
Membrane
TECHNOLOGY FORUM®
BROUGHT TO YOU BY
Dairy
FOODS
ADPI
American Dairy
Products Institute

Zwitterionic Membrane Process Enables High-Strength Dairy Wastewater Reuse

Presented by:

Umang Yagnik

Senior Channel Growth Manager

ZWITTERCO

The State of Dairy Wastewater Treatment

Common Dairy Wastewater Treatment Options

Dissolved Air Flotation[1]

Activated Sludge Treatment[2]

Water Reuse Quality
Not Typical

Anaerobic Digestion[3]

Hauling[4]

Source:
1. https://en.wikipedia.org/wiki/Dissolved_air_flotation
2. https://aosts.com/how-does-activated-sludge-wastewater-treatment-work/
3. https://www.biocycle.net/anaerobic-digestion-in-the-northwest/
4. https://home.howstuffworks.com/home-improvement/plumbing/septic-tank-cleaning.htm

Water Reuse, Good for Your Brand and Bottom Line

Achieve Sustainability Goals

- Water efficiency/conservation
- Carbon footprint (reduce hauling, chemicals, embedded energy)
- Marketing/Branding

Cost Savings

- Reduce freshwater and wastewater costs
- Eliminate municipal surcharges (positive barrier)
- Reduce wastewater management spend (hauling, chemicals)
- Potential to valorize the concentrate (where applicable)
- High system uptime and cost-effective cleaning

Challenges Recovering Dairy Wastewater

Reuse Water Quality = Membrane / RO Treatment

Images from: The MBR Site, ESE Mag, WUR, and Hazen & Sawyer

Barriers to Reuse:

Elevated concentrations of **fat and protein** left in wastewater, usually > 100 mg/L

Unsustainable **fouling** on conventional membranes

High **chemical cleaning cost** and **downtime**, low productivity

Zwitterionic Membranes Enable Water Reuse

Advantages of Zwitterionic Membranes

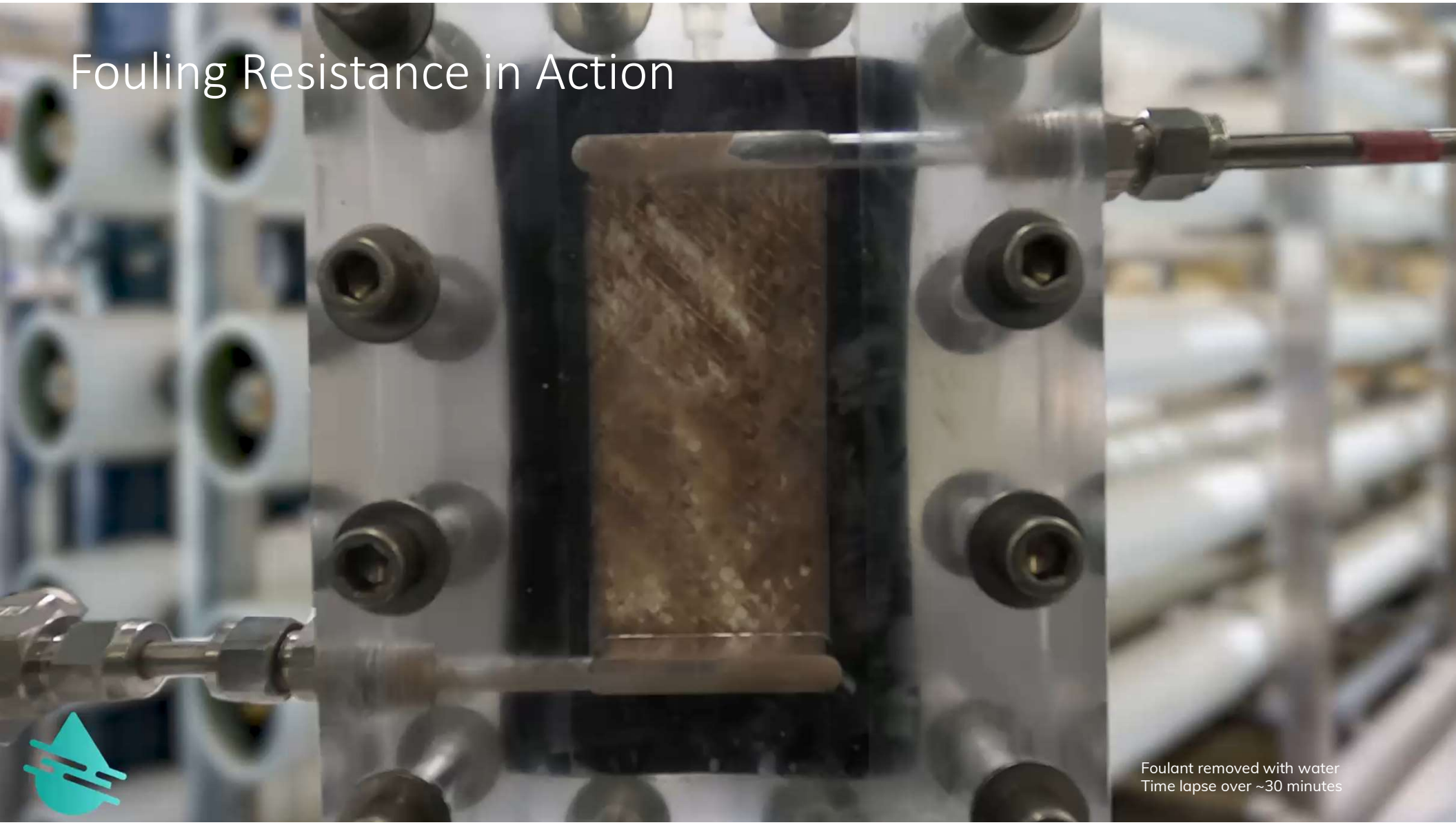
Can handle feed streams **up to 5% fats, oils, and grease**

Clean with **water flushes** and mild chemical maintenance washes

Are **chlorine** and high and low pH **tolerant**

Can achieve **extreme clean water recoveries** (> 90%) even in high strength organic wastewaters

Fouling Resistance in Action



How far can zwitterionic membranes go without irreversible fouling?

Milk Solids Extraction

Whole Milk

Skim Milk

3% wt. Whey Protein

Zwitterionic + RO Membranes Enable Water Reuse

Water Reuse Quality Achievable

Plant Reuse Locations
Cooling water
Boiler makeup
Equipment washing
Packaging washing
Floor washing
Non-potable uses (toilet flushing, irrigation, etc.)
Irrigation

Alternative to Reuse:

- Surcharge-free municipal or surface water discharge

Case Study

Project Background

MILK SPECIALTIES GLOBAL

Project Location: Milk and whey processing facility in Fond du Lac, WI

Project Description:

- The site discharges low strength wastewater to the sewer
- Additionally, the site generates 100,000 GPD high-strength wastewater (HSW) that gets hauled away to nearby farms & anaerobic digesters
- Close monitoring for high BOD and TSS made it infeasible to discharge to sewer
- Customer spent millions of dollars hauling high-strength dairy wastewater
- Space constrained site needed a solution with compact footprint
- Digested Organics invited to offer a treatment solution that would fit within a confined space and reduce the hauling costs

https://www.dairyindustries.com/news/37272/milk-specialties-global-begins-lactoferrin-production/

Digested Organics Solution

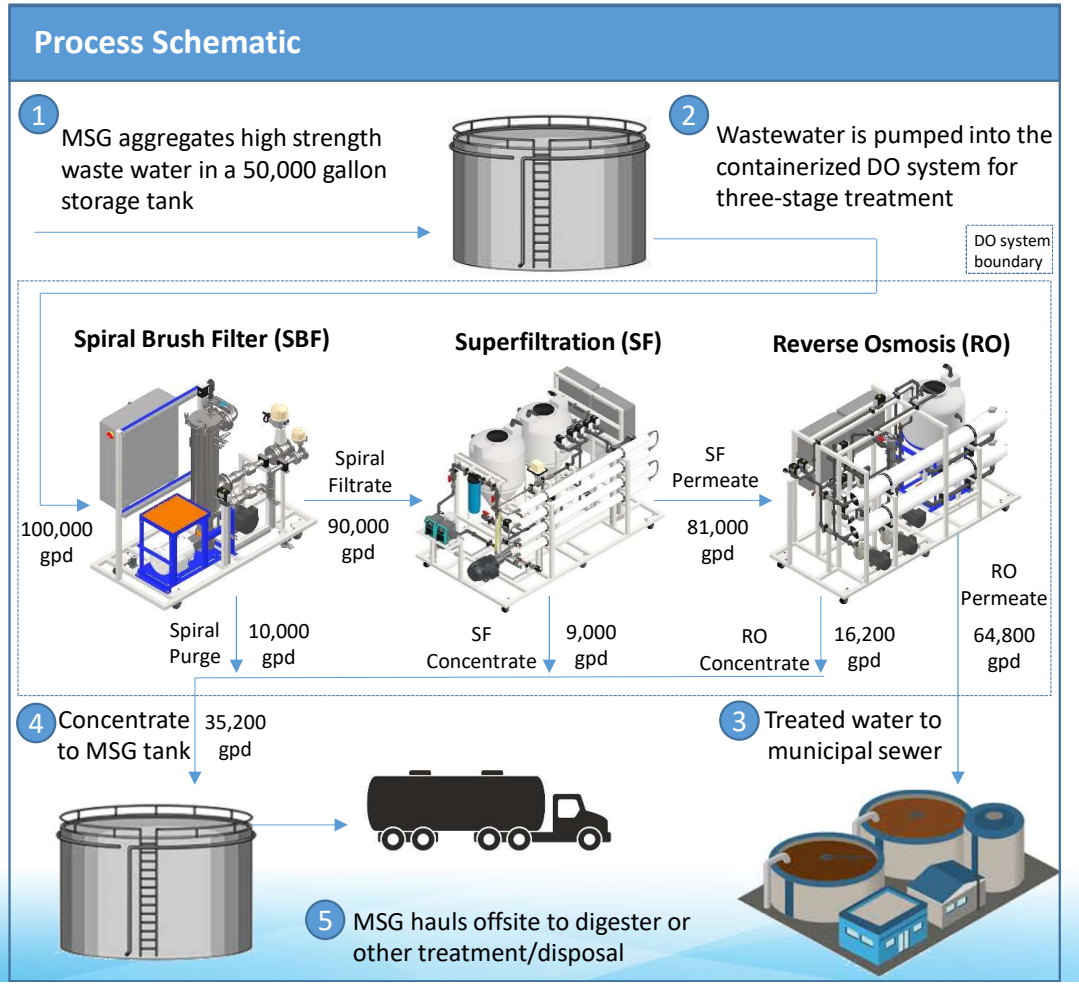
- Digested Organics supplied filtration system and operates under a 20-year service contract (WaaS model)
- System processes up to 100,000 gallons per day (gpd) liquid wastewater from milk and whey processing operation
- **Targets ~ 65% reduction in hauling costs and fuel emissions** *(Return ~35,000 gpd concentrate to MSG; discharge ~65,000 gpd to sewer)*
- Solution leads to est. **21% annual savings** with **no upfront CAPEX investment**

Process Flow Diagram

- Solution design basis

Process	Recovery
SBF	90%
SF	90%
RO	80%
Overall	65%

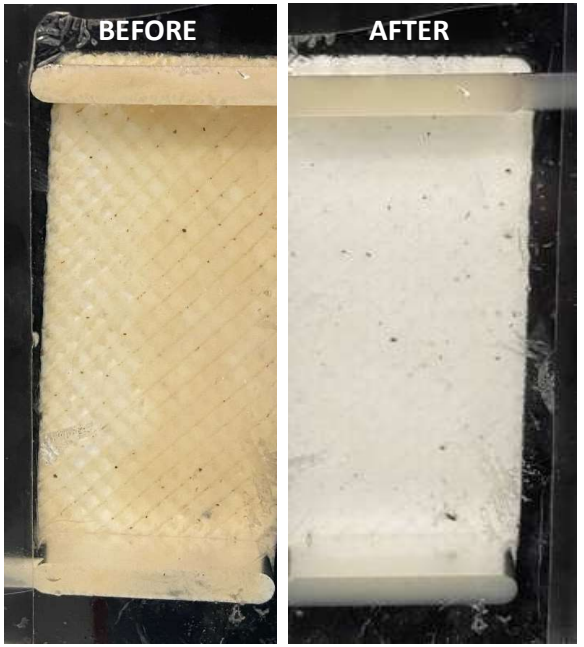
- No biological and / or chemical treatment
  - Physical and membrane filtration process
- Benefits of membrane system
  - Ease of operation & maintenance
  - Small footprint
- RO permeate use
  - Discharged to city sewer – meeting discharge limits
  - Quality fit for cooling tower, boiler feed water, washing



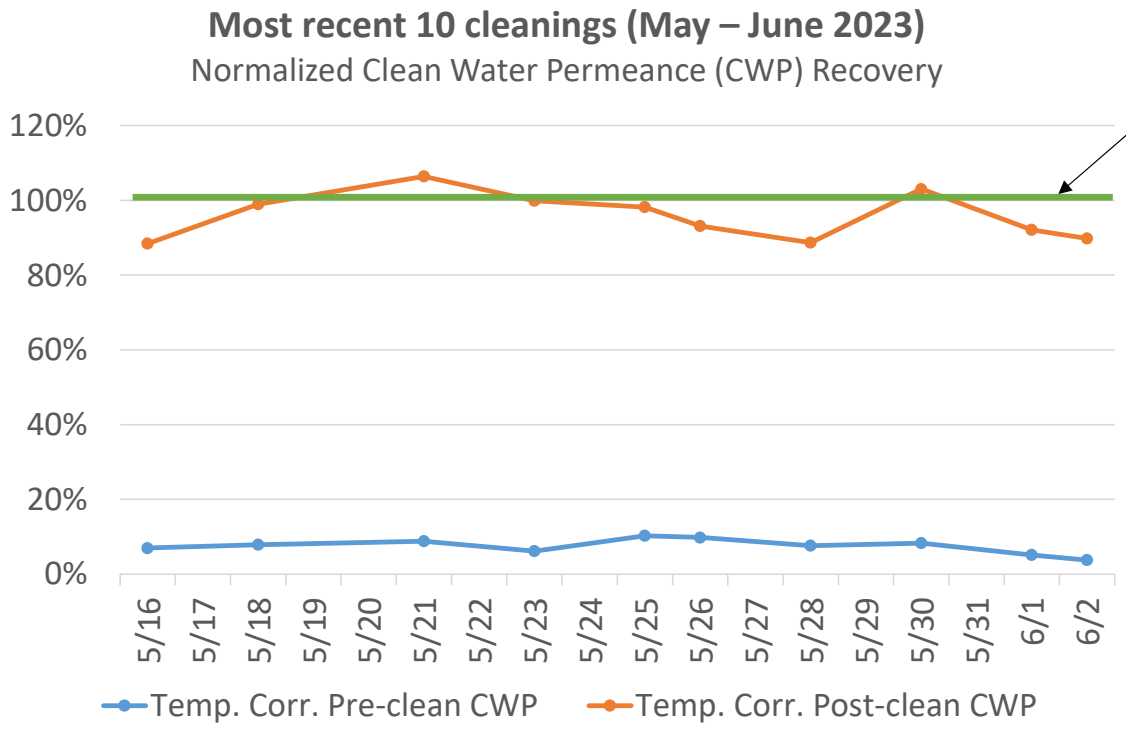
ZwitterCo

Maintenance Wash Information

- Maintenance Wash Cycle:
  1. Flush to drain with water & Clean Water Permeance test @ 50 psi
  2. Recirculation of 100 ppm Cl_2 @ pH 12 / ambient temperature for 1 hour
  3. Flush to drain with water & Clean Water Permeance test @ 50 psi



Full-scale Permeance Recovery



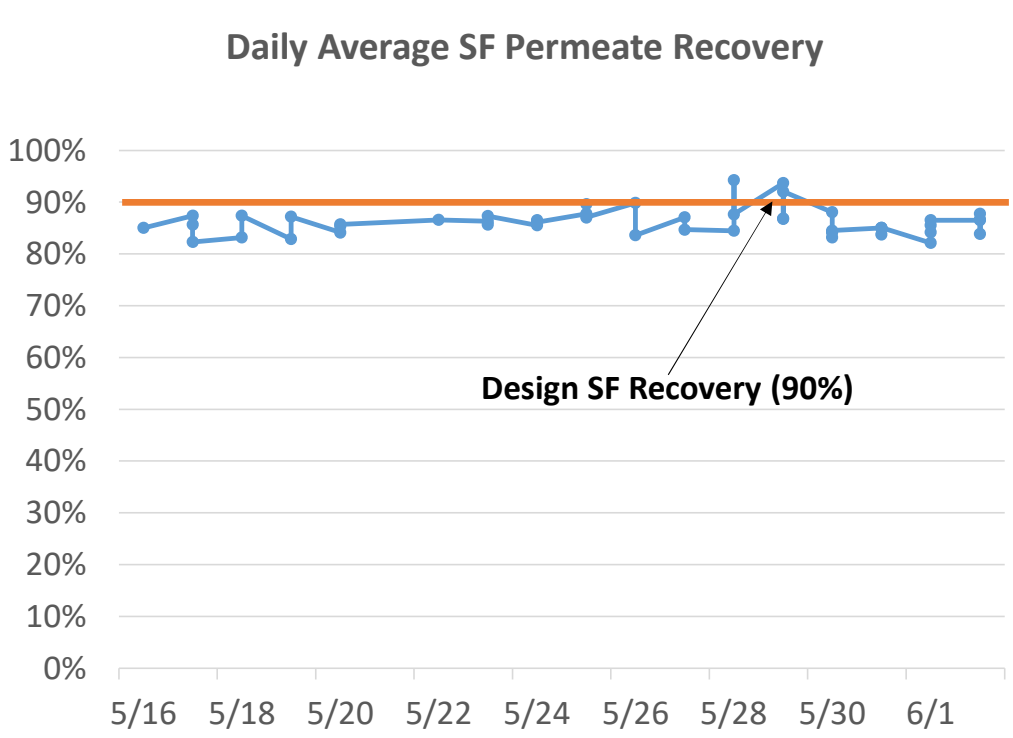
Plant Start-up Clean Water Permeance (CWP)

- Plant Start-up: **Oct. 27, 2022**
- CWP data points after > 7 months of operation
- Normalized to clean water permeance upon start-up in Oct. 2022
- ~ 60-70 mild maintenance wash (MW) since start-up

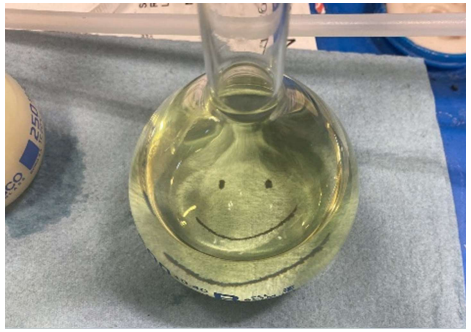
Key Learnings

Key Learning	Recommendation
Variation in wastewater characteristics • High strength wastewater (HS WW) from evaporator, low strength wastewater (LS WW) from wash water/ CIP) • Limited tank size (~ 50K gal) leads to process variability	**Sufficient tank volume** • Allow proper blend of high strength wastewater and low strength wastewater • Consistent feed water quality to the membrane system • Continuous supply of wastewater to the membrane system
Temperature variance • Temperature spikes (> 122°F) - wastewater straight from the feed tank (high temp. process) • CIP wash water at 95°F	**Heat Exchanger** • Maintain temperature of incoming feed • Suitable for optimal membrane operation
Site Location • Wastewater treatment system located inside the building close to the boiler room • High ambient temperature • Cooling required for control panel	**Standalone building** • Containerized solution
Process Integration • Facility not used to continuous wastewater treatment operations	**Training** • Training to adopt to the process changes

Pushing the limits of spiral membranes



Stage-1 Permeate & Raw Feed



Stage-2 Permeate

'Successfully taking trucks off the road and saving the customer money'

– Kam Braxton (Project Engineering Manager, Digested Organics)

Q&A

Umang Yagnik
Senior Channel Growth Manager
uyagnik@zwitterco.com

PS: Are you ready for Episode-III at MTF 2024?

Appendix

Common Dairy Wastewater Treatment Options

Technology	Pros	Cons	Water Reuse Quality?
Dissolved Air Flotation (DAF)	• Low CAPEX • Easy install • Mature technology	• Frequent upsets/pass-through (surcharges) • Sludge management • High chemical costs • Large footprint	No
Aerobic Treatment / Activated Sludge	• Customizability	• High electricity consumption • Sludge management • Bio upsets • Pass-through	No
Anaerobic Digestion (AD)	• Generates RNG (if captured)	• Large footprint • Not modular • Bio upsets • Pass-through	No
Hauling	• Low to no CAPEX	• Highest OPEX	No

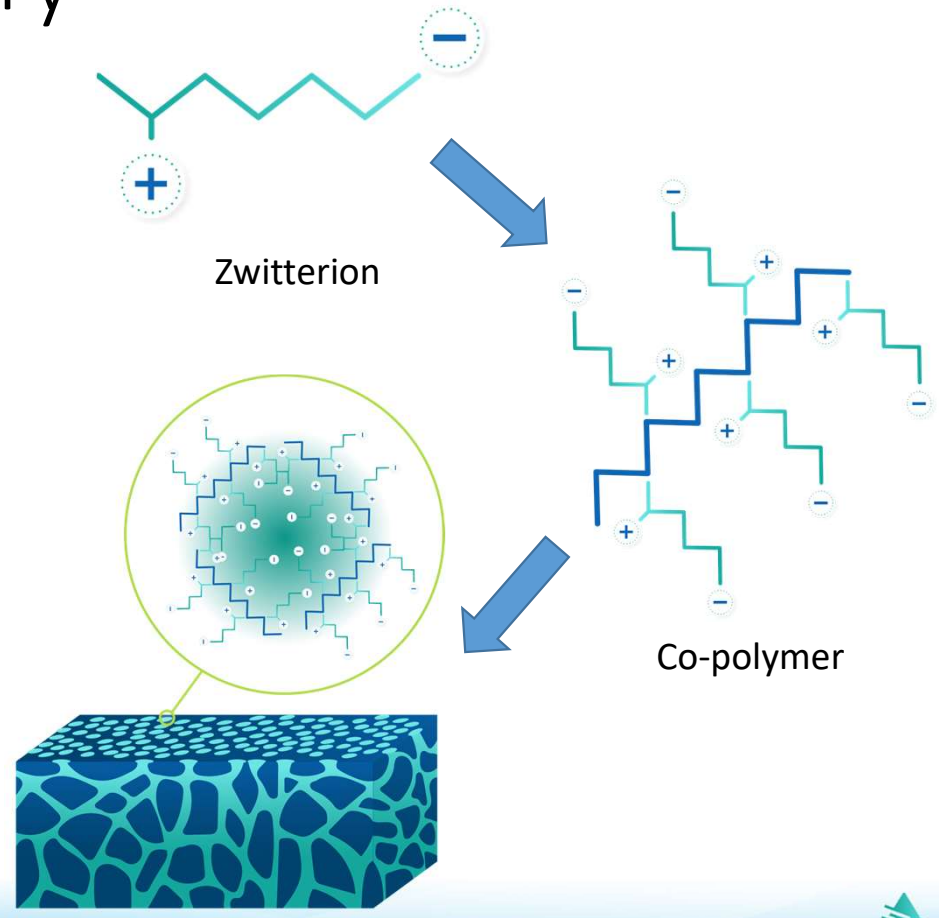
Zwitterionic Membrane + RO Treatment

Technology	Pros	Cons	Water Reuse Quality?
Membrane (Zwitterionic SF + RO)	• Modularity • High effluent quality • Robustness	• Moderate CAPEX (skid, membranes) • Concentrate management	Yes
Dissolved Air Flotation (DAF)	• Low CAPEX • Easy install • Mature technology	• Frequent upsets/pass-through (surcharges) • Sludge management • High chemical costs • Large footprint	No
Aerobic Treatment / Activated Sludge	• Customizability	• High electricity consumption • Sludge management • Bio upsets • Pass-through	No
Anaerobic Digestion (AD)	• Generates RNG (if captured)	• Large footprint • Not modular • Bio upsets • Pass-through	No
Hauling	• Low to no CAPEX	• Highest OPEX	No

The Science behind Zwitterionic Membranes

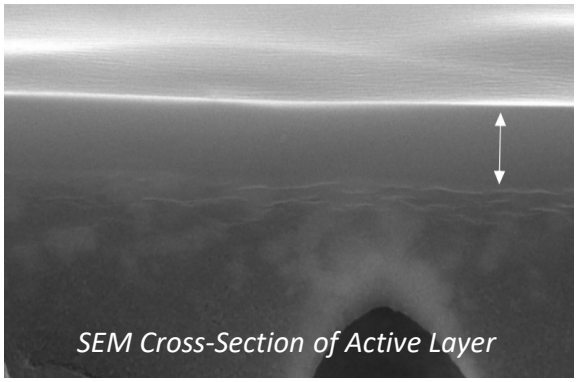
A New Material Chemistry

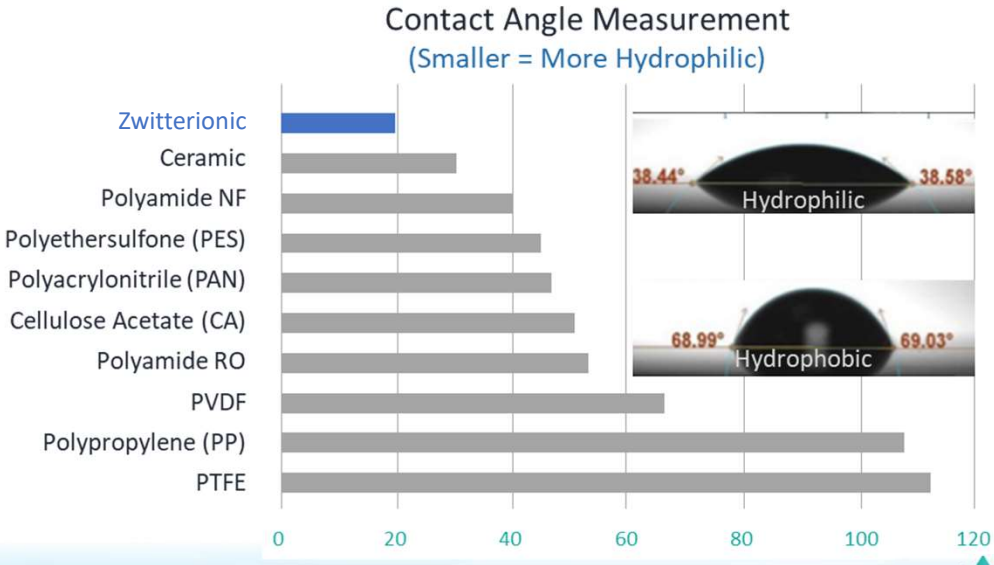
- Patented zwitterionic co-polymer chemistry
- Water-loving zwitterions are combined with a strong, hydrophobic backbone
- The zwitterionic surface and pores **attract water and repel organics** to prevent fouling and **easily regenerate upon cleaning**



Extremely Low Fouling

- Smooth Surface
  - Resistant to Macro-Fouling
- Net-Neutral Surface Charge
  - No ionic interactions
- Lowest Surface Contact Angle
  - Extremely hydrophilic

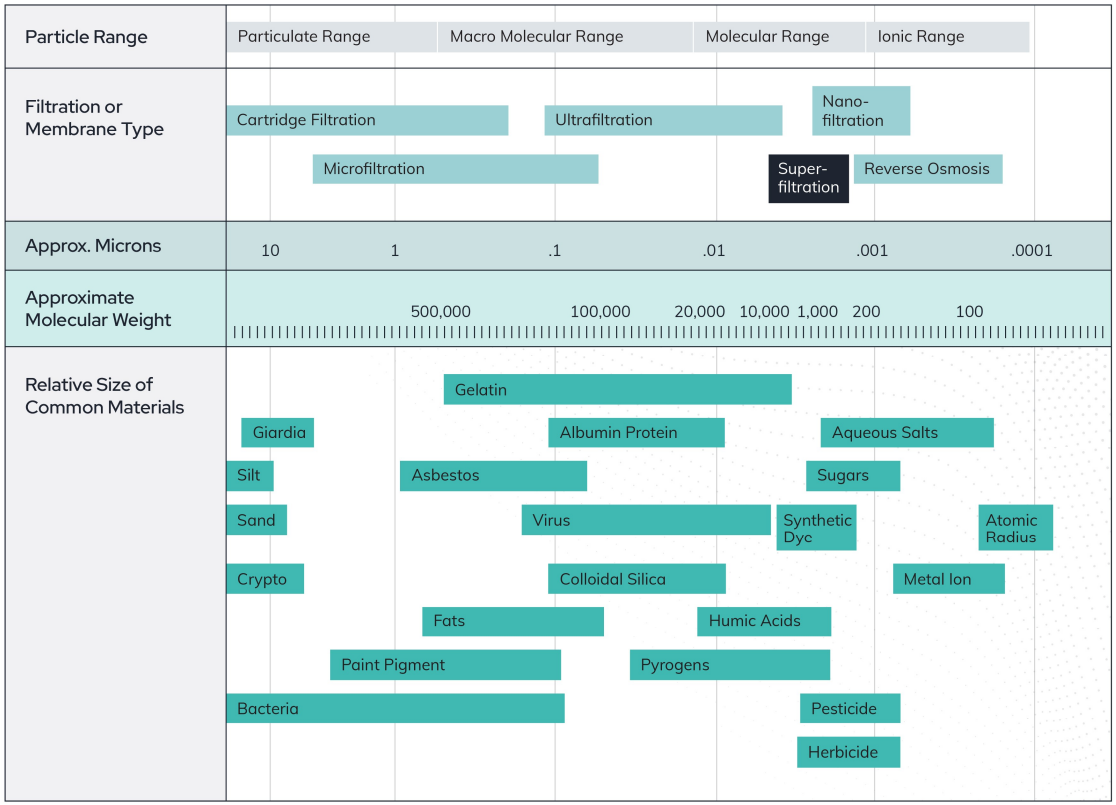




A Unique Superfiltration Membrane

- **Superfiltration** (SF) membranes are a class of membrane that **falls between ultrafiltration (UF) and nanofiltration (NF)**

- SF membrane characteristics:
  - MWCO of 500 – 3,500 Daltons
  - Lower salt rejection than NF
  - Generally used in process separations or wastewaters
  - Often have special properties (chlorine-tolerance, wide pH, etc.)



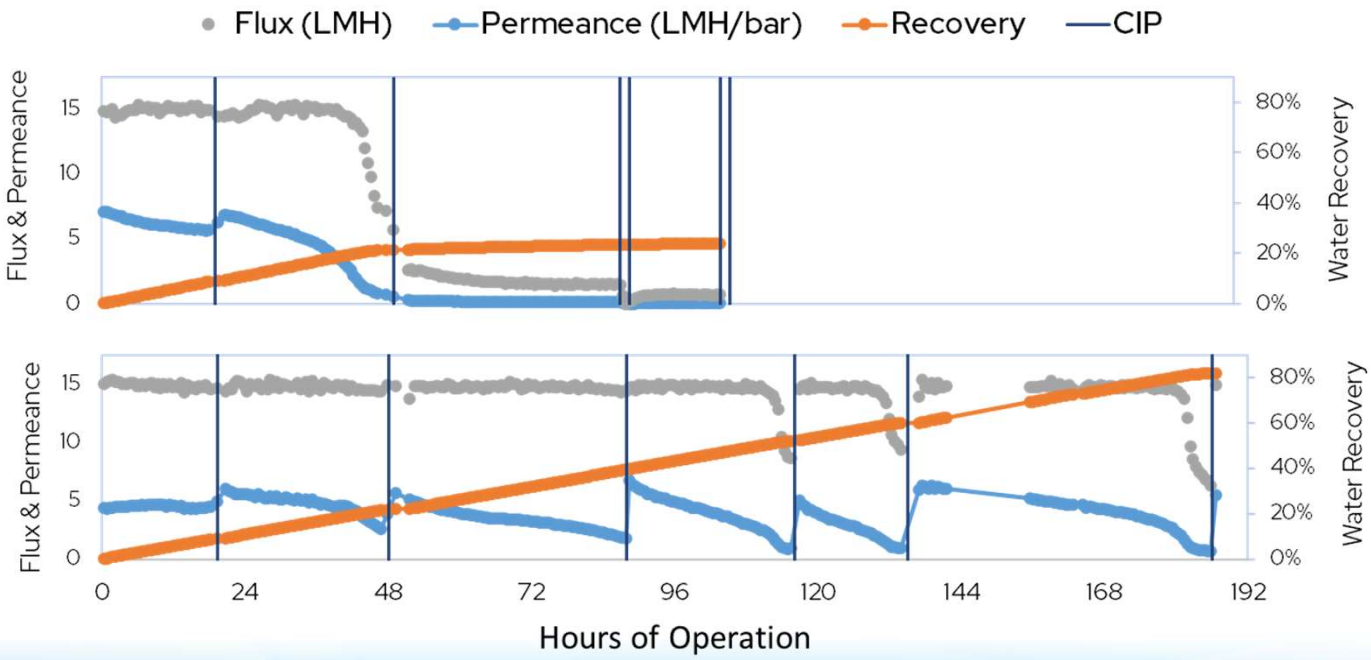
Case Study

Dairy WW Bench Test vs. Standard Membrane

Dairy wastewater fouls standard membranes. A competitive UF membrane rapidly lost performance. Zwitterionic membranes recovered flux after maintenance wash and concentrated the organics by 5x.

Competitive Membrane (PES, 5 kDa)

Zwitterionic Membrane (Zwitterionic, 1 kDa)



Irreversible performance loss
- < 48 hours
- 20% recovery

Full recovery after every wash
- > 180 hours
- 80% recovery

Dairy WW Field Test Results