2nd Annual WIN Workshop, BGNDRF

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Selective and Anti-fouling Ion-Exchange Membranes for Water Reuse and Desalination

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NM STATE

EnLiTe

Environmental Lab of Innovative Technologies

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- BGNDRF
- Charlie He (Carollo Engineers)
- El Paso Water
- City of Scottsdale
- SUEZ Water Technologies & Solutions

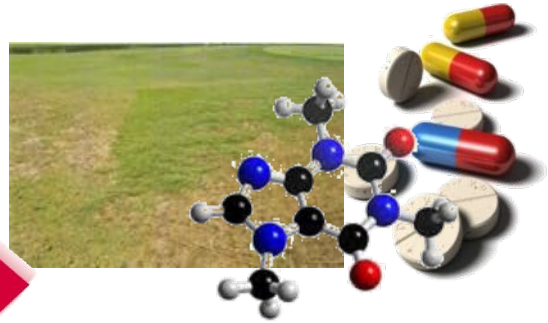
Development of Alternative Water Supplies is Crucial for Water Security

Water Conservation

Elevated Salinity
High sodium adsorption ratio

Water Scarcity

Water Reuse



Contaminants of emerging concerns

Desalination

Concentrate

High Sodium to Hardness Ratio Resulted in Reuse Challenges

- SAR = Sodium Adsorption Ratio

$$SAR = [Na^{+}] / \{([Ca^{2+}] + [Mg^{2+}]) / 2\}^{1/2}$$ (use meql units)

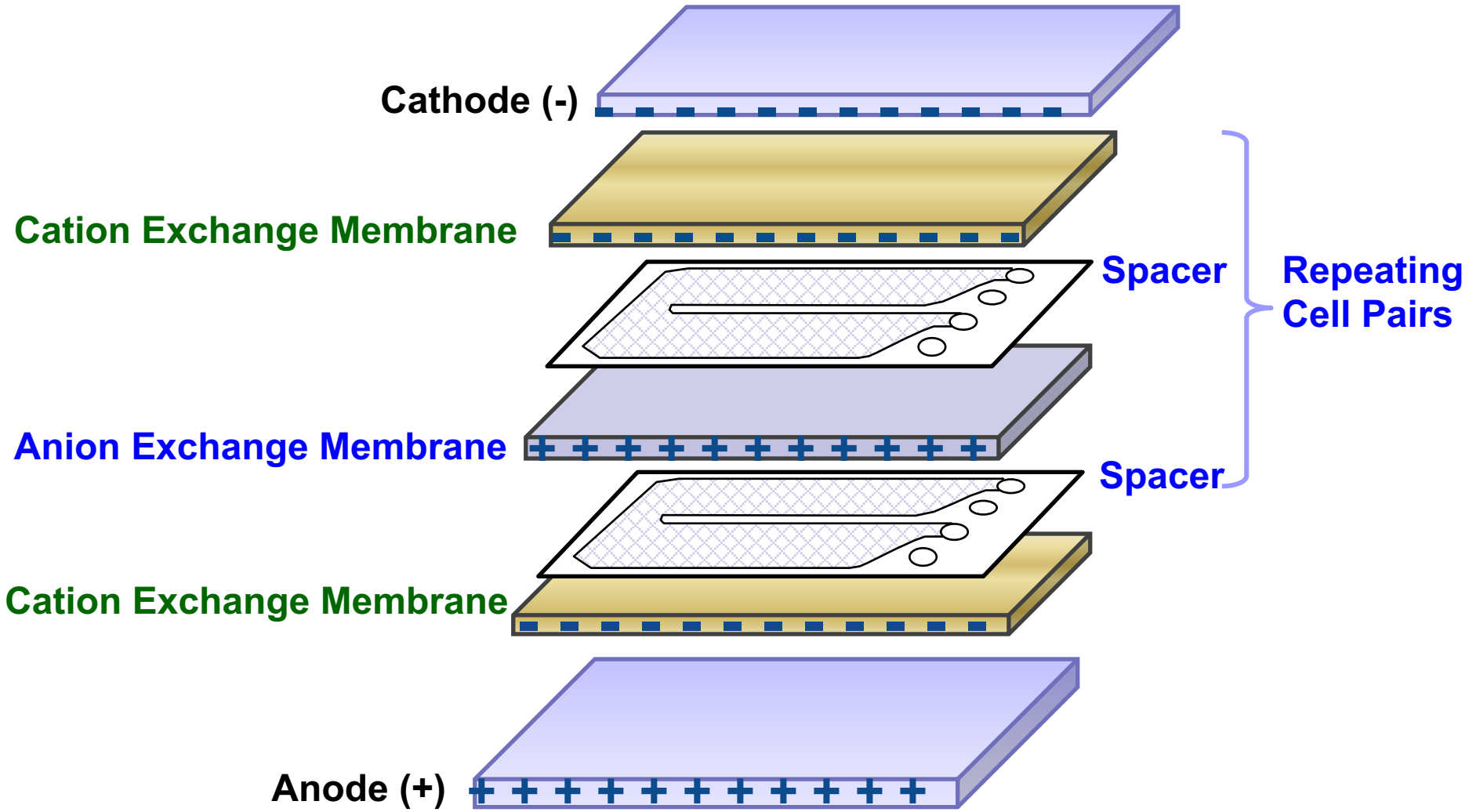
≤3	6 to 9	> 9

85%

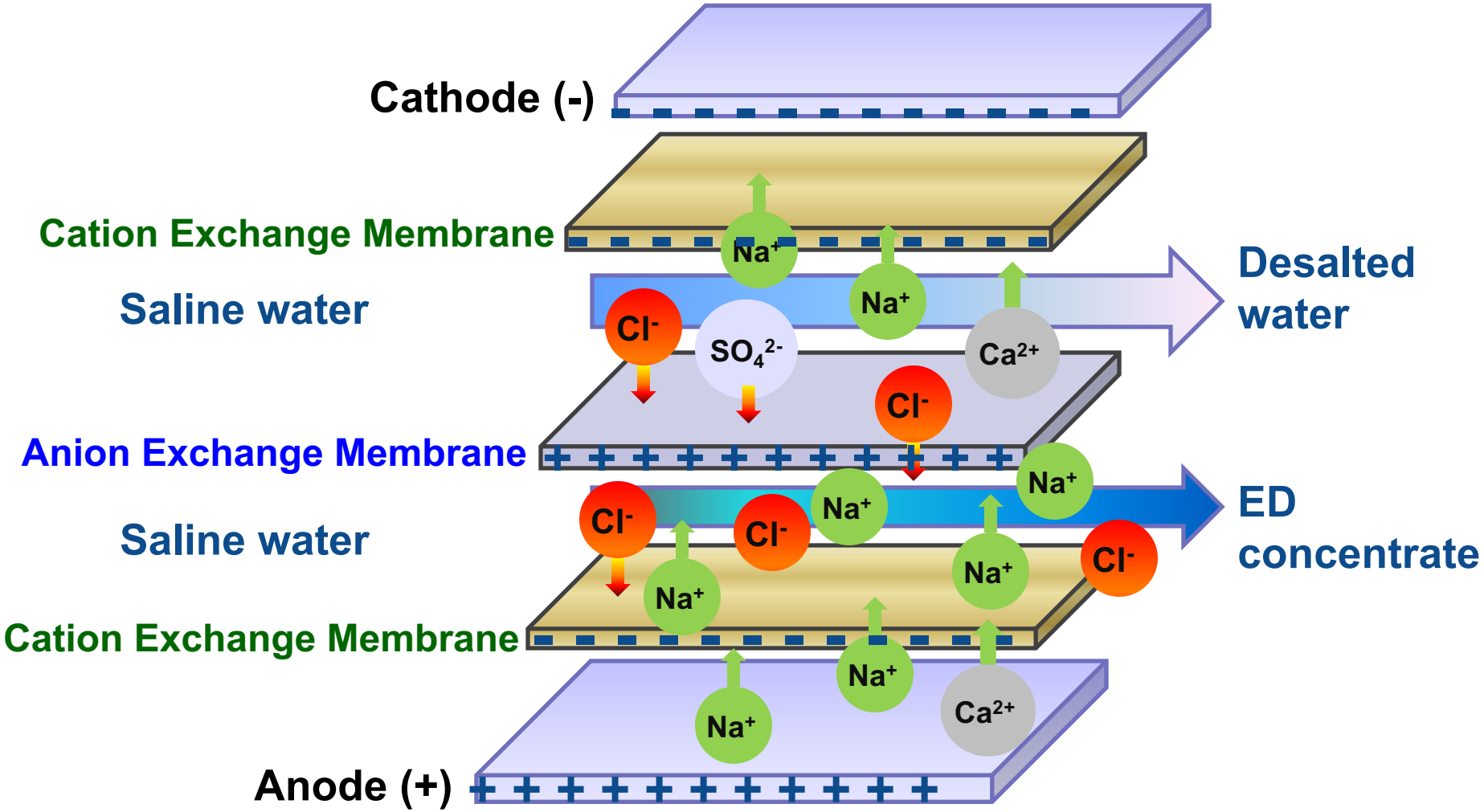
15%

Concentrate

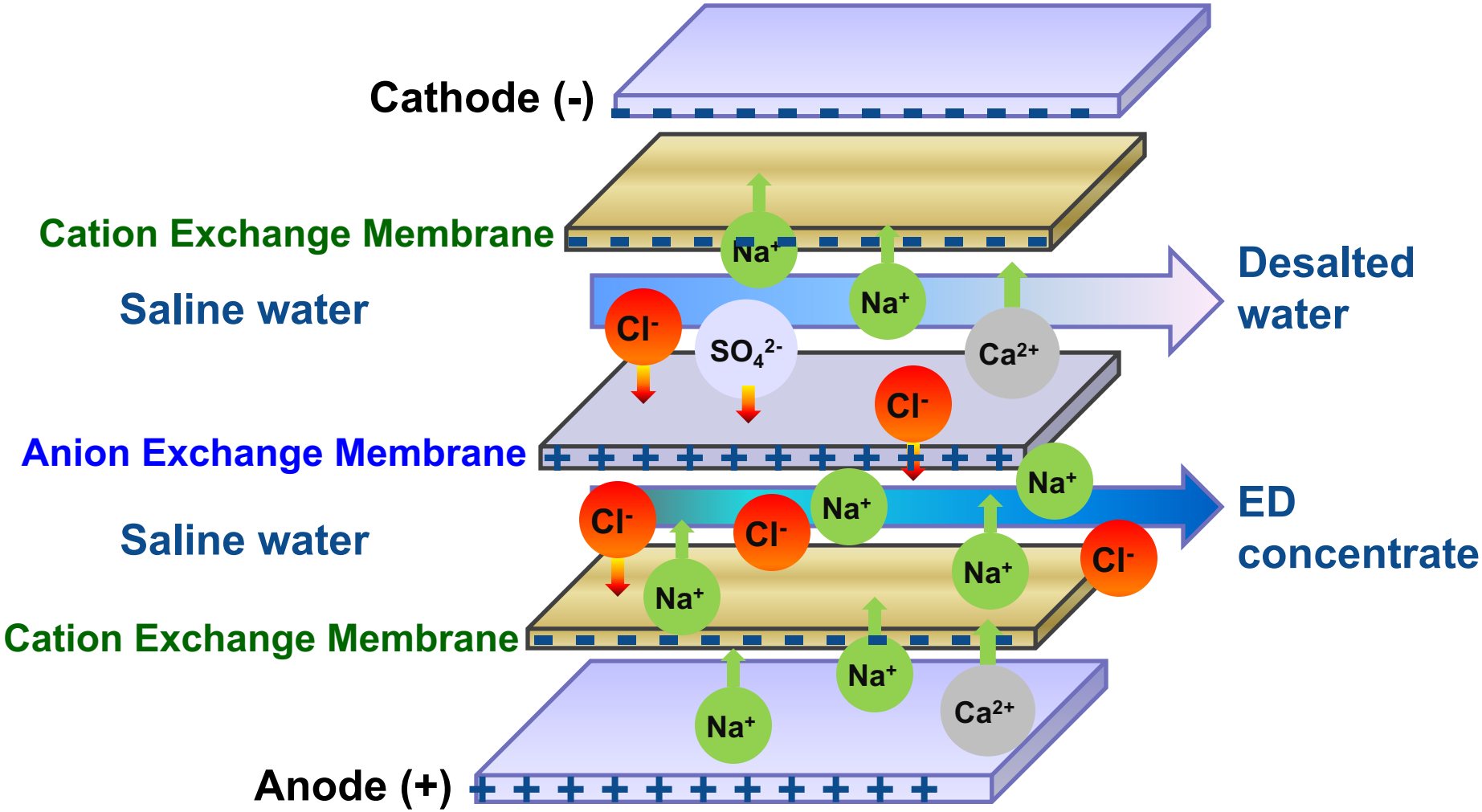
Electrodialysis (ED) Consists of Electrodes and A Stack of Membrane Cell Pairs



Electrodialysis (ED) with Normal Grade IX Membranes Removes Cations and Anions

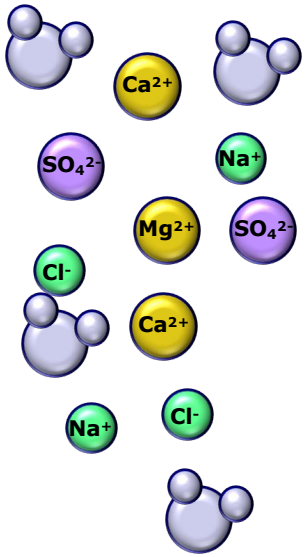


Electrodialysis with Selective IX Membranes Remove Preferentially Monovalent Ions



Selective Electrodialysis for ZLD of Reclaimed Water

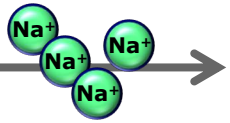
Salty Reclaimed Water



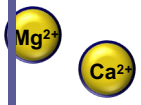
Selective ED

Na_2SO_4
NaCl

Reclaimed water with low hardness, higher salinity



$CaSO_4$
$MgCl_2$
$CaCl_2$



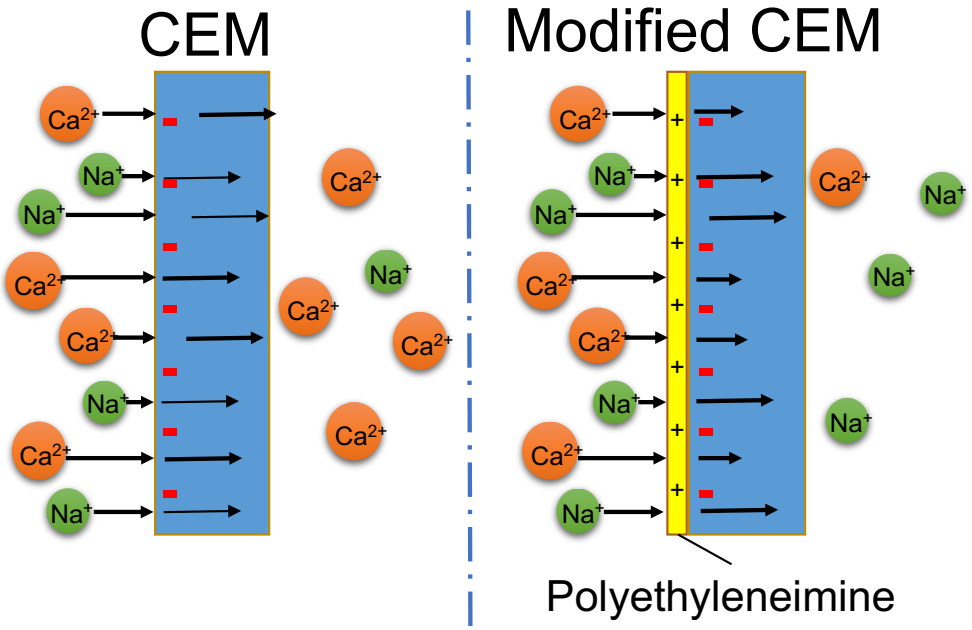
Reclaimed water with low sodium, lower salinity

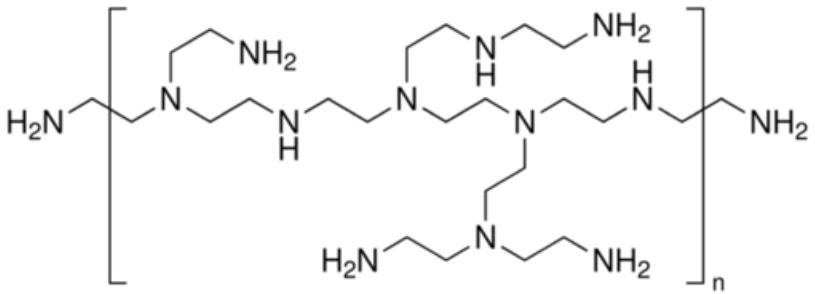
Cooling Water

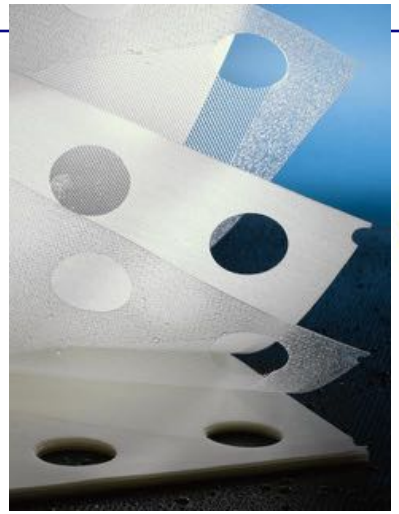
Wetland

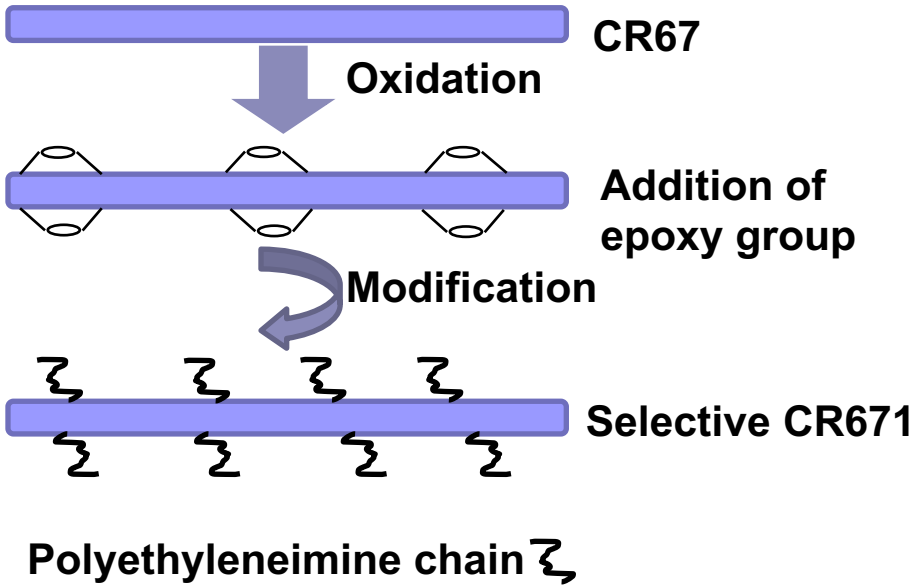
Irrigation

Modified Selective Membranes

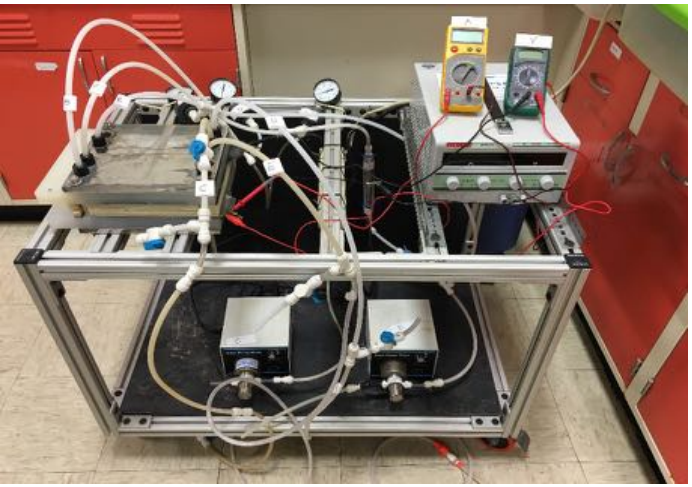


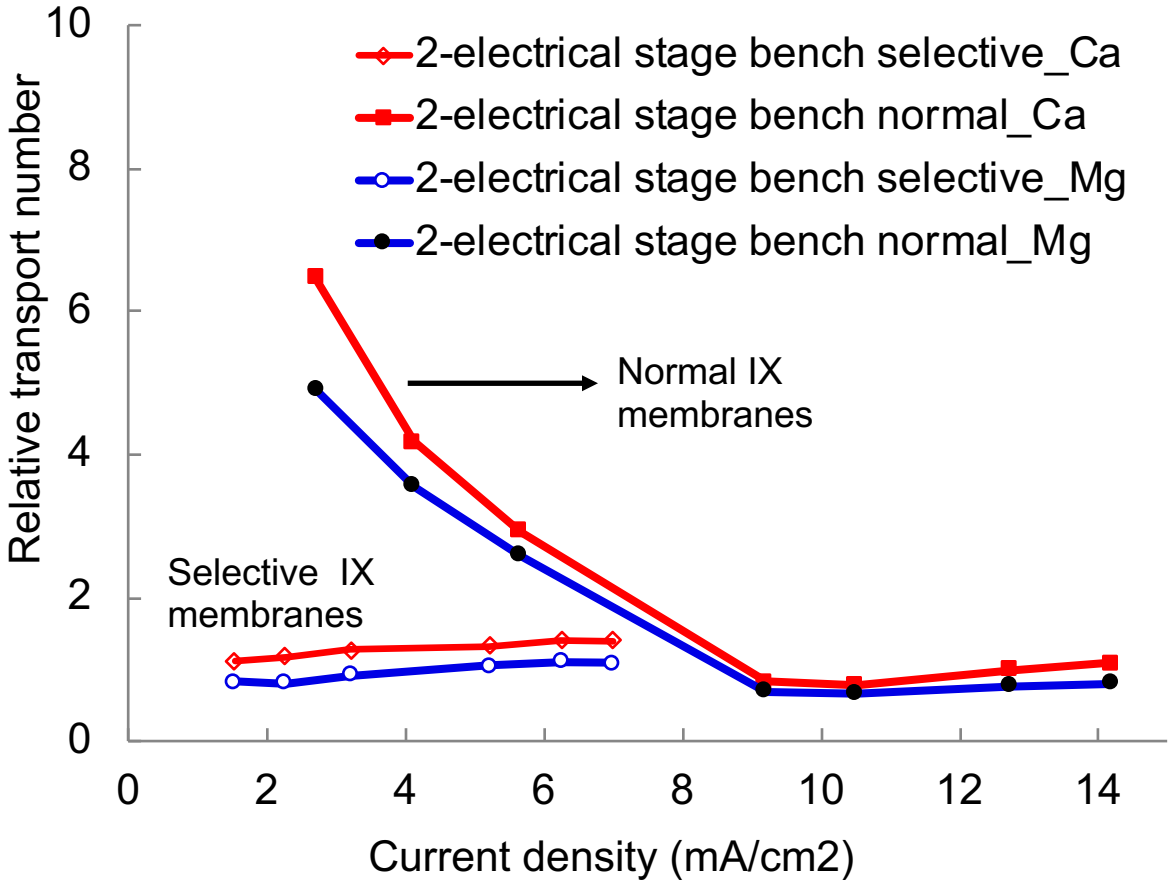






Bench-Scale Testing Results

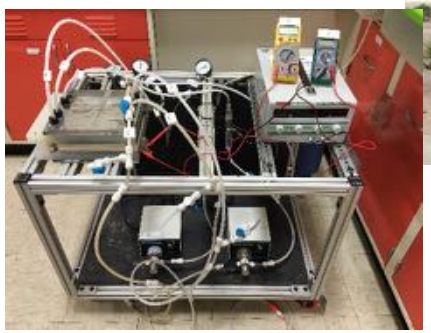




Xu et al, Desalination 2018

Field Testing at Three Sites

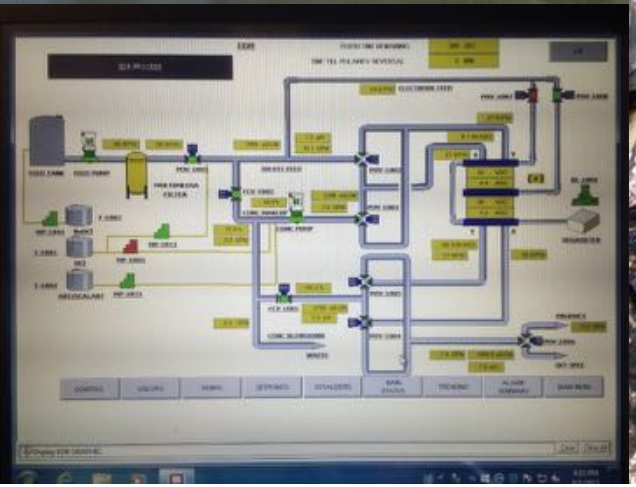
Scottsdale Water Campus



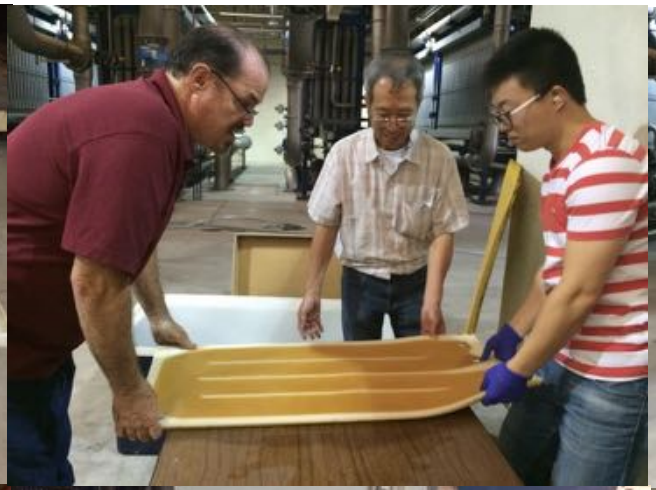
BGNDRF

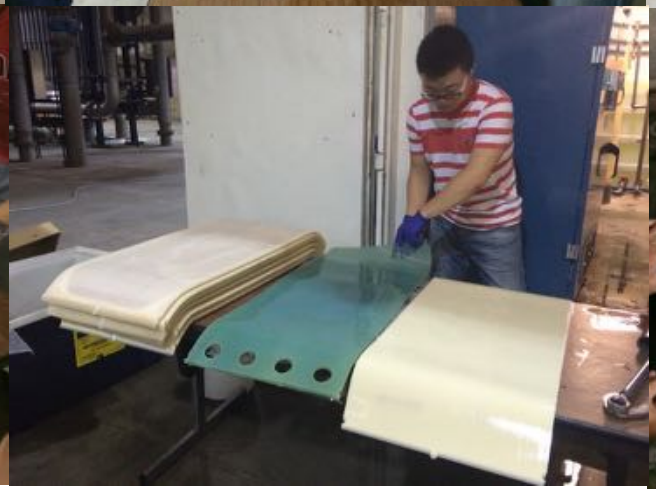
El Paso KBH Desalination Plant

Pilot Site Development

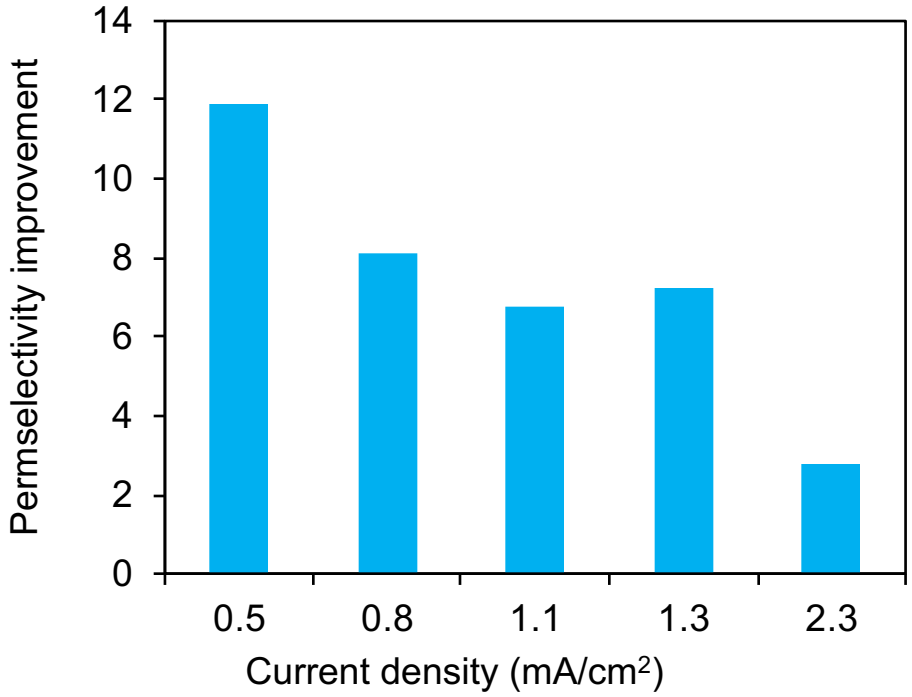


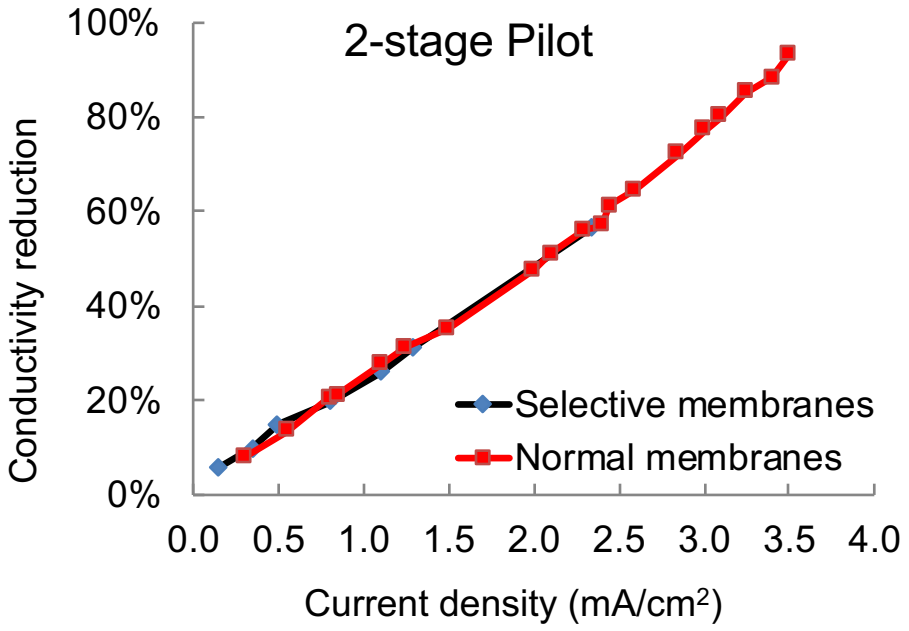
Selective Membrane Coating

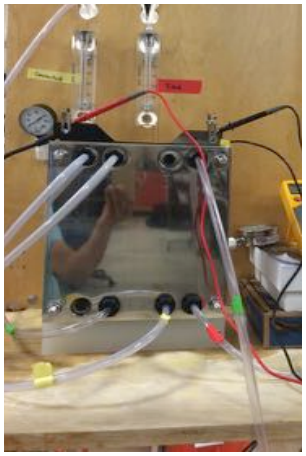

Selective Membranes Demonstrate Better Selectivity of Monovalent Cations over Divalent than Normal Membrane





Xu et al, Separation & Purification Tech 2018

Modeling and Full Scale Design



Bench Testing

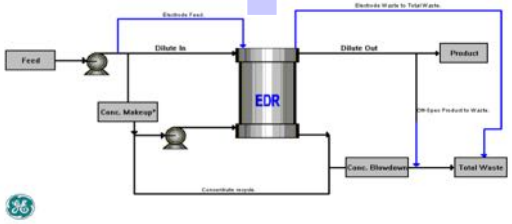
Pilot Testing

Minitab 17

Data Fitting and Mathematical Modeling

BLUE PLAN-IT™
DECISION SUPPORT SYSTEM

Water and Salt Balance, Process Modeling
Cost Analysis



WATSYS: Specialty EDR Projection Model by GE
(Normal Grade Membrane Only)

Full Scale Design

Scottsdale Blending Analysis and Cost Comparison – 1 MGD Reclaimed Water (4-stage)

	Baseline Alternative	Alternative 1A	Alternative 1	Alternative 2
	UF + RO	Normal EDR - WATSYS	Normal EDR - Testing	Selective EDR
Feed Water Flow (mgd)		1		
Feed Water Sodium (mg/L)		235		
Overall Recovery	**88%**	**93%**	**92%**	**94%**
Unit Recovery	**85%**	**90%**	**90%**	**90%**
Product Water Sodium (mg/L)		110		
Product TDS (mg/L)	530	522	433	634
Number of Stages	-	4	4	4
Capital ($/gpd product flow)	$6.1	$6.5	$7.6	$6.5
O&M ($/kgal)	**$1.09**	**$0.88**	**$0.83**	**$0.81**

Selective ED achieved higher water recovery and 26% cost reduction treating municipal reclaimed water

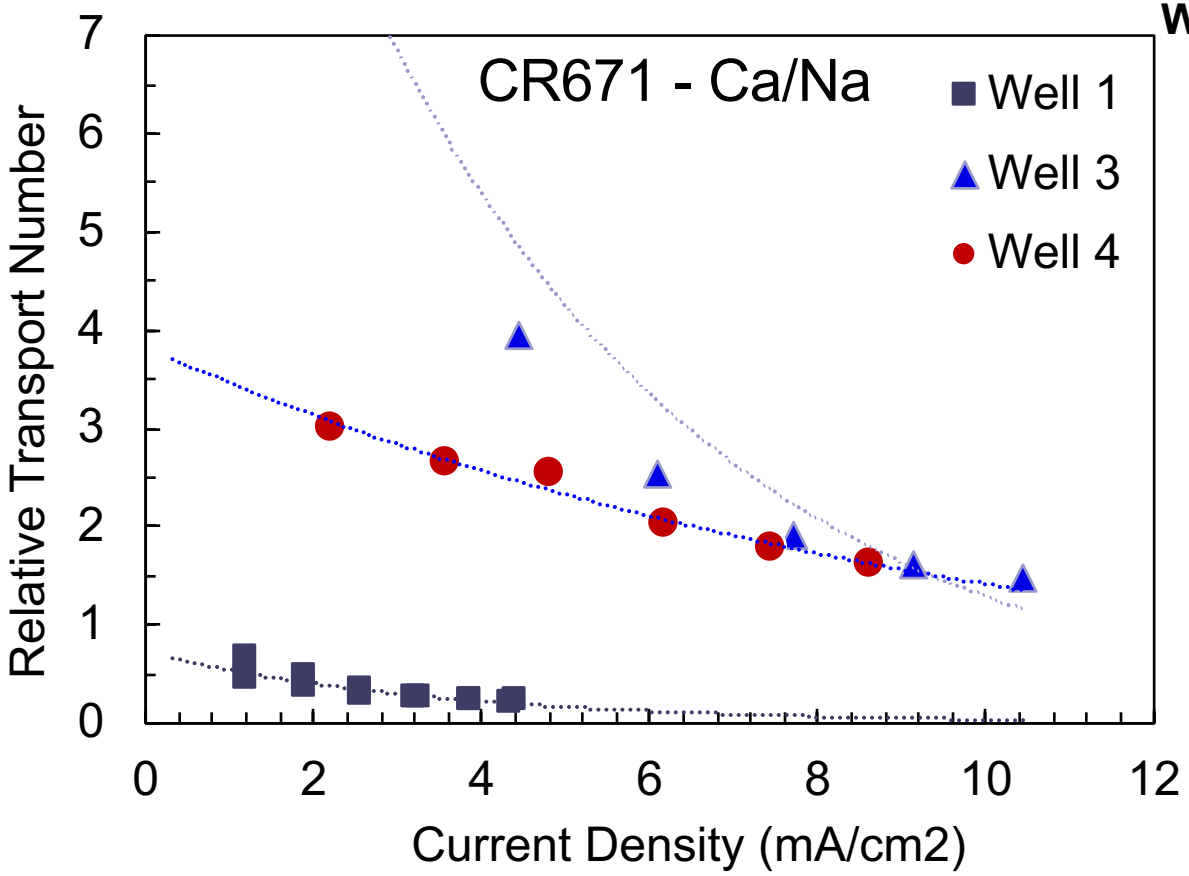
Selectivity Decreased with Increasing Salinity

BGNDRF Groundwater – Bench-scale

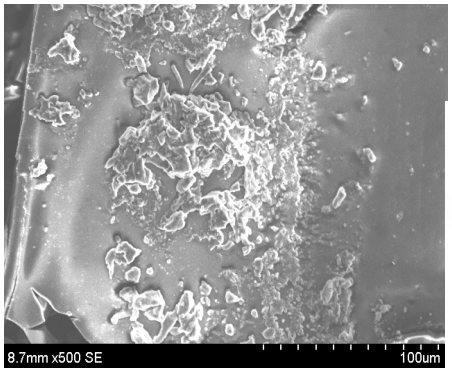
Well 1: TDS 1200 mg/L, SAR 11.5

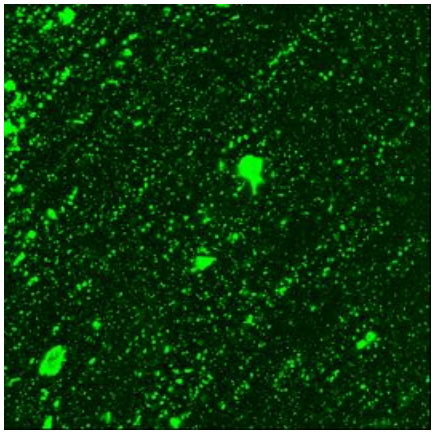
Well 3: TDS 3600 mg/L, SAR 4.7

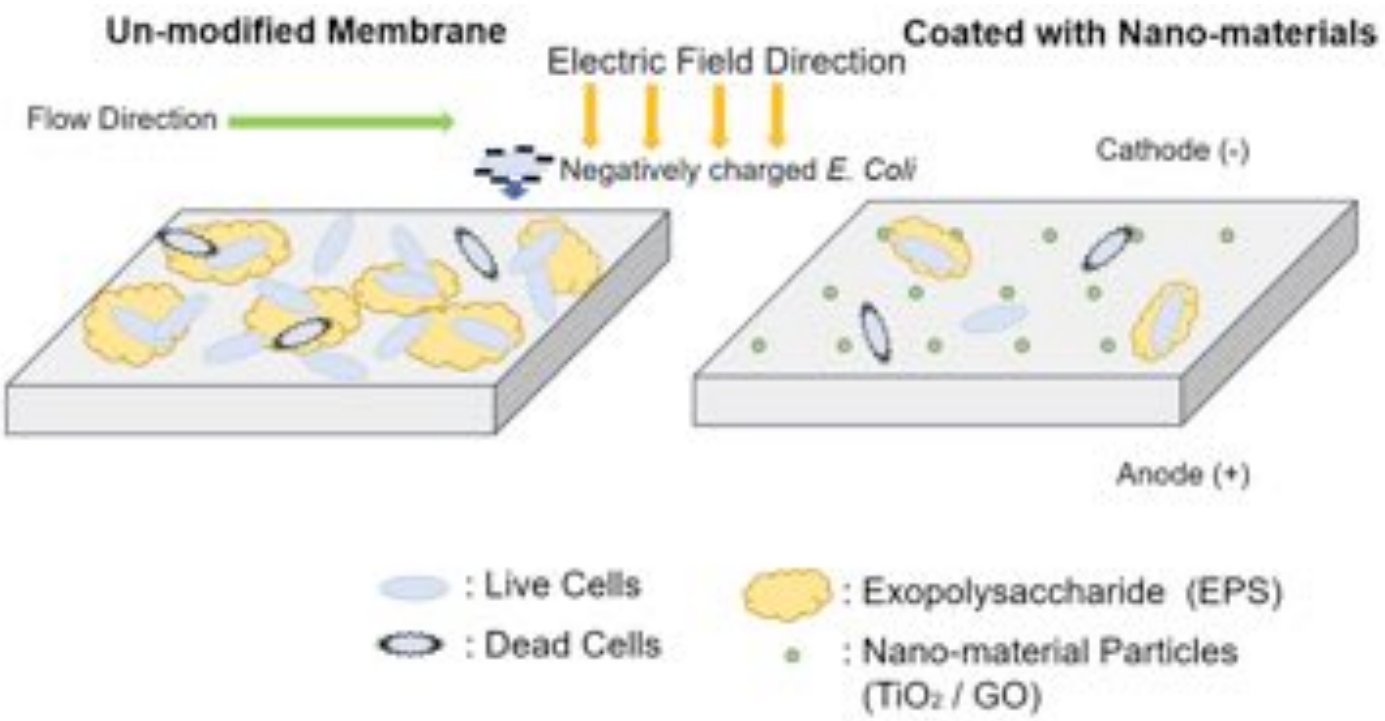
Well 4: TDS 4100 mg/L, SAR 4.7



Development of Antifouling Ion-exchange Membranes

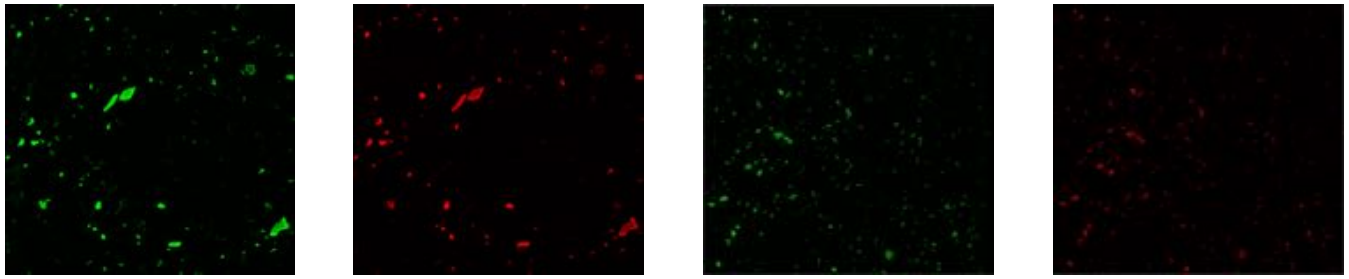






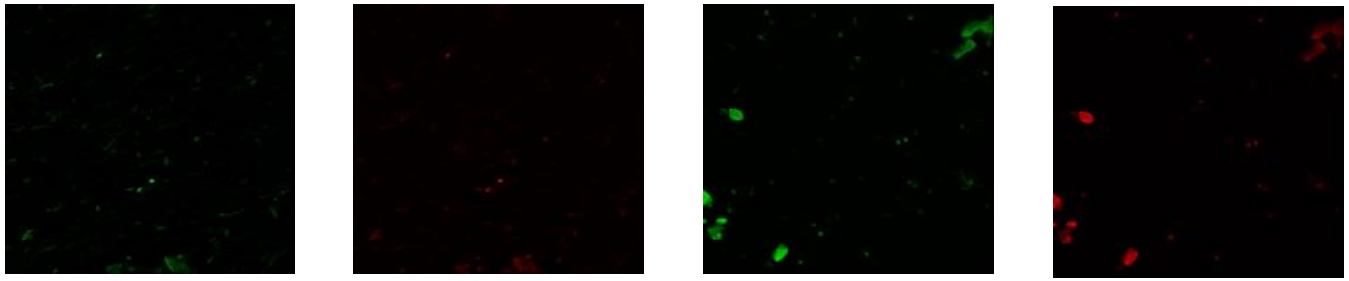
Development of Antifouling Ion-exchange Membranes

- Compilation of brightest pixels for all spots



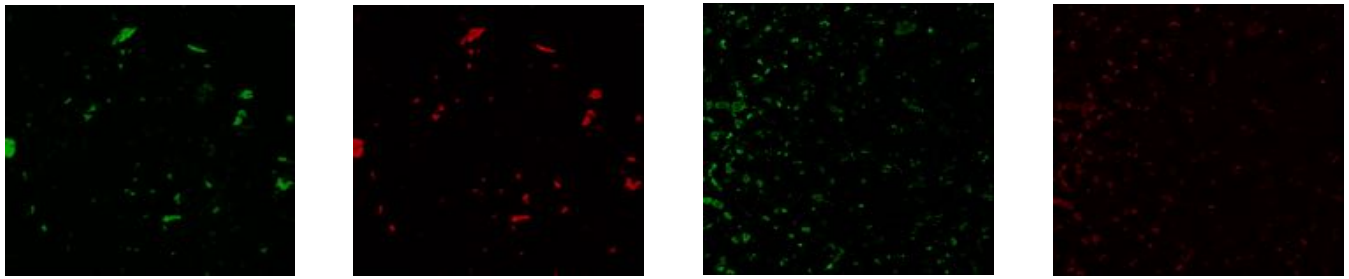
Raw CR671

CR671 w/ PEI



CR671 w/ PEI + 3% TiO2

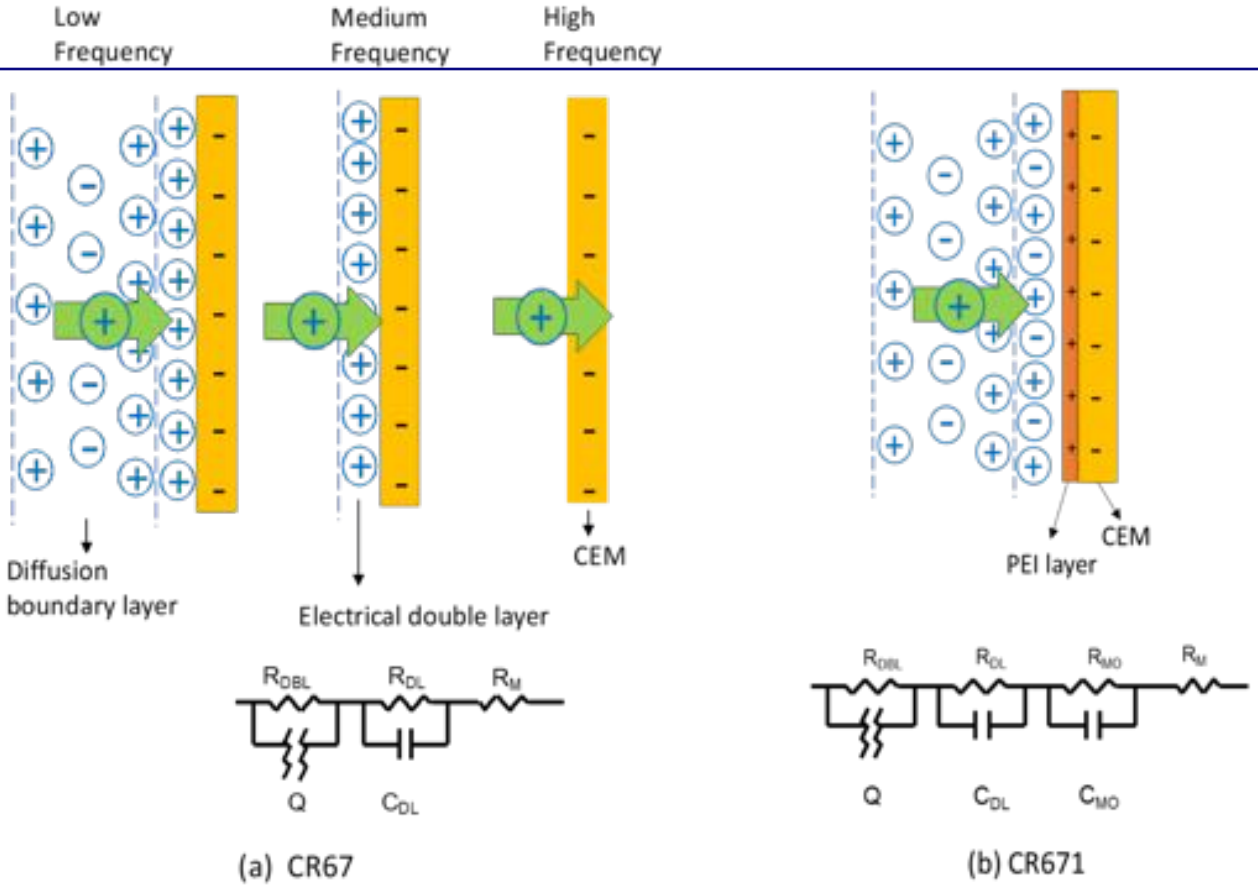
CR671 w/ PEI + 5% TiO2



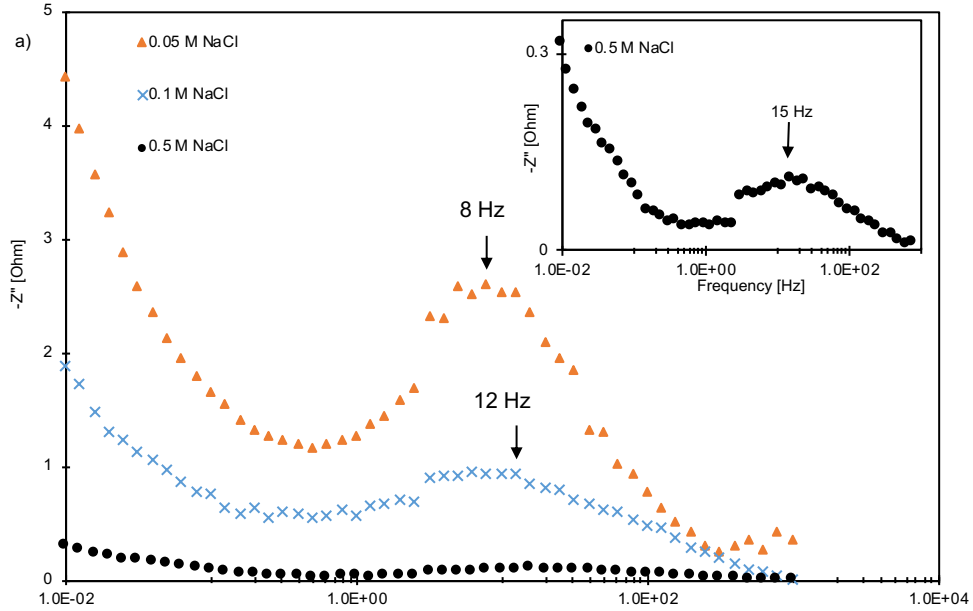
CR671 w/ PEI + 7.5% TiO2

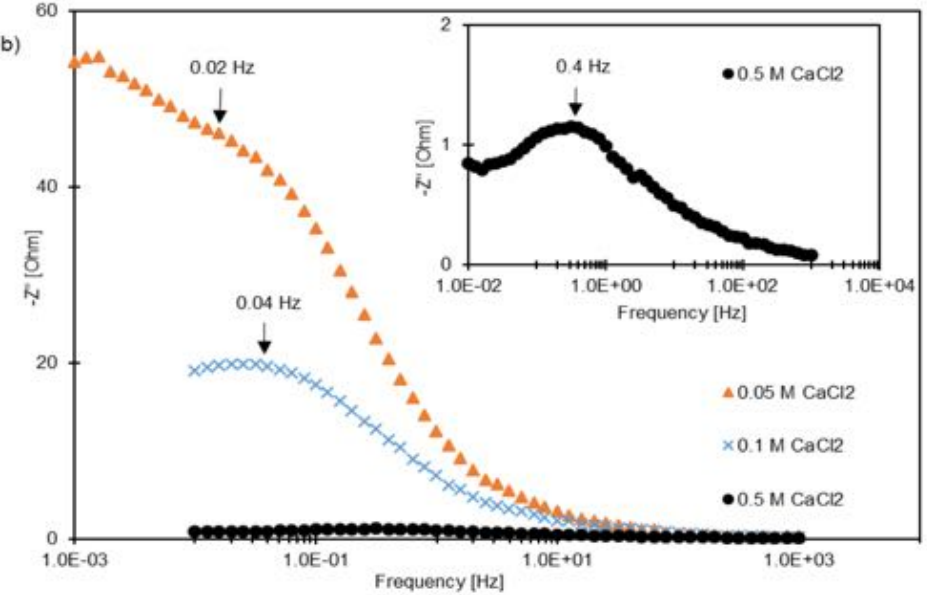
CR671 w/ PEI + 10% TiO2

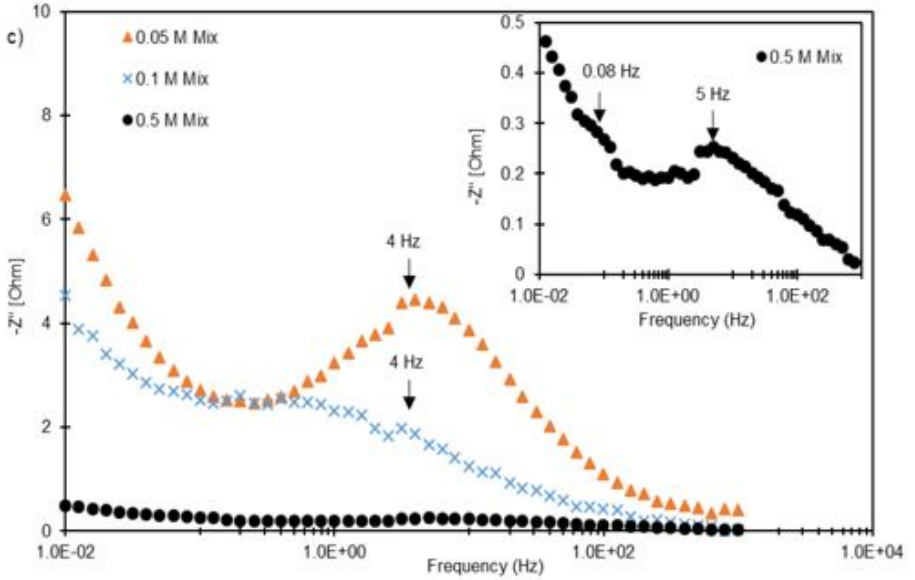
Electrochemical Characterization of Modified Ion-exchange Membranes



Electrical equivalent circuits and the schematic representation of the different transport layers for (a) the normal grade CR67 and (b) the modified CR671 with polyethyleneimine (PEI) coating. R_M, R_{DL}, R_{MO}, and R_{DBL} represent the resistances of the membrane, the electrical double layer, the modification and the diffusion boundary layer, respectively. C_{DL} and C_{MO} represents the capacitances of the electrical double layer and the modification. Q is the constant phase element from the diffusion boundary layer.







Bode plots for different ionic strengths solutions of CR671. (a) NaCl, (b) $CaCl_2$, (c) Mixed NaCl + $CaCl_2$ (Na^+/Ca^{2+}, 7.2:1).

Concluding Remarks

- Selective ED is more cost effective to treat municipal wastewater for irrigation than RO
- Monovalent permselectivity of selective membranes decreased with increasing feed salinity and current density
- Coating polymers and nanoparticles (TiO_2 and graphene oxides) can significantly reduce membrane biofouling increase monovalent permselectivity.

Thank you!

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