POWERING THE FUTURE

An Evolution in Reverse Osmosis for Power Generation

ZwitterCo

OVERVIEW

Reverse osmosis (RO) membranes are a cornerstone in industrial applications, particularly in power generation, where water is essential. However, despite their crucial role, traditional RO membranes often face significant challenges that can disrupt operations.

In the power generation industry, two main challenges often arise: **frequent membrane cleaning** and **unplanned system downtime** due to upstream upsets.

In the past 40+ years, membrane development has been incremental, but the era of new membrane chemistry has finally arrived. ZwitterCo has developed an advanced RO membrane that uses zwitterionic chemistry to solve these challenges. This innovative membrane technology ensures **reduced cleaning, which means less downtime, longer membrane life, and lower costs.** ZwitterCo is not reinventing the wheel – just making it *better*.

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CHAPTER 1

Identifying Problems with RO Membranes

Power generation plants use fuels such as coal, gas, or nuclear energy to make heat, which is converted into electrical energy. Most of them heat water to transform it into steam, which spins the turbines that produce electricity. After passing through the turbine, the steam is cooled down and condensed to start the cycle again, closing the “steam cycle”. Because power plants require large quantities of water for their processes, the plants are often built near surface water sources such as rivers, lakes, and oceans.

Maintaining water volumes in a power plant is vital for ensuring effective operations. In the steam cycle, water and steam losses occur naturally, usually by evaporation or process use. These losses need to be replaced by adequately purified make-up water.

Just as maintaining water volumes is crucial to power generation, so is the water quality. Surface waters typically contain higher concentrations of impurities including suspended solids, organic constituents, and dissolved salts (e.g., calcium, magnesium, silica, etc.), all of which must be removed prior to sending the make-up water to boilers for heating. For this reason, make-up water is first pretreated to remove floating and suspended materials. It is then treated by reverse osmosis membrane elements to remove dissolved organics and salts.

One of the biggest challenges with RO systems at power generation plants is **membrane fouling** from the organic material found in surface waters, or when unexpected upstream upsets occur.

While RO membranes may be chemically cleaned to remove these organic materials and recover performance, **cleaning accelerates the deterioration of RO membranes, requiring regular replacements, causing significant operational burdens, and driving up operational costs.**

UNPLANNED DOWNTIME DUE TO **UPSTREAM UPSETS**

While upstream system upsets are undesirable, they are inevitable and can severely impact downstream processes, including the RO system. **Such upsets often lead to membrane fouling, resulting in system downtime required for maintenance.**

This downtime is detrimental to consistent power generation, incurs unexpected costs, and presents additional headaches as these interruptions typically occur without warning. Often to address these issues, power plants redirect staff from critical tasks to restore operations or resort to costly alternatives such as renting mobile units or purchasing water from local authorities to maintain adequate water supply.

DOWNTIME DUE TO **FREQUENT CLEANING**

Due to the high organic and biological content found in surface waters, many existing RO systems treating boiler make-up water struggle with organic fouling or biofouling challenges, resulting in a rapid decline in RO system performance. To restore performance, the system is shut down to perform chemical cleanings. The more fouling the feed stream, the more frequently cleaning is performed, which results in excessive system downtime.

Frequent system shutdowns to clean membranes place a significant strain on boiler make-up water production and, consequently, on power generation. The associated costs of this downtime and maintenance can be substantial, further highlighting the need for innovative solutions to address these fouling challenges.

CHAPTER 2

Real-Life Example in the Pacific Northwest

In the United States, a power plant treating river water for boiler make-up in the Pacific Northwest has been struggling with persistent maintenance issues and frequent downtime. The facility relies on RO systems to produce the necessary high-quality boiler make-up water.

CLEANING FREQUENCY

Despite the previous installation of conventional fouling-resistant RO elements, the plant continued to face persistent organic fouling issues, conducting chemical cleanings at least once a month. This high frequency of maintenance not only disrupted operations but also led to the replacement of RO elements every 12-18 months when performance standards were no longer met. In search of a solution, they put ZwitterCo RO elements to the test.

The power plant's RO system includes two parallel trains, each a three-stage array with six elements per vessel. One train was equipped with a new set of conventional fouling-resistant RO elements, while the other housed ZwitterCo's Low Energy RO elements. The plant wanted to determine whether the ZwitterCo RO elements would allow them to benefit from less frequent element cleaning and downtime.

Figure 1: Coupons demonstrating the increase in SDI due to the upstream coagulant upset in November 2023.

UPSTREAM UPSET

Shortly after the installation, the plant experienced an unplanned upset: an accidental overdose of coagulant upstream of the RO system.

This event caused a **significant increase in the Silt Density Index (SDI)** of the feed water, spiking from 0.932 to 4.97, which posed a severe challenge to the RO membranes (Figure 1).

The accidental overdose of coagulant caused the first stage of the conventional elements to experience a high pressure drop, forcing the plant to shut down and clean the elements multiple times to restore membrane performance.

CHAPTER 3

ZwitterCo RO Membranes as a Solution

> Our process would not be **profitable or possible** without ZwitterCo membranes.
>
> Dr. Kondrad Miller
> *VP, Manufacturing, Science, & Technology,* Solugen

CONSISTENT IN UPSTREAM UPSET

Despite the coagulant, the ZwitterCo RO elements were unaffected, continuing to produce stable permeate flow and seeing a minimal increase in pressure drop.

Due to their consistent performance, the ZwitterCo RO elements did not require any chemical cleaning, offering the power plant reliable operation and zero system downtime (Figure 2). This incident highlighted the vulnerability of conventional RO systems to upstream upsets and underscored the need for more resilient solutions.

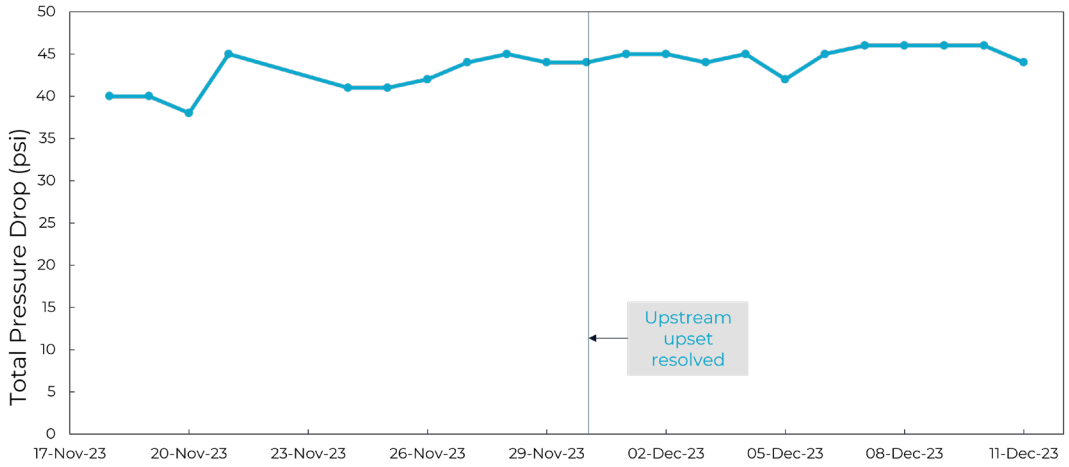
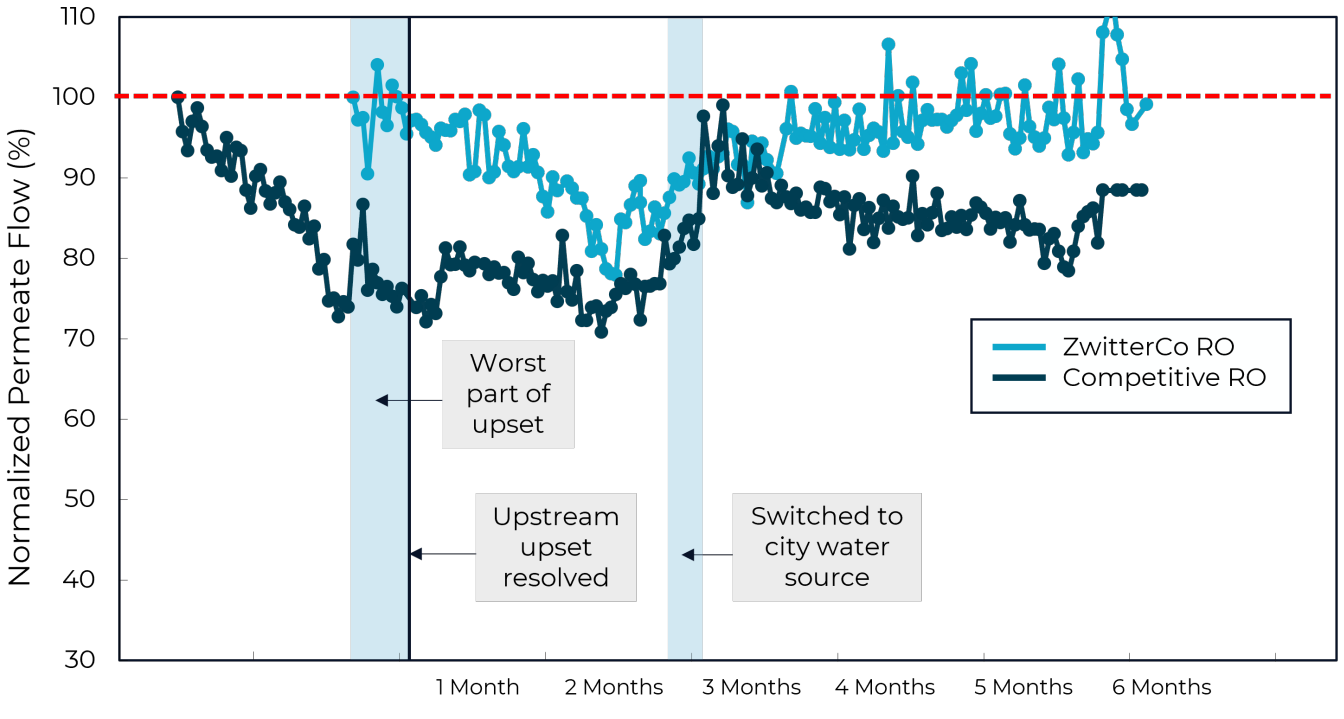


Figure 2: ZwitterCo RO elements demonstrated stable performance (minimal increase in pressure drop) during and after the increase in feed SDI due to the upstream upset.

LESS CLEANING NEEDED/LESS CHEMICALS

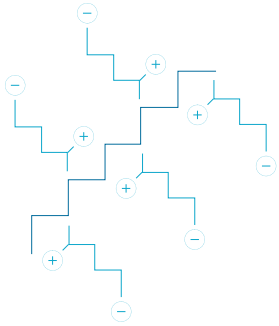
Over the first six months of operation at the power generation plant, the first stage of the train housing the conventional fouling resistant RO elements repeatedly showed significant performance decline, with permeate flow dropping noticeably after start-up (Figure 3). Because of this, the plant had to shut down and clean these elements four separate times in an effort to restore membrane performance. Despite these cleanings, the conventional RO elements have not fully recovered performance.



The ZwitterCo RO elements, on the other hand, demonstrated more stable performance and continue to operate at similar permeate flows as they did at start-up. At the time of writing, the installation had been operating without needing a chemical cleaning for more than six months.

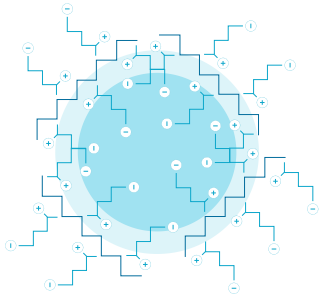
CHAPTER 4

Why ZwitterCo Membranes Are Different



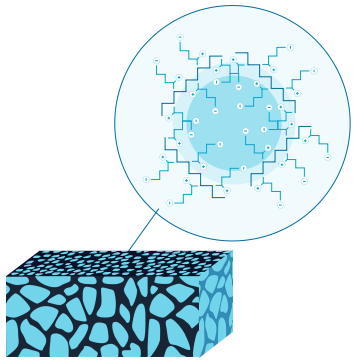
POSITIVE & NEGATIVE CHARGES

First, zwitterions attract to water molecules, displacing or repelling organic compounds.



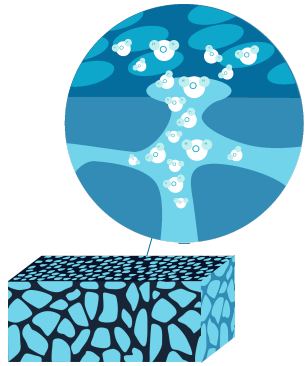
PROPRIETARY CO-POLYMERS

Co-polymers bind zwitterions with hydrophobic molecules for stability, preventing wearing away over time.



FOULING IMMUNITY

Zwitterions create water-loving channels, ensuring immunity to fouling internally and externally.



CLEAN PERMEATE

Zwitterionic channels retain contaminants and produce clean water and can operate for years at full capacity.

THE SCIENCE

ZwitterCo has set new standards in the membrane industry with its innovative zwitterionic technology. By integrating the technology with proven commercial brackish water membranes, ZwitterCo RO addresses the critical and persistent issue of irreversible organic fouling - making it a thing of the past.

A zwitterion is simply a small organic molecule that carries both positive and negative charges, which balance each other out, resulting in a molecule that is net neutral. In 2013, researchers at Tufts University made a breakthrough, discovering that specialized copolymers combining hydrophilic zwitterionic monomers with hydrophobic monomers could yield stable materials with the astonishing ability to form self-assembled pore structures.

Being extremely hydrophilic, the zwitterions are central to ZwitterCo's membrane technology, as they create water-loving channels that prevent organic compounds from adhering to the membrane surface, significantly enhancing fouling resistance.

OPERATIONAL BENEFITS

ZwitterCo membranes offer unparalleled organic fouling resistance, reducing the frequency of high pH chemical cleaning by up to 90%. This means longer operational periods without the need for shutdowns and maintenance, enhancing overall system efficiency.

ECONOMIC BENEFITS

The economic advantages of ZwitterCo RO membranes are substantial long-term. By reducing cleaning frequency by up to 90%, ZwitterCo RO elements may also last at least twice as long as conventional RO elements, reducing element replacements and lowering overall operating costs.

Not only can ZwitterCo RO membranes reduce your overall operating expenses (OPEX) by 50% over four years, but they are also designed to be drop-in replacements, offering a no-risk opportunity for users to upgrade their system and lower costs without additional capital expenditure (CAPEX).

SUSTAINABILITY BENEFITS

Designed to offer stable performance even in high-fouling streams, ZwitterCo membranes can be fully restored with a simple water flush or mild cleaning. This results in at least twice the membrane life, which keeps OPEX costs low, minimizes waste, and reduces chemical usage.

Additionally, the longer element life helps reduce the number of used elements ending up in landfills, ensuring long-term performance with minimal environmental impact.

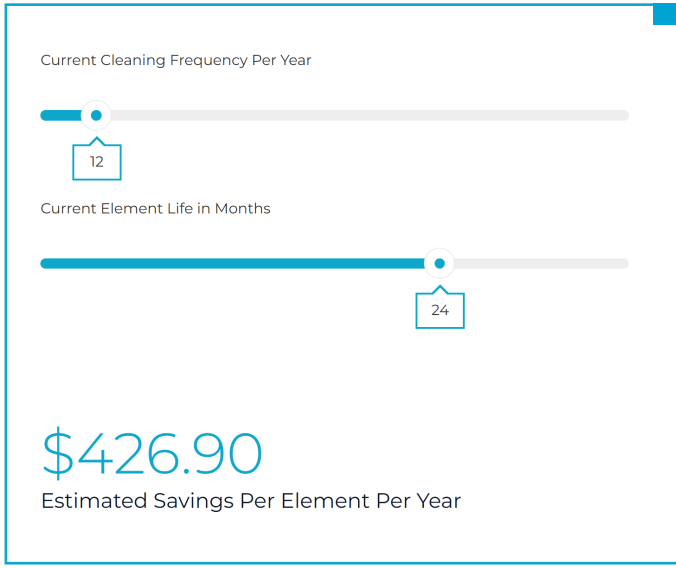


Figure 4: An industrial water treatment system using 150 x 8040 RO elements could reduce annual costs by $426.90 per element.

90%

Reduce cleaning cycles by up to 90% with ZwitterCo.

CHAPTER 5

Pricing and Availability

Both ZwitterCo RO High Rejection and Low Energy elements are generally available from stock or with very competitive lead times to meet customer requirements.

While the value delivered from lower cleaning costs, more uptime, and longer membrane life justifies a price 2-3 times that of a conventional RO membrane, ZwitterCo offers special pricing and terms as part of an RO Early Access Program. Our goal is to make it easy for users **to see the performance benefits for themselves.** This program not only allows early adopters to benefit from special pricing, but also offers tier 1 technical/operational support and direct access to our product team.

To learn more about the Early Access Program, click here.

Learn More

CONCLUSION

The introduction and adoption of new membrane chemistry is critical to make real change in the water industry, and as we often say – *every industry is a water industry*. This new era of membrane technology will enhance efficiency, sustainability, and cost-effectiveness, setting a new standard for water treatment and reuse.

ZwitterCo's innovative membranes are at the forefront of this change, offering solutions that are not only more effective but also more resilient. If you are interested in discovering how much your operation could save by switching to ZwitterCo membranes, we invite you to use our savings calculator or contact us directly for more information.

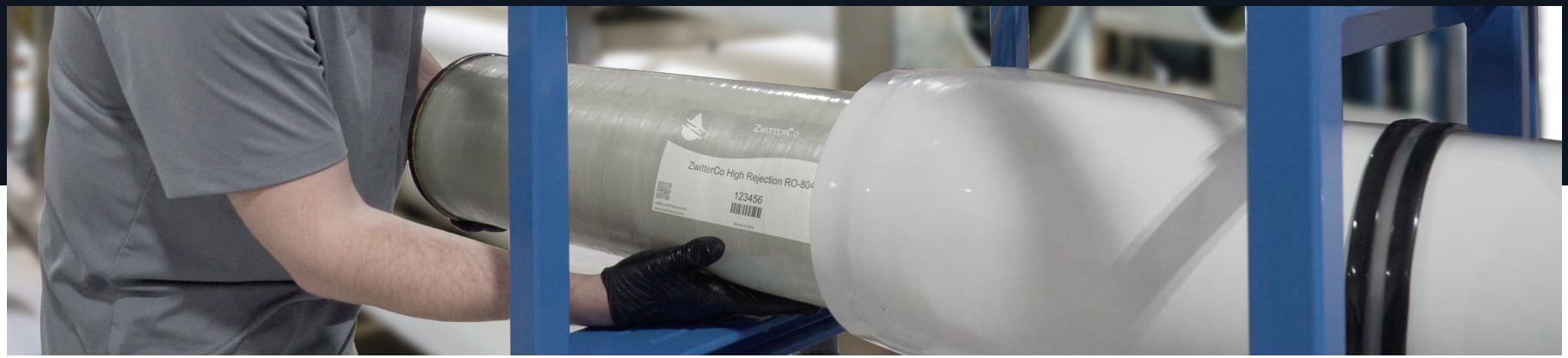
ADDITIONAL RESOURCES

APPLICATION BRIEF - DOWNTIME DUE TO CLEANING

APPLICATION BRIEF - DOWNTIME DUE TO UPSTREAM UPSETS

ABOUT ZWITTERCO

ZwitterCo has developed a breakthrough in materials science, a new class of zwitterionic membranes that are immune to irreversible organic fouling, making it practical and affordable to treat challenging water and wastewater. Our mission is to provide industries with the tools to create clean water from every source, whether it involves accessing novel sources of water, shoring up distressed assets, or enabling onsite wastewater reuse. The company has been recognized as Breakthrough Technology Company of the Year at the Global Water Summit and by the Department of Energy and the National Science Foundation as a leader in clean water technologies.



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