Panel Discussion: Advances in Membrane Cleaning, Sanitation & Wastewater Management

3:30 – 4:25 PM, June 12, 2024

Membrane TECHNOLOGY FORUM®

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Panel Discussion: Forward Osmosis for Wastewater Management

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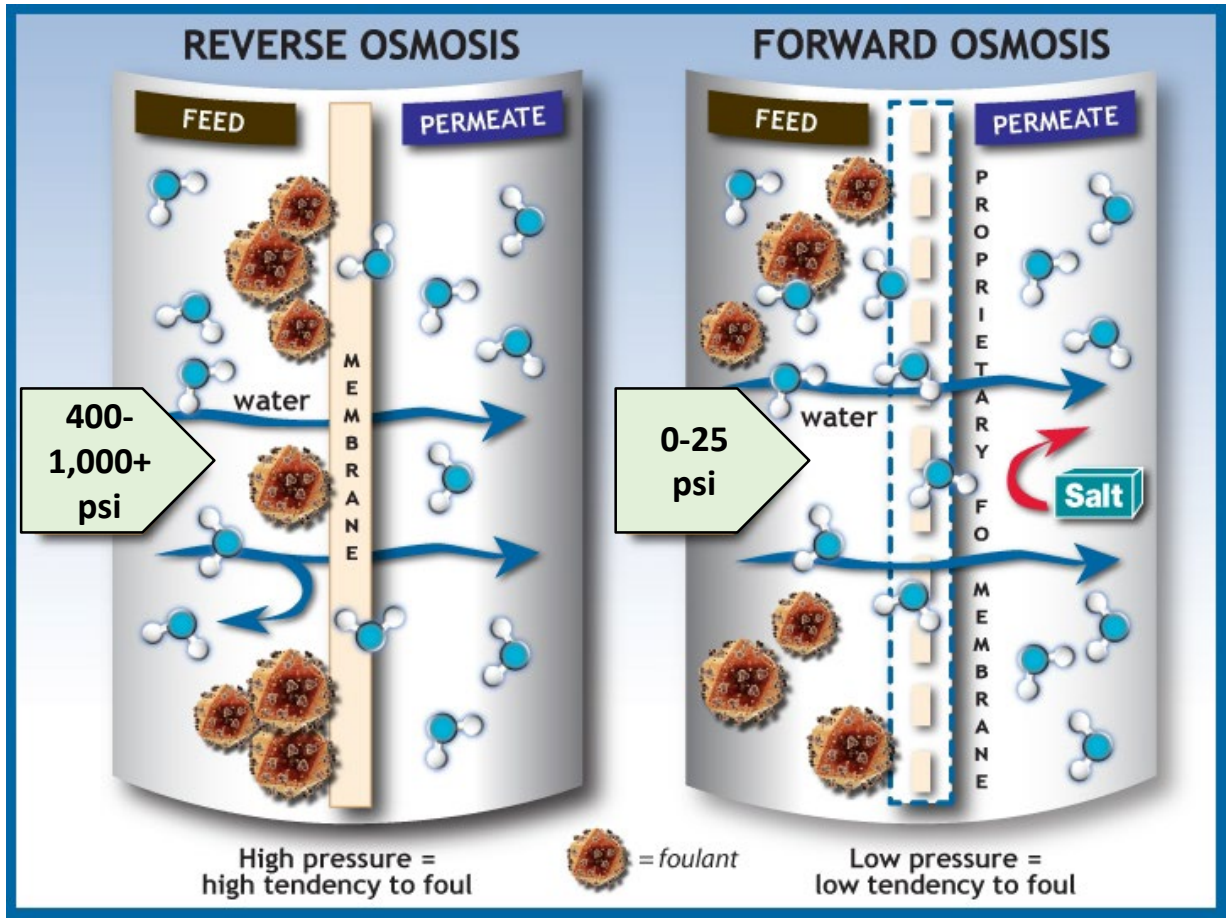
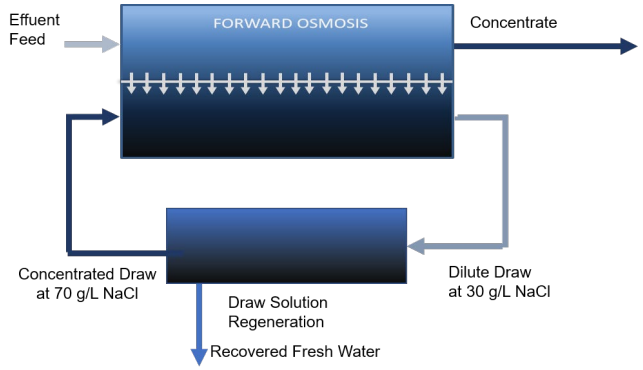
Osmosis Explained: FO/RO Comparison

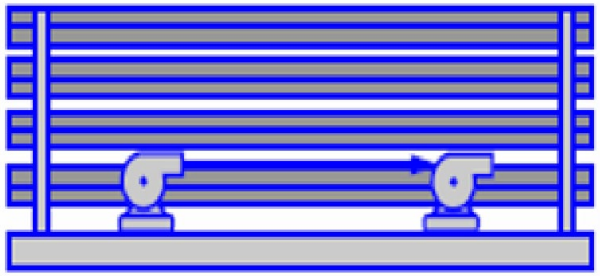


- Osmosis is the flow of water across a semi-permeable membrane from a solution of lower osmotic pressure to a solution of higher osmotic pressure. In general, the higher the dissolved solids concentration, the higher the osmotic pressure.
- The rate of osmosis is controlled by diffusion of the solutes on *both sides* of the membrane and *within* the membrane.
- FO membranes reject organics, minerals and other solids — similar to reverse osmosis (RO) — but resist typical fouling problems

Core Technologies

- We are pioneer and system developer in two important membrane technology areas





OsmoARO™ System

<u>Forward Osmosis (FO)</u>

Osmotic separation of water from a lower TDS stream to a higher TDS draw solution

Salt rejection similar to RO but with osmotic driving force instead of pressure driving force

Treats highly fouled waters from 5000 mg/L TDS to ~40,000 mg/L TDS with final brine up to 130 g/L TDS

<u>Osmotically Assisted RO (OARO) via low salt rejection SWRO</u>

Stepwise concentration of pretreated wastewater stream by membrane separation

Maintains delta-π similar to SWRO throughout the process

Max pressure of 80 bar is required

Final brine concentration of 250 g/L TDS can be achieved

Applications Where FO is Advantageous

- A concentrated stream (*e.g.*, saturated brine) needs to be diluted and a highly fouling wastewater is available.
- A stream is so fouling that reverse osmosis (RO) requires either too much cleaning or pretreatment (*e.g.*, process wastewater).
- A draw solution is free (e.g., high salt brine in pickling)
- The draw solution can be consumed. Specifically, a concentrated syrup or powder can be used to extract water
- A product needs to be concentrated that is too fragile for evaporation, *e.g.*, concentrating grape juice to make a dessert wine, tomato paste without evaporation, pharmaceuticals
- FO ***concentrated wastewater has value*** (Certified Organic fertilizer produced as a byproduct from a biogas facility)

Membrane for High Fouling Feeds

- Minimal pretreatment for most wastewaters
  - 100 micron filtration
  - pH adjustment
- Higher Recoveries of high fouling feeds
  - Up to 95% recovery compared to 60 – 70% for other membrane processes

Ideal for ZLD – especially where the crystallizer is the mostly costly step

Simple flux recovery from feed upsets (i.e. organic fouling or scaling)

- 1 bar (15 psi) hydrostatic pressure minimizes fouling and membrane damage
- Simple osmotic backwashing and water flushing for performance recovery

Fertilizer Value of Digester Effluent

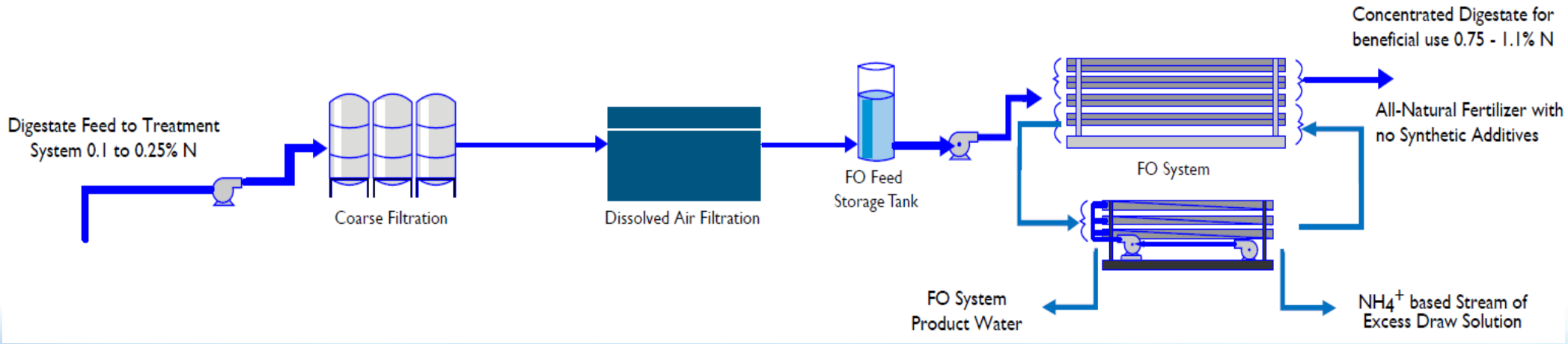
Biogas is a growing energy source; the wastewater generated must be handled.

- Depending on the feed source, a 1 MW Anaerobic Digester can produce up to 10,000,000 gallons a year of effluent
- The effluent (digestate) contains between 0.1% to 0.4% nitrogen in ammoniacal form – about 0.25% average
- The benefit: farming practices are on the rise requiring locally sourced fertilizer, including organic certified fertilizer
    - The key component of organic fertilizer is nitrogen. Depending on the source, liquid organic fertilizer (applied in drip irrigation) is valued between $4 to $8 per lb of N
- Our technology reclaims water from the digestate creating a nutrient concentrate that has been approved for use on farms, including organic certified land

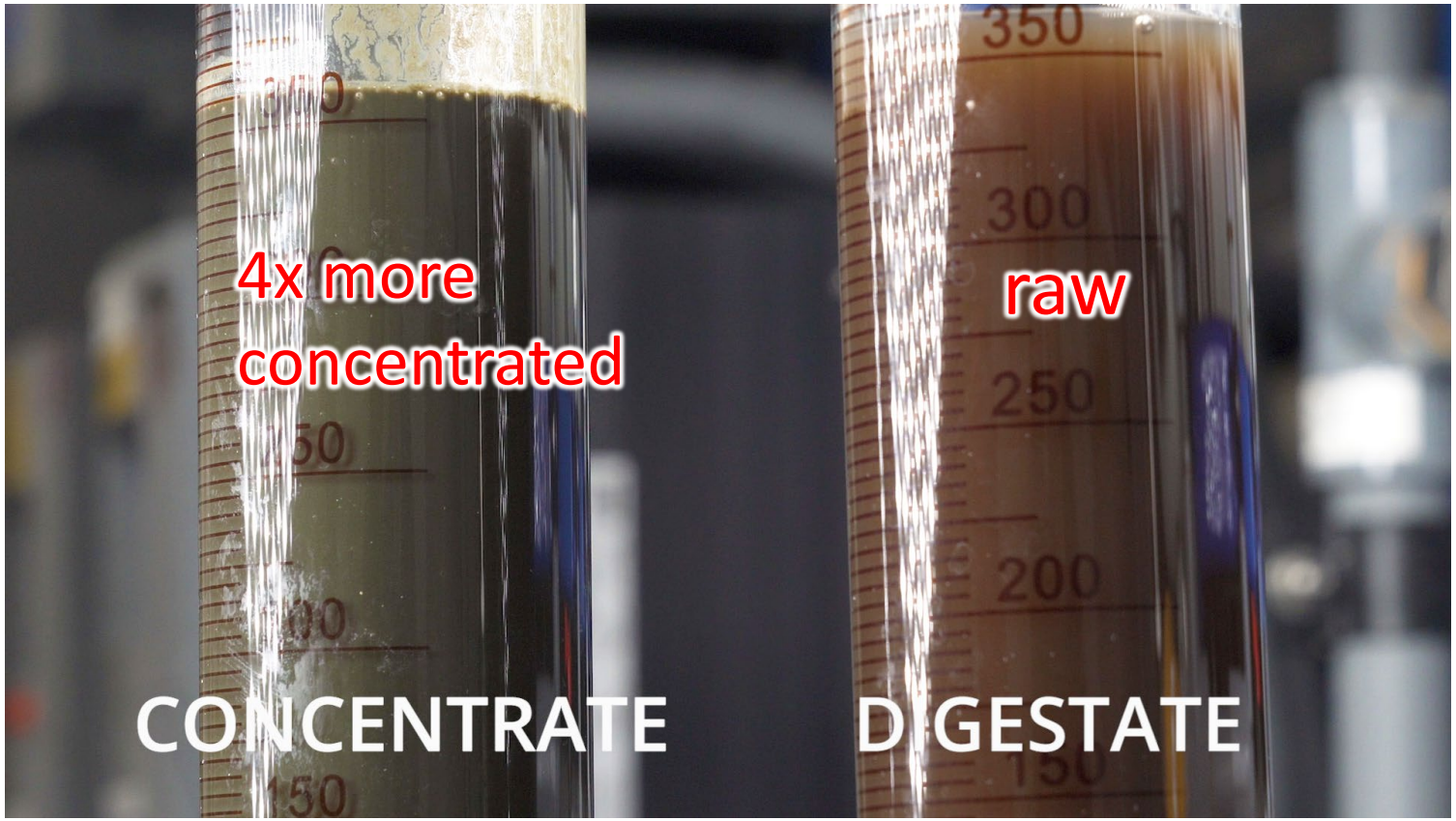
FO Concentrator Approach

Primary objective: reduce volume and keep in its natural form

- Coarse filtration and DAF removes TSS and sticky lignin's prior to FO concentration.
  - No flocculant (polymer) is added.
- Forward Osmosis Concentration System - up to 4X
- Draw Solution Regeneration System - RO quality permeate suitable for plant reuse



Concentrate vs. Raw Feed



Visual comparison of the raw digestate to the FO concentrate. The FO pilot has achieved 75% water recovery producing a concentrate 4x more concentrated than the feed.

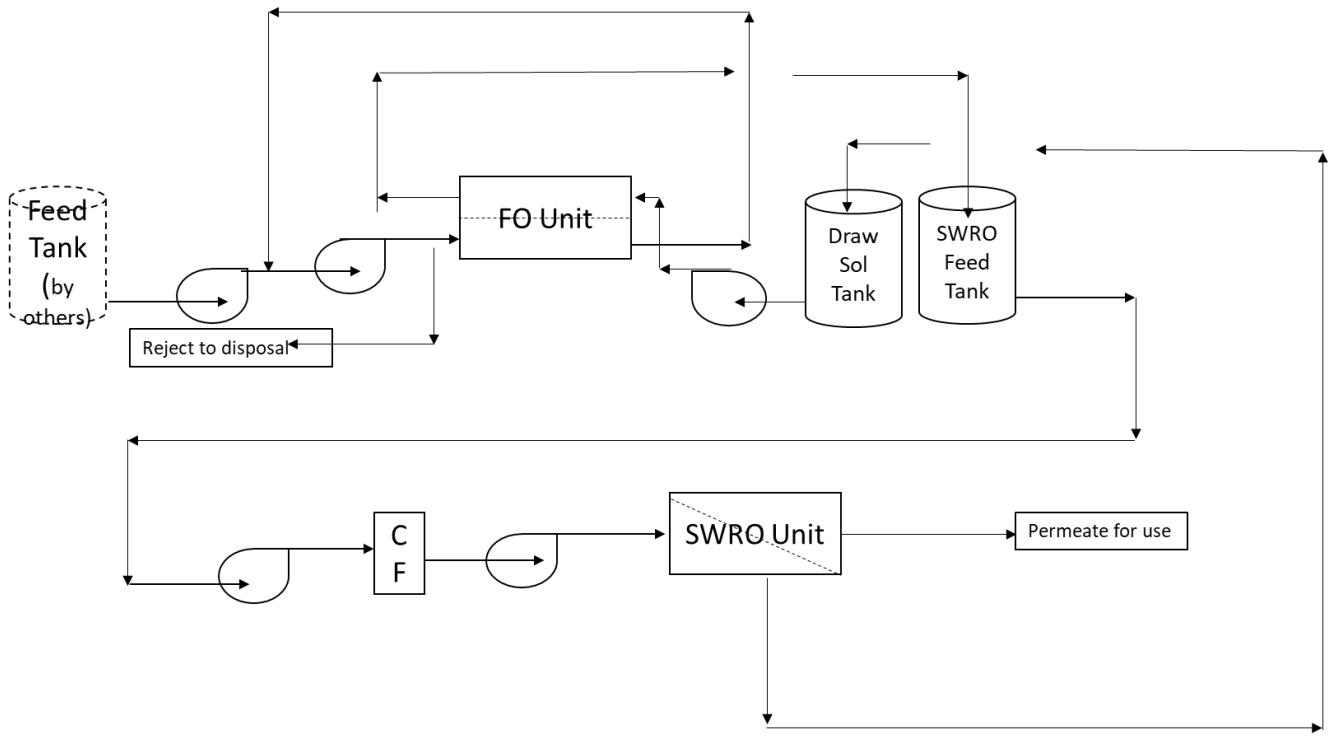
Pilot System For 2,500 gpd

Forward Osmosis Membrane Concentrator

SWRO Draw Solution Regeneration and Permeate Production

Package System For 10,000 gpd Process Water

- ConcentratOAR™
- Treatment Flow 10,000 gpd
- Operation 8 Hours (16.67 gpm)
- Recovery - 90% clean water for reuse
- Brine 10% haul or treat



Final Comments

- Robust and reliable at variations of quantity and quality of high fouling feeds with minimum pre-treatment
- Stable flux while achieving high recoveries
- Compact modular design, flexible construction, and small footprint
- Treated permeate can be discharged back to the environment or can be utilized for irrigation or process water
- Concentrated digestate can have commercial value as fertilizer
- Depending on source, fertilizer may be classified as organic
  - Organic fertilizer has a significantly higher value

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