Integrated Membrane Desalination Systems - Potential Benefits of Combined Technology

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With the commercial introduction of modern ultrafiltration (UF) and microfiltration (MF) technologies, it was expected that these membrane filtration processes would provide the optimum pretreatment technology for reverse osmosis (RO) applications. These expectations have been realized in the reclamation of municipal wastewater. Practically, all new wastewater reclamation systems that use RO for salinity reduction apply UF or MF technology as a pretreatment step before RO. Effectiveness of membrane pretreatment in producing good quality RO feed water is proven and well documented. However, improved quality of MF/UF effluent, as compared to conventional pretreatment comes at a cost that is still significant and in most cases higher than the comparable cost of conventional pretreatment based on media filtration. In a wastewater reclamation process with integrated membrane pretreatment, the benefits of significantly lower fouling rates of RO membranes, low cost of chemicals and disposal of pretreatment waste stream, outweighs the higher cost membrane pretreatment equipment. For other difficult RO applications, such as the treatment of surface water, the relative economics of MF/UF pretreatment is still being evaluated. Outside wastewater reclamation applications, the number of installations using Integrated Membrane Solutions® (IMS) is relatively small.

However, there are a number of markets and regions where the use of IMS for brackish and seawater applications is growing. In the Pacific Rim, many large capacity IMS systems produce process water for electric power stations. A representative example is the seawater RO system at the Yu-Han Power Plant, China, with output capacity of 34,500 m^3/day. Outside of the Pacific Rim, membrane pretreatment is being gradually introduced in seawater plants producing potable water. So far the RO units operated on UF/MF effluent are designed in a similar way as the RO system operating with conventional pretreatment. It is possible however, that future RO systems will be designed for higher permeate flux rates, taking advantage of better feed quality and improving economics of the integrated desalination process.

IMS SYSTEMS FOR SEAWATER TREATMENT

For RO seawater desalination systems, capital and operating costs are major drivers of process selection. Due to low product recovery in RO seawater units, any cost difference incurred in the pretreatment system will strongly affect cost of water produced. Until recently, the conventional media filtration has been used almost exclusively as part of the pretreatment in large RO seawater plants. Lately, a limited number of medium size plants that utilize membrane filtration as the pretreatment step are being built and some are operational already (Table 1). The better known plants with membrane pretreatment are Addur, Bahrain (1), Fukuoka, Japan, Kindasa, Saudi Arabia (2) and Yu-Han, China (3).

Table 1. RO seawater plants with membrane pretreatment.

Location	Addur, Bahrain	Valdaliga Sud – Italy - Enel	Fukuoka, Japan	Kindasa, Saudi Arabia	Yu-Han, China
Membrane filtration capacity, m3/day	140,000	1,250	96,000	90,000	70,000
Operational status	Operational since May 2000	Operational since May 2004	Operational since May 2005	Start-up mid-2006	Start-up Early 2006
Membrane technology	Pressure driven UF backwashable spiral	Pressure driven UF capillary	Pressure driven UF backwashable spiral	Pressure driven UF capillary	Submersible UF capillary
Pretreatment Membrane module manufacturer	Nitto Denko	Hydranautics	Nitto Denko	Hydranautics	Zenon

The Ad Dur plant is probably one of the first seawater plants where the concept of integrated membrane solution (IMS) has been implemented. The UF filtration system was added as a part of the plant rehabilitation process of DuPont's hollow fiber desalination plant that was initiated in 1999. The UF filtration equipment used is unique as it is based on spiral wound elements that are backwashed by reversing the direction of the filtrate flow, so called reversible spiral (RS). At the time of implementation (year 2000) the RS technology was at the early stages of commercial development and a number of operational and performance problems were encountered. Subsequently, the problems were solved by product modifications and improvement of operating conditions. Presently, the performance of the UF filtration unit is according to specifications.

The Kindasa RO seawater plant – Phase A - commenced operation in year 2000. RO permeate capacity was 14,000 m³/day utilizing Hydranautics spiral wound elements. Feed water is supplied from open intake located in the far corner of berthing basin in the Islamic Port of Jeddah and treated prior to RO using a conventional filtration system. The pretreatment system operated satisfactory most of the time. However, during seasonal periods of stormy weather or algae bloom as well as during movement of large ships and tug boats in the basin, poor performance was encountered. Due to increasing potable water demand Kindasa Water Services decided to increase system capacity to 40,500 m³/day and built Phase B. For the pretreatment of the expanded system, membrane pretreatment was considered. Extensive pilot testing confirmed the prior assumption that membrane pretreatment will produce stable feed water quality, even during periods when raw water has high turbidity due to algae bloom or stormy weather. Pressure driven, capillary UF membrane technology was chosen for the

pretreatment of the expanded system. The membrane modules that have been selected for the pretreatment system are HYDRAcap® UF modules made by Hydranautics. The plant start-up occurred during the middle-to-late part of 2006, and results indicate that the UF filtrate has very good and steady quality with turbidity less than 0.05 NTU despite high quality fluctuation in raw water with turbidity peaking sometime at 20 NTU and high organic content. The RO plant met all projected pressures, flows and water quality and was performing during the worst season without any change in normalized or real flows, pressures and quality. The SWRO trains are equipped with Hydranautics' SWC3 membranes that operate at 50% recovery while achieving product quality at a consistent rate below 800 µS, at temperatures around 32°C. On average, raw water has TDS of 41,500 mg/l, but sometimes reaches 42,000 mg/l.

Figure 1 UF and RO Systems at the 26,000 m3/d Kindasa Plant

UF Rack   RO Train

Recent economic evaluations indicate that the cost of equipment in large RO seawater systems utilizing membrane pretreatment may be about 30% higher than in a plant using conventional pretreatment. Experience with the operation of the Kindasa IMS, until now, indicates that operating costs may be lower than conventional pre-treatment. Sulphuric acid is the only chemical dosed in the membrane-based pre-treatment process. Assuming the overall water costs produced by large RO seawater plants is to be about $0.70/m³, the overall difference represents about 2 – 3%. At sites with good and stable raw water quality, the conventional pretreatment will continue to be sufficient. At locations with difficult raw water, use of membrane pretreatment at somewhat higher water costs could be justifiable to assure stable plant operation. Further development of the UF technology may lower costs and make membrane pretreatment an even more competitive alternative.

There continues to be a trend toward the use of membrane pretreatment in RO-based systems. When difficult feedwaters are encountered, such as wastewater or difficult surface water, UF/MF pretreatment can effectively reduce membrane fouling rates. The reduced fouling rates lead to lower energy consumption, lower chemical usage, longer membrane life, less maintenance and greater system on-line time. Additionally, the improved water quality may allow the RO to run at higher flux. This will result in a smaller RO system and further capital cost savings.

REFERENCES

1. K. Barushid, A. Hashim, T. Kannari, T. Tada and H. Iwahori, UF membrane performance at Addur: expectation, reality and prospects, Intern. Desalination Assoc., World Congress on Desalination and Water Reuse, September, 2005, Singapore
2. Graeme K. Pearce, Santi Talo, Kamran Chida, Amir Basha, Aziz Gulamhusein, Pretreatment options for large scale SWRO plants: case studies of UF trials at Kindasa, Saudi Arabia, and conventional pretreatment in Spain, Desalination 167(2004)175-189
3. Zenon press release