September 10, 2024

Technology Evaluation for Midland and Delaware Basin Produced Water

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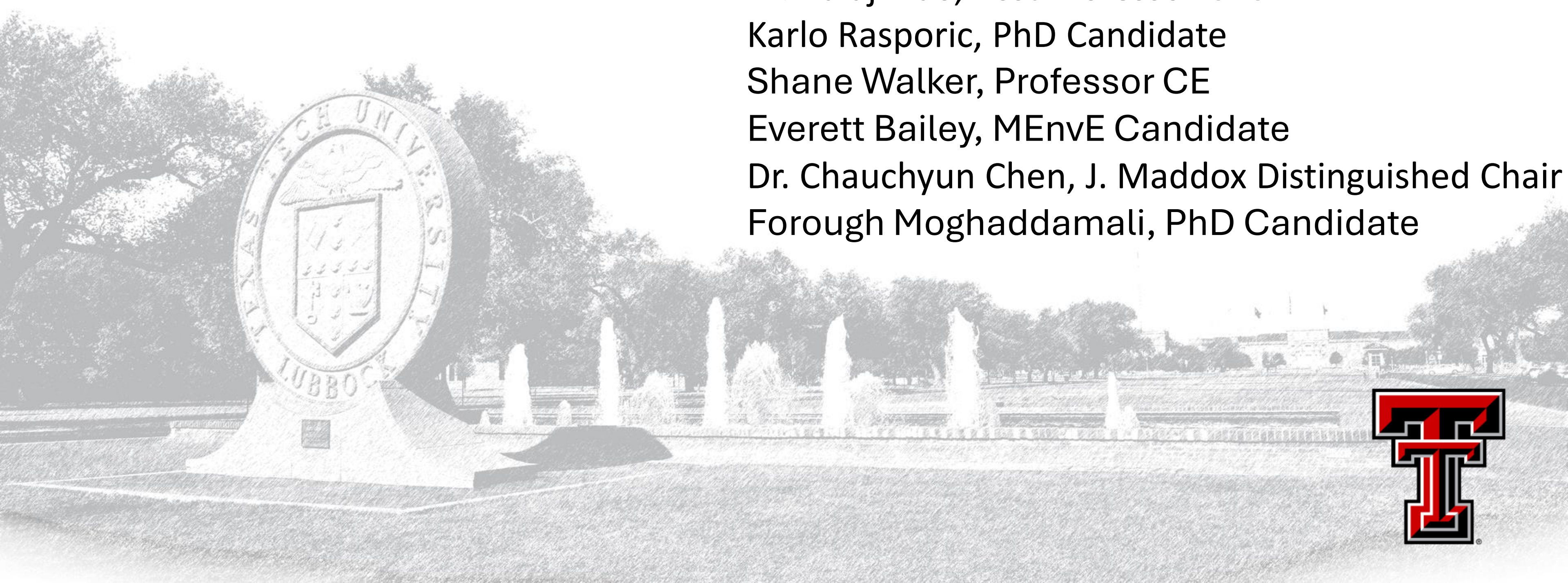


Objectives

- **Provide technical information to assist in expanding treatment of produced water and beneficial uses of that treated water**

- **Evaluating treatment technologies**
  - ✓ Application of ASPEN process evaluation tool
    - **Ensuring mass and energy balances are satisfied and understood**
    - **Developing a framework for evaluating demonstrations**
    - **Assessing precipitation and scaling (e-NRTL framework)**
  - ✓ Analytical support for pilot scale testing

- **Evaluation appropriate technologies for Delaware and Midland Basin**

Comparison of Delaware & Midland Basins

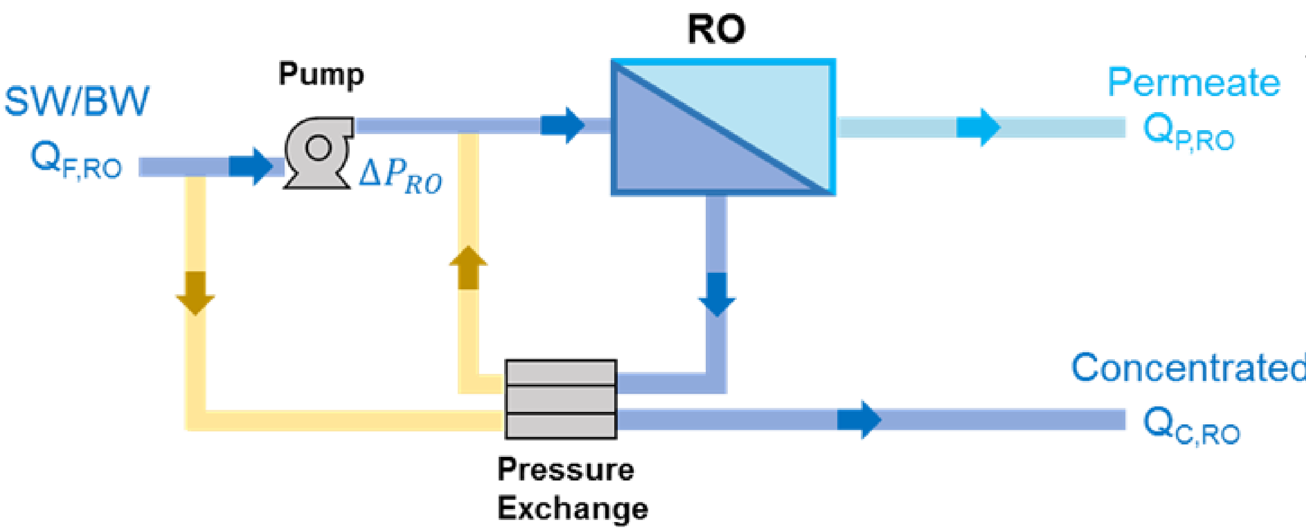
Delaware Basin

- 25%ile 50,980mg/L
- 50%ile 71,700 mg/L
- 75%ile 98,100 mg/L

Midland Basin

- 25%ile 109,000 mg/L
- 50%ile 129,000 mg/L
- 75%ile 145,000 mg/L

Desalination of Delaware Basin Produced Water by RO/UHP-RO



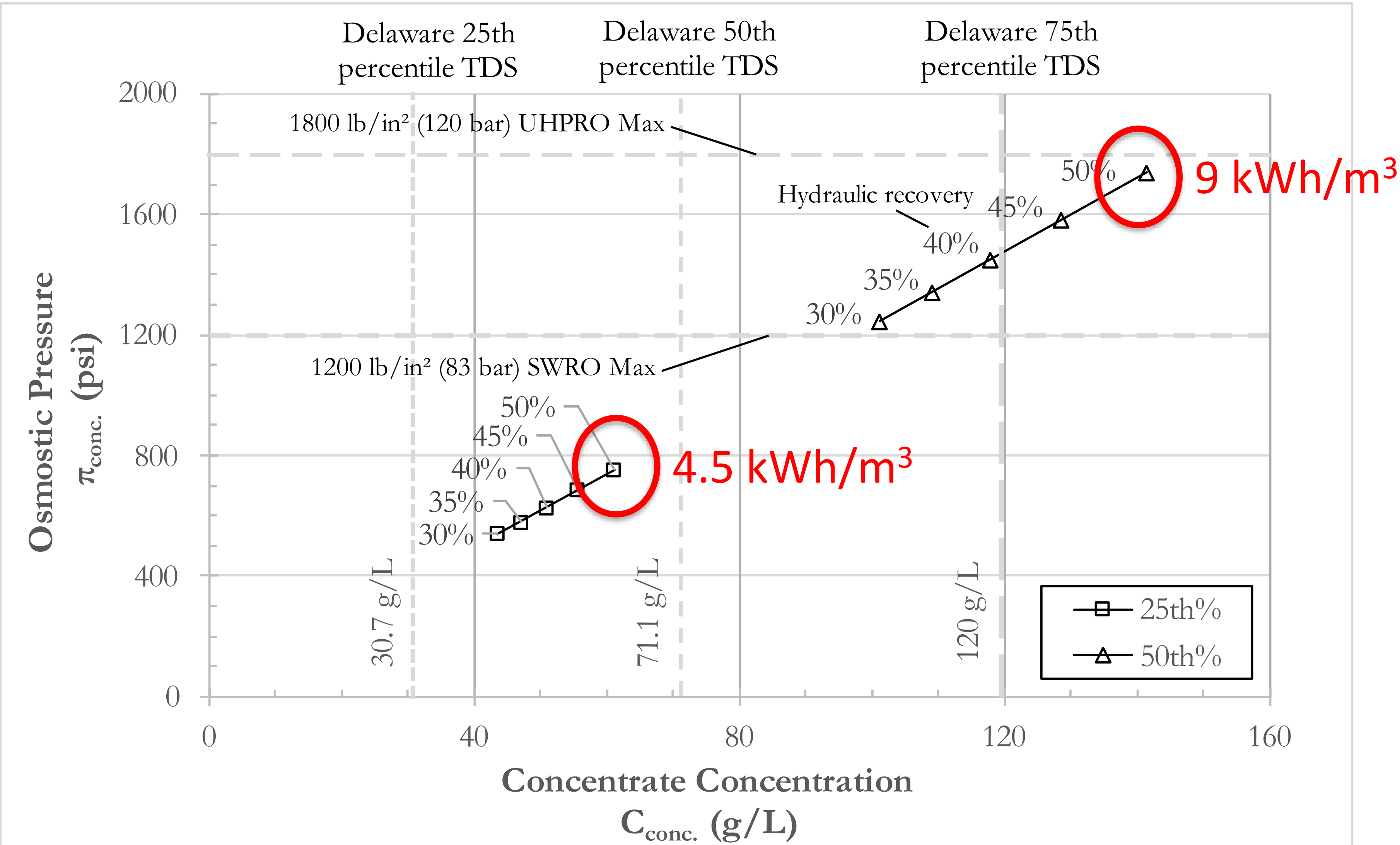
Texas average retail power cost $0.15/kWh

RO – Seawater ~$2000/acre-ft or $6/1000 gallons or $0.26/bbl
Actual SEC – 3 to 5 kWh/m^{3*} $0.07-0.12/bbl 30-50% of total cost

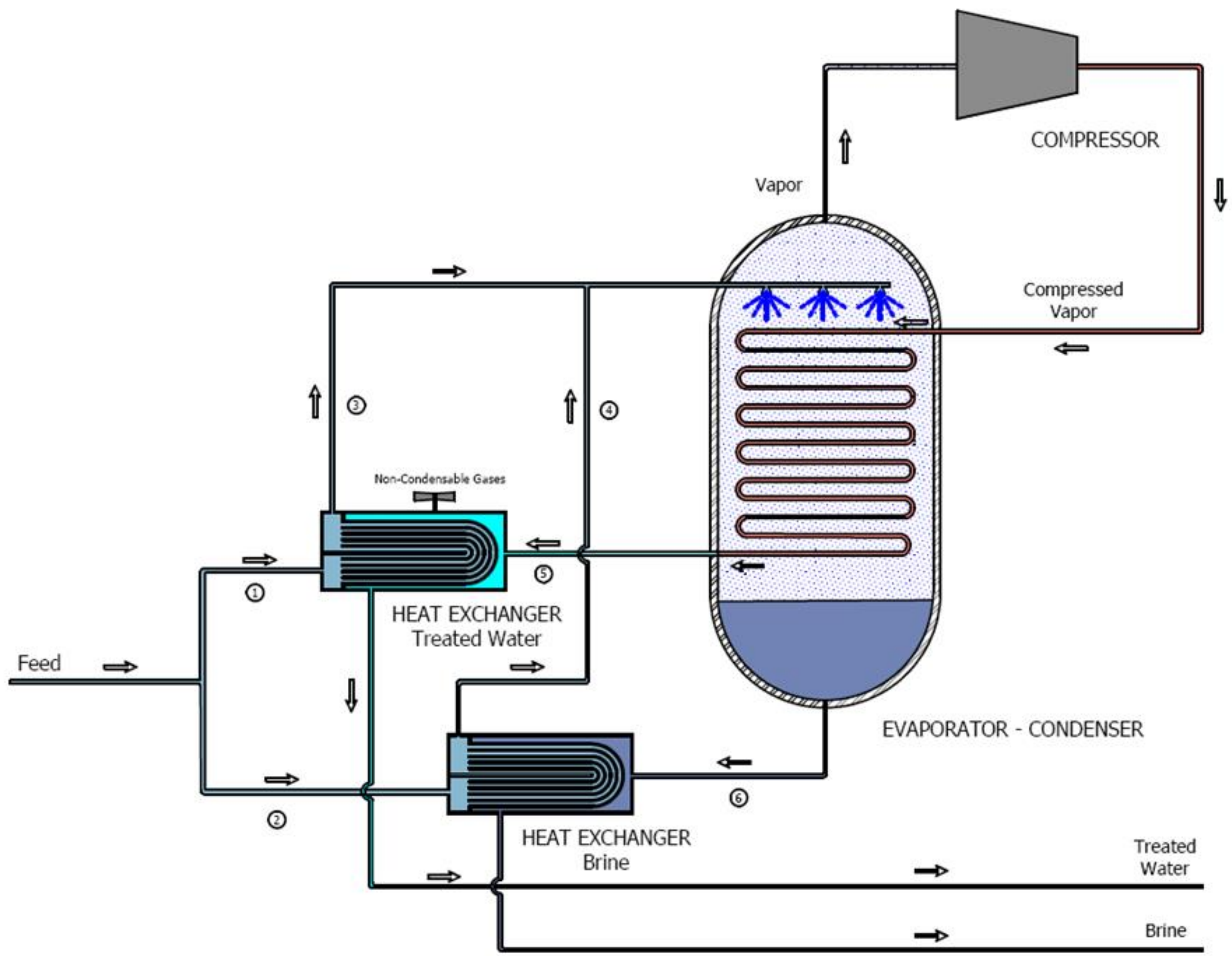
RO – Median Delaware Basin Water
8-10 kWh/m^{3*} $0.19-0.24/bbl or total of $0.50-0.60/bbl

*Integrated Membrane Solutions Model Nitto Hydronautics

RO Limited by Osmotic Pressure Requirements



Desalination of Delaware Basin Produced Water by MVR



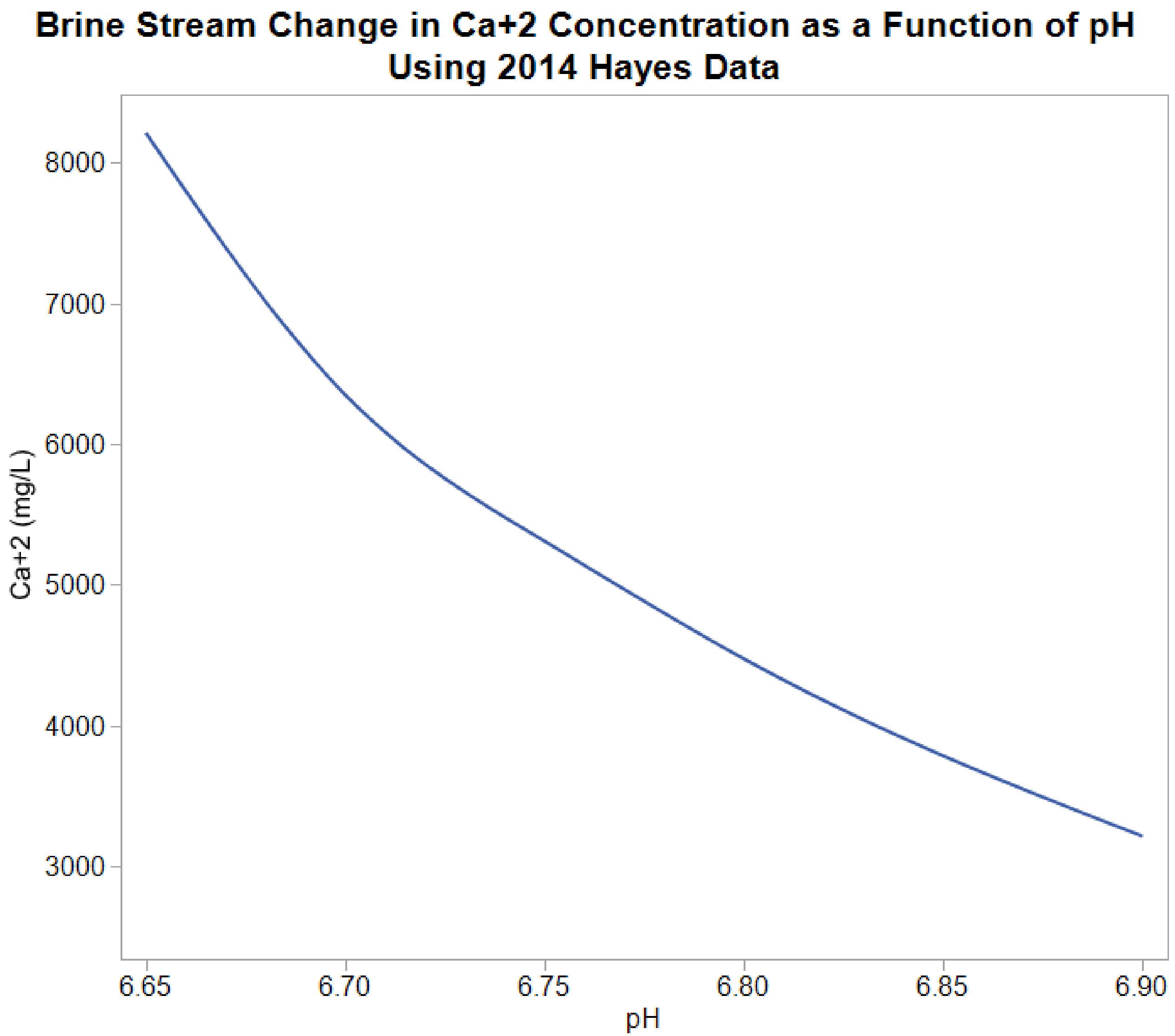
Shale Water Demonstration (Hayes et al. 2014)

			Influent Water	Post Clarifier	Distillate	Concentrate
TDS	mg/L		44900	46900	103	162000
Calcium	(Ca),	mg/L	2570	2705	0.8	8960
Magnesium	(Mg),	mg/L	291	296	0.1	1055
Sodium	(Na),	mg/L	10700	12100	3.6	39000
Potassium	(K),	mg/L	296	349	0.1	1670
Barium	(Ba),	mg/L	7	7	0.1	5
Strontium	(Sr),	mg/L	467	467	0.1	1735
Iron	(Fe),	mg/L	27	27	0.1	2
Lithium	(Li),	mg/L	11	11	0.1	38
Sulfate	(SO4),	mg/L	316	205	5	793
Chloride	(Cl),	mg/L	-	-	-	-
Phosphate	(PO4),	mg/L	9	6	0.3	18
Boron	(B),	mg/L	18	16	0.4	62
Bicarbonate	(HCO3),	mg/L	-	-	-	-
Carbon Dioxide	(CO2),	mg/L	-	-	-	-
	(CO3),	mg/L	-	-	-	-
Ammonia		mg/L	84	84	64	114
BTEX		mg/L	2.9	2.1	0.1	0

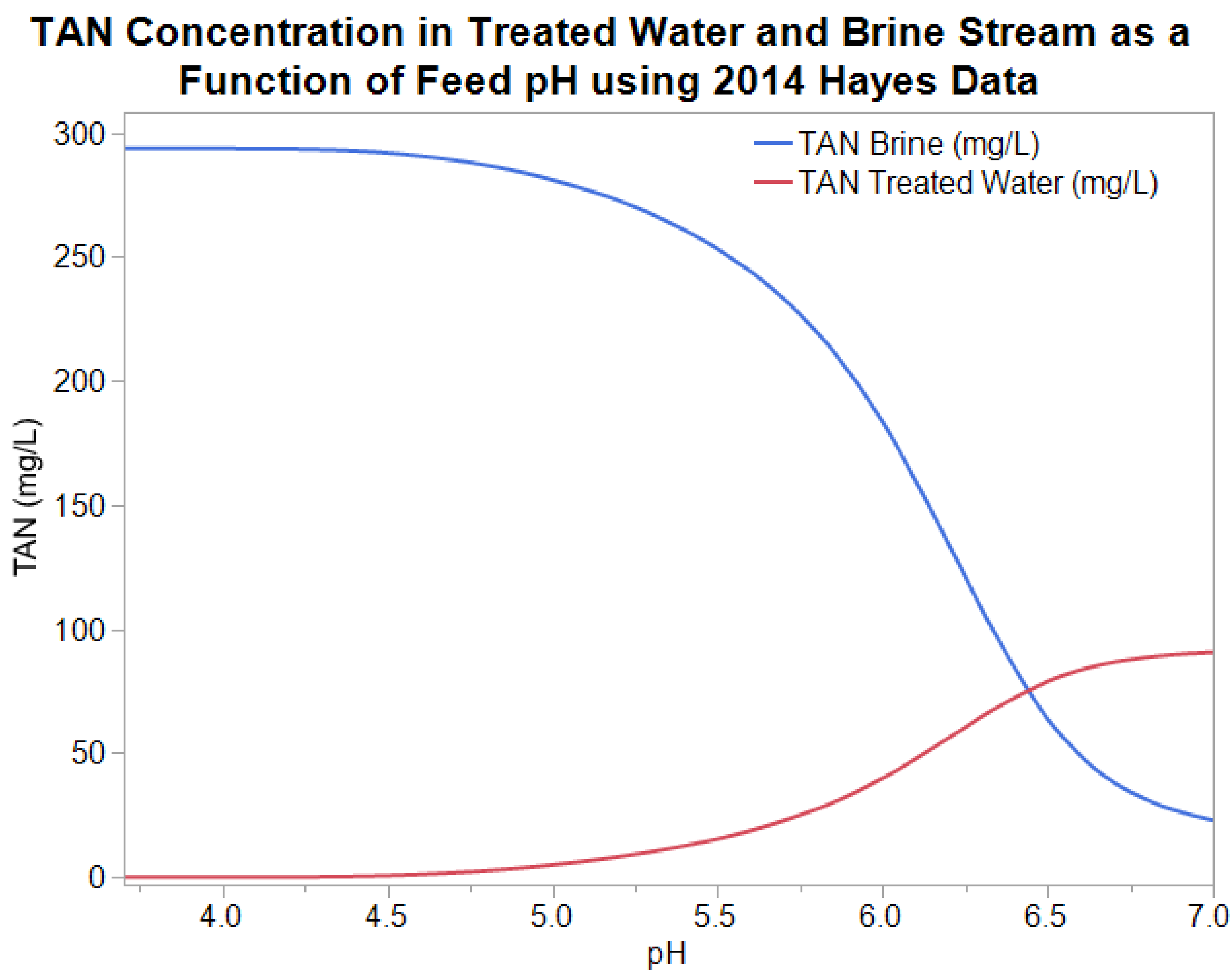
Recovery 68% based upon mass

Estimated SEC – 18 (Aspen)-20 (observed- estimated efficiency) kWh/m^3

$CaCO_3$ precipitation

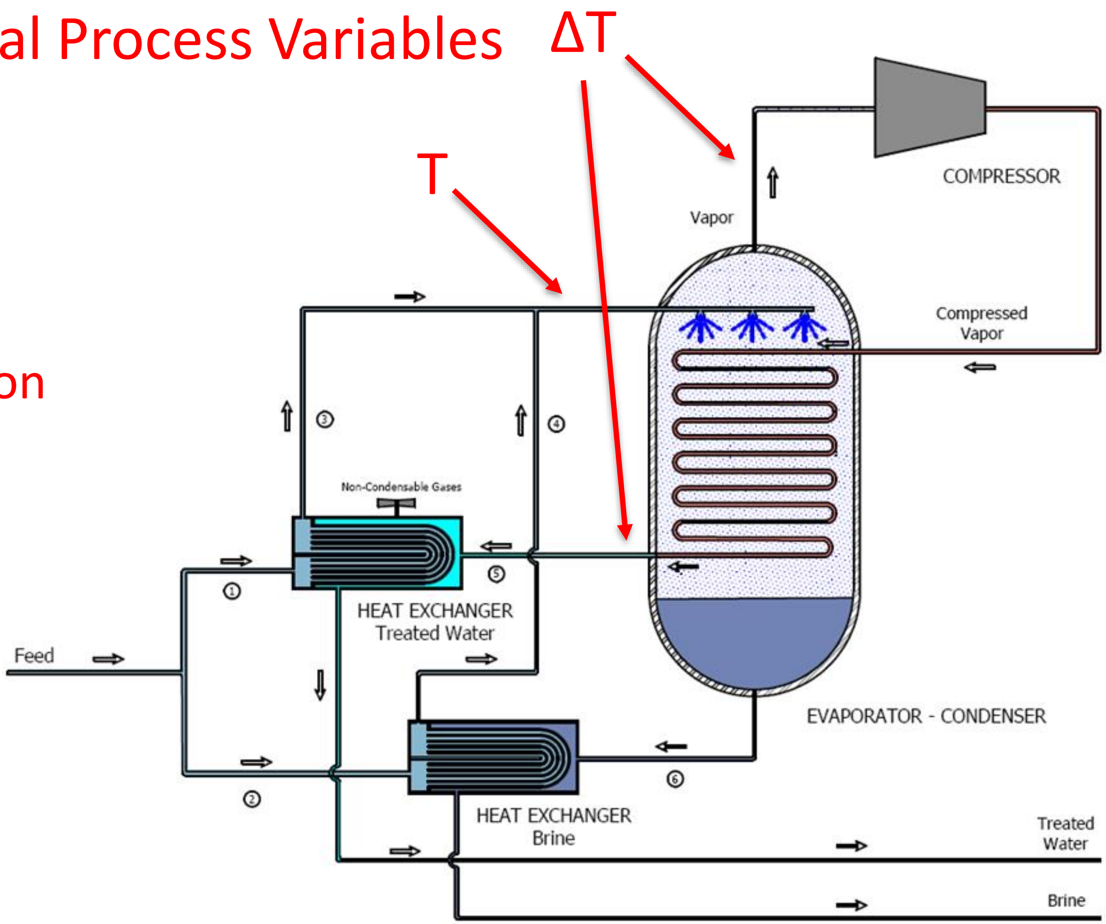


Total Ammonia Nitrogen (TAN)



Desalination of Midland Basin Produced Water by MVR

Critical Process Variables



Important Feed Conditions

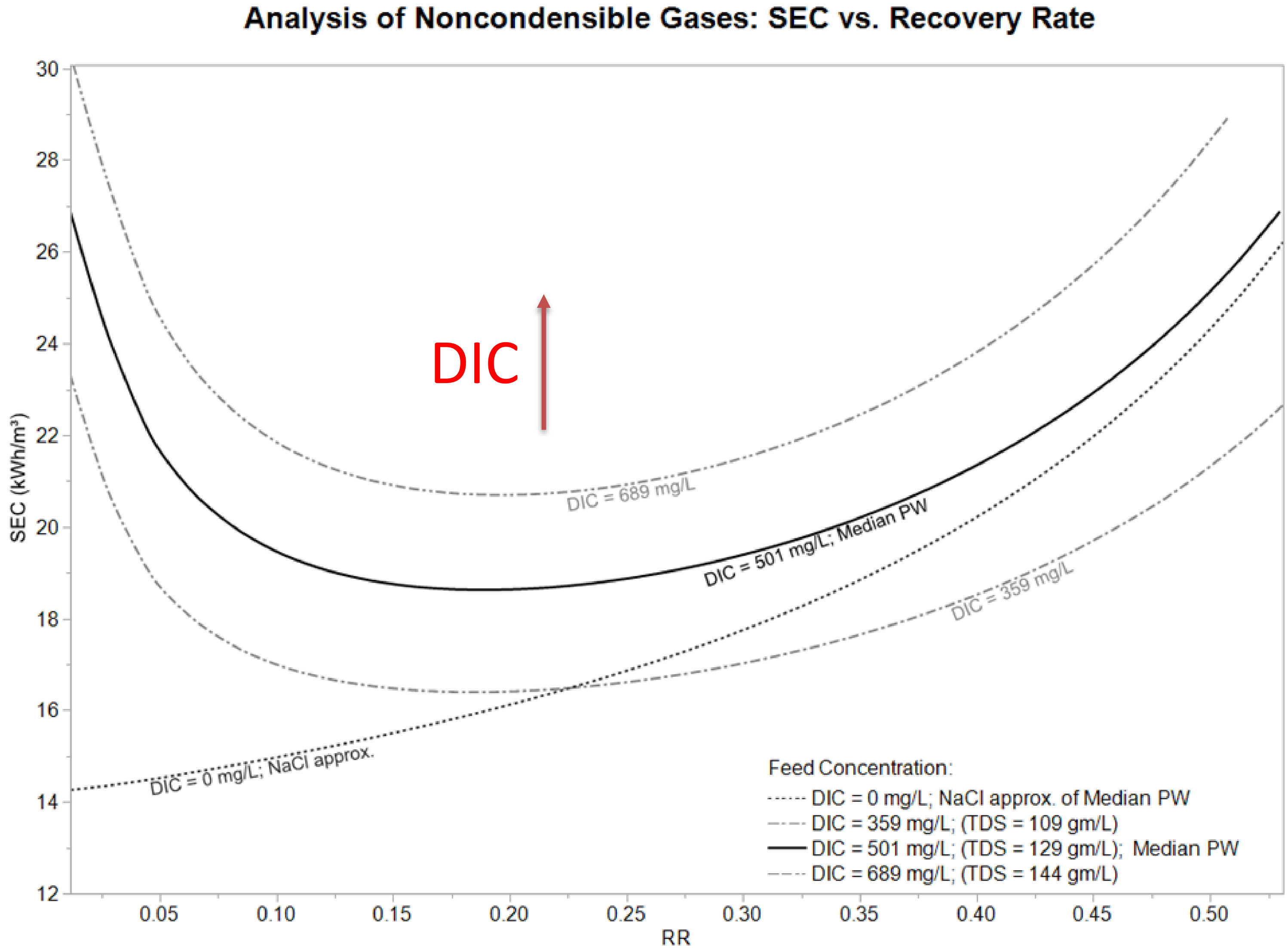
- Dissolved inorganic carbon
- Total Ammonia Nitrogen
- pH

Effect of Operating Conditions

SEC in kWh/m³ by Evaporator Temperature				
ΔT	60 C	70 C	80 C	90 C
1 C	18.9	19.2	19.6	19.9
2 C	21.8	22.0	22.2	22.4
3 C	24.8	24.9	24.9	25.0
4 C	27.8	27.7	27.7	27.7

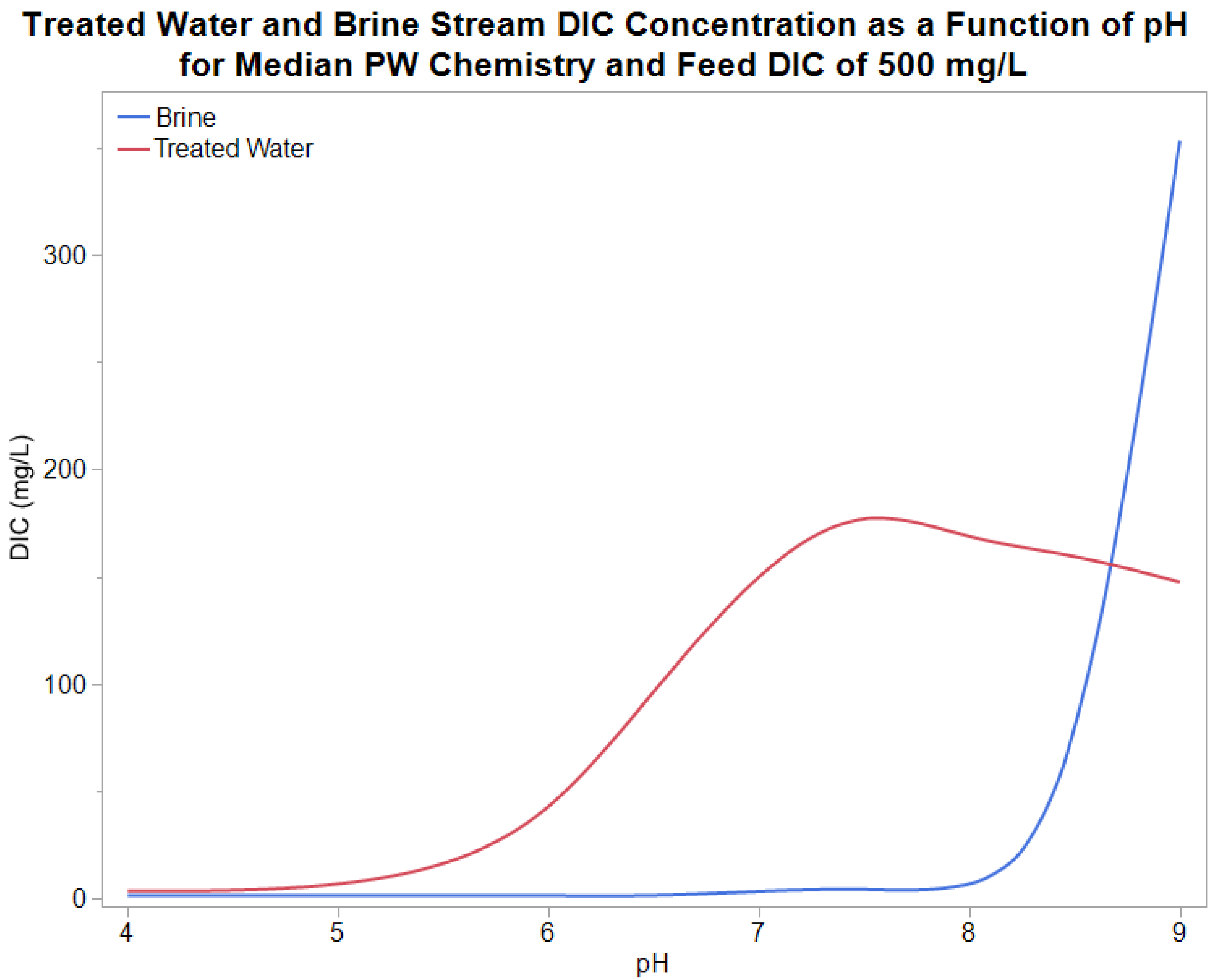
ΔT – Approach Temperature Condenser – Evaporator
T – Temperature of feed to evaporator
50% recovery

SEC for MVR

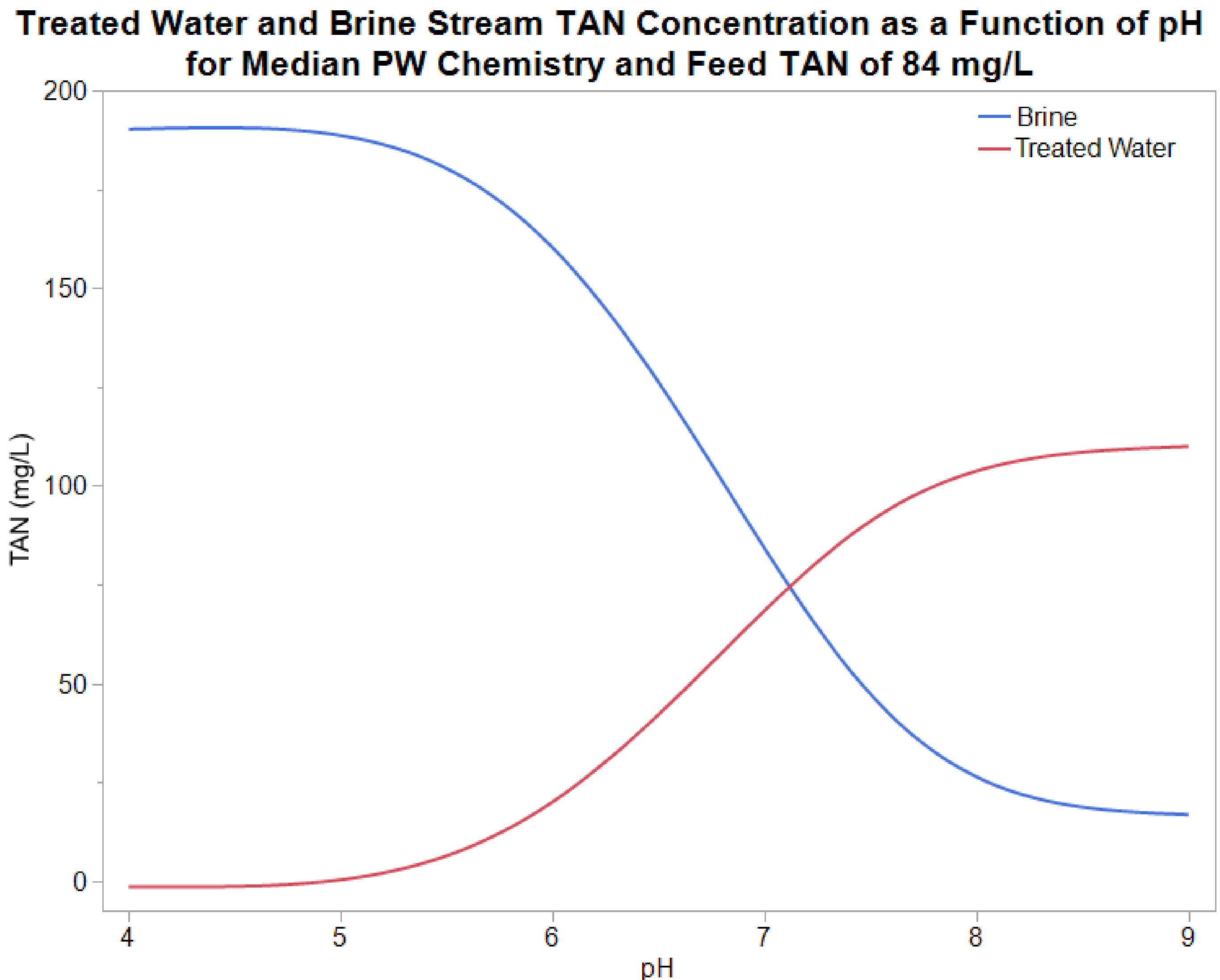

Analysis of Noncondensible Gases: SEC vs. Recovery Rate
SEC (kWh/m³)
RR
30
28
26
24
22
20
18
16
14
12
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
DIC
DIC = 689 mg/L
DIC = 501 mg/L; Median PW
DIC = 359 mg/L
DIC = 0 mg/L; NaCl approx.
Feed Concentration:
DIC = 0 mg/L; NaCl approx. of Median PW
DIC = 359 mg/L; (TDS = 109 gm/L)
DIC = 501 mg/L; (TDS = 129 gm/L); Median PW
DIC = 689 mg/L; (TDS = 144 gm/L)

DIC (Carbonates/CO_2) and TAN

50% recovery



DIC (Carbonates/CO_2) and TAN



50% recovery

Conclusions

- **Delaware Basin Produced Water**
  - Median 71,700 mg/L, (25%ile 51,980 mg/L)
  - Up to 50% recovery by UHP-RO should be possible
  - Energy requirements of 8-10 kWh/m^3
  - Total cost of $0.50-0.60/bbl (excluding significant pre/post treatment)
  - MVR – SEC of 18-20 kWh/m^3 for 25%ile (Hayes et al. 2014)

- **Midland Basin Produced Water**
  - Median 129,000 mg/L (25%ile 109,000 mg/L, 75%ile 145,000 mg/L
  - Limited to 50% recovery (precipitation of concentrated brine)
  - SEC 18-28 kWh/m^3 significant influence of non-condensables (DIC)
  - Potential for raising pH in feed step to precipitate and separate DIC
  - Potential for control of $CaCO_3$ scale and Ammonia by pH of feed <6