ZwitterCo

Elevation Case Study

Fouling resistant ZwitterCo Elevation RO Membrane Deployment

for High-Strength Biorefinery Wastewater Treatment

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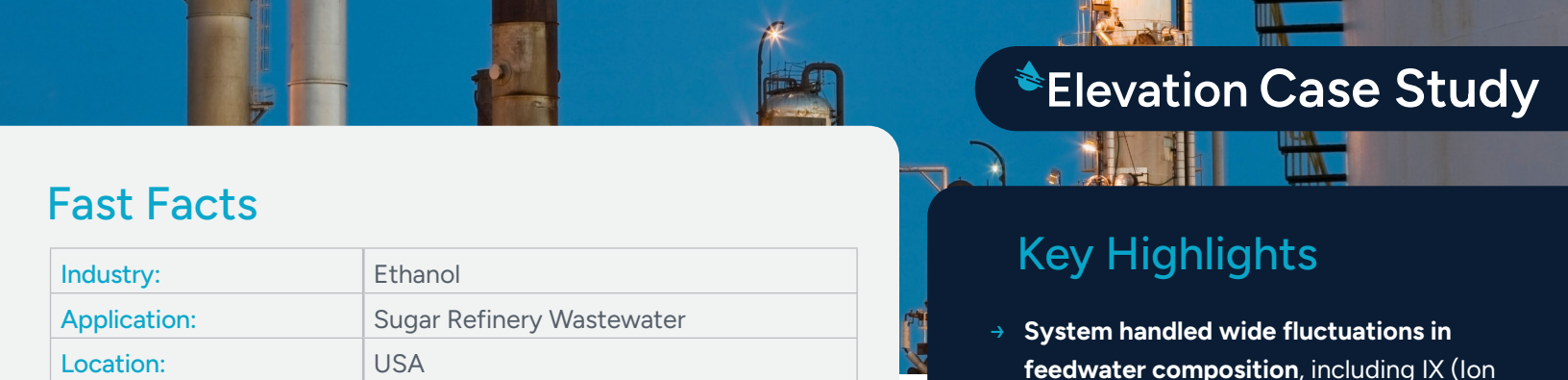

Elevation Case Study

Fast Facts

Industry:	Ethanol
Application:	Sugar Refinery Wastewater
Location:	USA
Technology:	ZwitterShield™
Element Type and Model:	Elevation High Rejection RO 8040
No. of Elements Supplied:	96
No. of Elements per Pressure Vessel:	6 per vessel x 16 PVs
System Design:	1 x train – single-stage with recirculation design (max. pressure ~ 405 psi (28 bar))
System Operating Conditions:	**Feed Flow:** 240 GPM (55 m^3/h) **Max Operating Pressure:** 385 psi (26 bar) **Feed temperature:** 90-100°F (32-38°C) **Feed pH:** 3.5-9
Year of Installation:	2024

Key Highlights

- **System handled wide fluctuations in feedwater composition**, including IX (Ion Exchange) washwater with sugars, proteins, color, and trace oil
- **Recirculation-enabled RO design** accommodated swings in feed conductivity while maintaining high recovery across dynamic operating conditions.
- **Delivered consistent permeate quality** to support stable clarifier and MBBR performance under variable loading.
- **Reduced chloride load** prior to biological treatment, supporting compliance with stringent discharge limits.
- **Minimized municipal discharge dependency**, contributing to more self-contained wastewater management

The Opportunity

In pursuit of a more robust solution for complex sugar refinery wastewater, a biorefinery partnered with ZwitterCo to evaluate the use of fouling-resistant reverse osmosis membranes. This collaboration was part of a broader initiative to assess innovative membrane technologies for industrial wastewater management. The goal was to determine whether advanced RO membranes could meet the site's stringent requirements for recovery, salt rejection, and cleanability, particularly under conditions of high salinity, and elevated nutrient and organic loads.

The Challenge

The site generated a complex wastewater stream containing high levels of dissolved salts, nutrients, and organic residues. The effluent routinely exceeded permissible limits for key parameters such as chloride, phosphate, total dissolved solids (TDS), and nitrogen compounds. The situation was further complicated by significant variability in wastewater composition, driven by fluctuations in upstream operations.

The facility relied on a moving bed biofilm reactor (MBBR) for biological treatment. However, elevated salinity and conductivity inhibited microbial performance and reduced nutrient removal efficiency, increasing the risk of non-compliance with discharge permits. To protect the biological system and stabilize overall plant performance, a pretreatment solution was required, one capable of reducing ionic load and salinity without introducing additional operational complexity. The solution also needed to maintain reliable cleanability, high recovery, and strong salt rejection while accommodating fluctuating feedwater quality.

The Solution

To address elevated conductivity and its impact on downstream biological treatment, a high-rejection reverse osmosis (RO) membrane system equipped with fouling-resistant membranes was deployed. The system was configured as a single-stage, high-recovery RO with recirculation, optimized to manage variable feedwater conditions while minimizing brine volume and maximizing water recovery. ZwitterCo Elevation RO membranes are powered by ZwitterShield™ technology. ZwitterShield is an additive membrane technology using ZwitterCo's patented zwitterionic chemistry that may be bonded to proven membrane chemistries to equip them with a permanent barrier to irreversible organic fouling.

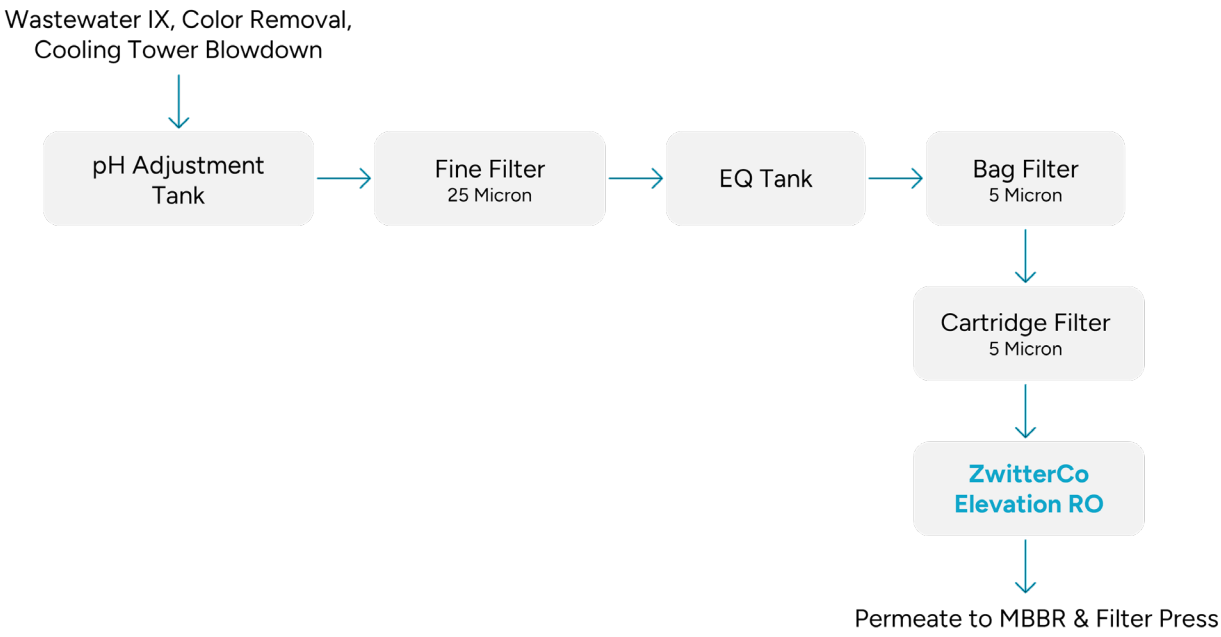

Figure 1: *Process Flow Diagram (PFD) for sugar refinery wastewater treatment*

As illustrated in the flow diagram, the wastewater stream was first pretreated using 25-micron and 5-micron filtration to remove particulates and protect membrane surfaces. The filtered feedwater was then routed to the Elevation RO system, which operated at pressures up to 385 psi (26 bar) with dynamic concentrate recirculation and staged brine management to sustain high recovery and extend membrane life.

A simplified two-step Cleaning-in-Place (CIP) protocol was implemented, using sequential acid and caustic cycles conducted at 85–90°F (29–32°C). Each CIP was completed in under three hours using standard cleaning infrastructure, without requiring system modifications or specialized hardware. The deployment of ZwitterCo Elevation RO system provided the required reduction in conductivity and inorganic loading prior to biological treatment, while delivering stable performance, reduced fouling, and high recovery across a variable operating window. The integration of this membrane solution improved effluent conditioning, supported compliance, and enhanced the overall reliability of downstream biological processes.

Parameter	Avg. Feed (mg/L)	Max. Feed (mg/L)	Permeate (mg/L)	Rejection (%)
TDS	7,580	23,000	544	92.8%
COD	2,739	85,000	280	~90%
Chloride	2,670	7,655	250	90.6%
TKN	100	400	6	94.0%
Phosphorus (total)	480	2,115	2.24	99.5%
Potassium	579	1,332	57.0	90.2%
Sulfur	24.4	55	0.5	98.0%
Phosphate (P_2O_5)	1,100	2,115	5.1	99.5%
TSS	110	500	9	91.8%

Table 1: Rejection (%) chart for ZwitterCo Elevation RO membranes

The Results

Table 1 summarizes the influent water quality faced by the ZwitterCo Elevation RO membranes. The feedwater exhibited not only high baseline salinity and nutrient loading, but also extreme variability, particularly during IX regeneration cycles. For example, Total Dissolved Solids (TDS) averaged 7,580 mg/L but peaked at 23,000 mg/L, representing a nearly 3× increase.

Despite these challenging and dynamic conditions, the Elevation RO membranes consistently delivered high rejection performance across all major contaminant classes. Dissolved ions such as chlorides, TDS, potassium, and phosphorus were rejected at rates between 90–99.5%. Nutrients like Total Kjeldahl Nitrogen (TKN) and phosphorus achieved removal efficiencies exceeding 94%, supporting downstream compliance. Organic and particulate loads, reflected by COD and total suspended solids (TSS), were also reduced by approximately 90% or more, ensuring stable downstream operations and system protection.

Stable and continuous operation of the Elevation High Recovery RO system enabled consistent data collection across a representative operating window. Volume recovery at the RO outlet ranged from 60% to 80%, and this recovery range was maintained across feedwater variability and loading fluctuations. No significant deviations were observed, and recovery trends remained consistent throughout the evaluation period, as shown in Figure 2.

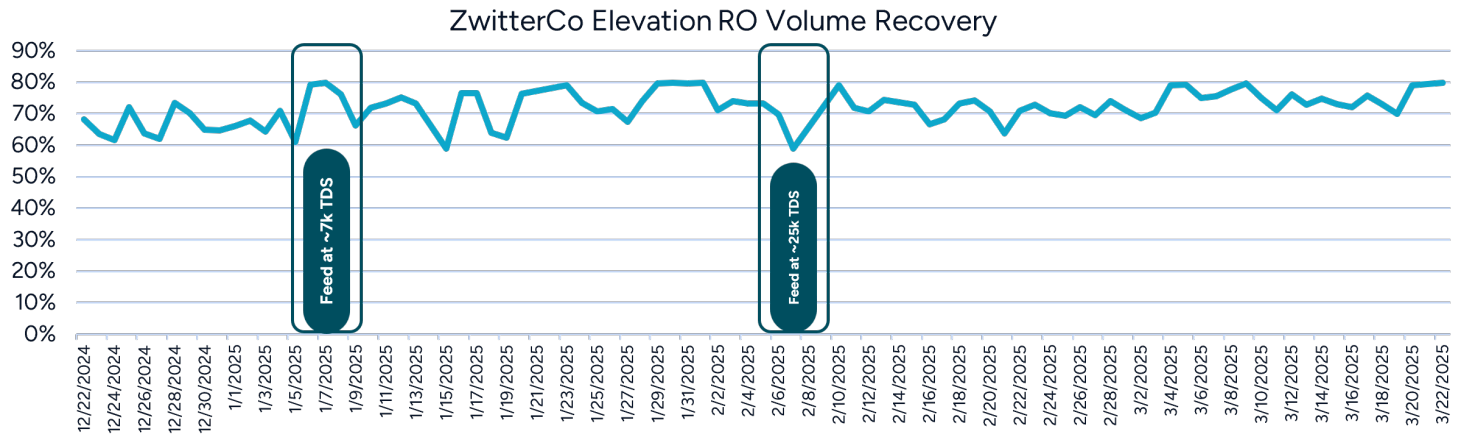

Figure 2: Volume Recovery of ZwitterCo Elevation RO membranes treating high strength sugar refinery WW

Flux remained stable between 5.5 and 8.5 GFD (9.4–15 LMH) across the observation period and fully recovered following each CIP, confirming effective fouling removal and operational stability. Differential pressure (dP) peaked above 25 psi (1.7 bar) prior to each cleaning event and consistently returned to baseline after CIP cycles—indicating surface-level fouling with no evidence of irreversible blockage or membrane stress.

Salt rejection performance also remained high, with conductivity rejection exceeding 90% throughout operation, as illustrated in Figure 3. Occasional dips in rejection were attributed to low pressure flushes and an idle RO system during plant downtime, which inherently provided low salt rejections.

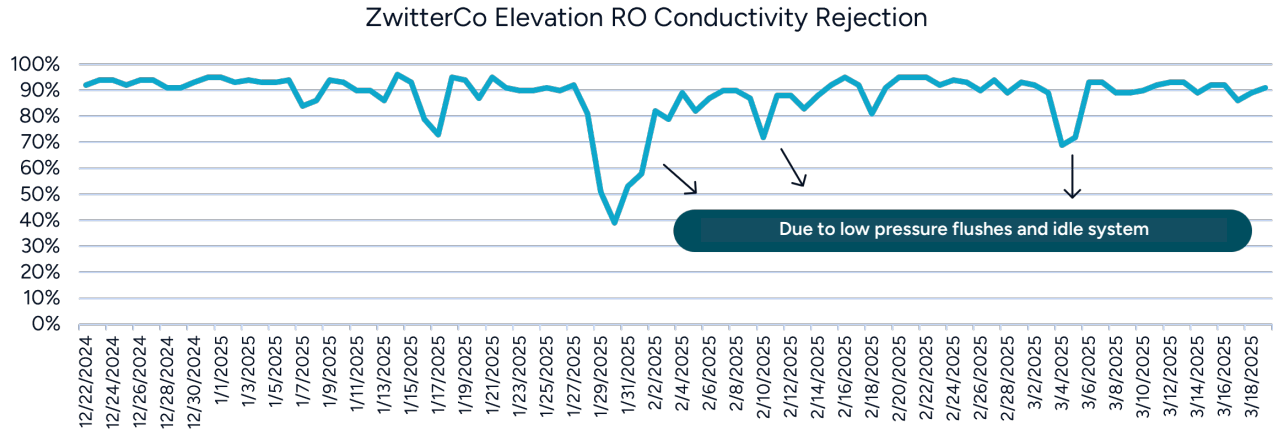

Figure 3: *Conductivity Rejection of ZwitterCo Elevation RO membranes treating high strength sugar refinery WW*

Conclusion & Outlook

ZwitterCo Elevation high-recovery RO system with recirculation demonstrated the ability to treat a saline, organic-rich wastewater stream with variable composition using a low-fouling membrane platform. Volume recovery ranged from 60–80% across the operating window, with pressure and flow trends remaining within design expectations. Cleaning cycles restored membrane performance with no signs of irreversible fouling or baseline drift. Recovery performance was maintained under fluctuations in feed conductivity, without compromising salt rejection or system stability. Salt and nutrient rejection exceeded 90%, including chlorides and phosphorus, contributing to stable permeate quality for downstream clarification and biological treatment.

The system managed organic fluctuations including residual sugars, proteins, color, and trace oil without increasing cleaning frequency or impacting throughput. By reducing the burden on municipal discharge systems, the solution contributed to more autonomous wastewater handling within the facility's treatment train and improved the overall resilience of the treatment process.

ZwitterCo

ZwitterCo has developed a breakthrough in materials science - a new class of zwitterionic membranes with unprecedented fouling resistance. Our membrane solutions perform beyond the limits of conventional filtration, making it practical to treat complex wastewater, purify water for reuse, and maximize efficiency in food processing applications. ZwitterCo serves customers in more than 20 countries across food and beverage, agricultural, and industrial sectors. We are rapidly investing in our technology, equipment, and global services platform to help our industrial customers achieve their most ambitious sustainability and growth targets.

We are grateful to have been named as Global Water Intelligence's 2023 Breakthrough Water Technology Company of the year and Fast Company's Top Innovators of 2024.

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