Integration of Accelerated Precipitation Softening - Microfiltration (APS-MF) Assembly to Maximize Water Recovery from the Treatment of Brackish Water

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Outline

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Problem

- The largest byproduct of oil and gas production is produced water
- On average, 9 ½ barrels of water are generated for each barrel of oil
- In the US alone, 21 billion barrels of produced water are generated every year
- Disposal of produced water has large environmental and economic implications

*1 barrel = 42 US gallons

Produced Water

- Physical and chemical properties of produced water vary greatly
- Generally, the main concern with produced water is salt content (often expressed as salinity, conductivity, or total dissolved solids (TDS))

Image source: greentechmedia.com/articles/read/produced-water-an-economic-opportunity

Research Goals

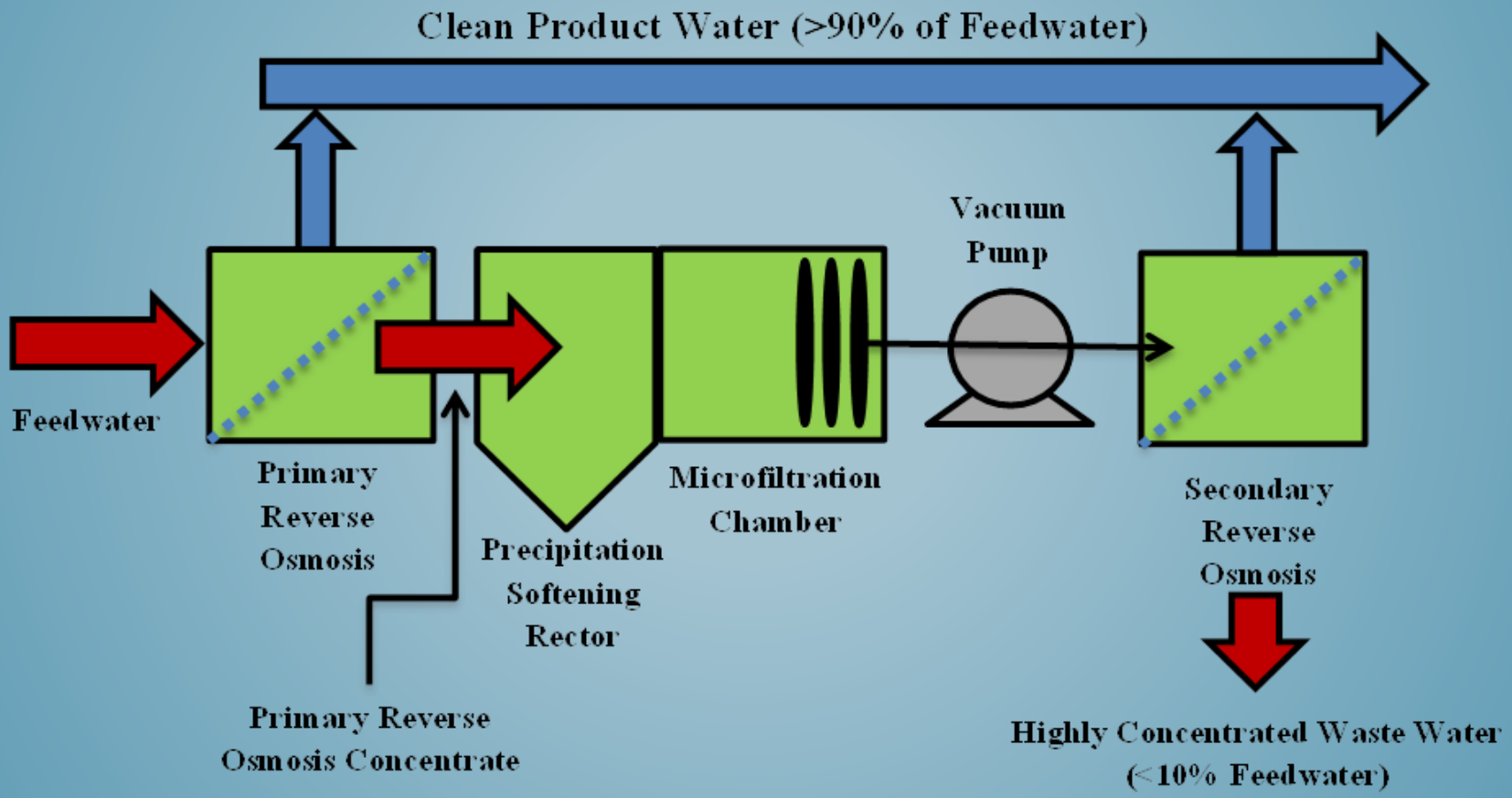
- Current standard recovery methods yield recoveries from ~50%-75%
- This research seeks to increase the recovery of usable water to near or above 90%
  - Treats the Primary Reverse Osmosis (PRO) concentrate to remove calcium and other scale forming agents
  - Provides higher quality feed water for a Secondary Reverse Osmosis (SRO) treatment
  - Allows for the substantial increase in overall water recovery

APS-MF

- APS involves increasing the pH and dosing the PRO concentrate with $CaCO_3$ seeds to increase the precipitation kinetics of scaling minerals

- MF serves as a polishing step to remove any solids prior to the SRO treatment

Overall System



Model Water: Important Observations

- PRO recovery is limited by mineral scaling
- Mineral scaling indices are greatly reduced with Accelerated Precipitate Softening-Microfiltration (APS-MF) treatment to a level at which they no longer limit recovery in the SRO
- SRO Recovery is instead limited by osmotic pressure which is dependent on TDS
- Overall Water recovery of 91% predicted in the model water with the use of APS-MF treatment

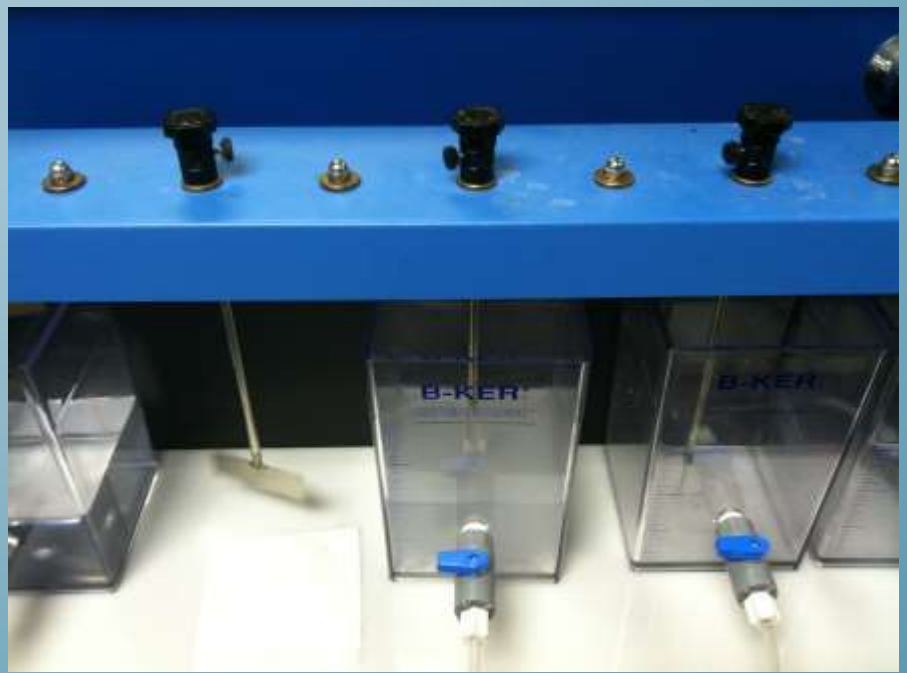
Model Produced Water

- Based on the average composition of water samples from the Powder River Basin in Wyoming

	Well	Acidified	PRO-Conc	APS	S-Feed	SRO-Conc
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Ca^{2+}	400	400	800	16.03	16.03	89.07
Na^{+}	2,064	2,064	4,129	4,985	4,985	27,698
Cl^{-}	2,500	2,500	5,000	5,000	5000	27,777
CO_2	85.78	638.92	638.92	36.32	2.73	1.36
HCO_3^{-}	1,000	235.53	471.07	24.40	24.40	135.58
CO_3^{2-}	2.46	0.02	0.04	154.72	0.06	0.35
SO_4^{2-}	1,100	1,709	3,418	3,418	3,402	18,902
S&D SI	0.60	-1.55	-0.93	0.40	-3.12	-2.13
$CaSO_4$ % Sat	31.41	47.00	106.97	3.05	2.24	16.63
pH	7.00	5.5	5.8	10.40	7.0	7.01
TDS	7,070	6,909	13,818	12,742	13,428	74,650

Experimental Procedure

- Determine precipitation kinetics, optimal pH, and optimal seeding with jar testing
- Sample contents determined with an Ion Chromatograph
- Two Primary Divisions of Jar Testing:
  - pH Jar Test
  - Seeded Jar Test



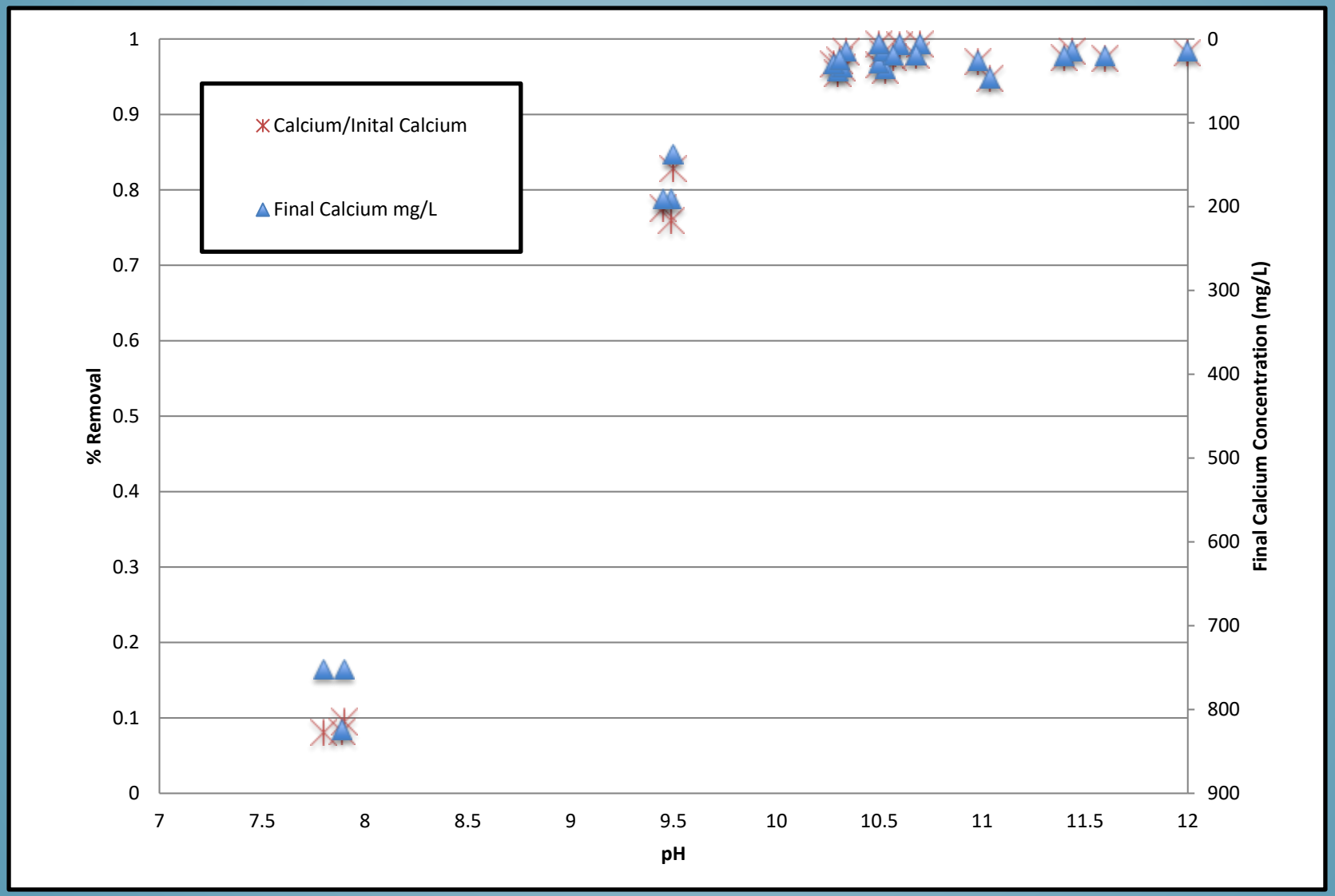
pH Jar Test

- Uses 4 jars with 1L of model PRO concentrate
- Take initial (t_0) sample for each jar
  - Sample water is taken with a 10mL syringe from the jar and filtered with a .45µm filter into a sample vial
- The pH of each jar is adjusted with NaOH solution [pH 7.7, 9.5, 10.5 and 11.4] and stirring begins
- Final sample is collected after 60 minutes (t_{60})
- This test shows the maximum amount of precipitation (lowest calcium concentration) at different pH levels

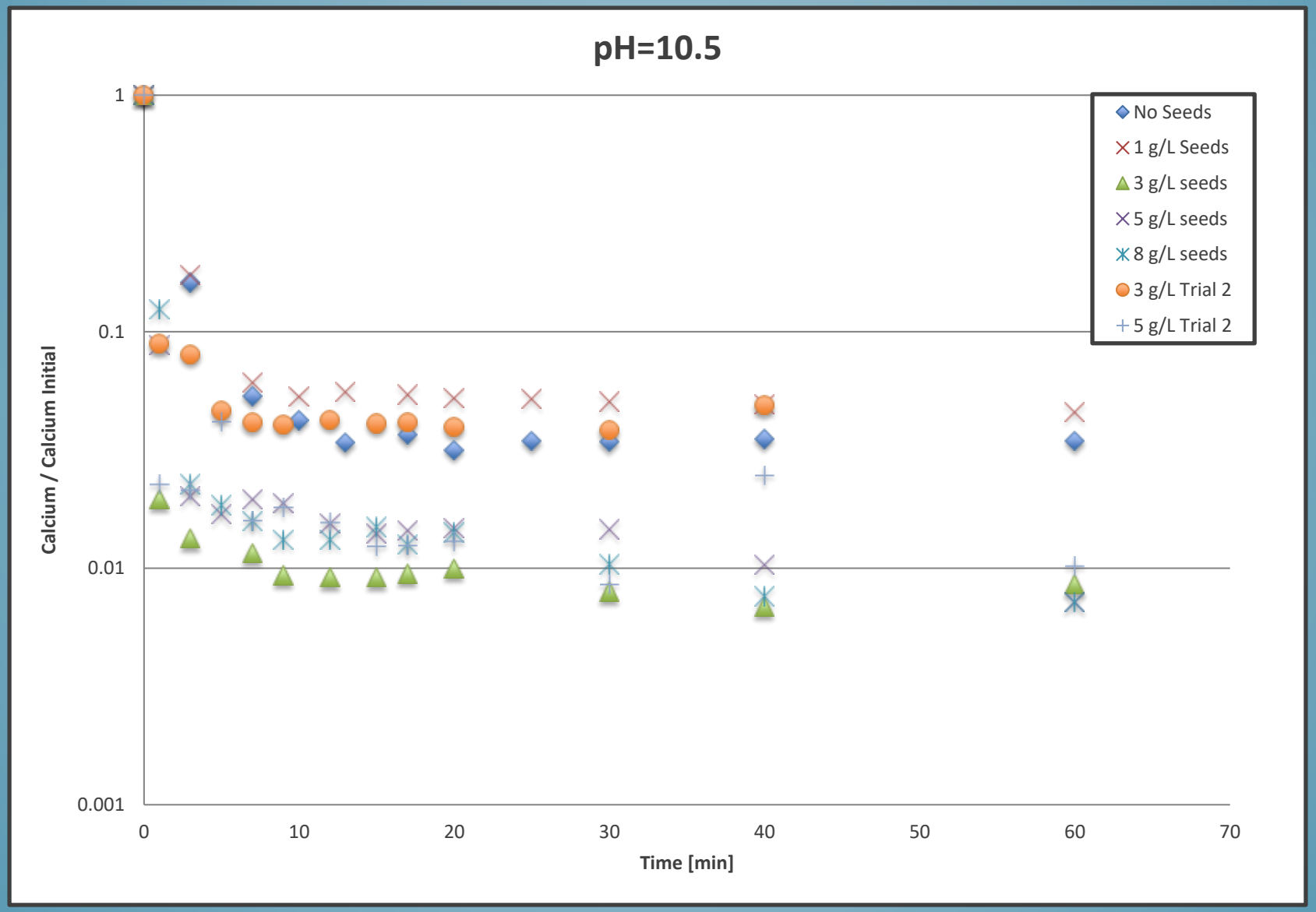
Seeded Jar Test

- Uses 1 jars with 1L of model PRO concentrate
- Take initial (t_0) sample for each jar
  - Sample water is taken using the same method
- The pH of the jar is adjusted to 10.5 and a known mass of $CaCO_3$ seeds is added
- Stirring begins
- Samples are collected every 2-3 minutes for 60 minutes
- This test shows the rate of precipitation for a specific seeding concentration

pH Jar Testing Data



Seeded Jar Testing Data



Observations and Conclusions

- pH tests indicate optimum calcium removal is found at pH 10.3
  - Highest calcium removal without going over pH 10.5 where unwanted precipitation products occur
  - pH adjustment to 10.3 results in an average calcium concentration of 20 mg/L (results in significant reduction in saturation indices in feed for SRO)
- Seeded tests indicate 3 g/L of seeds provides the optimal area for nucleation
  - Kinetics show equilibrium is reached with seeds after about 7 minutes (important for reactor design)

Future Goals

- This summer testing will begin with the bench scale system
  - Evaluate process performance
  - Optimization of process conditions
- Diversification of water sample composition
- Develop a database for finished water quality based on specific inputs

Questions

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