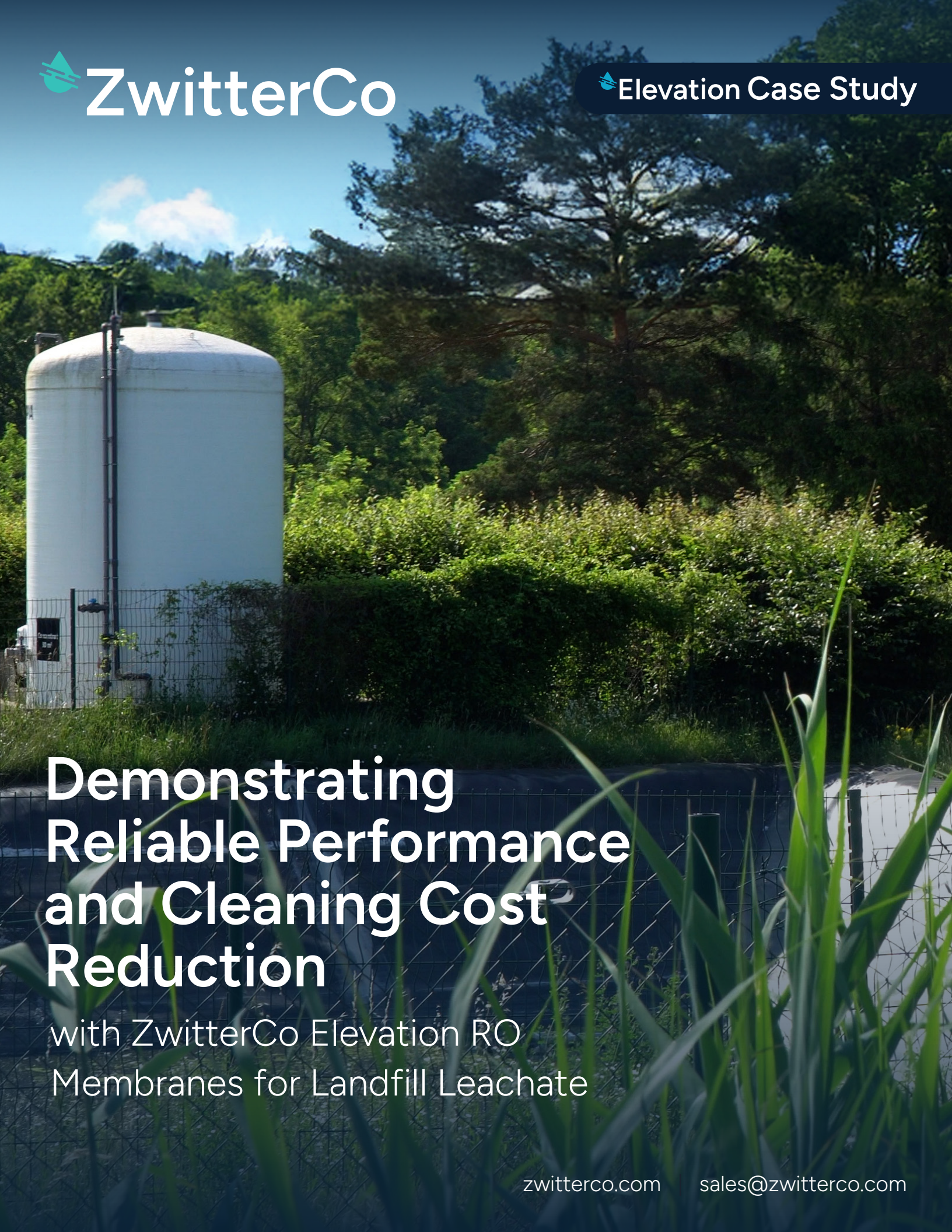
ZwitterCo

Elevation Case Study



Demonstrating Reliable Performance and Cleaning Cost Reduction

with ZwitterCo Elevation RO Membranes for Landfill Leachate

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Elevation Case Study

Fast Facts

Project Partner	Serpol
Industry	Waste Management
Application	Landfill Leachate
Location	Sytraival, France
Technology	ZwitterShield™
Element Type and Model	Elevation High Rejection BWRO 4040
System Operating Conditions	**Feed pressure:** 250 to 365 psi (17 to 25 bar) **Feed temperature:** 50 to 68°F (10 to 20°C) **Feed pH:** Adjusted to 6.5 by injecting sulfuric acid at the treatment inlet
Year of Installation:	2024

Key Highlights

- **~50% reduction in cleaning cost per m^3,** driven by lower chemical usage, extended membrane life, and reduced downtime.
- **Cleaning water usage reduced by 43%,** saving high value permeate used for CIP.
- **Membrane replacement frequency decreased by 65%,** enabling longer uninterrupted operation.
- **Maintained stable conductivity rejection** with >90% removal of organics, metals, and nitrogen, consistently meeting leachate treatment specifications.
- **Permeate suitable for reuse in non-potable applications,** supporting water reuse goals for truck washing and dust suppression.
- **Fully complatible with existing infrastructure,** requiring no changes to operating strategy or control logic.

The Opportunity

Serpol is a leading environmental services company in France with over four decades of expertise in contaminated site remediation, effluent treatment, and sustainable waste management. With advanced in-house process development capabilities and a strong record of full-scale implementation, Serpol delivers technically robust solutions across a wide range of industrial and environmental applications.

Among its most complex and demanding operations is the treatment of landfill leachate, a highly variable wastewater stream containing elevated levels of organic compounds, nitrogen species, heavy metals, and inorganic salts. To meet strict discharge and reuse standards, Serpol applies membrane-based separation processes alongside biological and chemical treatment methods. In 2017, the municipality of Sytraival launched a design, build and operate (DBO) tender aimed at reducing the cost of leachate treatment while also minimizing the consumption of potable water used for non-potable onsite tasks such as truck washing and dust control. Serpol was awarded the project with a membrane-centric treatment solution designed to address both treatment performance and water reuse.

The Challenge

The landfill leachate treated at the Sytraival site presents a complex and variable wastewater profile, containing elevated levels of organic compounds, nitrogen species, heavy metals, and inorganic salts. These constituents contribute to a combination of fouling mechanisms in reverse osmosis membranes, including organic adsorption, biofouling, colloidal deposition, and scaling. The result is a gradual decline in membrane performance, typically indicated by increased transmembrane pressure and reduced permeate production. Following the installation of a brackish water (BW) RO system, Serpol encountered significant operational challenges. Membranes required

daily clean-in-place procedures using alternating alkaline and acidic formulations. Despite this routine, cleaning effectiveness declined over time, and membrane elements had to be replaced every two to three months. A membrane autopsy confirmed that organic fouling was the dominant issue.

To address the situation, Serpol trialed various solutions, including specialized cleaning agents and alternative membranes from different suppliers. None were able to provide sustained improvement in membrane performance or system stability. These issues led to elevated chemical consumption, increased operating costs, and frequent downtime. Serpol set out to identify a membrane solution that could maintain stable flux, resist fouling, extend membrane service life, and reduce the frequency and complexity of cleaning under real-world landfill leachate conditions.

The Solution

In early 2024, Serpol initiated membrane evaluation at its landfill leachate treatment facility in Sytraival to assess the performance of ZwitterCo Elevation BWRO membranes under standard site conditions and without modifying the existing system design or control strategy. One pressure vessel was retrofitted with ZwitterCo Elevation High Rejection BWRO membranes for side-by-side evaluation against incumbent elements under identical feed and hydraulic conditions. Operating pressures ranged from 250–365 psi (17 to 25 bars), feed temperature was maintained between 50–68°F (10 to 20°C), and inlet pH was adjusted to 6.5 using sulfuric acid. A recirculation loop maintained ~70% system recovery. All control strategies, alarm thresholds, and cleaning protocols were unchanged. Permeate rinse occurred every 3–5 hours based on flow thresholds, with CIP triggered by post-rinse osmotic pressure. ZwitterCo Elevation BWRO membranes delivered stable flux and improved cleanability within the existing setup. Following performance validation, Serpol expanded ZwitterCo Elevation BWRO membranes across the entire system, achieving improved operational consistency without process modifications. Figure 1 provides an overview of the treatment process including prefiltration and reverse osmosis.

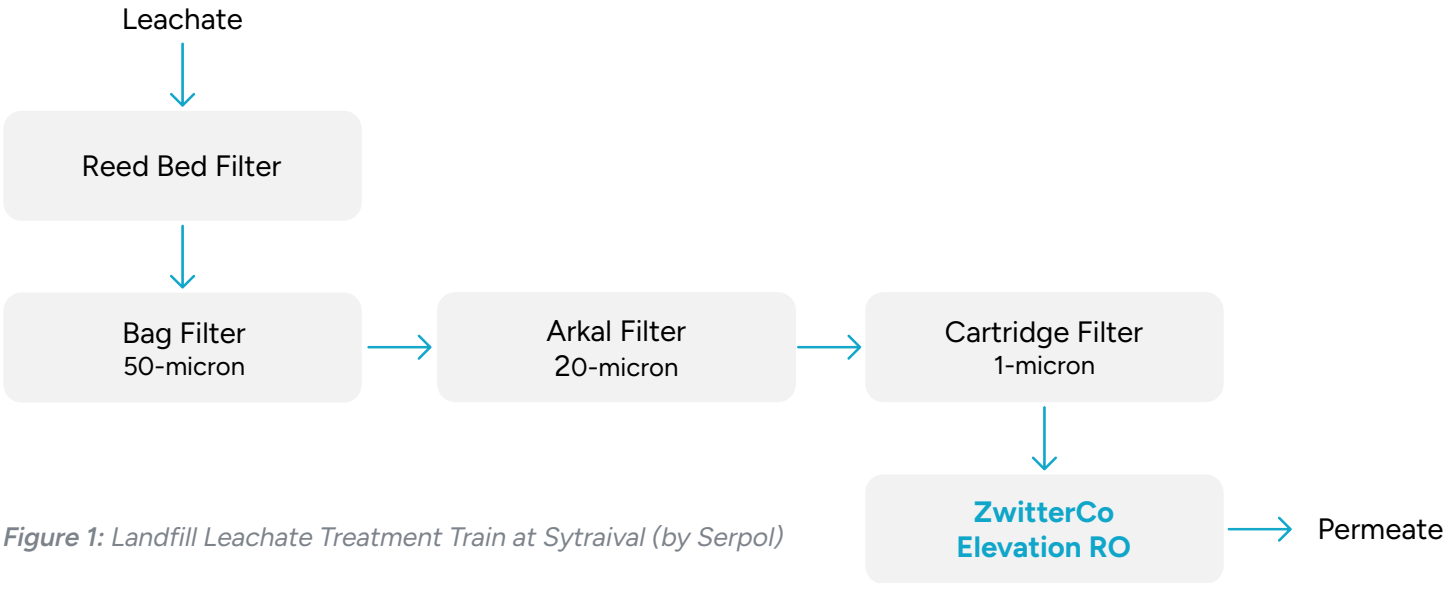

Figure 1: *Landfill Leachate Treatment Train at Sytraival (by Serpol)*

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The Results

The evaluation demonstrated a clear performance advantage for ZwitterCo Elevation BWRO membrane compared to a conventional BWRO element operating under identical landfill leachate conditions.

Normalized flux remained stable throughout the evaluation period for the ZwitterCo Elevation BWRO membrane, whereas the standard membrane exhibited a progressive decline in flux. To quantify performance consistency statistically, the coefficient of variation (CV) was calculated for each dataset. ZwitterCo Elevation BWRO normalized flux exhibited a CV of 6.7%, while the standard BWRO membrane showed a CV exceeding 23%, indicating significantly greater variability and fouling progression in the conventional system.

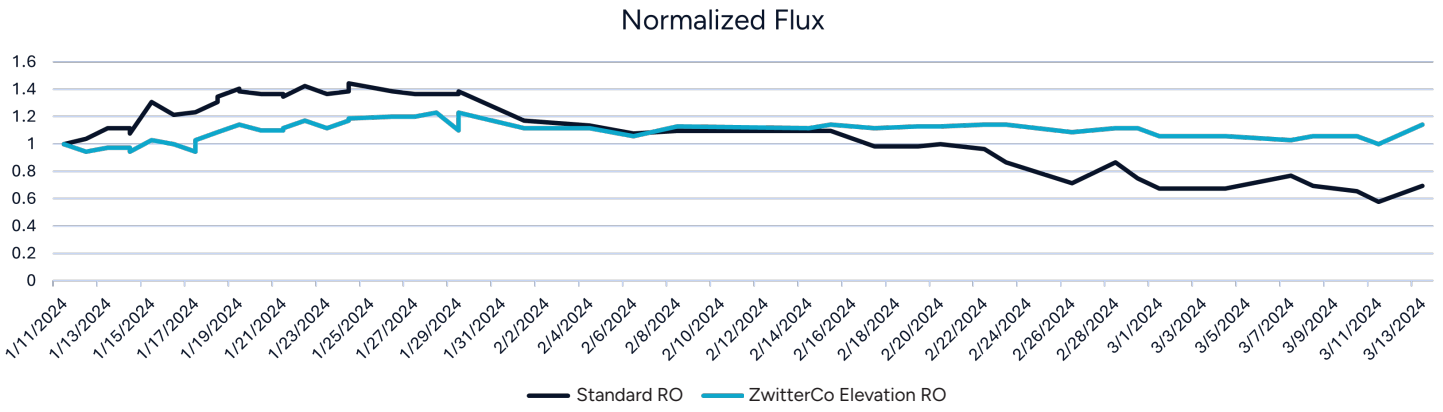

Figure 2: Normalized flux comparison of ZwitterCo Elevation BWRO and Standard RO

The conductivity rejection profile in Figure 3 illustrates consistent salt separation performance from both the ZwitterCo Elevation and standard RO membranes over the evaluation period. The ZwitterCo Elevation BWRO membrane exhibited a stable and repeatable rejection trend following a brief stabilization phase, maintaining high conductivity rejection across variable leachate conditions. This level of performance confirms that the membrane consistently achieved the site's conductivity-based treatment objectives.

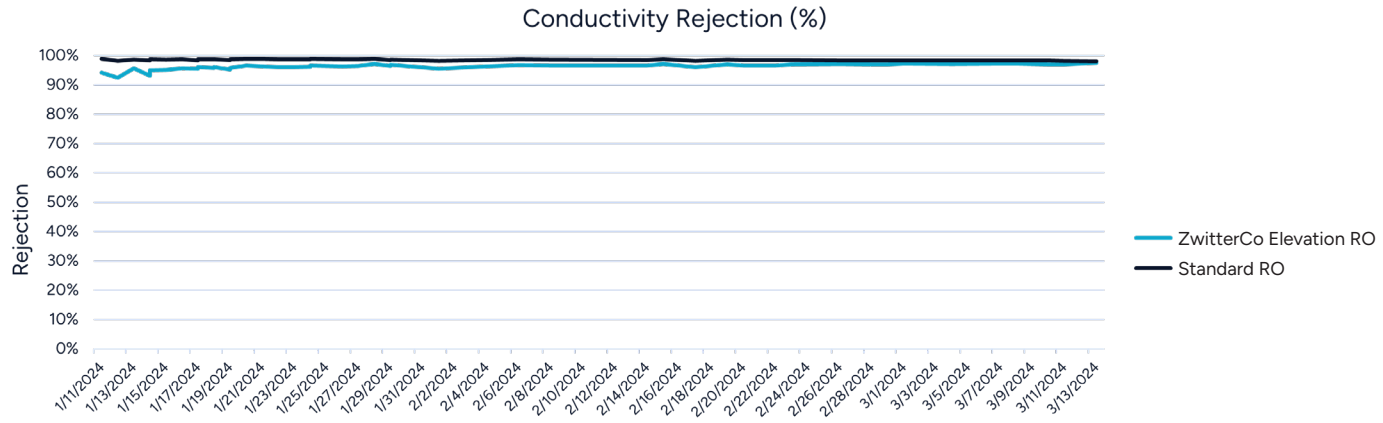

Figure 3: Conductivity Rejection (%) comparison of ZwitterCo Elevation BWRO and Standard RO

Analytical results illustrated below confirm that the ZwitterCo Elevation BWRO membrane delivers high rejection efficiency across critical leachate contaminants. Metals such as iron and manganese were removed to below detection limits, with rejections exceeding 97% and 98%, respectively. Phosphorus was effectively controlled with over 99.8% removal, contributing to a total metal rejection rate of approximately 94%. Organic compounds were also well retained: TOC was reduced by 94%, AOX by over 95%, COD by more than 99%, and BOD_5 by over 94%, indicating strong barrier performance against both biodegradable and recalcitrant organics. Nutrient rejection was similarly robust, with total nitrogen species reduced by ~93%, including ~95% removal of Kjeldahl nitrogen. These results demonstrate the membrane's capability to produce high-quality permeate and manage the complex and variable composition of landfill leachate.

Parameter	Leachate Concentration	Permeate Concentration	Rejection
Iron (Fe)	0.89 mg/L	<0.02 mg/L	>97%
Manganese (Mn)	0.73 mg/L	<0.01 mg/L	>98%
Phosphorus (P)	11.5 mg/L	0.02 mg/L	>99.8%
Sum of Metals	1.89 mg/L	0.12 mg/L	~94% total metal
Total Organic Carbon (TOC)	250 mg/L	15 mg/L	~94%
AOX (Organo-halogens)	1.1 mg Cl/L	<0.05 mg Cl/L	>95%
COD (Chemical Oxygen Demand)	672 mg O_2/L	<5.00 mg O_2/L	>99%
BOD (Biological Oxygen Demand)	53 mg/L	<3.0 mg/L	>94%
Total Nitrogen (NO_2+NO_3+NTK)	451 mg N/L	29.5 mg N/L	~93% overall N

Table 1: Rejection Performance of ZwitterCo Elevation BWRO Membrane Treating Landfill Leachate

The results in Table 1 demonstrate that the ZwitterCo Elevation BWRO membrane maintained both hydraulic stability and contaminant removal performance under challenging wastewater conditions without degradation or operational instability.

Figure 4: Raw Leachate, Elevation BWRO Permeate and Concentrate from Sytraival Site

The Benefits

The performance evaluation of ZwitterCo Elevation High Rejection BWRO membrane against a conventional High Rejection BWRO membrane demonstrated significant advantages across all operational and financial performance indicators. Cleaning frequency was reduced from 7 times to 4 times per week, with all cleanings performed using a caustic-only and acid + EDTA protocol. This simplification led to a measurable reduction in chemical usage and cost.

Parameter	ZwitterCo Elevation BWRO	Standard BW 4040 RO
CIP Frequency	Caustic-only: 4x/week Acid + EDTA: 4x/week Caustic + EDTA: Not Applicable	Caustic-only: Not Applicable Acid + EDTA: Daily (7x/week) Caustic + EDTA: Daily (7x/week)
Average CIP Duration	2 hours	2 hours
Membrane Lifespan	> 6 months	2 months

Table 2: CIP and Maintenance Comparison

As illustrated in figure 5, ZwitterCo Elevation BWRO system reduced total cleaning-related operating costs by approximately 50% per m^3 compared to a conventional High Rejection BWRO membrane. This reduction was enabled by a 57% per m^3 decrease in chemical cost, a 43% per m^3 reduction in cleaning-related water consumption, and a 65% per m^3 decrease in membrane replacement frequency. Downtime-related operating expenses were reduced by 43% per m^3, driven by fewer cleaning events and improved membrane cleanability. The use of RO permeate for cleaning was significantly reduced, resulting in improved resource efficiency and reclaimed water value. The system operated with high process stability, maintaining consistent flux recovery and transmembrane pressure without signs of foaming, irreversible fouling, or progressive performance decay.

Cleaning triggers were predictable, and the membranes consistently returned to baseline performance with minimal operator intervention. Additionally, the treated permeate consistently met quality targets for on-site reuse in non-potable applications such as truck washing and dust suppression. The cost savings, operational consistency, and ease of use demonstrate the ability of ZwitterCo Elevation BWRO to address key challenges in landfill leachate treatment and deliver long-term value under demanding conditions.

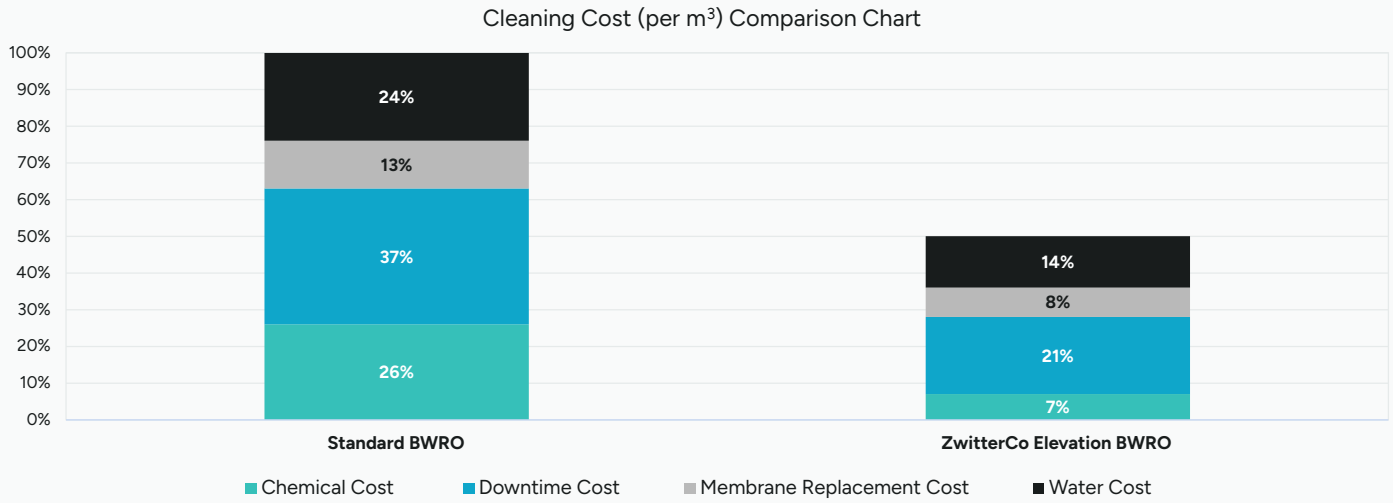

Figure 5: Cleaning Cost Comparison of ZwitterCo Elevation BWRO and Standard BWRO

Conclusion & Outlook

The evaluation at Serpol confirmed that ZwitterCo Elevation fouling-resistant BWRO membranes deliver stable performance and consistent contaminant rejection under the variable and challenging conditions of landfill leachate treatment. The membranes maintained hydraulic and separation stability throughout the trial, with no signs of irreversible fouling or performance degradation.

Compared to conventional High Rejection BWRO membranes, the ZwitterCo solution reduced cleaning frequency, eliminated the need for aggressive cleaning formulations, extended membrane service life, and lowered downtime-related operating expenses. These improvements resulted in an approximate 50 percent reduction in cleaning costs. Permeate consistently met internal reuse targets for non-potable applications such as truck washing and dust suppression. These results validate ZwitterCo Elevation BWRO as a technically robust and cost-efficient solution for landfill leachate and other high-fouling industrial wastewater streams. The performance achieved at Serpol supports long-term process reliability, regulatory compliance, and operational efficiency.

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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