

Factsheet: Ultrafiltration and nanofiltration membranes as pre-treatment for reverse osmosis

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Ultrafiltration and nanofiltration membranes as pre-treatment for reverse osmosis



Unique selling points:

- ✓ Protection of RO from organic and /or colloid fouling
- ✓ Reduction in the number of clean in place or membrane replacements of RO
- ✓ Reduction of the operating costs

Description of the technology

Ultrafiltration (UF) and nanofiltration (NF) membranes in combination with reverse osmosis (RO) membranes can be applied as a post-treatment of wastewater to produce fit-for-purpose water. It can be used to treat different water qualities such as pre-treated industrial wastewater from breweries as in the [Lleida case study](#) in Ultimate (Fig. 1) and secondary effluent of a municipal WWTP (treating a mix of industrial and municipal wastewater) as in the [Kalundborg case study](#) (Fig. 2).

To improve the pre-treatment process new ultrafiltration and nanofiltration membranes with different MWCO were developed for pilot testing.

The novel ultra-tight UF membrane was developed using the Layer-by-Layer (LbL) technology and consists of hollow fibres with a diameter of 0.8 mm and filtrates from inside out. The materials of the fibres are polyvinylpyrrolidone and polyethersulfone ([Pentair 2022a](#)). A module has a diameter of 0.2 m and is 1.5 m long, with 12.000 membrane fibres and a membrane area of 40 m² (see Fig. 3).

The novel ultra-tight UF membrane has a much smaller separation cut off of around 4 kDa compared to a conventional UF with a molecular weight cut off between 10 kDa and 150 kDa ([Jerman et al. 2009](#)) and a wider MWCO than an open nanofiltration membrane with 1 kDa. It is assumed to be very well suited to protect a downstream reverse osmosis membrane from organic and/or colloid fouling. The better protection of the RO from fouling targets significant savings of cleaning chemicals for RO or membrane replacements that would be otherwise necessary by using a conventional UF instead ([Jähriq et al. 2023](#)).

Due to the small molecular weight cut off and depending on the composition of the wastewater, coagulant dosing upstream of the novel membrane might be reduced or in some cases might not even be necessary in comparison to the conventional membranes.





Flow scheme of the technology

In the case study Lleida, brewery wastewater is treated via a conventional activated sludge process. The effluent shall be further treated in order to produce fit-for purpose water to be reused in cooling towers or as process water. In this case study, the combination of a NF with a MWCO of 0.8 kDa is used as pre-treatment for the RO (Fig. 1).

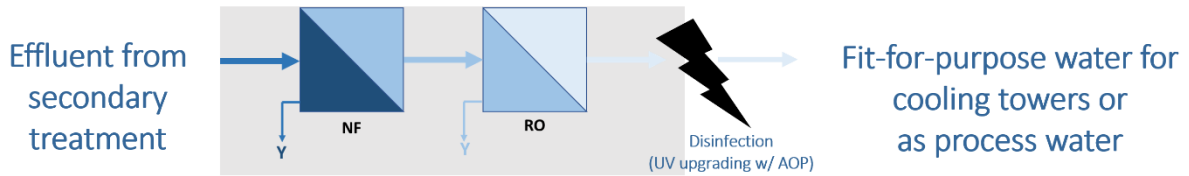


Fig. 1 Flow scheme for CS Lleida: effluent from the wastewater treatment plant of the brewery: nanofiltration membrane with MWCO of 0.8 kDa.

In the case study in Kalundborg, the treated wastewater still contains a high fraction of non-degradable organic matter (COD > 60 mg/L) originating from the biotech wastewater. Two pilot plants are operated in parallel to assess the performance of UF and NF membranes as pre-treatment for the RO as shown in Fig. 2. The following membranes will be tested: a novel ultra-tight UF (MWOC of 4 kDa), a conventional UF (MWCO of 150 kDa) and an open NF (MWOC of 1 kDa).

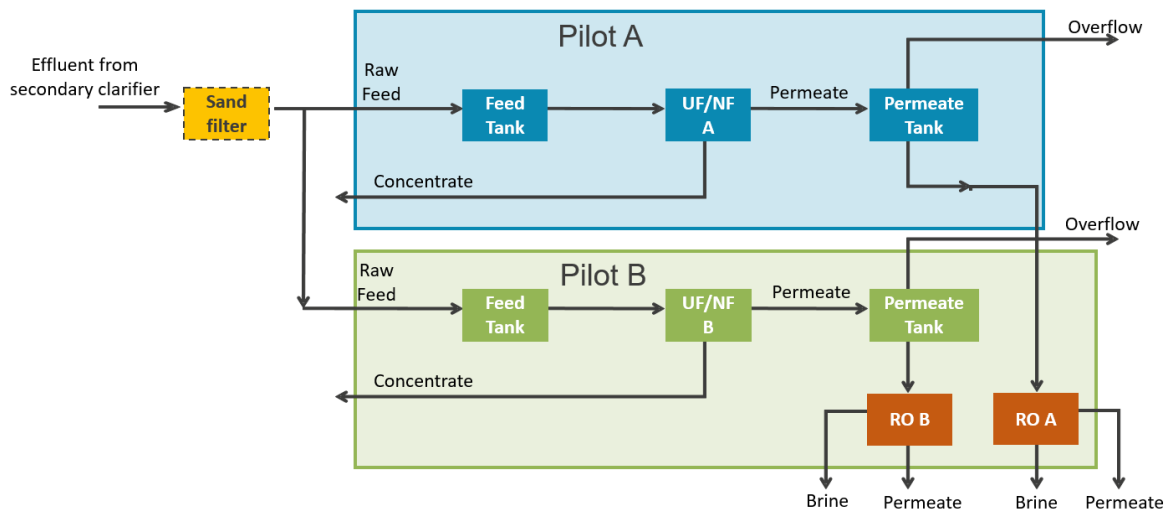


Fig. 2 Flow scheme for CS Kalundborg: pilot plants treat effluent from the municipal WWTP containing industrial wastewater resulting from the biotech industry

Pictures

Fig. 3 shows the profile of the fibre of a novel ultra-tight UF membrane and of the UF module. Fig. 4 displays the novel ultra-tight UF module and the downstream RO units of the pilot plant in Kalundborg.



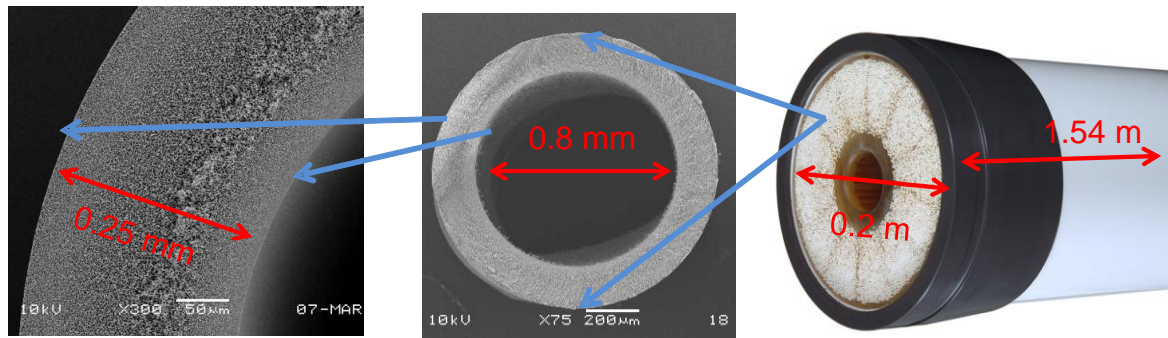


Fig. 3 UF/NF membrane with microscopic details and dimensions of membrane fibres; left: fibre wall, middle: fibre, right: module head



Fig. 4 Pilot plant in Kalundborg (from left to right): UF module, RO units

Synergetic effects and motivation for the implementation of the technology

- ✓ Protection of RO from organic and /or colloid fouling

Due to the much smaller molecular weight cut-off of the ultra-tight UF or open NF membranes compared to a conventional UF, colloids and large organic molecules such as biopolymers can be better retained from the RO than by a conventional UF and thus, the risk of fouling is reduced.





✓ **Reduction in the number of clean in place or membrane replacements of RO**

The retention of smaller particles and compounds that would otherwise lead to fouling on the RO membrane reduces the frequency of cleaning in place (CIP) procedures, the replacement of membranes and hence, reduce the demand for chemicals.

✓ **Reduction of the operating costs**

During first test period of the Ultimate project it was shown, that the ultra-tight UF could be operated without coagulant.

In the next test period of the Ultimate project, the impact of ultra-tight UF/ open NF on RO operation will be investigated including a cross-evaluation of potential savings regarding chemical cleanings and exchange of membranes, obtaining higher flux and recovery rates as well as less flushing cycles, etc. on the RO side against additional operational efforts and costs on the UF/NF side.

Requirements of the technology and operating conditions

Tab. 1 shows the feed water conditions for the application of this type of membrane. In the case the chemical composition of the wastewater does not comply with the indicated ranges, a pre-treatment prior to the inflow to the ultra-tight ultrafiltration unit is recommended. Typical design parameters and measured values are shown in Tab. 2.

Tab. 1 Typical feed water conditions to apply the novel ultra-tight UF membrane*

Parameter	Units	Feed water requirements
Temperature	°C	0 – 40
pH	-	2 – 11
Particle size	µm	< 300
Total suspended solids	mg/L	< 200
Ozone	mg/L	0
Free chlorine	mg/L	< 500

* Similar to X-Flow HFW1000 [Pentair 2022b]

Tab. 2 Typical ranges for operating parameters of the novel ultra-tight UF membrane

Parameter	Unit	Design by Pentair	Measured during pilot time
Operation		crossflow with bleed	crossflow with bleed
MWCO	kDa	4	
Permeability	L/(m ² *h*bar)	40-80	
Flux	L/(m ² *h)	20-40	25 – 32.5
Recovery	%	60-80	80
Cross flow velocity	m/s		0.3 – 0.5
System pressure	bar	max. 6	
TMP	bar	0.2 – 1 (max. 6)	0.25 – 2.0*
Chlorine resistance	ppm hour	100 000	
Specific energy consumption	kWh/(m ³ WW)	0.1 – 0.3**	

* depending on feed water quality

** Estimation by Pentair



**Key performance indicators**

Depending on the source of the wastewater the key performance indicators can vary as shown on Fehler! Verweisquelle konnte nicht gefunden werden..

Tab. 3 Key performance indicators for the novel ultra-tight UF membrane

Parameter	Unit	Value	References
Turbidity Permeate	NTU	< 0.2	Estimated based on X-Flow XF64 Membrane [Pentair 2022a]
Total suspended solids Permeate	mg/L	< 0.2	Estimated based on X-Flow XF64 Membrane [Pentair 2022a]
Bacteria (<i>E. coli</i>)	Log removal	> 4 – 6	Estimated based on X-Flow XF64 Membrane [Pentair 2022a]
Viruses (som. Coliphage)	Log removal	>2 – 4	
Parasites (<i>C. Perfringens</i>)	Log removal	>4 – 6	
Intervals backwash of UF	min	30 – 60	Jährgig et al. 2023
Intervals of CEB/CEC of UF	h	24	
Intervals of CIP of UF	months	3 – 12	
Intervals CIP of subsequent RO	weeks	1 – 2	

CEB – chemical enhanced backwash

CEC – chemical enhanced cleaning

CIP – cleaning in place

Links to related and or similar topics and reference projects

Process/technologies	Reference
Novel ultrafiltration in Kalundborg	Case study factsheet “Kalundborg” (Ultimate)
Novel ultrafiltration in Lleida	Case study factsheet “Lleida” (Ultimate)
Ultrafiltration or nanofiltration with RO regenerated membranes	Technology factsheet (NextGen)
Ultrafiltration or nanofiltration with RO regenerated membranes in Costa Brava	Case study factsheet “Costa Brava” (NextGen)





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