COMPARISON OF HIGH-WATER RECOVERY METHODS IN REVERSE OSMOSIS (RO) OF BRACKISH WATER USING RO MODELING SOFTWARE

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Background

With population increase and growing economies there is a higher demand for fresh water, but our supply is threatened by climate change, water waste, and pollution. With freshwater reserve depletion it causes a need for an alternative water source to sustain future generations. Therefore, scientists have been exploring methods such as desalination to meet the water demand. Desalination processes such as Reverse Osmosis (RO) use alternative water sources such as brackish water and sea water by removing salts and minerals from the water to make it potable.

Problem

Membranes

RO uses high pressure to force water through a semi-permeable membrane with small pores filtering salts, minerals, and organics to produce clean drinkable water. This subjects the membranes and spacers to fouling and scaling: the accumulation of foreign materials from feed water on the membrane surface and/or on the feed spacer causing operational problems.

Anti-Scalant/Foulant

This calls for a need of a chemical pre-treatment to change the feed characteristics of the water. Chemicals anti-scalants/foulants create an added cost, health risk, and environmental impact to the RO process.

Proposed Solution

An electromagnetic field (EMF) serves as an alternative non-chemical pre-treatment. The inducer produces an electric signal of ±150 kHz causing clusters to form, The clusters precipitate out of the solution which do not adhere to the membranes or spacers. The induction of the signal prevents scale and biofilm from accumulating on membranes and piping and gradually removes existing deposits. EMF can also address algae and bacteria by using the process of osmosis forcing water in the bacteria causing it to burst.

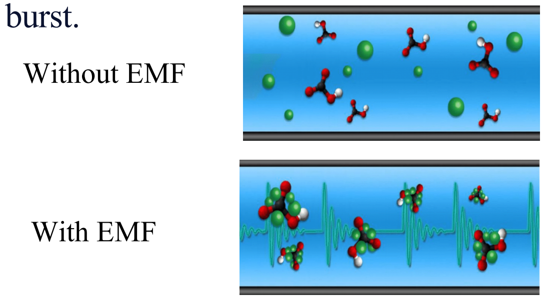

Figure 1. EMF comparison Source: Hydroflow-usa.com

Objectives

1. Compare energy consumption of chemical vs electromagnetic field (EMF) pre-treatment
2. Compare water recovery and cost of conventional RO to HRRO using RO software

RO Software System Design/Methods

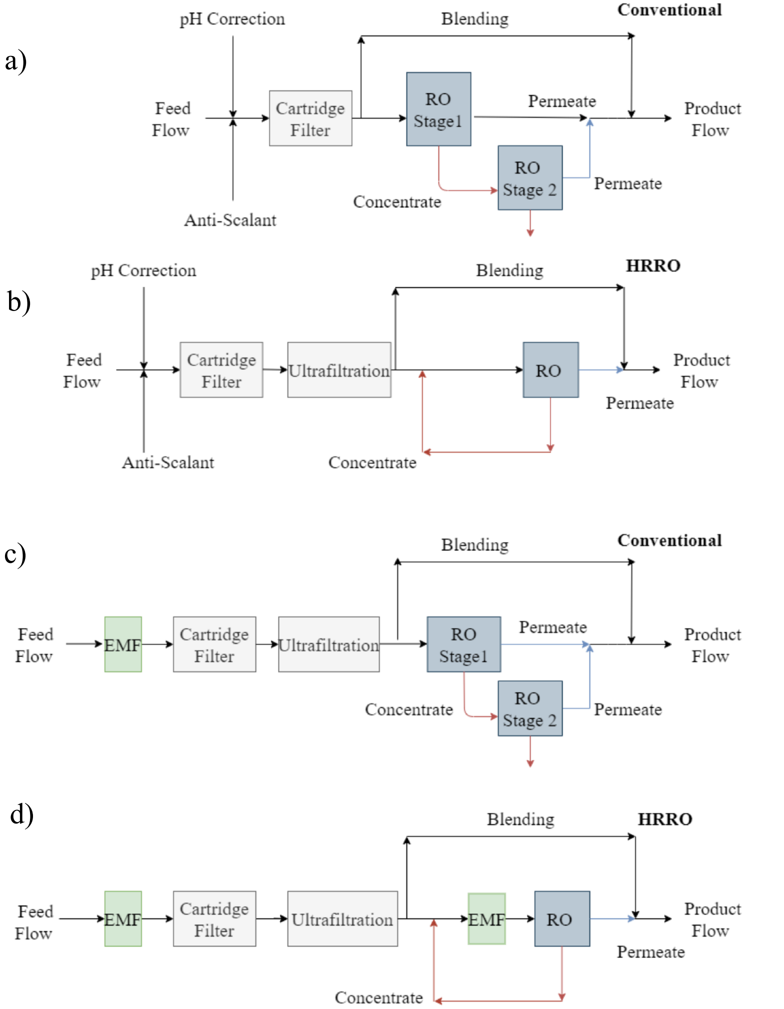

Figure 2. System design with chemical (a,b) and EMF (c,d) pre-treatment

These four systems compared energy consumption. RO Models were run on ROSA, Avista CI, and IMS Design for a baseline. Water constituent data was consistent across all software programs; acquired from the 2019 Bureau of Reclamation report analyzing the brackish ground water supply in Santa Teresa, New Mexico. All water parameters were collected from Camino Real Regional Utility Authority (CRRUA) Well 19 and a functional unit of 1 MGD of permeate was consistent across software. The system was then designed based off the capabilities of the software. The full energy consumption was then calculated based off of software values and literature values.

Table 1. Water constituent data

CRUUA Well 19		
Parameter	**Unit**	**Avg Value**
pH	pH Unit	7.65
Calcium	mg/L	72.95
Magnesium	mg/L	12.71
Sodium	mg/L	262
Potassium	mg/L	8.85
Arsenic	mg/L	0.0534
Chloride	mg/L	333
Nitrate	mg/L	6.98
Silica	mg/L	40.2
TDS	mg/L	~1200-1500
Boron	mg/L	0.469
Sulfate	mg/L	393

Results

Table 2. Comparison of the design of high recovery RO systems using software

High Recovery RO Software Comparison							
Software	ROSA		ROSA	IMS Design		Avista	
System	Conventional		HRRO	Conventional **		Conventional (RRO)	
Feed Flow (gpm)	1390		772.22	1275		952	
Stage	Stage 1	Stage 2	Stage 1	Stage 1	Stage 2	Stage 1	Stage 2
Feed TDS (mg/L)	1567		1613	1572		1425	
RO Water Recovery	81%		90%	90%		88%	
Overall Water Recovery	85%		92%	93%		*	
Membrane Type	XLE-440	XLE-440	BW30XFRLE-400/34	ESPA2-MAX	ESPA2-MAX	ESPA2-MAX	ESPA2-MAX
Membrane Area (ft^2)	440	440	400	440	440	440	440
Spacer Thickness (mil)	28	28	37	28	28	28	28
Elements x Pressure Ves	8 x 18	8 x 8	5 x 42	8 x 12	8 x 4	8 x 12	8 x 4
pH Adjustment	Require pH correction		Require pH correction	H_2SO_4 dosing (109 mg/L)		Require pH correction	
Permeate Flow (gpm)	621.5	72.8	694.3	563.3	131.8	*	*
Permeate TDS (mg/L)	131		140	52		*	*
Blending Flow (gpm)	291		292	290		*	*

* Information not provided by software

** System uses energy recovery device (ERD)

- Four systems were run: ROSA (conventional), ROSA (HRRO) with concentrate recycle, IMS Design (conventional) and Avista (conventional).
- Each system had blending to bring the TDS to 500 mg/L to meet the secondary drinking water standard.

- IMS Design conventional method achieved a water recovery of 93% with the addition of an energy recovery device while ROSA with the HRRO function achieved a water recovery of 92% (Table 1).
- Energy Consumption was then calculated by literature and the software values provided a baseline (Figure 2)
- EMF data was provided by the supplier to estimate power consumption. This was then converted to energy/year and greenhouse gas emissions (Figure 3).

Table 3. Power comparison of RO software

Total Energy Consumption				
Software	**IMS Design**	**EMF**	**ROSA**	**ROSA (HRRO+EMF)**
Process	Energy (kWh)	Energy (kWh)	Energy (kWh)	Energy (kWh)
Feed Pump	59.5	43.2	43.2	56.2
RO Pump				
EDR		*	*	*
pH Correction Dosing Pump	0.1	*	0.1	*
Anti-scalant Dosing Pump	0.1	*	0.1	*
Ultrafiltration (UF)	*	13.0	*	16.9
Hydropath device	*	0.06	*	0.1
Total	59.7	56.2	43.4	73.2

* Not included in treatment

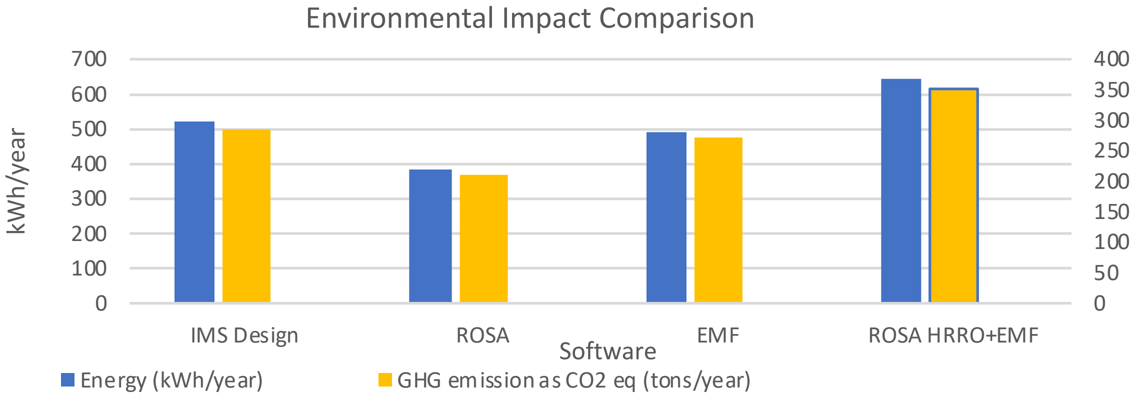

Figure 3. Energy and greenhouse gas emissions comparison

Conclusions

- EMF can achieve high water recovery without the use of chemicals and be implemented with both a conventional and HRRO system
- Less chemical usage is safer, cheaper and reduces the negative environmental impacts on water treatment
- Further research can help enhance this technology and implement on a larger scale