Membrane Desalination for the Arab World: Overview and Outlook

Arab countries in the Middle East and North Africa, where 5% of the world’s population has just 1% of the world’s fresh water supply, have witnessed an explosive growth in reverse osmosis (RO) membrane technology applications for desalination of water since its first commercial introduction in the late seventies and early eighties of the twentieth century. The City of Riyadh, Saudi Arabia, was the first recipient of this technology represented in the supply of almost 9,000 8”X40” hollow-fine fiber permeators by DuPont, the industry’s pioneer membrane manufacturer, with productivity totaling over 125,000 m³/day (33 MGD) of desalinated water in 5 large-scale RO plants (Salboukh, Manfouha I & II, Shemaisi and Maleiz), and 2,100 8”X40” spiral-wound RO plant was contracted and commissioned by the Saline Water Conversion Corporation (SWCC), which is responsible for installing and operating seawater desalination plants throughout the Kingdom, to provide drinking and potable water for the village of Al-Birk. Almost at the same time, the government of Malta had contracted and commissioned the world’s first and largest seawater RO plant in Ghar Lapsi with a capacity of 20,000 m³/day (5.3 MGD). The success of these two strategic plants was crucial for RO membrane technology to emerge as a viable, reliable and cost-effective alternative to the aging and expensive thermal desalination processes. Despite initial technical and commercial problems and setbacks at both plants, the age of membrane desalination in the water-scarce Arab World has arrived. The rest, as they say, is history.

Today, RO is a fairly mature, yet still evolving, and highly-competitive technology, utilizing state-of-the-art membrane manufacturing techniques, advanced pre-treatment integrated processes and cost-effective and operationally-efficient system designs. GCC and North African Arab countries now have an estimated installed membrane desalinated water output of 1.5 million cubic meters a day (about 400 million gallons a day), with over 4 million m³/day (more than a billion gallons a day) already planned by many countries for the next 2-5 years. Saudi Arabia, Bahrain, the United Arab Emirates and recently Kuwait, are leading the Arab World, if not the entire world, in utilizing large-scale RO membrane desalination as the technology of choice to meet the ever-growing demands for drinking, potable and agricultural water at a reasonable cost.

In Saudi Arabia, the world’s largest producer of desalinated water with over one billion cubic meters annual output, SWCC alone is currently producing 21% of the world’s total, including about 350,000 m³/day using 8 seawater RO plants in Al-Jabal, Jeddah, Yanbu and several remote locations on the Red Sea, with plans to build more plants and upgrade existing ones on the West Coast using RO/NF (nanofiltration). Saudi Aramco played a role in “experimenting” with RO in its commercial infancy with two seawater plants at Ras Tanajib, used for producing utility water, and at Ras Safaniya (the first dual-stage seawater RO plant in the world with 45% conversion) for providing fresh water for its gas plant’s crude oil desalter. According to a recent forecast, Saudi Arabia will be the world’s third largest purchaser of RO membranes and systems by 2007, after only the US and Japan.

Bahrain was quick to follow the lead of Saudi Arabia in exploring the viability of RO technology in actual practice. A 46,000 m³/day (12 MGD) RO plant was contracted and commissioned in 1984 at Ras Abu Jarjar to usher in the era of large membrane plants utilizing high-brackish well-water feed. Although the plant used DuPont’s hollow fine-fiber seawater membranes, it was unrealistically too expensive to build at over $3,000 per m² ($11.5 per gallon) of water, partly because of lack of experience and confidence in RO reliability resulting in over design, it was critical to demonstrate that the new technology can deliver just as reliably at this capacity as MSF and other thermal processes. The plant is still operating with full force, following a major refurbishment in the early nineties.
and has been operating virtually fouling-free for the past 14 years. The success of this plant quickly led to the design and construction of what would become the largest seawater RO plant at Ad-Dur, at a capacity of 46,000 m³/day (12 MGD). In sharp contrast to the Ras Abu Jarur plant, Ad-Dur plant costed about less than one third of that of RAJ and has been plagued with serious pre-treatment performance and membrane fouling problems, even after it was refurbished with new membranes and a UF system replacing the traditional gravity filtration system.

Kuwait has contributed significantly to the development of RO technology by extensively studying over several years its technical and economic feasibility early-on via the operation and evaluation of the seawater demonstration plant at Doha under a special agreement between the Kuwait Institute of Scientific Research (KISR) and the German Research Institute, GKSS, in the mid-eighties. The plant operated and tested 3 RO trains with different membrane manufactures and configurations, using a common intake and pretreatment system. Kuwait, a major user of thermal desalination for many decades, has recently adopted RO as a commercially viable process and is in the process of commissioning a 380,000 m³/day (100 MGD) wastewater treatment plant utilizing both RO and UF processes, and is tendering its first large-scale RO plant at Al-Zur North with a production capacity of 56,500 m³/day (15 MGD).

The United Arab Emirates, which started utilizing RO technology in the late Eighties, is now the third largest producer of desalinated water in the world, after Saudi Arabia and the United States, and is in the process of commissioning the world’s largest seawater RO plant in Al-Fujairah (170,000 m³/day or 45 MGD) and is planning a 190,000 m³/day (50 MGD) seawater RO plant at Al-Taweelah, the first IWPP (Independent Water & Power Plant). Both plants are part of an MSF/RO hybrid scheme combining the production of water with power generation.

Algeria is following suit with plans to construct 4 brackish RO plants totaling about 500,000 m³/day (130 MGD), and USAID is funding a 54,800 m³/day (14 MGD) seawater RO plant for the Palestine National Authority in the Gaza Strip with future expansion to 165,000 m³/day (42 MGD). Morocco, Tunisia, Egypt and other Arab countries are embarking on plans to incorporate RO technology in order to satisfy their demands for water.

Jordan and Palestine will witness the world’s most ambitious water transport and desalination project yet to come. Known as the Red-to-Dead Conveyor Project, 1.5-1.8 billion cubic meters of Red Sea water will be carried annually via a 200-kilometer pipeline to replenish the Dead Sea level that has been badly deteriorating in recent years. An RO desalination plant will use part of the transported water to produce 850 million cubic meters annually (614 MGD). Two-thirds of the desalinated water will go to Jordan and a third will go to the Palestinian Authority in the West Bank as well as Jerusalem. The project is estimated to cost $3-5 billion to be funded mostly by international grants over 13 years of construction.

Technology Issues and R&D Opportunities
Although the RO process is no longer thought of as “too sensitive” or hardly reliable and its application is accelerating as an established and reliable technology, several key issues still need to be seriously addressed, especially in membrane plants in the Arab World:
1. Membrane Fouling (Biological and Colloidal)

This is the single most critical and persistent issue hindering the commercial-scale application of RO membrane technology since its advent and to the present day, especially when dealing with tough-to-treat, open-surface Arabian Gulf waters. Most of the early RO plants in Saudi Arabia, Bahrain and the UAE suffered one form or another of severe fouling, most notably colloidal and biological fouling. The main reasons for this problem can be largely blamed on the pre-treatment and disinfection processes commonly used. Surface seawater, with its high content of fine colloidal matter and high potential for biological contamination and “after-growth”, presented a major problem to membrane manufacturers and end-users alike. The other aspect promoting the incidence of fouling, often resulting in heavy but ineffective cleaning frequencies and eventually irreversible loss in membrane system performance characteristics and plant availability, and subsequently significant cost burdens, is the lack of adequate universal performance monitoring and evaluation techniques that can measure and diagnose membrane fouling or scaling early and before significant symptoms of deterioration are exhibited. Recent advances in pre-treatment designs and optimization, disinfection “revolutions”, membrane chemistry and smart analytical technologies that can measure the degree of fouling in real-time, rather than “trend” it, can go a long way in resolving this major issue.

2. Performance Monitoring

Since the beginning, plant operators, engineers and supervisors had a difficult time monitoring the real performance of their plants due to lack of set procedures for data collection, analysis and reporting. At many plants it was not unusual to see piles of often incomplete data sheets gathering dust while no one had the time (and sometimes the interest) to utilize such data in making sure their plants are well monitored and well maintained on a daily basis. Membrane manufacturers offered free out-of-date data normalization software to end users but only for commercial warranty claim purposes and showed no real interest in helping plant owners monitor and evaluate the plant’s performance and fouling status. While this situation is changing, many plants have a long way to go in instituting proper standards and procedures for data collection, management, evaluation and reporting, based on actual experience, including more aggressive use of reliable instrumentation, automatic data sensors (such as the Supervisory Control and Data Acquisition System, known as SCADA) and sophisticated computer software (i.e., expert systems). Again, the fundamental problem is the lack of universal industry-wide technology and procedures to evaluate collected data on a real-time basis and not on a long-term trending basis.

3. Training

Most operators and engineers responsible for the operation and maintenance of RO plants do not receive adequate classroom and field training on their vital functions, and they are often expected to learn on-the-go as they gain practical experience only through working at the plant for long periods. The issue of training deserves its own priority and budgeting through integrated and full-scale programs as a continuing education process no matter what the education level of plant personnel and their practical experience. Technology developments, advances and innovations are occurring at an increasingly rapid pace, and plant personnel need to be continually educated and trained as part of optimizing the operation and performance of their plants on an ongoing basis.

The Future

With current consumption of Bahrain, Iraq, Kuwait, Saudi Arabia and United Arab Emirates reaching about 16 million cubic meters per day (4.2 billion GPD), Arab countries will spend over $30 billion through 2025 on desalination, according to UAE Industrial Bank Newsletter, Aug. 2004 issue. About $40 billion has been spent so far on desalination plants with 35 new plants planned for the GCC countries. Therefore, the future of membrane technology application in the Arab World carried tremendous prospects. Technology areas likely to gain focus, include wider and more effective use of:
- Integrated membrane technologies as alternative pretreatments with UF/MF to traditional media filtration and chemical treatments.
- Innovative hybrid systems (MSF/RO/NF/IX) customized for particular needs.
- Automation & computerization (SCADA, silent alarms, etc.)
- Privatization of IWPP (Taweela RO & ADEWA, UAE; Arzew, Algeria)
- Mega-capacity plants (50-150 billion GPD)

<table>
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<tr>
<th>Country</th>
<th>Total Capacity m³/day</th>
<th>Installed</th>
<th>Under Construction or Planned</th>
<th>Process</th>
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<tr>
<td>Algeria</td>
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<td>888,000</td>
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<td>Palestine</td>
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