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Experiences with a reinforced UF hollow-fiber water filtration system for pretreatment of desalinated water

C. Thiemig[a,*], H. Yacubowicz[b], K. Phillips[b]

[a]*Koch Membrane Systems, Kackertstr 10, 52072 Aachen, Germany, Tel. +49 241 41326 21; Fax: +49 241 41326 59; email: thiemigc@kochmembrane.com*
[b]*Koch Membrane Systems, 850 MAIN Street Wilmington, MA 01887, USA*

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ABSTRACT

There are several ultrafiltration (UF) systems on the market for pretreatment of desalinated water. Existing hollow-fiber UF systems usually focus on low TSS-loaded water sources (pressure-driven inside-out filtration) or higher loaded sources (submerged systems). This paper describes a newly developed product that bridges the feed water solids tolerance gap between these operational configurations, coupling the advantages of a reinforced hollow-fiber UF membrane with a pressure-driven, outside-in filtration process. Experiences and key findings from several pilot trials at different locations and diverse feed water compositions are summarized.

Keywords: UF membrane; Pressure-driven; Pre-filtration; Desalinated water

1. Introduction

Desalinated water has become more important over the years. Ultrafiltration (UF) is a key process that is incorporated in multiple applications, including reverse osmosis (RO) pretreatment. The importance of UF is that it serves as a physical barrier to essentially allow complete removal of solids. UF systems produce permeate with low silt density index (SDI) and can reduce total organic carbon (TOC), arsenic (As) and phosphorous (P) with coagulant addition. Over the past 10 years, UF pretreatment has become a reliable and cost-effective pretreatment solution for highly variable seawater. Compared with conventional chemical- and physical-based water treatment, UF membrane systems require significantly less space and often have lower labor, chemical and waste disposal costs.

A new UF product has been developed by Koch Membrane Systems (KMS) to process the vast number of feed streams that are not clarified enough to be processed by an inside-out drinking water membrane, but do not warrant a submerged membrane system. The PURON® MP cartridges combine the advantages of several existing and proven membrane configurations. Its reinforced membranes and single potting design help avoid downtime associated with frequent cleaning cycles, sludging, and fiber repair. Along with new operating protocols, the membrane cartridge is designed to produce high-quality permeate at low

*Corresponding author.

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fouling rates. As seawater pretreatment, permeate quality would be SDI <2 and turbidity <0.1 NTU.

Its high flux and solids tolerance capabilities can help operators eliminate the need for costly and large footprint clarifiers for tough applications. Minimal system connections, an intelligent user interface, and outstanding membrane reliability are the highlights of the PURON® MP filtration system.

Nine PURON® MP pilots have been running on different applications, to evaluate the performance of this new product, to optimize the operating parameters, and to demonstrate long-term performance for technical discussions and presentations. The piloting sites were chosen to accrue data on a wide variety of feed water sources.

2. Material and methods

Koch Membrane Systems manufacture a wide range of products to handle different applications as shown in Fig. 1:

This paper focuses on the experiences with the PURON® MP cartridge which is usually applied for applications, where the feed water TSS does not exceed concentrations of 250 mg/L.

The PURON® MP cartridge houses a bundle of several thousand UF fibers made of low-fouling Polyvinylidine Fluoride (PVDF)-coated polyester braid to produce "unbreakable" hollow fibers that are fixed in a single header at the top of the cartridge. The membrane cartridge properties are shown in Table 1.

The fibers are fixed only at the top (Fig. 2). This method of design allows for lower solids building potential in the membrane fiber bundle. Another benefit of the design is a multiport aeration system at the bottom of each cartridge. These aeration nozzles allow air to be injected at the bottom of the fiber tips, equally scouring each fiber for effective cleaning, and solids removal. The open fibers concept also allows solids to be easily drained after air scour and backflushing. This product design allows for higher feed solids and flux rates than traditional UF systems. Narrow pore size distribution, high porosity, and smaller pore size keep foulants away resulting in high and stable long-term permeability.

The feed water is introduced at the bottom of the cartridge (Fig. 3, right). The dead-end, outside-in filtration mode ensures a maximum recovery rate. During dead-end mode, all the feed water that enters the membrane cartridge is pushed through the fiber walls. The cleaning of the cartridge can be done in different ways. Typically, every 20–30 min a backwash cycle with permeate, combined with an air scouring of the fibers is conducted to remove deposited solids from

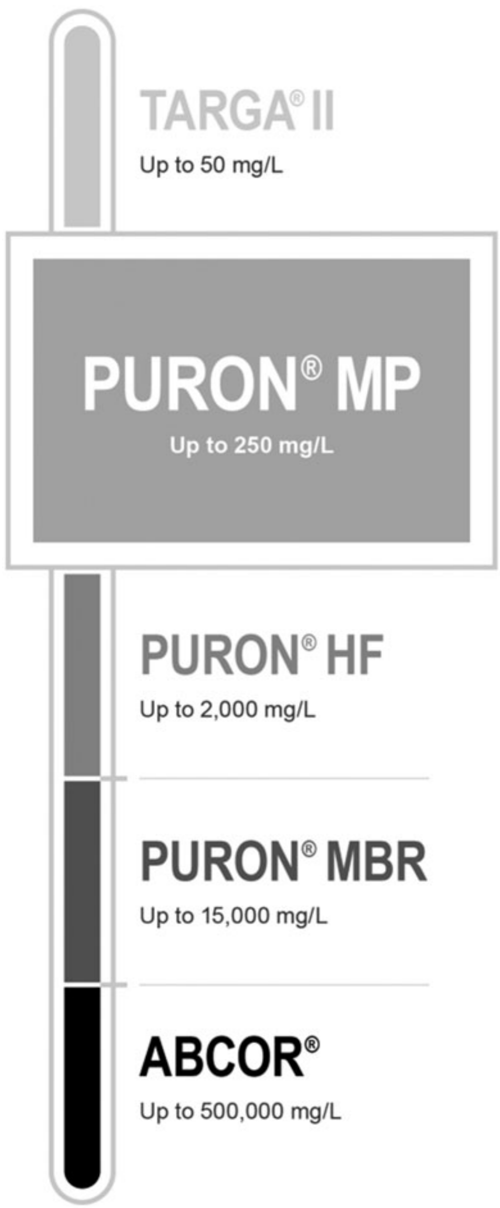

Fig. 1. Complete solids tolerance solutions. PURON® MP is in line with the other water and wastewater products of KMS.

the membrane surface that accumulate during production. Chemically enhanced backwashes and maintenance cleans (MC) may be performed to remove fouling or scaling from the membranes. Periodic backwash and maintenance cleaning is incorporated to keep the membrane transmembrane pressure (TMP) low to minimize energy consumption during the filtration process.

Depending on the application, the system can be operated with very high feedwater recoveries to help minimize solids handling. Backwash and maintenance

Table 1
PURON® MP cartridge parameters

Technical data	
Membrane area	51 m^2 (546 ft^2)
Pore size	0.03 μm
Membrane chemistry	PVDF
Feed flow path	Out to in
Wet new cartridge weight	38 kg (83 lbs)
Active membrane area per element	51 m^2
Height	200 cm (81´´)
Diameter	8´´ (20 cm)
Membrane surface characteristics	Hydrophilic
Membrane charge	Neutral
Acceptable range of operating pressures	0.07–1.7 bar
Acceptable range of operating pH values	5–9
Acceptable range of CIP pH values	1.5–10.5
Oxidant tolerance	Total chlorine: 1,000 ppm at pH < 10.5 Lifetime total chlorine exposure: 50,000 ppm-hrs Hydrogen peroxide: 10% Potassium permanganate: 5.5 ppm
Regulatory status—drinking water	Classified by UL to NSF/ANSI Standard 61 and in accordance with NSF/ANSI Standard 372

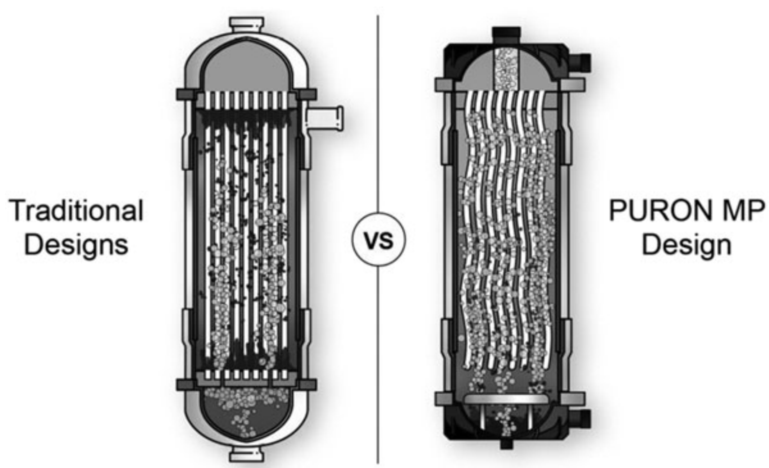

Fig. 2. PURON® MP cartridge configuration.

cleanings may be optimized offering flexibility for the system to handle variable feed water qualities.

The source of the seawater has significant impact on design parameters for an UF system. The two main types of seawater intake are “Open Intake” and “Beach Wells.” Open intake lends itself to higher biological activity, higher turbidities, bigger temperature range as well as increased potential for the presence of foulants, such as hydrocarbons (from ship traffic) and marine life (mussels). Beach wells tend to supply more consistent feed water quality with lower TSS and biological activity however, beach wells are more expensive and some locations may not allow for them due to geological issues. Beach wells are typically used for small or medium projects, whereas open intakes may be used in small and medium projects but are typically always used in large projects.

For low flow rates, the cartridges are embedded in a skid-mounted full packaged system, including a cleaning in place (CIP) system, backwash system, and pretreatment with chlorine and coagulant dosage, if feed water quality requires. For larger flow rates, the cartridges are mounted on separate skids, supported by shared CIP, backwash and pretreatment skids (Fig. 4).

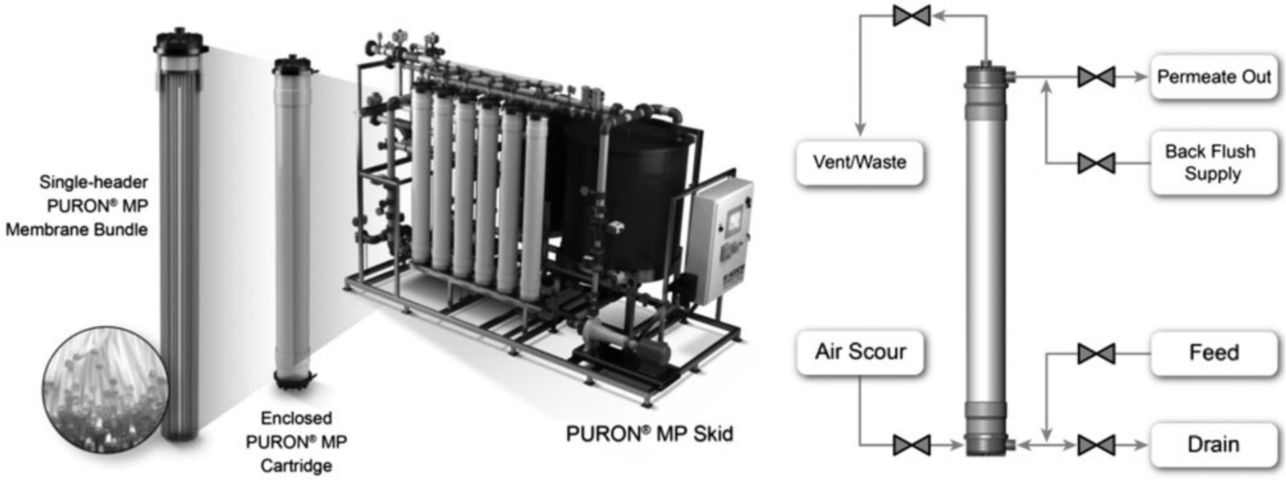

Fig. 3. PURON® MP cartridge and system (left) and process connections (right).

KMS is operating a fleet of about 10 PURON® MP pilot plants all over the world. A simplified depiction of the pilot flow during production is shown in Fig. 6. The pilot's major components include: feed and permeate tanks, feed and backwash pumps, an air scour blower, and chemical dosing systems. The pilot is controlled with a Programmable Logic Controller, and the operation is fully automatic. During production mode, the feed pump creates pressure and provides the driving force to push the feed water through the membrane. During this permeation step, the feed water solids are retained by the membrane surface. Coagulant may be injected into the feed water to coagulate dissolved solids; these solids are then removed during the filtration process (Fig. 5).

The pilots operate in an automatic mode as depicted in the flow chart in Fig. 6. During operation, the pilot runs in production mode for a period of

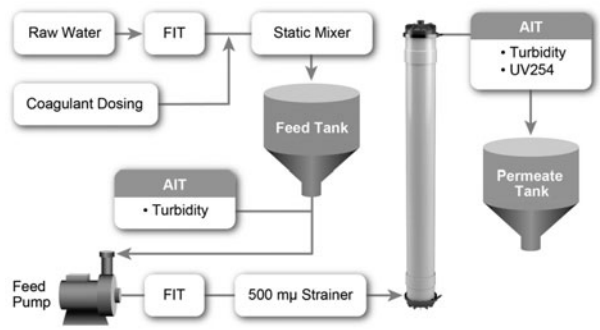

Fig. 5. Simplified pilot flow diagram.

time, and then performs automatic backwash sequences and MC. The backwash consists of reverse permeate flow (backflushing), followed by air scouring the fibers, draining and filling the cartridge, and a

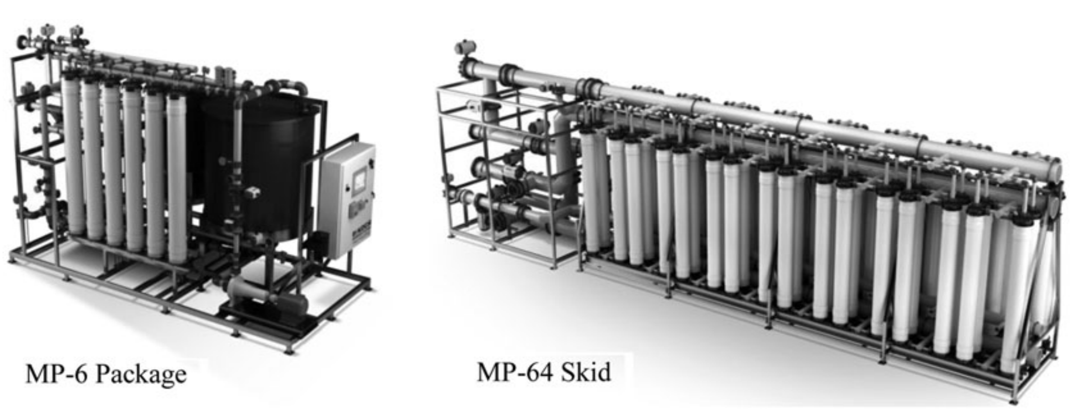

Fig. 4. MP-6 packaged system (left) and MP-64 skid (right).

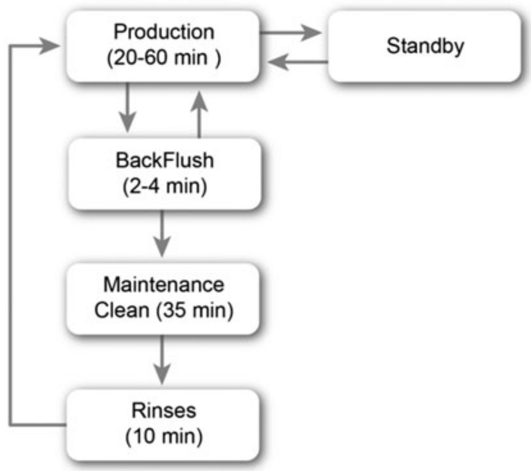

Fig. 6. Pilot flow chart.

short fast flush (rinse) to further remove solids. The maintenance cleaning consists of a short recirculation of permeate with chemicals (chlorine or acids) and soaking the cartridge; the membrane cartridge and pilot are then rinsed.

3. Results and discussion

KMS operated PURON® MP pilot plants in more than 10 locations worldwide. Feed water origin was surface water from various locations (reservoir, river, and lake) or biologically pretreated water (effluent of secondary clarifier or wastewater treatment lagoons). Fluxes in tertiary applications strongly depend on the efficiency of the biological treatment steps upfront and ranged between 50 and 95 LMH. The filtration of surface water with lower TOC concentrations was possible with flux levels higher than 100 LMH. Peak feed turbidity conditions did not require operating at lower flux, due to the unique cartridge design and effective cleaning of the cartridges, which allows the product to recover easily from upset conditions.

The importance of coagulant usage was studied for the different applications. It has been shown that coagulant dosing is helpful in maintaining steady operation through varying feed water quality. However, it appears to only be necessary to dose coagulant when the TOC/Organics levels in the feed are elevated. Some units have demonstrated stable performance without coagulant. The increase in TMP between backwash cycles is noticeably higher when coagulant is not used, but since the baseline is not impacted markedly, this can be managed.

The following section describes in detail the results of two PURON® MP pilot studies, where surface water was treated to evaluate the feasibility and cost efficiency of this technology for such application.

Figs. 7 and 8 display the online recorded data of the two pilot studies.

Fig. 7 shows results of a pilot study in North America filtering surface water from a reservoir. Feed water characteristics are changing seasonally. The

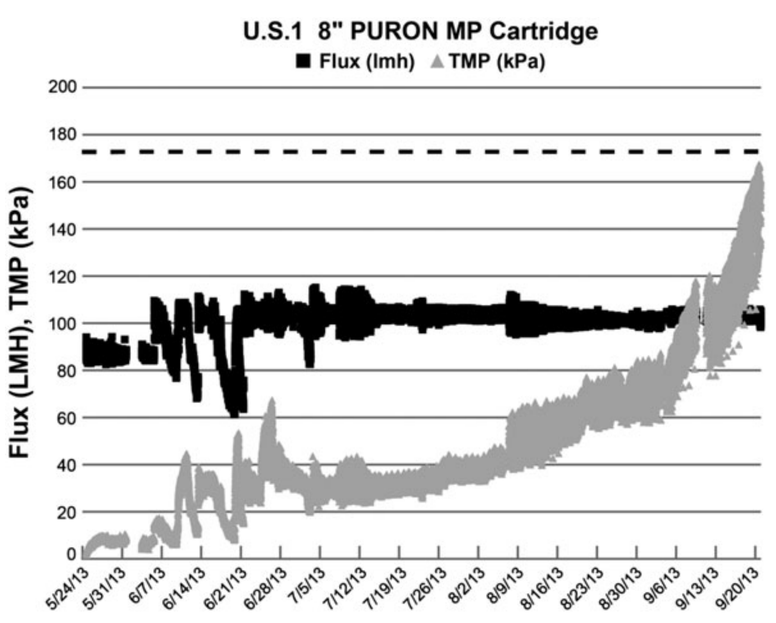

Fig. 7. U.S. 1 pilot data (surface water).

average feed TSS is about 20–30 mg/L. The system demonstrated a stable permeate flux of 100 LMH, operating at 95% recovery. An addition of 100 ppm PACl to coagulate the incoming suspended solids and TOC (5–7 ppm) was beneficial in this case. Feed iron levels range between 0.1 and 0.4 ppm. TMP increased in this example up to the operational limit of 170 kPa (1.7 bar) within four months. A CIP cycle consisting of chlorine and acid cycles, conducted when TMP reached the maximum operational limit, fully recovered the initial permeability. For full-scale systems treating, such feedwater, a more frequent CIP schedule will be considered (once every 2–3 months).

Fig. 8 shows the results of a pilot study in China, filtering surface water after plant sedimentation. The feed turbidity varies mostly between 2 and 40 NTU but occasional spikes have been recorded up to 75 NTU. The system demonstrated a stable permeate flux of 90 LMH, operating at 95% recovery. This pilot operated without coagulant addition, but in order to maintain consistent operation, two chlorine maintenance cleanings were incorporated weekly. The permeability calculated for this pilot slowly declined from around 270 lmh/bar, leveling off around 200 lmh/bar. A CIP cycle conducted after five months of operation, consisting of chlorine and acid cycles fully recovers the initial permeability. The operating pressures recorded during the pilot study were far below the maximum TMP of 1.7 bar at all time.

All conducted pilot studies demonstrated the following aspects:

(1) PURON MP can handle high solids surface water and tertiary effluent waters. It can operate successfully at average solids levels of up to 100 NTU. Occasional spikes up to more than 5,000 NTU can be handled by the fully automated maintenance cleaning procedure and the system smart controls.
(2) In most applications the PURON® MP product can run successfully for 3 months or longer between CIP cycles.
(3) During all times (including high solids spikes) produced effluent complied with most stringent regulations and typical bid requirements.
(4) The use of coagulant for many of the applications was proven to be very helpful for high TOC and high solids applications.
(5) The PURON MP piloting demonstrated the “smart controls” feature of the system. Coagulant dosage rate can be easily controlled based on UV-254 monitoring, thus improving the membrane performance at optimal chemical costs.
(6) Design guidelines and flux tables for the different applications and feed water types were refined and justified.
(7) Many applications can be quoted without the need to run pilot tests.

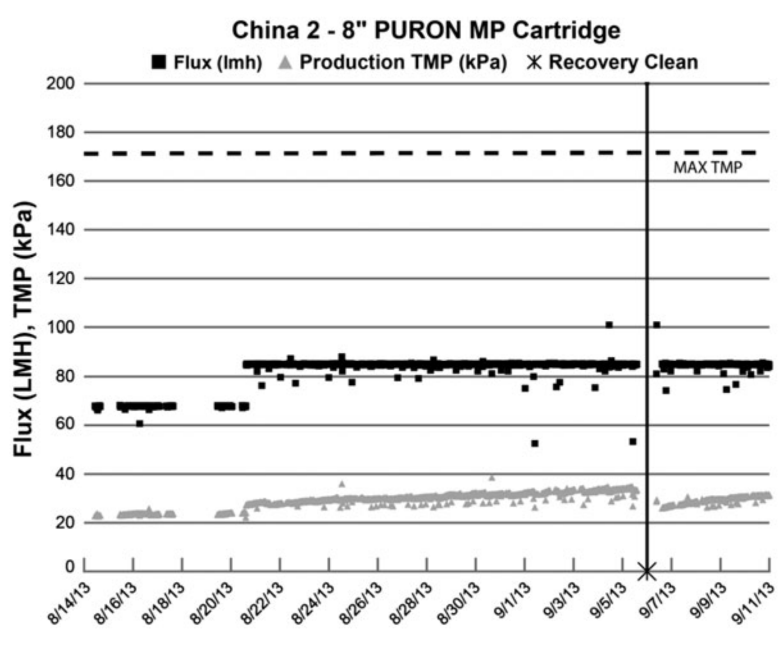

Fig. 8. China 2 pilot data (surface water).

4. Conclusions

Permeate coming from PURON® MP UF cartridges is ideal to feed a Seawater spiral RO system, due to low values in SDI (less than 2) and turbidity (less than 0.1 NTU) that makes the RO system more efficient and cost effective. Using the PURON MP UF technology helps reducing RO CIP frequency and results in more stable operation of the RO system.

This cartridge was introduced in order to cover the existing gap in the market between low TSS-loaded water sources (inside-out filtration) and higher loaded sources (submerged systems). It provides significant improvement and ensures high process efficiency.

Additionally, using enhanced coagulation, pretreatment facilitates the removal of soluble organics by the PURON® MP membrane.

PVDF membrane chemistry-coated over polyester braid produces an "unbreakable" reinforced hollow fiber, and together with a single header design (fibers free at the bottom of the cartridge) and multiport aeration system it allows for lower solids building potential in the membrane fiber bundle. As a result, it is possible to treat feedwater streams with higher feed solids at higher flux rates than traditional UF systems.

The narrow pore size distribution, smaller pores, and high membrane porosity keep foulants away from the membrane surface, resulting in stable long-term permeability.

PURON® MP systems compared with conventional chemical- and physical-based water treatments require less space, lower labor, less chemicals, and lower waste disposal costs.

Pilot systems have demonstrated long-term performance on different applications.

PURON® MP summary of advantages

Avoid pretreatment	Its high flux and solids tolerance properties can eliminate the need for costly clarifiers and chemical pretreatments in tough applications
Less downtime	Polyester reinforced membranes and an unique single-potting design help to avoid downtime associated with frequent cleaning cycles, sludging, and fiber repair
Less chemicals	Superior chemistry and a tight pore structure deliver more stable membrane performance without the need for extensive chemical cleans
Simple operation	Minimal system connections, intelligent user interface, and outstanding membrane reliability: one of the easiest-running filtration systems available
Save money	Superior output, simplified operation, reduced maintenance, and pre-treatment costs, and a compact footprint, all add up to cost savings for you!