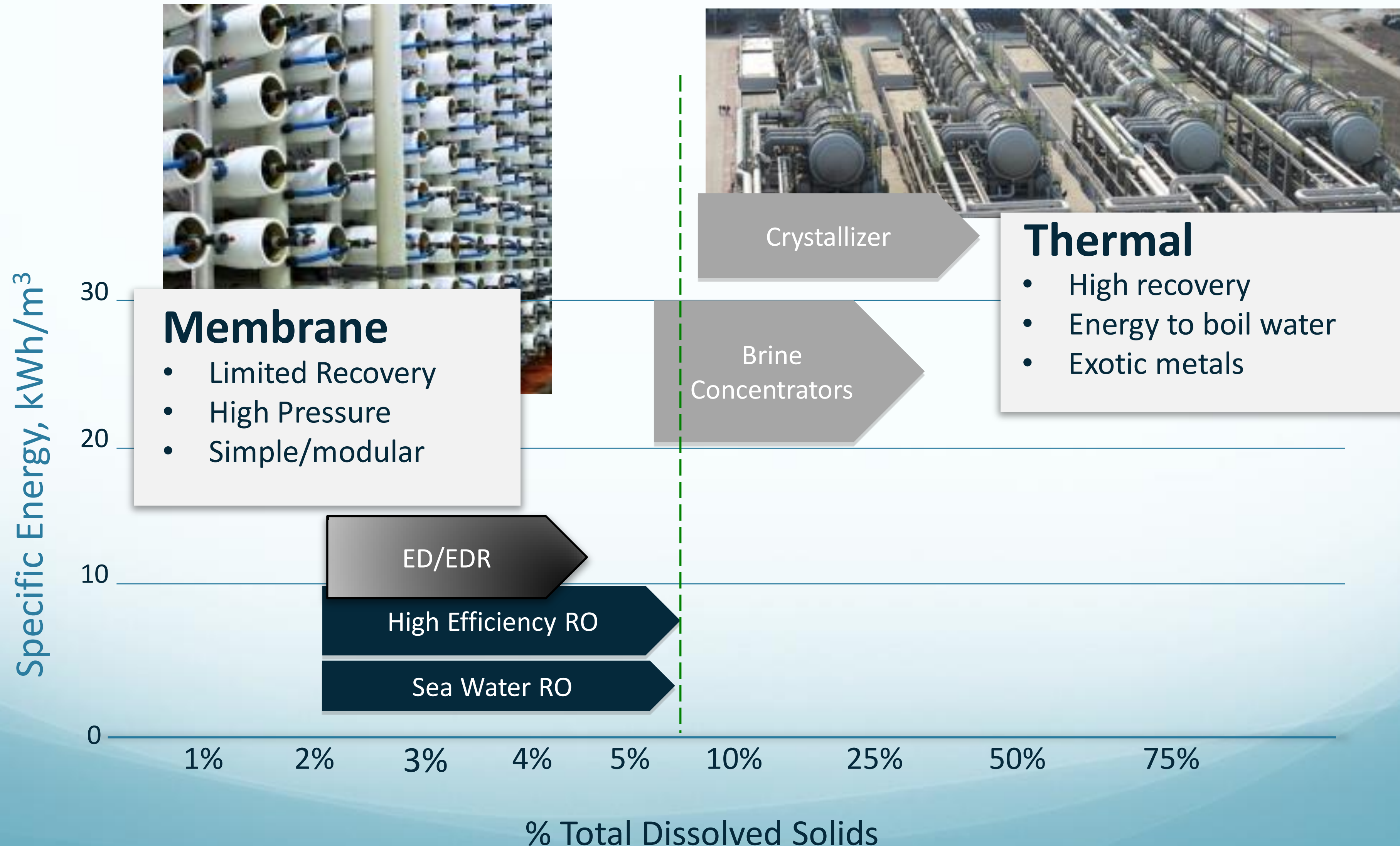


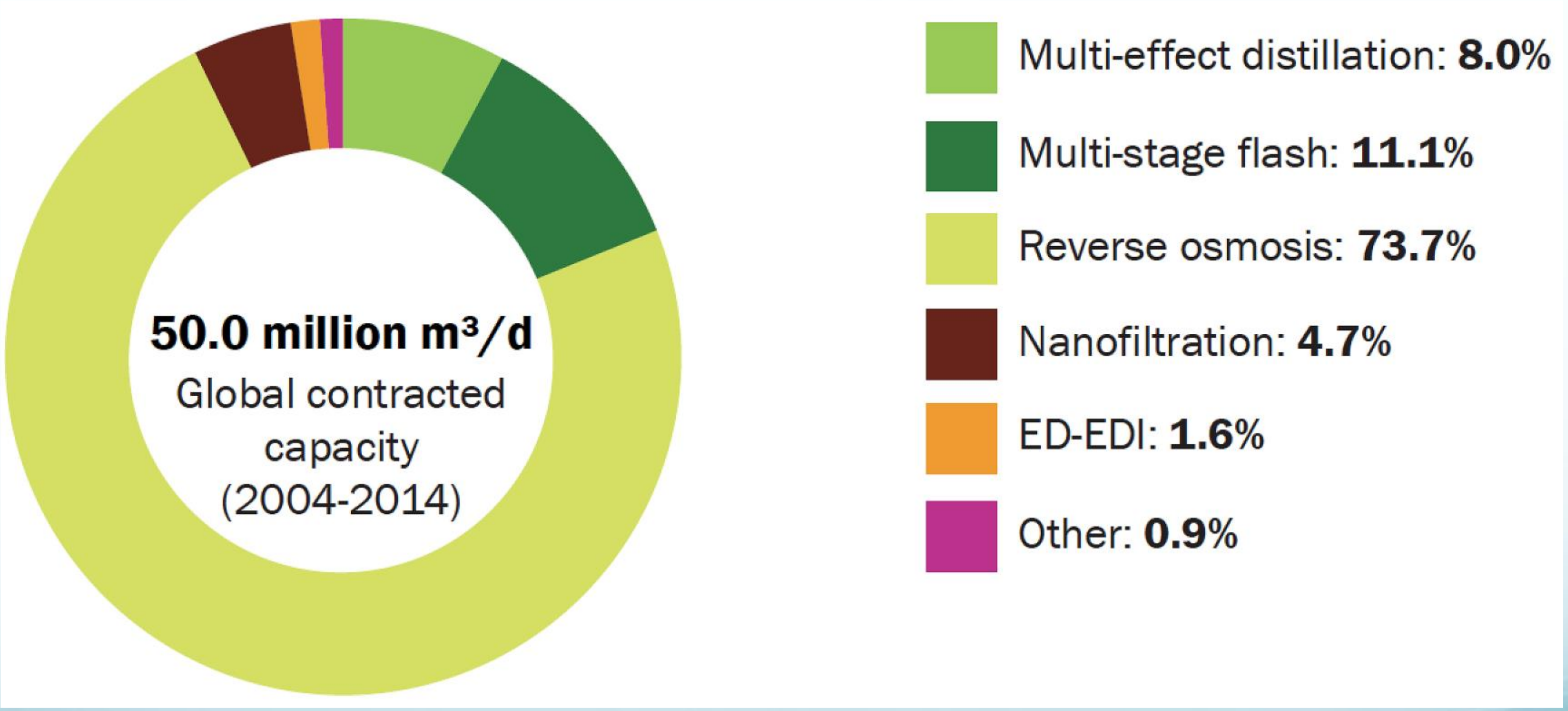


Desalination Technologies



Adapted from: Oasys Water

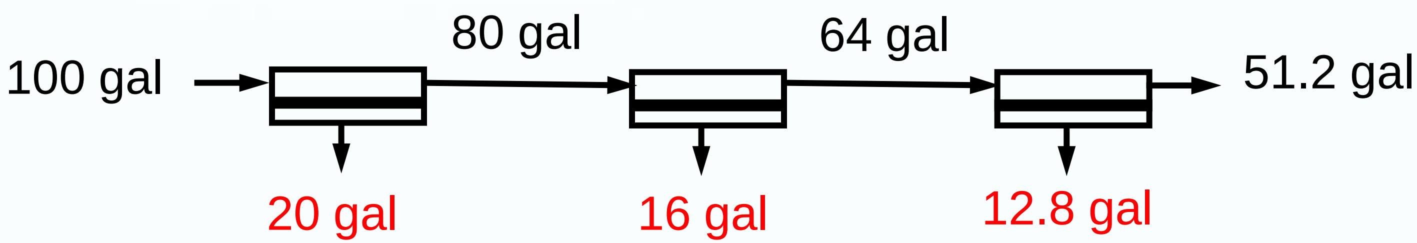
Contracted Capacity by Technology



Courtesy of Tom Pankratz, tp@globalwaterintel.com

Water Recovery in RO/NF Systems

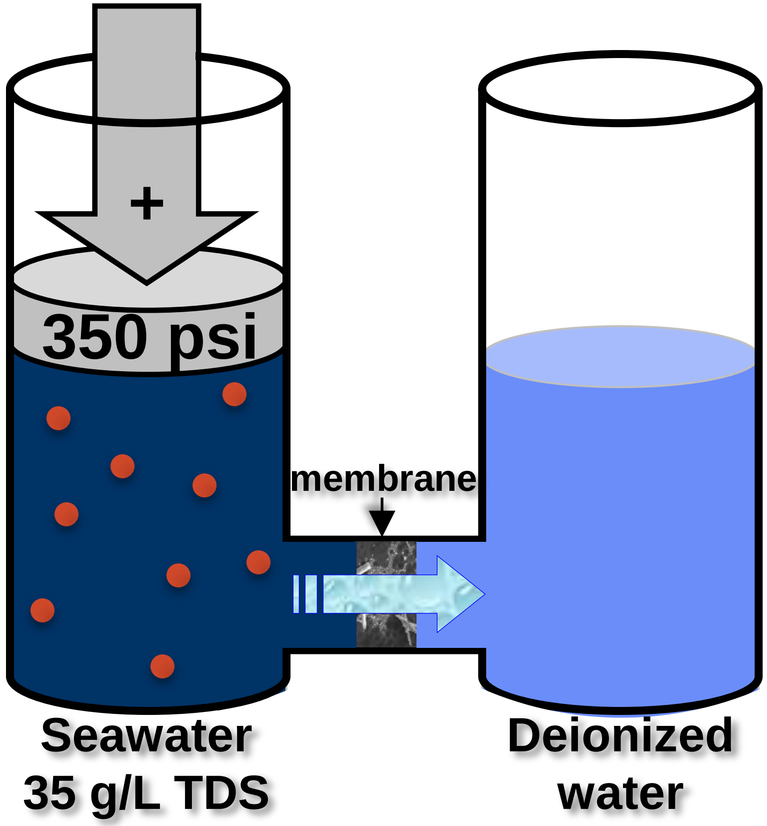
- Assuming each membrane (or each stage) operates at 20% recovery



- Total permeate from all membranes (stages) = 48.8 gal

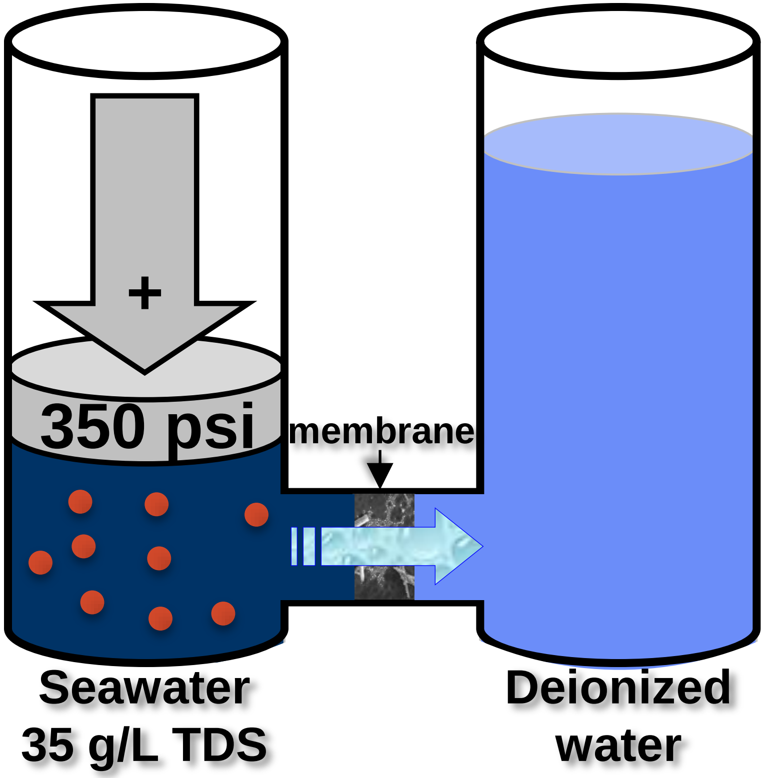
$$Overall\ Recovery = 100\left(\frac{48.8\ gal}{100\ gal}\right) = 48.8\%$$

Overcoming Osmotic Pressure



Overcoming Osmotic Pressure

Rule of thumb: 1 g/L salt ≈ 10 psi of osmotic pressure



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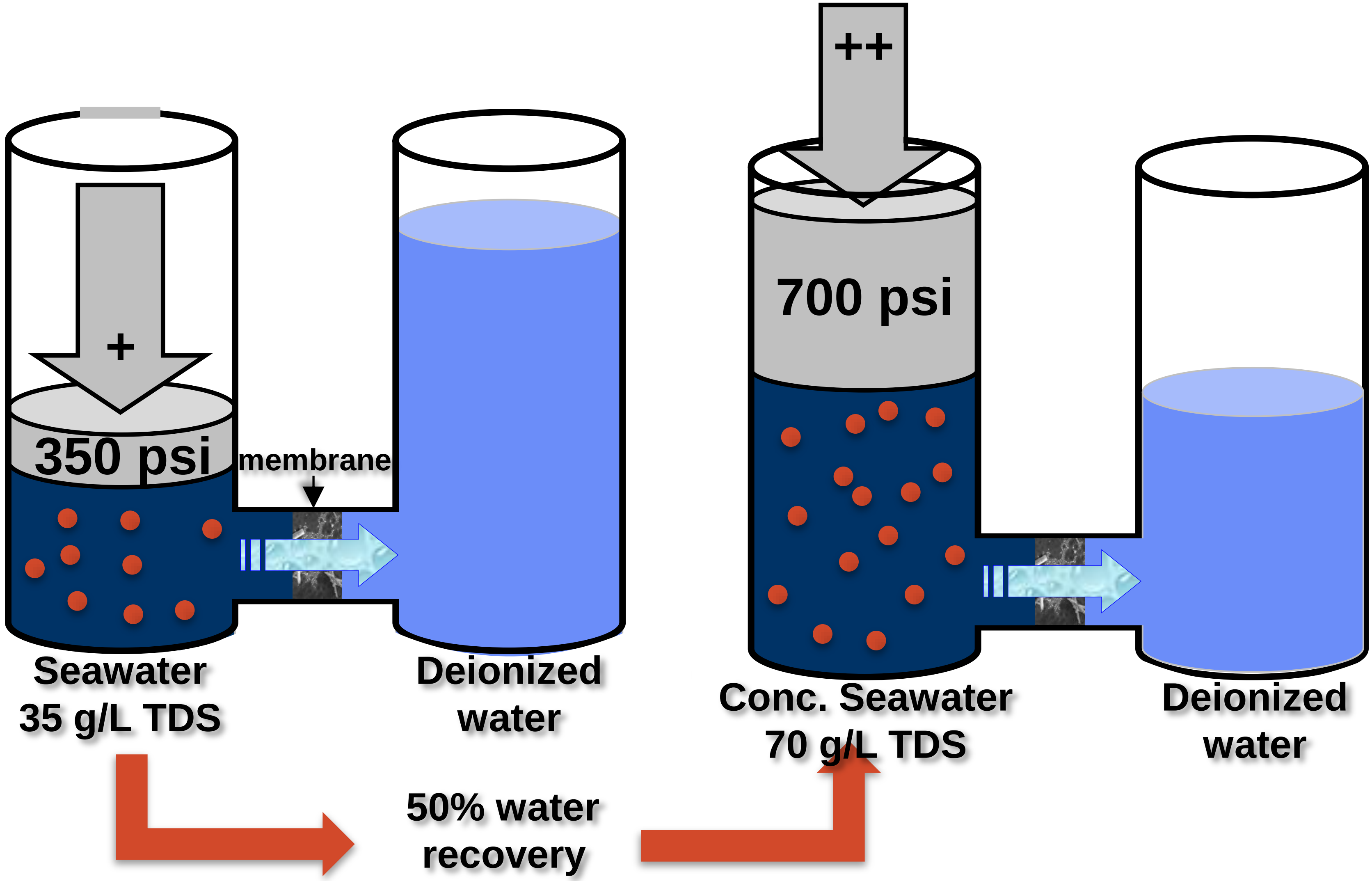

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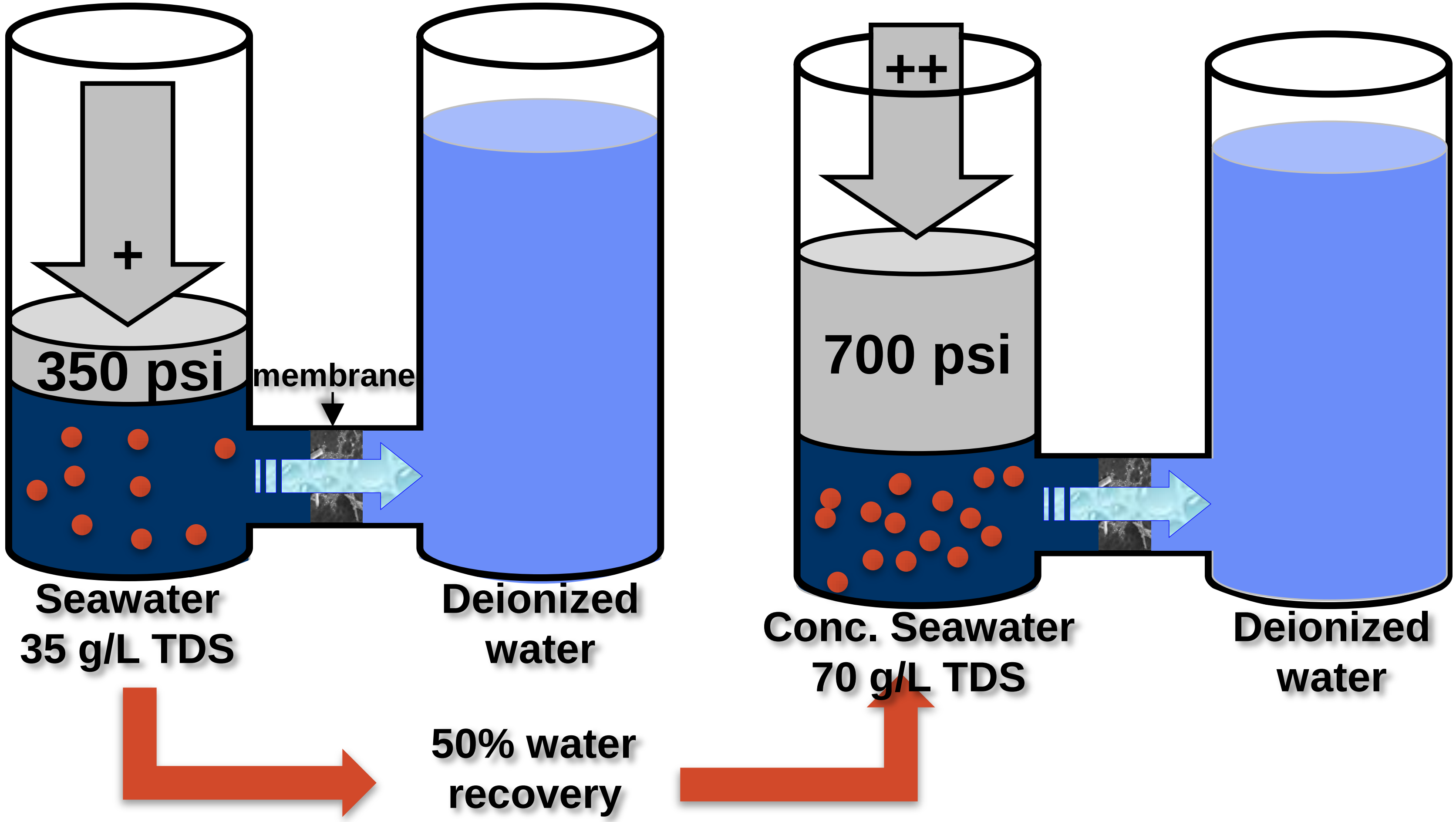
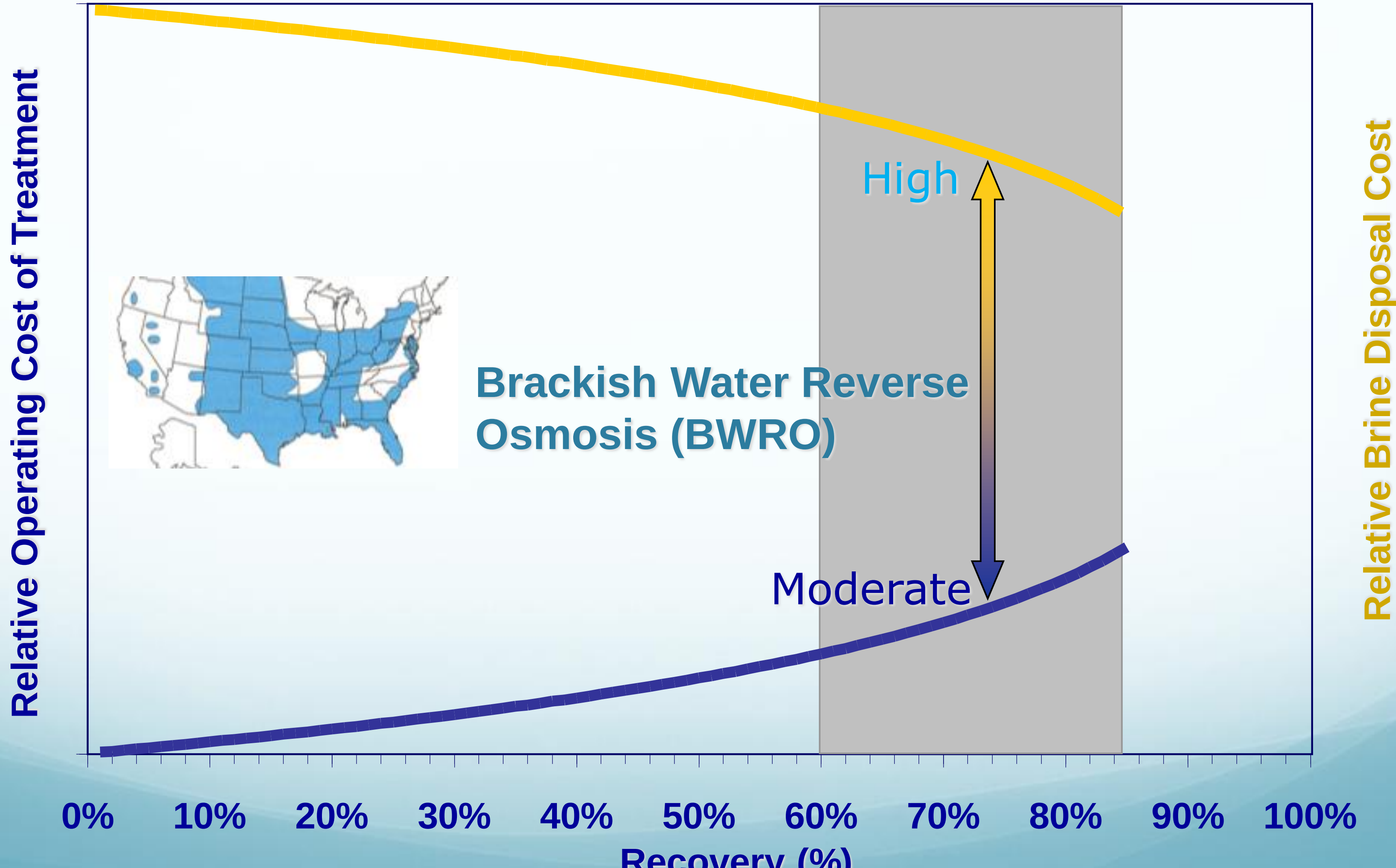


Water Recovery and Associated Costs



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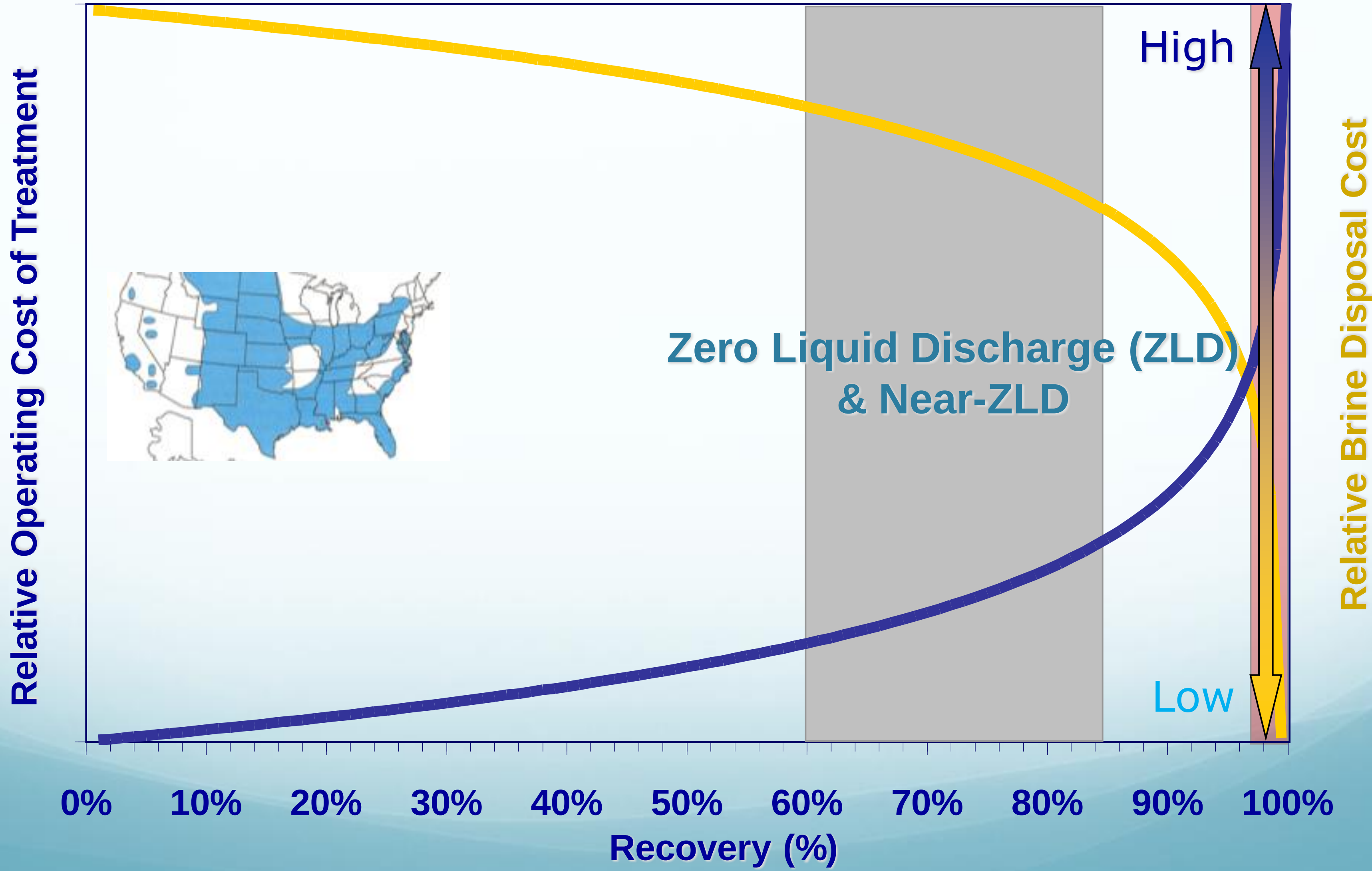

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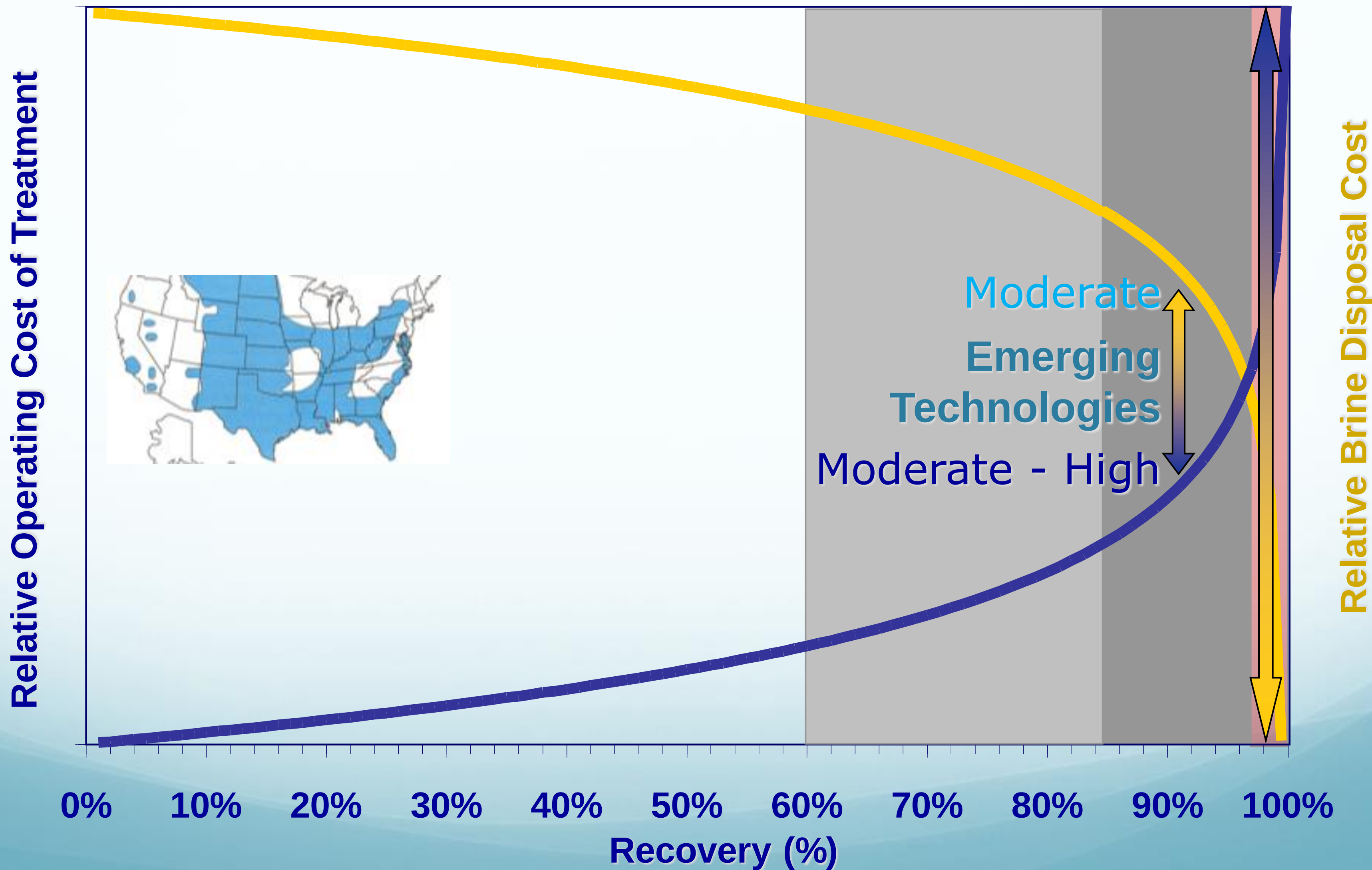


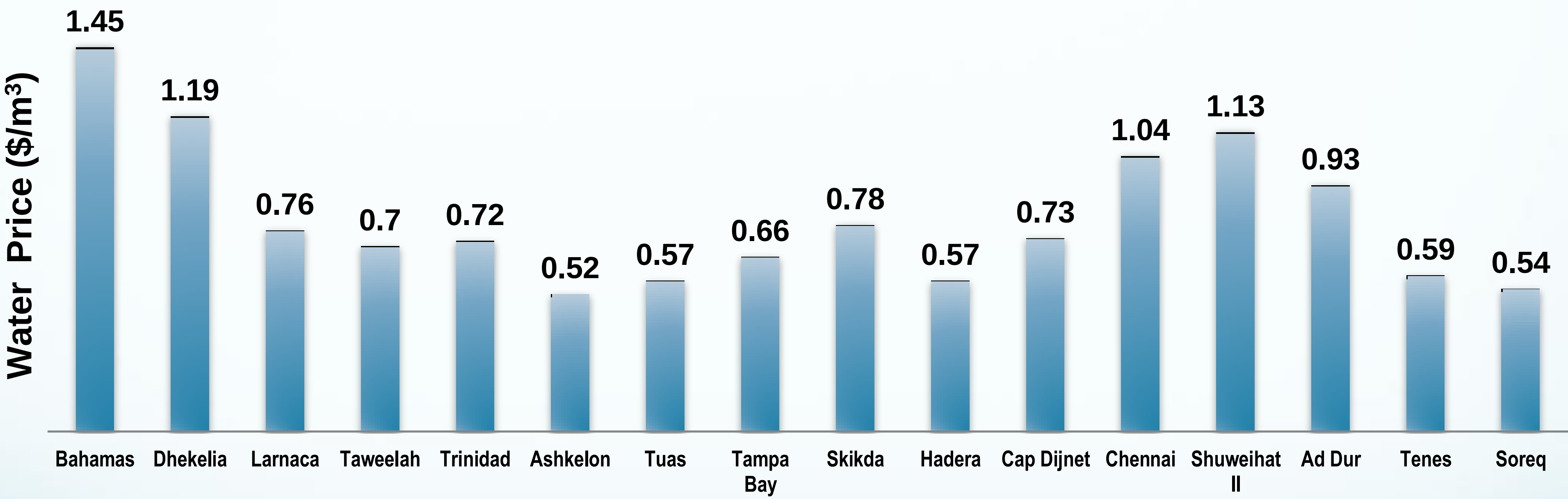
Relative Desalination Costs

Process	Capital Cost $/GPD	O&M Cost $/kgal	Water Cost $/kgal ($/m^3)
Nanofiltration	1.00 – 1.30	0.40 – 0.70	0.60 – 1.00 (0.16 – 0.26)
Brackish water Reverse Osmosis	1.20 – 2.50	0.80 – 1.50	1.50 – 3.00 (0.40 – 0.80)
Seawater Reverse Osmosis	3.50 – 5.00	2.00 – 4.00	2.50 – 7.00 (0.66 – 1.85)

GPD – gallon/day
kgal – 1,000 gallon

Courtesy of Tom Pankratz, tp@globalwaterintel.com

Seawater Reverse Osmosis Desalination Plants



Cost difference:

- Energy cost
- Concentrate management
- Project cost (engineering, permitting, etc.)
- Tax credits and other financial costs/incentives
- Size

Adapted from: Global Water Intelligence (2010)

Pre-treatment

Removal of:

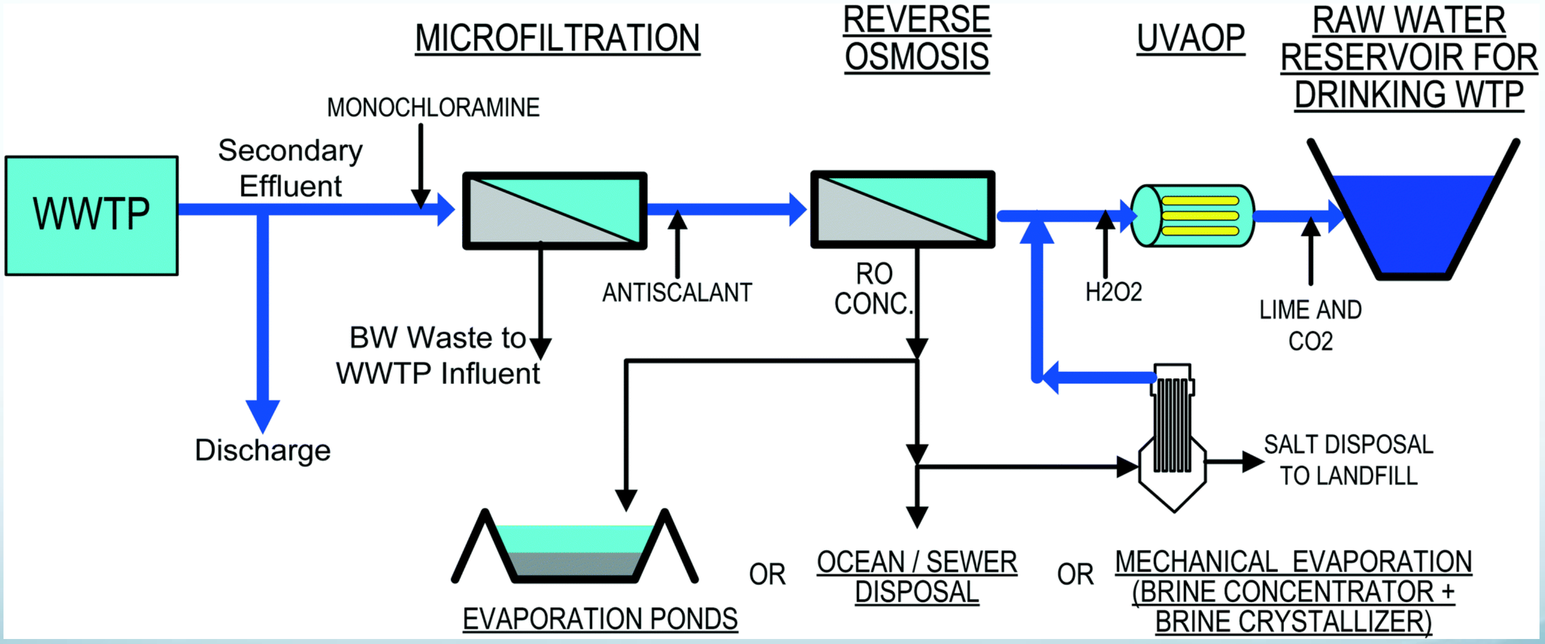
Suspended solids or emulsions

Microorganisms

Organic matter

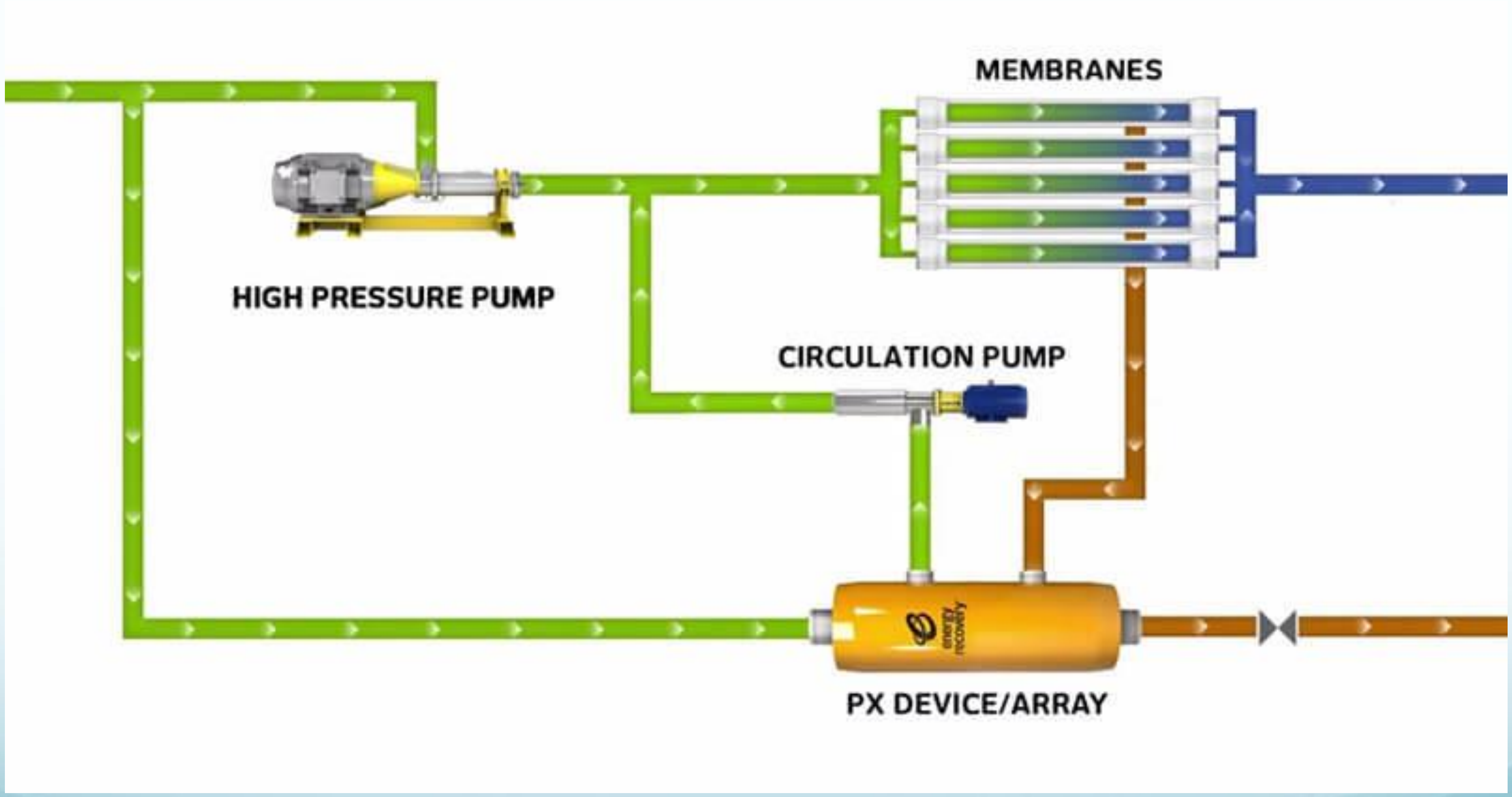
Specific ions (iron, calcium, magnesium, silica, etc.)

Pre-treatment and Desalination for Potable Reuse

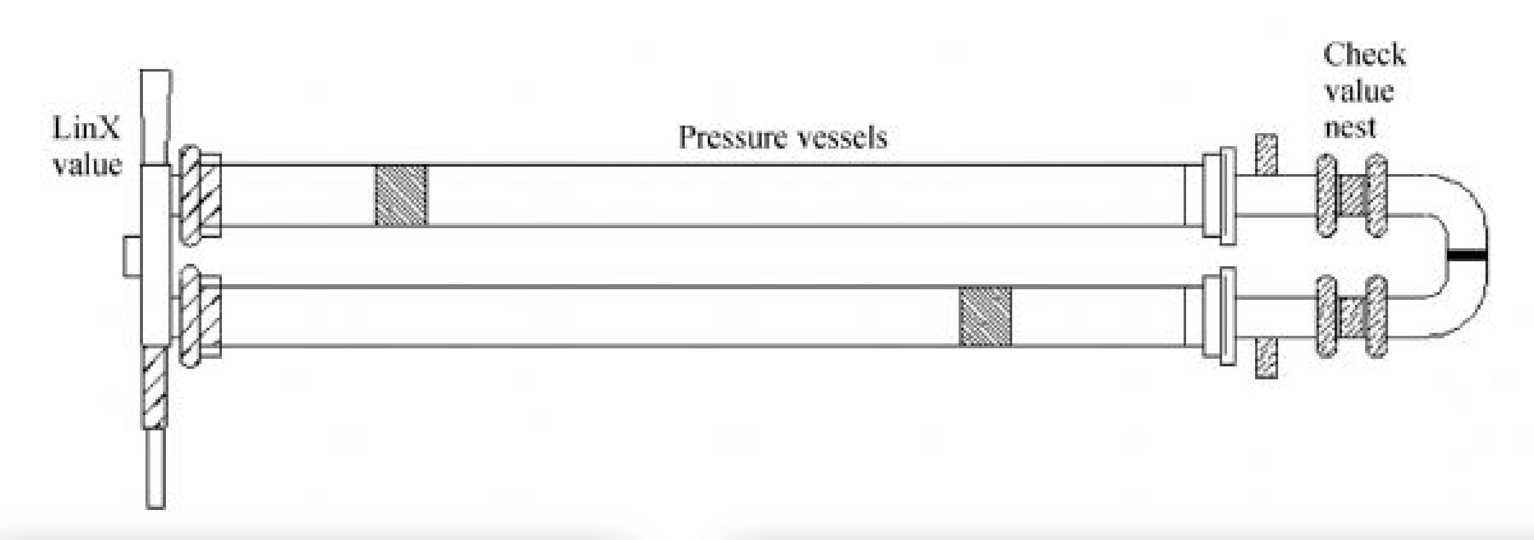


Energy Recovery

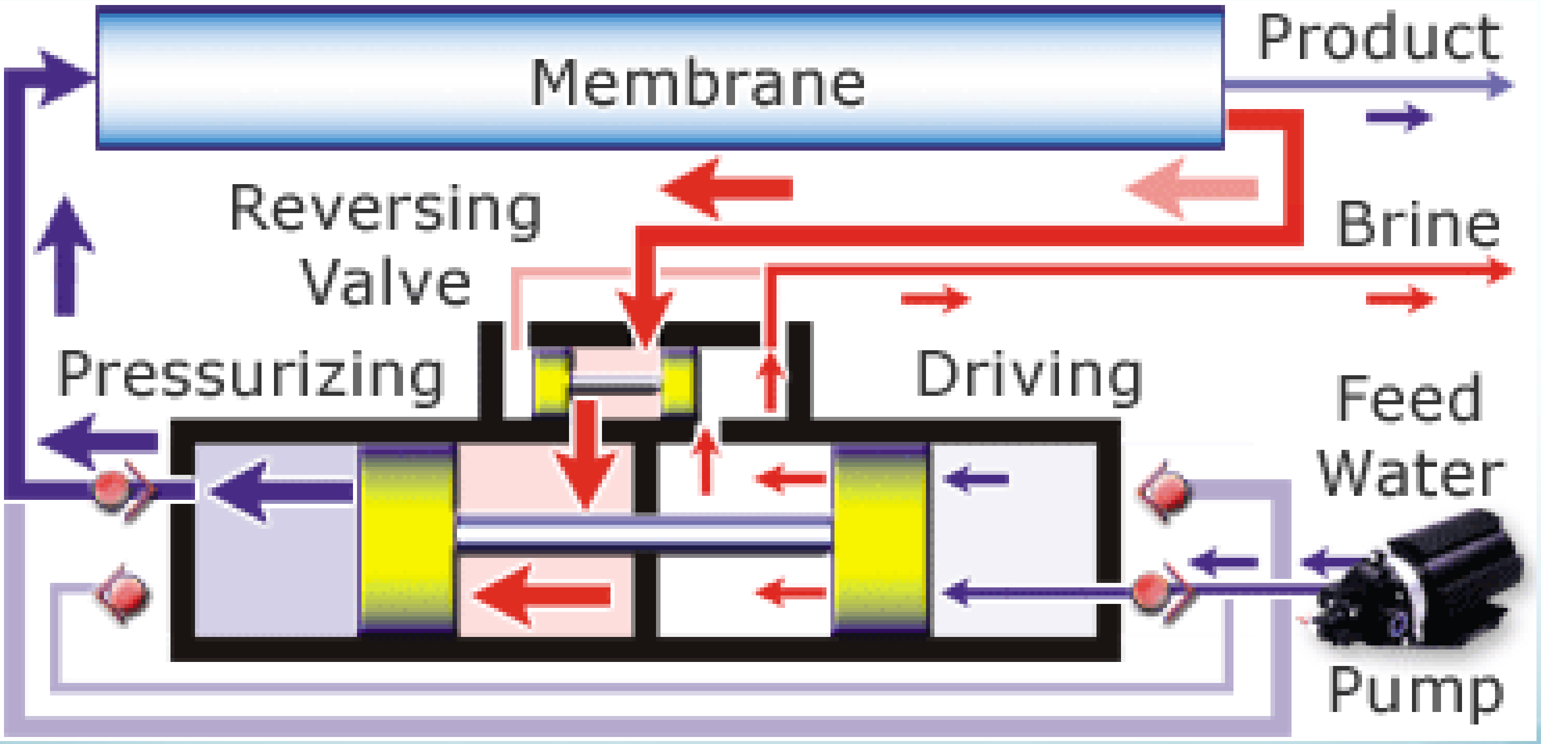
Pressure Exchangers ERI (Energy Recovery Inc.)



Pressure Exchangers
DWEER (Dual Work Exchange Energy Recovery)



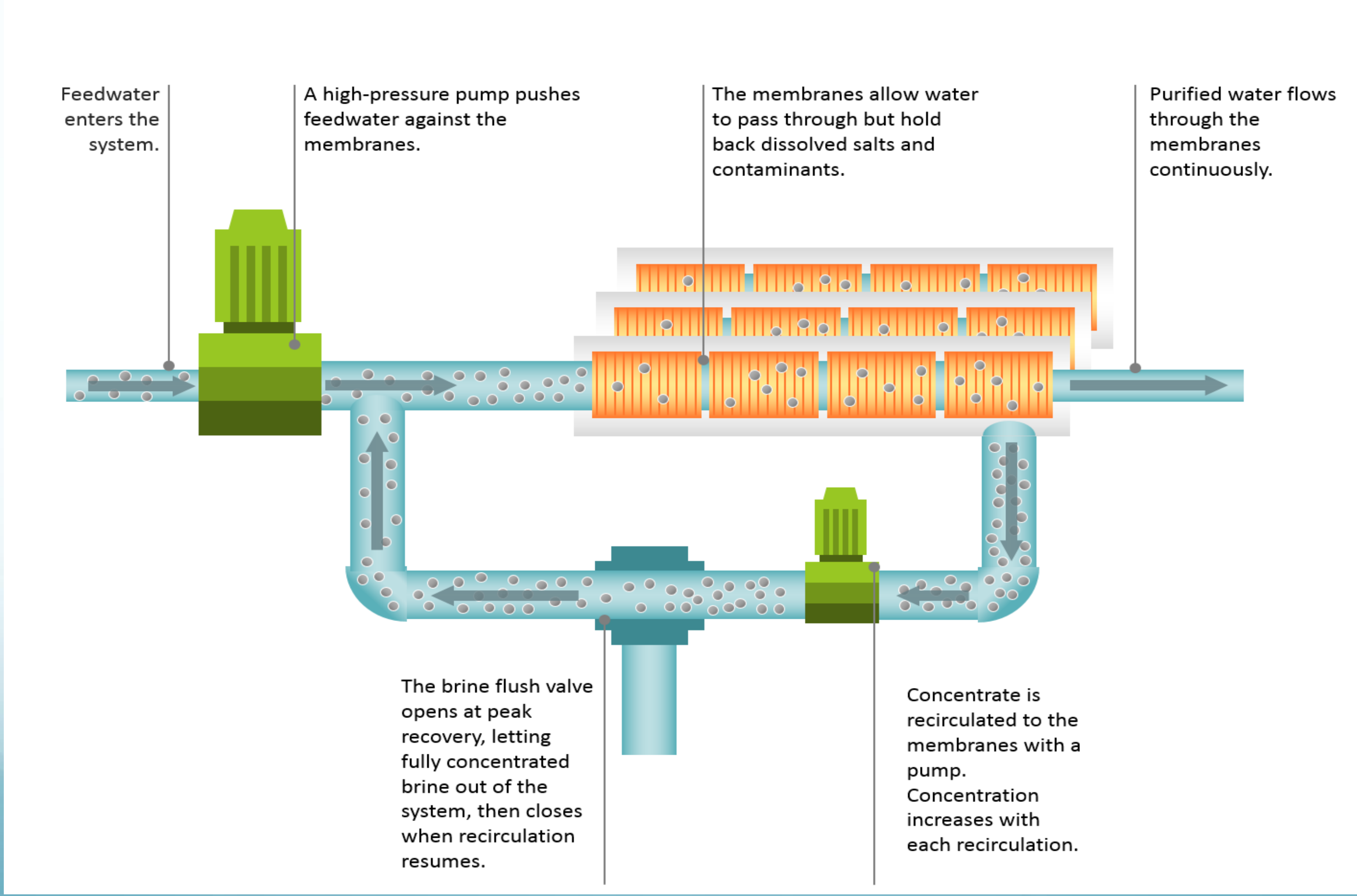
Clark Pump



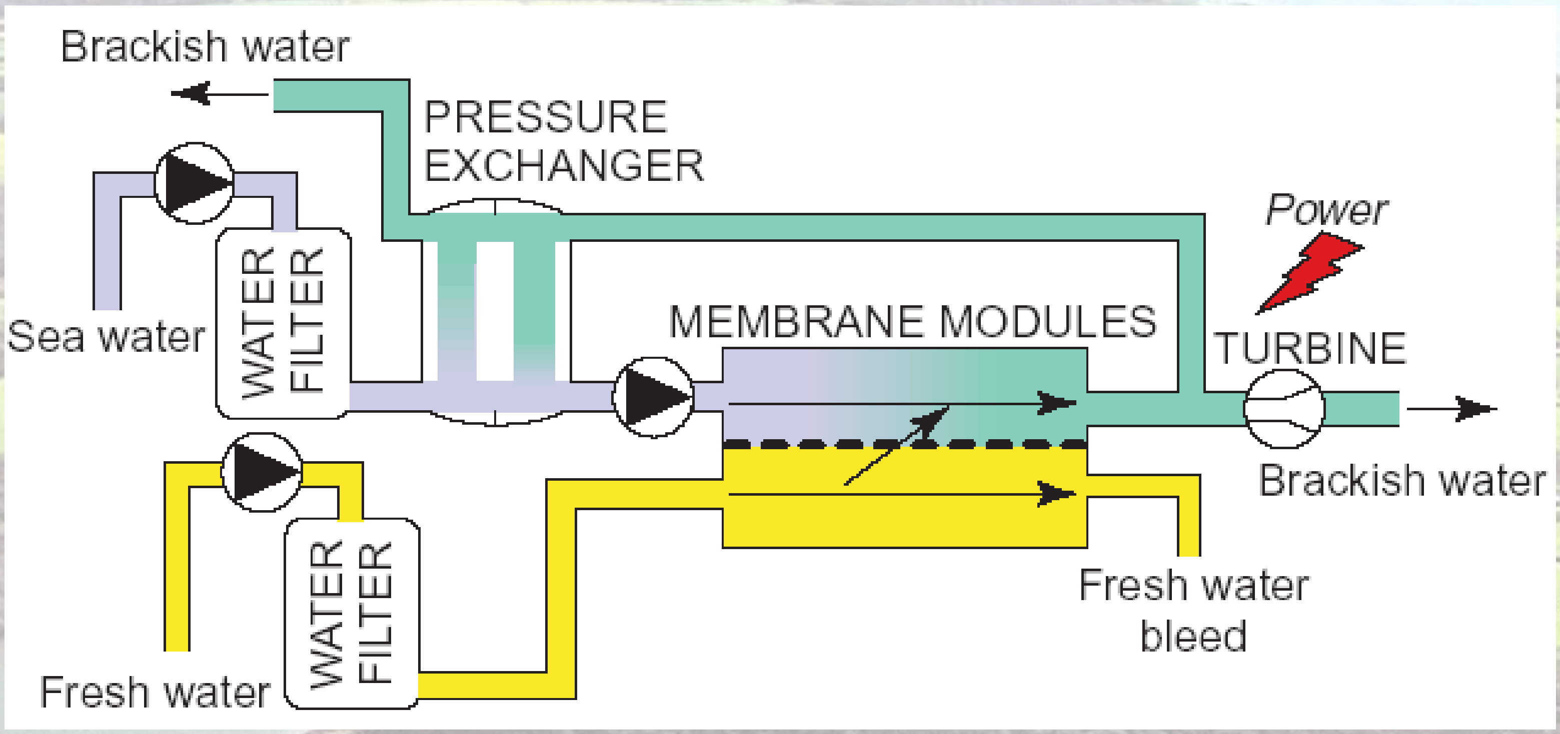
Membrane
Product
Reversing
Valve
Brine
Pressurizing
Driving
Feed
Water
Pump

Desalitech CCD

(Closed Circuit Desalination)



Osmotic Power Energy Recovery: Pressure Retarded Osmosis



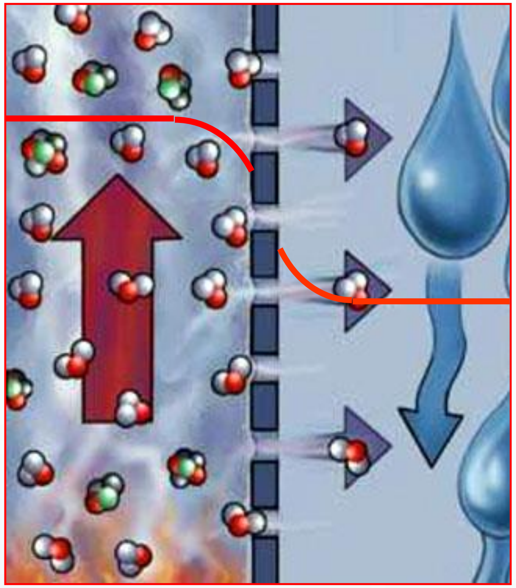
From: R. J. Aaberg, Osmotic power - A new and powerful renewable energy source, ReFocus, 4 (2003) 48-50

Concentrate Management

- Coastal
  - Ocean outfall
- Inland
  - Surface discharge (bad!)
  - Sewer disposal (not good!)
  - Deep well injection
  - Land application/dust control
  - Zero liquid discharge (ZLD) (crystallization, expensive…)
  - Pipeline to ocean (not common)

Future Technologies (?)

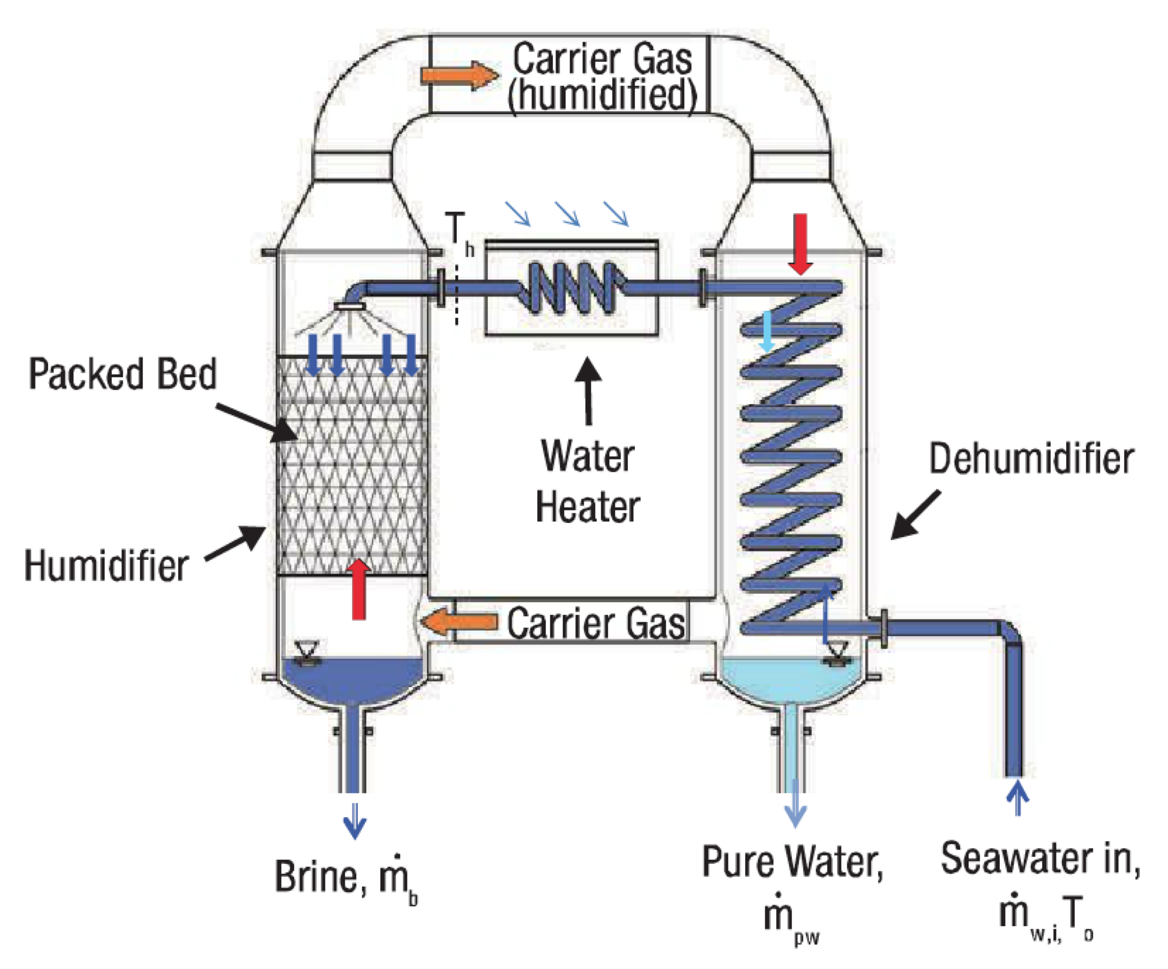
Other Desalination Technologies: Membrane Distillation



adapted from: http://www.water-technology.net/

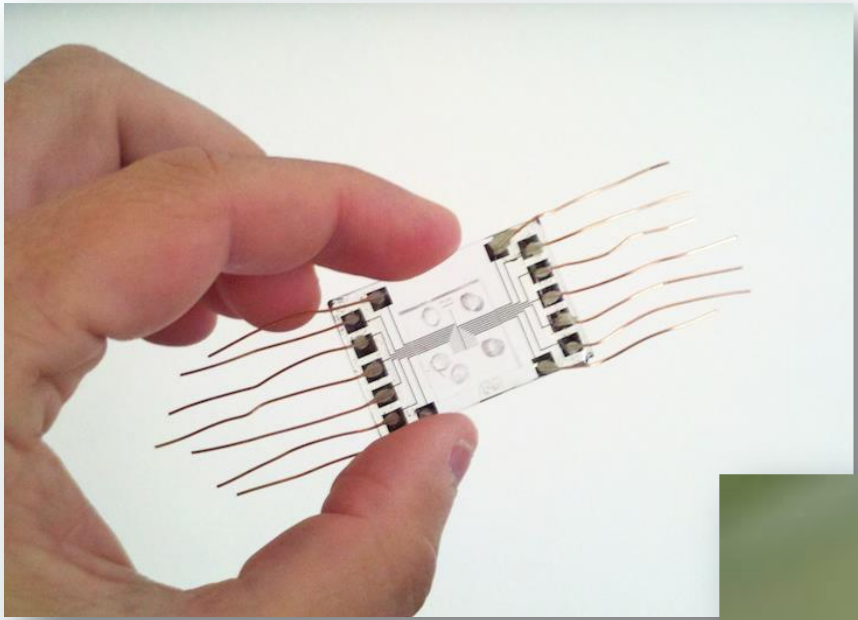
- Heated aqueous feed solution is brought into contact with the feed side of a hydrophobic, microporous membrane
- Colder water or gas is in contact with the distillate side of the membrane
- Vapors diffuse through the pores and condense in the colder stream

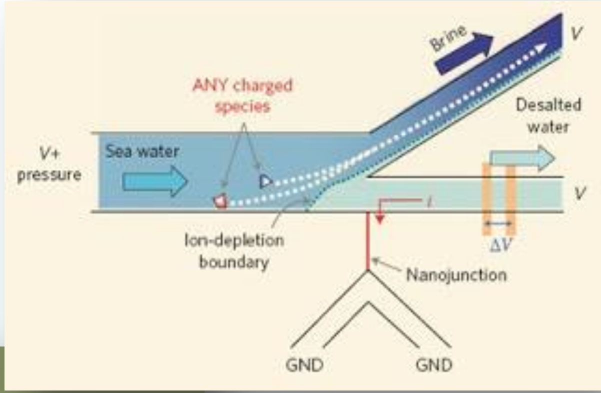
Other Desalination Technologies: Humidification-Dehumidification



Courtesy of Tom Pankratz, tp@globalwaterintel.com

Other Desalination Technologies: "water chip"





In summary…

- Desalination is used for salt removal, but also for purification of water and removal of other contaminants
- Development of new membranes focuses on increasing water flux, increasing solute rejection, and increasing chemical resistance of membranes
- Reverse osmosis is a core process to enable potable water reuse
- Desalination (especially reverse osmosis) is affordable and provides a reliable source of potable water; and efficient energy recovery makes it possible
- Brine management is a prevailing problem, especially at inland installations, and it drives development of high-recovery desalination (ZLD)

Thank you

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