



Salinity[™]
SOLUTIONS

Treat Water Better

A comparative study of membrane scaling

Hybrid Batch RO (HyBatch[™])
vs 2-stage continuous RO

February 2026



Introduction



Membrane scaling remains one of the most persistent and costly challenges in modern water treatment and desalination systems. In reverse osmosis (RO) and nanofiltration plants, inorganic scale—most commonly silica and calcium carbonate accounts for approximately 70% of all scaling-related incidents, leading to reduced membrane productivity, increased differential pressure, and premature membrane failure. Industry analyses estimate that membrane fouling and scaling collectively impose annual losses exceeding USD 4.5 billion worldwide, driven by higher energy consumption, frequent chemical cleaning, unplanned downtime, and membrane replacement. ([Source](#))

Calcium carbonate scaling is typically managed through acid dosing and antiscalants, yet high-recovery systems still experience localized supersaturation and rapid deposition at the tail elements. Silica scaling is even more problematic; once reactive silica polymerizes and deposits on membrane surfaces, it forms a dense, glass-like layer that is extremely difficult or impossible to remove, often resulting in irreversible membrane damage and forced replacement. Field data show that scaling events can cause 15–30% reductions in permeate flow within days, accompanied by significant increases in feed pressure and energy demand. ([Source](#))

As utilities and industrial operators push toward higher recoveries to reduce brine volumes and operating costs, reliance on chemical antiscalants and frequent cleaning-in-place (CIP) is becoming a limiting factor. The Salinity Solutions HyBatch™ technology addresses the root cause of scaling by fundamentally changing system hydraulics and concentration profiles. By avoiding continuous concentration build-up on membrane surfaces, HyBatch RO has the potential to radically reduce scaling propensity, lower chemical dependency, extend membrane life, and deliver step-change improvements in operational resilience, energy efficiency, and total cost of ownership.

It is important to recognise that the sparingly soluble scaling species: silica and calcium carbonate, exhibit distinct scaling behaviours and formation mechanisms. Accordingly, the trial results demonstrate that HyBatch RO provides enhanced operational performance and effective control for both crystalline and amorphous scale types.

This report presents results from a targeted scaling trial designed to quantify these benefits under real-world operating conditions.

Executive summary



This report outlines the process and results from Silica and Calcium Carbonate trials. Testing on other scalants is ongoing and updates will be released as fresh data becomes available.

Approach: A HyBatch RO system was tested side-by-side with a 2-stage continuous RO system. The trial environment was normalized - membrane, flux, feedwater concentration were directly comparative. The HyBatch RO was tested at 80 - 95% recovery, whereas the continuous RO system was able to operate up to 80% recovery. The duration of the trials was determined by the time it took the membrane in the continuous RO to be irreversibly scaled and the permeability to drop by 50%.

Results summary:

Trial 1 (Silica). HyBatch RO reduced CIP frequency by 20 times compared to 2-stage continuous RO.

Trial 2 (Calcium Carbonate) – at the point the 2-stage continuous RO membrane irreversibly scaled, the HyBatch RO showed no scaling effect.

Conclusion: HyBatch RO reduces the total cost of operation by reducing or removing the need for pre-treatment, reducing cleaning frequency, extending membrane life and achieving much higher recovery.

Introduction to Silica Scaling



High concentrations of silica are commonly found in industrial effluents and groundwater worldwide, posing a problem for membrane-based water treatment processes. At the same time, the need to treat and reuse industrial wastewater is increasing rapidly. India is a leading example, where legislation now mandates Zero Liquid Discharge (ZLD) across many industrial sectors, and similar regulations are expected to become standard practice globally.

To minimize the large volumes of waste typically managed through energy-intensive evaporation processes, high-recovery reverse osmosis (RO) solutions are essential. These systems enable greater water reuse while significantly reducing evaporation volumes.

Silica is often the primary factor limiting RO recovery. Due to the complexity of silica chemistry, extensive pretreatment and frequent membrane cleaning are commonly required. Silica scaling presents an even greater challenge: when reactive silica polymerizes and deposits on membrane surfaces, it forms a dense, gel-like layer that is extremely difficult—often impossible—to remove with traditional chemicals in market. This typically results in irreversible membrane damage and premature replacement.

HyBatch reverse osmosis offers a potential solution by reducing silica scaling through enhanced fouling-reduction capabilities. By lowering the risk of silica deposition, higher water recovery can be achieved, enabling increased reuse and substantially reducing the volume of waste requiring disposal (eg evaporation).

Trial 1 - Silica: Trial criteria



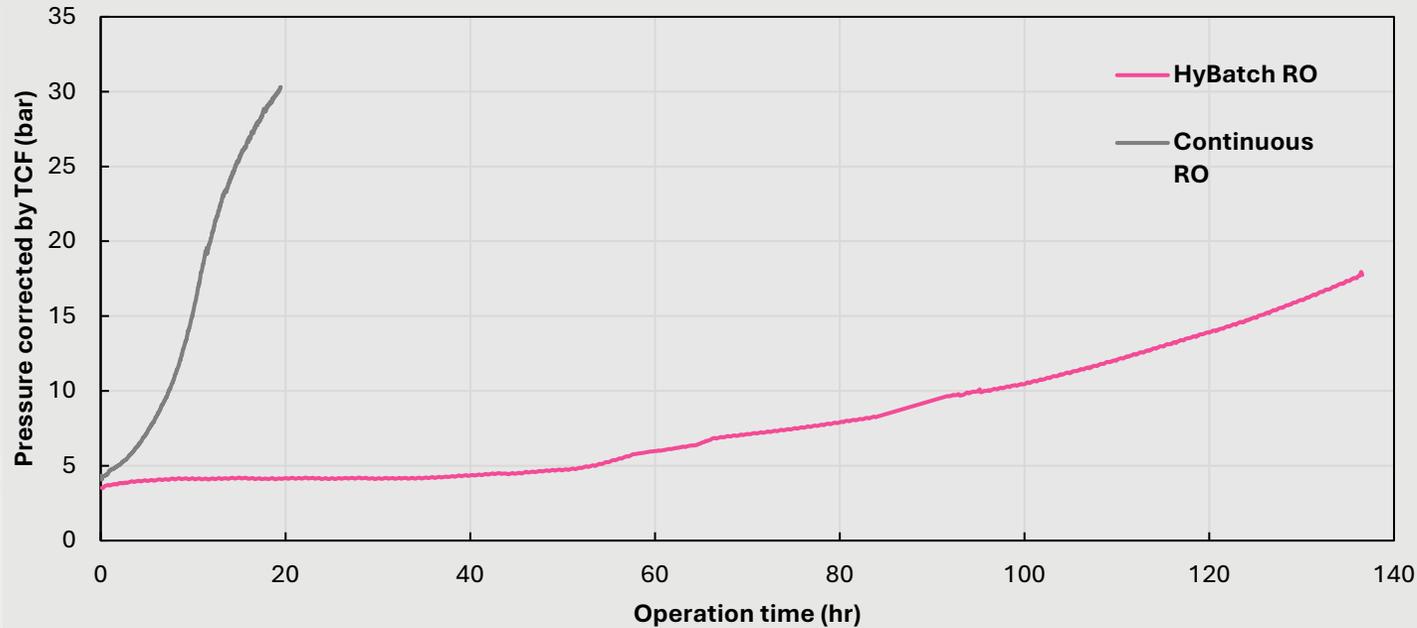
Salinity Solutions carried out a series of accelerated trials to compare the performance of a HyBatch and a 2-stage continuous RO system when treating water with elevated reactive silica levels.

All three trials were conducted at feed pH levels between 7 - 8, using reactive silica concentrations of 60.0 mg/L, 121.0 mg/L and 176.2 mg/L. Both systems operated at a flux of 20 LMH and 80% recovery, using the same type of membranes and drew from the same feed source.

Operational Parameters	HyBatch	Continuous RO
Recovery (%)	80	80
Flux (LMH)	20	20
Membrane	ERO-8040-HF	ERO-2540
Temperature (C)	25-30	25-30

Feed Water Quality	Trial 2a	Trial 2b	Trial 2c
TDS (mg/L)	818	620	377
pH	7-8	7-8	7-8
Calcium (mg/L)	12.3	12.3	12.3
Magnesium (mg/L)	3.3	3.3	3.3
Bicarbonate as CaCO3	13.2	13.2	13.2
Reactive silica (mg/L)	176.2	121.0	60.0

Trial 1 Scaling effect: pressure vs time graph (rate of scaling)



The graph shows data from Trial 1c compares a continuous RO system with the HyBatch RO system, both operating at 80% recovery.

HyBatch RO was able to operate 20x longer until CIP would be required (20 % increase in pressure).

This trial demonstrates that the HyBatch process can reduce silica scaling, the need for pre-treatment and increase recovery ratios.

Introduction to Calcium Carbonate Scaling



High levels of calcium hardness—primarily present as calcium carbonate—are commonly found in tap water, industrial effluents, municipal wastewater, and both surface and groundwater sources worldwide. As industries increasingly prioritize water reuse, higher system recoveries, and lower operating costs, the effective management of calcium carbonate scaling has become a critical global challenge for membrane-based treatment systems.

High-recovery reverse osmosis (RO) systems are essential for maximizing water reuse and minimizing concentrate volumes that require further treatment or disposal. However, operating at higher recoveries inevitably concentrates calcium and alkalinity, pushing system conditions toward and in some cases beyond supersaturation and precipitation.

Calcium carbonate scaling remains one of the most prevalent and persistent operational constraints in RO processes. Once precipitation occurs, dense crystalline scale forms on membrane surfaces and within feed spacers, leading to reduced permeate flux, increased differential pressure and energy consumption, and more frequent chemical cleaning.

HyBatch reverse osmosis directly addresses this challenge by minimizing calcium carbonate scaling through advanced scaling-reduction performance. By enabling stable operation at higher recoveries and limiting scale formation on membrane surfaces, HyBatch increases water recovery, enhances system reliability, and significantly reduces waste stream volumes that require downstream treatment—delivering measurable operational, energy, and sustainability benefits across a wide range of industries.

Trial 2 - Calcium Carbonate: Trial criteria



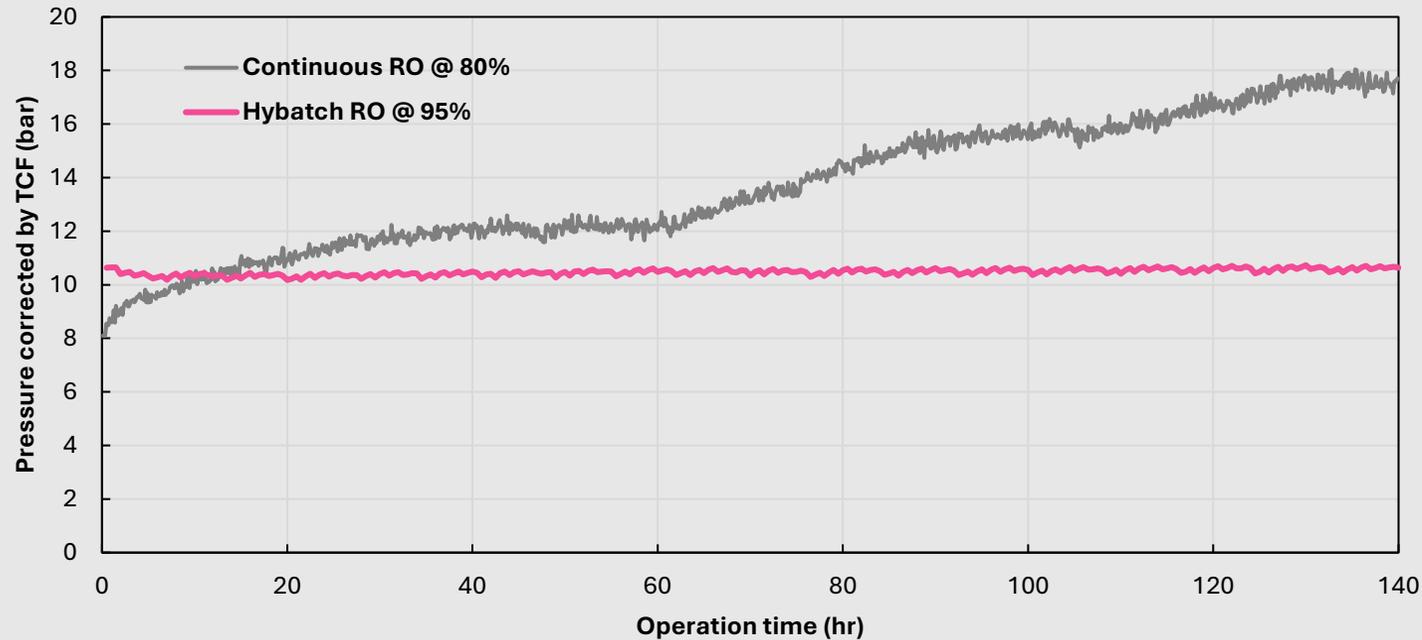
Salinity Solutions carried out trials to compare the performance of HyBatch RO and 2-stage continuous RO systems when treating water with elevated calcium carbonate levels.

HyBatch and continuous RO system were run in parallel to evaluate scaling, using the same feedwater, the same membranes and comparable operating conditions. HyBatch ran at 95% recovery, while the continuous RO system ran at 80% recovery and drew from the same feed source.

Operational Parameters	HyBatch	Continuous RO
Recovery (%)	95	80
Flux (LMH)	21	20.4
Membrane	ERO-8040-HF	ERO-2540
Temperature (°C)	24	24

Feed Water Quality	Concentration
Calcium	17.3 mg/L
Magnesium	2.7 mg/L
Sodium	265 mg/L
Bicarbonate	555.1 mg/L
Chloride	42.8 mg/L
Sulphate	112 mg/L
Nitrate	3.5 mg/L
pH	8.4
TDS	663 mg/L
LSI (feed)	0.6
LSI (brine) at 80% R	2
LSI (brine) at 95% R	4.2

Trial 2 Scaling effect: pressure vs time graph (rate of scaling)



The graph compares a continuous RO system operating at 80% recovery with the HyBatch RO system at 95% recovery.

The continuous RO shows significant scaling, indicated by a rise in pressure. In contrast, the HyBatch RO shows no signs of fouling.

This demonstrates that the HyBatch process can reduce fouling and the need for pre-treatment, even when operating at higher recovery levels.

Conclusion



The results from trials 1 and 2 clearly demonstrate the performance advantages of the HyBatch RO system compared to continuous RO across both silica and calcium carbonate scaling. Silica and calcium carbonate were selected because they are both major industrial scaling challenges and form scale through different mechanisms. Calcium carbonate precipitates as crystals directly on the membrane, while silica undergoes polymerisation to form amorphous polymeric or colloidal silica before depositing on the membrane. Demonstrating that the HyBatch process resists both types of scaling indicates it is likely to be more resilient to all forms of scale.

Trial 1 (Silica) - For silica, the HyBatch system took 20 times longer than the 2-stage continuous RO system to reach a 20% pressure increase (the CIP trigger). Across three tests, scaling rates consistently decreased at lower feed concentrations. Because these trials were intentionally run at elevated concentrations to accelerate scaling, it is reasonable to expect more than a 20 times reduction in CIP frequency for customers under normal operating conditions.

Trial 2 (Calcium Carbonate) - At 80% recovery, the 2-stage continuous RO system reached irreversible calcium carbonate scaling, while the HyBatch system showed no measurable scaling. Since HyBatch experienced no scaling at 80%, a second test was run at 95% recovery, where it continued to operate without issues. These results show that HyBatch can treat feedwaters with an LSI of 0.6 and concentrate them to LSI up to 4.2 without a softener, at pH 8.4, and temperature of 24 degrees Celsius.

These findings show that HyBatch provides a far greater operating window than continuous RO. Its superior resistance to scaling reduces or eliminates pre-treatment needs, reduces cleaning frequencies, extends membrane life, and enables much higher recoveries. Collectively, these advantages lower total operating costs and make HyBatch a strong choice for applications where scaling typically limits performance.

Report authors



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Tim is the Founder of Salinity Solutions having developed the technology first at Aston University and then University of Birmingham as a research fellow. He refined the technology and explored its commercial potential through programs like Innovate UK's ICURe "Innovation to Commercialisation of University Research" accelerator.



Dr Ebrahim Hosseinipour
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Ebrahim is a leading expert in reverse osmosis (RO) technology with over a decade of experience in desalination and water treatment. He holds a PhD from the University of Birmingham, where he pioneered research in batch RO, publishing eight peer-reviewed papers. Ebrahim has been instrumental in developing HyBatch (hybrid batch RO) systems from lab to field scale, with deep expertise in system design, process optimization and R&D.



Vena Jain
Chemical Engineer

Vena holds an MSc in Water and Sustainable Development and an MEng in Chemical Engineering. Her focus is on the effect of water chemistry on the HyBatch RO process, she analyses the impact of pre-treatment/chemicals to help optimize the technology for different feedwater qualities.



Thank you.

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