PRODUCTS IN ACTION

Membranes Reclaim Wastewater at 86% Recovery in Singapore

Filmtec fouling-resistant membranes provide a technical solution

By Niann-Tsyr Yuen

Singapore is a small island-state with few natural resources and a population of 4 million. About half of the country's potable water supply comes from neighboring Malaysia as a result of two supply agreements that expire in 2011 and 2061. To ease the strain on the potable water supply and reduce costs, the Jurong industrial area began to use industrial water as early as the 1970s. Industrial water is tertiary-treated sewage effluent reclaimed from the Ulu Pandan Water Reclamation Plant.

However, there was still a need for higher-grade process water—a need that increased as industry continued to grow on what is now known as Jurong Island. Surveys conducted in the mid-1990s indicated that an estimated 50,000 cu meters per day of higher-grade water would be required by the petrochemical and chemical plants planning to build on the island.

In 1997, Singapore officials and industry began to look for alternative sources of high-grade water that would be less expensive and more widely available than potable water. Filmtec fouling-resistant membranes provided a technical solution to help them achieve this goal.

The Membrane

Filmtec fouling-resistant elements are thin-film, spiral-wound polyamide composite membranes that are resistant to biofouling.

The membrane's fouling-resistant elements are very durable and can be cleaned at pH 12. They are also highly resistant to bacterial adhesion. These features extend the time between cleanings and reduce cleaning costs. A lower rate of biomass accumulation and biofouling on the fouling-resistant elements results in lower average feed pressure to operate a reverse osmosis (RO) facility, thus substantially reducing energy costs.

The BW30-365-FR2 element was used at the Singapore site. This element has a 34-mL feed spacer, which is 10% to 20% thicker than feed spacers in competing elements, making it easier to clean. This element has since been superseded by a new product, the BW30-365-FR, which offers the same benefits and can also be used to purify water for potable applications.

Water Issues & Projected Needs

The Jurong Industrial Water Works (JIWW) produces industrial water by treating effluent from the Ulu Pandan Water Reclamation Plant. Because the intrusion of seawater affects water composition, chloride levels in industrial water vary between 100 and 500 mg/L. Conductivity fluctuates between 800 and 2,000 µS/cm, corresponding to total dissolved solids (TDS) of 500 to 1,200 mg/L.

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ARTICLE SUMMARY

Challenge: Singapore needed to find a less expensive, widely available source of higher-grade process water to support the rapid industrial growth on Jurong Island.

Solution: Filmtec fouling-resistant membranes, which are thin-film, spiral-wound polyamide composite membranes resistant to biofouling.

Conclusion: The plant's RO system now reclaims wastewater at 86% recovery, and provides high-grade industrial water that is less expensive than potable water.

Figure 1. Silt Density of Feedwater to the RO System.

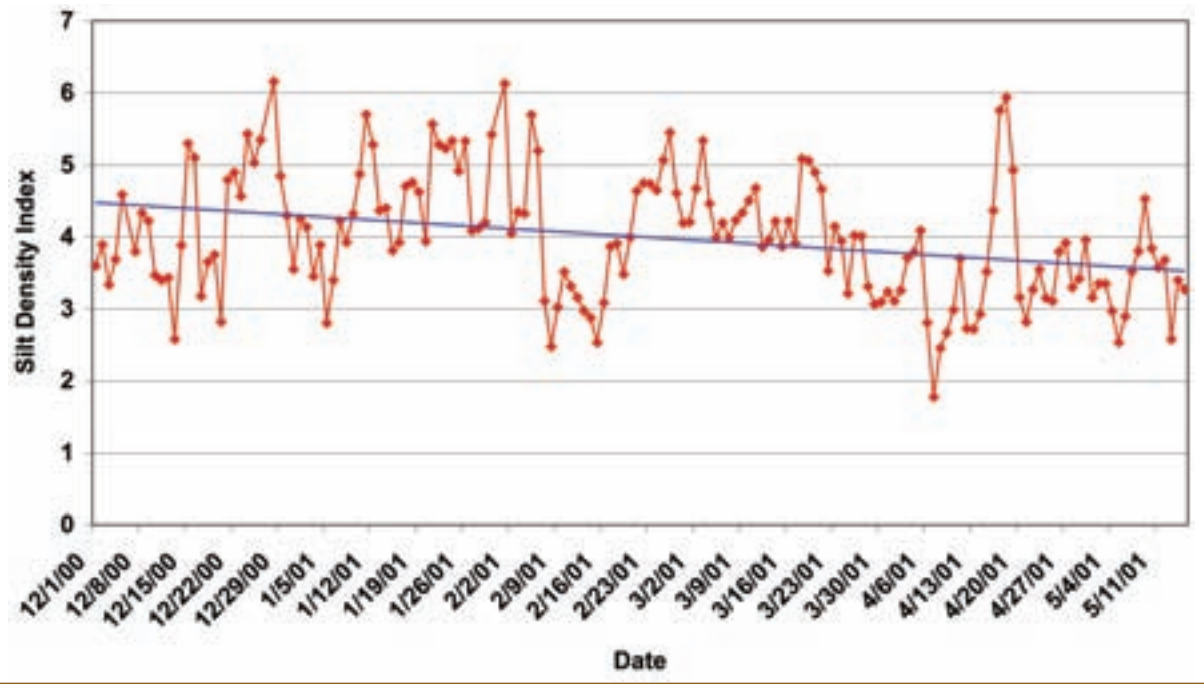

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Table 1. Design Parameters for RO Units.	
Flow rate per train, cu meters/day (gpd)	5,000 (1,320,860)
Number of trains	6
Recovery (%)	85 – 86
Temperature, °C	25-35
Feed TDS, mg/L	1,300
Feed pH	6.2 – 7.4
Average flux, L/sq meters/h (gfd)	<16.9 (<10)
Max. feed pressure, kPa (bar, psi)	980 (9.8, 140)

Table 2. Configuration of Each RO Train.	
Configuration	Three stages (28-16-8)
Pressure vessels	52 with 7 elements per vessel
Elements	Filmtec BW30-365-FR
Total elements in 1 train	364
Total elements in 6 trains	2,184

The planned high-grade industrial water system was projected to produce water of a slightly better quality than potable. The specification for conductivity was targeted at less than 250 µS/cm, compared to the specification for potable water at 300 to 350 µS/cm. Because of the fluctuation of conductivity in the industrial water supplied by JIWW, a conductivity specification corresponding to a TDS of 1,300 mg/L was set for industrial water feed. At an estimated demand of 50,000 cu meters/day, a 30,000 cu meters/day plant could supply a high-grade industrial water system to industries at a lower price than potable water through a separate supply system.

Plant Construction & Design

SUT Seraya, a subsidiary of SembCorp Utilities Pte., Ltd. operates the RO system, which was designed and built by Aquatech Intl. Corp. The system includes two dual-media filtration pretreatment stages to achieve a target silt density index (SDI) of 4 or less. Backwashing of the two pretreatment stages is staggered to ensure that filtration is always done through compacted beds, which helps maintain a stable SDI. Table 1 lists other design parameters.

Energy costs are reduced by using variable frequency drives and interstage booster pumps. The booster pumps allow flushing of third-stage elements while the other stages are operating. Because of the nature of the water being treated and the high recovery conditions, saturation levels reached in the third stage are extremely conducive to fouling and scaling. Third-stage permeate flushing removes precipitants before they become permanent. Table 2 describes the configuration of an individual train.

System Performance

Since the plant began operations in 2000, the RO permeate has been well within specifications. Table 3 shows the effect of treatment on selected parameters of the feedwater.

The raw effluent water can at times be high in SDI (>6) and total suspended solids (TSS) (6 to 6.5 mg/L), which can occasionally lead to an SDI in the feed to the RO system of >4. Figure 1 shows the trend in SDI in RO feedwater from December 2000 to May 2001. When SDI levels in the feedwater to the RO exceed 4 for an extended period of time, the plant recovery is typically reduced from 86% to 75%.

The time between cleanings was predicted to be once per month at 86% recovery. Cleanings are done every 4 to 5 weeks, during which time the normalized permeate flow decreases by typically 15% to 20%. After cleaning, the normalized flow returns to the original values. The chemistry of the Filmtec membranes allows cleaning to be carried out at pH up to 12 (at 30°C) without negative impact on membrane performance. Generic cleaning chemicals are used.

After one year of operation, a routine membrane analysis was carried out. As expected, slight biofouling was observed and minor residues of calcium, silicon and iron were detected, indicating mild colloidal fouling. Salt rejection and flow were within specification, which was expected since plant performance had not shown water deterioration, flux loss or increased feed pressure.

Conclusions

Since startup in January 2000, the RO plant has performed well and reliably within the design specifications. The high recovery of 86% pioneered by this project is now considered to be an industry benchmark in tertiary effluent wastewater reclamation.

The membranes have performed well under the stringent design and operating conditions imposed. Generic chemicals are adequate for cleaning, keeping the cost of

Table 3. Actual Values for Selected Parameters in Feedwater and RO Permeate.		
Parameter	Feedwater	RO Permeate
Conductivity, µS/cm	700 – 2,000	66 – 133
Total dissolved solids, mg/L	500 – 1,300	33 – 70
Turbidity, NTU	0.4 – 1.7	0.1 – 0.4
TSS, mg/L	1 – 2	0.07 – 0.13
Color, hazen unit	13	<5
Total hardness as $CaCO_3$, mg/L	100 – 160	1 – 3
Total alkalinity as $CaCO_3$, mg/L	40 – 80	16 – 22
Sodium, mg/L	150 – 200	10 – 12
Chloride, mg/L	150 – 200	6 – 21
Sulfate as SO^4, mg/L	120 – 160	<7
Silica as SiO_2, mg/L	6 – 10	0.1 – 0.4
Ammonia as N, mg/L	5 – 15	0.1 – 1.0
Phosphate as P, mg/L	2 – 4	0.04 – 0.10
Biological oxygen demand	<5	<1
Chemical oxygen demand	20 – 30	2 – 4
Bacteria, CFU/100 mL	<1,000	<1
Fluoride, mg/L	0.2 – 0.7	<0.02

cleaning low. This results in lower operating costs compared to older plants using membranes that are not designed to be resistant to fouling.

The high-grade industrial water provided by this RO facility is less expensive than potable water. For customers using industrial water, high-grade industrial water also results in lower demineralization costs because the membranes remove most of the dissolved solids in the reclaimed water.

Altogether, this new RO system using Filmtec fouling-resistant membranes is a win-win situation for Singapore. Industries now have access to process water that is less expensive than potable water yet cleaner than industrial water, and Singapore conserves precious freshwater. This technology can be used in other parts of the world to reclaim wastewater where water is scarce, thus preserving vital natural resources. WWD

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