Desalination Technology Trends

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Abstract

Texas' increased interest in desalination reflects a worldwide trend to include it as a viable alternative water supply option in any long-term water strategy. Recent technological developments and new methods of project delivery are driving this heightened level of interest to the point that desalination is now being seriously evaluated on projects where it would not have been considered ten years ago.

The most significant trend in desalination is the increased growth of the reverse osmosis (RO) market. Technological improvements have both dramatically increased the performance of RO membranes. Today's membranes are more efficient, more durable, and much less expensive. Improvements in membrane technology are complimented by improvements in pretreatment technology, which allow RO membranes to be considered on a much wider range of applications.

Energy costs are directly related to the salt content of the water source, and may represent up to 50% of a system's operational costs. There has been a growing trend to reduce energy costs through improvements in membrane performance and by employing modern, mechanical energy recovery devices that reduce energy requirements by 10-50%.

The growing trend to build larger desalination plants recognizes the inherent modularity of RO systems and the fact that the development, design, and permitting costs are somewhat independent of plant size. The result is that larger plants are being constructed to take advantage of economies-of-scale, which reduce the unit cost of desalinated water.

Other trends that will be reviewed in more detail include the co-siting of desalination plants with electric power generating plants and other industrial facilities, and the hybridization of distillation and membrane processes.

Introduction

The world's desalination capacity is expected to double in size over the next twenty years, resulting in an installed capacity of over 10.5 billion gallons per day. Historically, most of the installed seawater desalination capacity has been produced through thermal distillation processes. Since the late 1990s, reverse osmosis (RO) membrane systems have become the fastest growing segment of the seawater desalination market.

Technological improvements have both improved membrane performance and reduced capital and operating costs to the point that membrane desalination is now a viable alternative in many water supply applications — including desalination of marginal or brackish groundwater and water reuse/reclamation projects — where it had not previously been considered. These improved desalination economics are occurring at the same time the cost of producing water from traditional sources continues to increase.

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These advances in technology have resulted in a sharp decline in the “total water cost” of desalinated water. The following table includes examples of the reported contracted price for water produced by seawater desalination.

Table 1- Seawater desalination contracted water cost.

Project	**Size (mgd)**	**$/1000 g**	**$/acre-ft**
Tampa Bay	25	2.08	678
Ashkelon, Israel	36	2.00	652
Ashkelon, Israel 2	36	1.89	616
Larnaca, Cyprus	14	2.76	900
Trinidad	30	2.69	877
Shuweihat UAE **	120	2.61	851
Taweelah B, UAE **	63	2.65	864
Taweelah C, UAE	60	2.35	766
Texas *	50	2.10 – 2.30	684 – 750
Southern California *	50	2.41	784

** estimated   ** thermal desalination*

Most people associate the word “desalination” with seawater. However, the trend to use RO systems to desalinate inland, brackish water sources and to polish or “repurify” wastewater effluents is increasing at a much faster rate. These systems are usually limited by the ability to dispose of the concentrate or “brine” in an environmentally safe manner. As new, and more cost effective methods of concentrate disposal technology have been developed, the number of installations has increased accordingly.

Reverse Osmosis Process

RO uses a semipermeable membrane – with pumping pressure as the driving force – to separate a saline feedwater into two streams; a high-quality product stream, and a highly concentrated “reject” stream. By using modern membranes and pressures as high as 1000 psi, it is possible to produce potable water from seawater in a single pass; desalination of brackish waters can be accomplished at proportionally lower pressures.

Every RO systems consists of four major components: an intake to provide a consistent supply of feedwater; a pretreatment system to properly condition the feedwater; a high-pressure pumping system to provide the energy necessary for fresh water to pass the membrane; and a membrane module which performs the desalination process by reject the passage of salt. The performance of the entire system is dependent upon the proper design and operation of each component.

Not only have membranes become more efficient at rejecting salts and other ions, improvements in manufacturing techniques have reduced production costs and resulted in higher quality membranes with improved durability. It has been estimated[2] that for the same capital investment spent on seawater RO desalination in 1980, 27 times more water can be produced by today’s systems.

Pretreatment Advances

RO membranes capable of preventing passage of certain individual molecules are highly susceptible to fouling by organics and suspended solids. Therefore, it is important to remove these solids ahead of the RO membrane to maintain performance and prevent irreversible

[2] ARI Desalination Market Analysis

damage. In fact, the most critical aspect in the success of an RO system is the effectiveness of its pretreatment system.

The capital and operating cost of a membrane pretreatment system can be 50% of the overall cost of membrane desalination or reuse plant. The pretreatment system also represents a plants biggest performance and operating cost variable. Improved pretreatment alternatives now available have had a significant effect on the increase in the number of RO-equipped systems.

A greater emphasis is being placed on pretreatment system selection and more facilities are conducting pilot studies to optimize the pretreatment process before a plant is constructed.

One RO pretreatment trend is the use of porous, high flux, low-pressure microfiltration (MF) and ultrafiltration (UF) membranes used to remove suspended solids that would otherwise foul the membranes. MF/UF systems are so effective at removing suspended solids that they are used in virtually every new wastewater repurification system prior to RO desalination.

Energy Costs

Desalination energy costs are directly related to feedwater salinities and can represent more than one third of a seawater desalination system’s operating cost. There are a number of design considerations that can significantly reduce a system’s specific energy consumption.

New energy recovery devices are able to recover increasing amounts of energy from the concentrated – and still-pressurized – brine in seawater RO systems. Pelton wheel turbines, work exchangers, pressure exchangers and hydraulic turbochargers are available that can reduce energy requirements by 10-50%.

Membranes themselves have become more “energy efficient” in their improved ability to reject salts and operate at higher flux rates, and units can be arranged, or “staged”, to maximize product water recovery.

Some RO facilities may qualify for reduced, non-industrial electrical rates. Further energy cost reductions may also be available by negotiating favorable off-peak or “interruptible” power rates with a local electrical provider.

Plant Siting

Electric power generating plants with once-through cooling systems require large volumes of cooling water to condense power-cycle steam back to high-purity water for producing new steam. Many seawater desalination plants are now co-located with a power plant with which they share a common seawater intake. The avoided cost of constructing and permitting a new intake may reduce the capital cost of the desalination facility by several million dollars.

Further synergy between a power plant and a desalination facility can be realized by combining the power plant cooling water discharge with the SWRO plant concentrate. This may have environmental benefits to both processes by reducing the thermal footprint of the power plant discharge while diluting the salinity of the RO concentrate.

The co-location of a power and seawater desalination facility has recently proven beneficial in Tampa Bay, Florida and is being considered for most of the projects currently proposed on the California coast. However, environmental concerns with once-through power plant cooling systems may actually prove to be detrimental in the ability to permit some proposed co-located facilities.

A California study[3] recently determined that the impact of the seawater intake may be the most significant direct adverse environmental impact resulting from seawater desalination. Marine organisms are affected when they become trapped against the intake screens – known as “impingement” – or drawn into the reverse osmosis process equipment – known as “entrainment.”

Electric power plants and desalination facilities that may share infrastructure such as seawater intakes or concentrate must identify how the operation of both the power plant and desalination plant will be coordinated.

Plant Size

The design complexity and operation of a large-scale RO plant is not significantly different than that of a smaller plant, and economies-of-scale can contribute to a considerable reduction in the cost of water production. Development and permitting costs are much more dependent on siting-related issues than they are to a plant’s production capacity.

The inherent modularity of RO systems is an important consideration when planning very large desalination plants and there is no theoretical or design size limit for RO systems. Larger systems are able to use larger, more efficient pumps and energy recovery devices contributing to the lower energy/operating costs of the systems.

Prior to 1998, most SWRO plants ranged in size from 0.2 to 4 million gallons per day (mgd). Most of the SWRO projects announced in the past several years range in size from 14 to 72 mgd. Individual RO train sizes in many new systems frequently exceed 2.6 mgd.

The following chart[4] was adapted from the US Bureau of Reclamation Desalting Handbook for Planners and illustrates the relationship between production capacity and water cost.

[3] California Department of Water Resource’s
[4] US Bureau of Reclamation Desalting Handbook for Planners

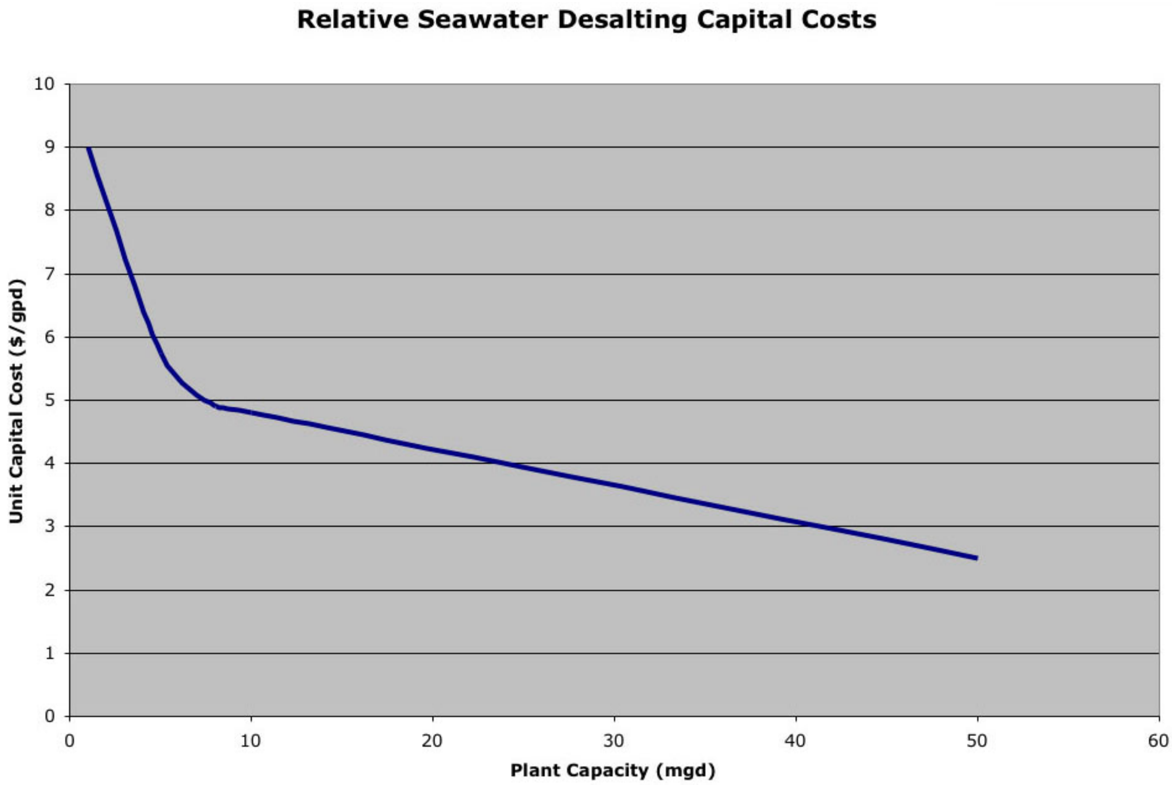

Figure 2 - Relative seawater desalting capital costs.

Hybrid Plants

A hybrid seawater desalination plant integrates the use of both thermal and membrane processes with an electric power generating station. This alternative provides flexibility by using two different forms of energy; electricity for the RO plant and low pressure steam for a distillation plant, eliminating the dependence on a single desalination technology.

Under this scheme, the thermal efficiency of the power plant improves as a greater percentage of the installed power capacity can be beneficially utilized, even during periods of low power demands.

Inland Brackish Water Desalination

Although brackish water desalination installations tend to be smaller than seawater desalination facilities, the number of brackish water reverse osmosis (BWRO) installations is growing at a faster rate.

It has already been noted that the cost of desalination is directly proportional to feedwater salt concentration, thus BWRO is inherently less expensive than SWRO. Brackish water aquifers are often located closer to the consumers than a seawater source, dramatically reducing treated water distribution costs. In addition, many brackish groundwater sources have a low level of suspended solids and require far less pretreatment than seawater sources.

RO concentrate disposal remains the biggest obstacle in the development of more BWRO installations. Disposal options at many inland locations are limited and may be environmentally and/or cost prohibitive. As technology further addresses this issue, the number of BWRO installations will increase at an even faster rate.

Nanofiltration (NF) membranes are very similar to RO membranes and account for approximately 6% of membrane production capacity. NF operates at a lower pressure than RO and is used in membrane softening applications to remove the ions that cause hardness in water, or to remove soluble organics from groundwater. They may also be used in sulfate removal to further improve performance of RO or thermal seawater desalination systems.

Wastewater Reclamation/Repurification

Combining low pressure MF/UF technologies with RO to treat secondary effluents from domestic sewage treatment plants water is referred to as wastewater *repurification*. By combining these membrane processes, it is possible to produce water that meets virtually any desired level of quality. Repurified water is most common for indirect potable reuse by groundwater recharge, or for industrial purposes such as boiler make-up and process water applications.

Direct potable reuse of municipal wastewater is currently limited to extreme situations, though advanced reuse technologies produce water that exceeds even the most stringent potable water requirements.

The number and size of projects where wastewater is reclaimed and repurified continues to grow. West Basin Municipal Utility District (Southern California) currently reclaims and recycles approximately 28 mgd for a variety of municipal and industrial purposes. Much of this water is repurified using dual membrane processes of MF/UF and reverse osmosis. Orange County California is constructing a similar facility to produce 72 mgd of repurified effluent. Singapore is well underway to reaching their 2010 goal of producing 25% of their fresh water needs through a combination of seawater desalination and water reclamation/repurification using membrane processes. Kuwait’s Sulaibiya project will use dual membrane processes to repurify 90 mgd of secondary effluent at the world’s largest such facility.

Summary

The benefits of research and development are apparent in the growth of desalination’s installed capacity, and new research and development initiatives have been announced that should continue this trend.

The US Bureau of Reclamation has recently developed a Desalination and Water Purification Technology Roadmap to serve as a strategic research pathway for desalination technologies.

Advances in desalination membrane technologies, pretreatment technology, energy recovery, improved integration of facilities, and more environmentally-conscious intake and outfall designs have resulted in better performance, lower capital & operating costs, and increased application of membranes in a variety of desalination applications. In the face of increased water shortages and growing costs of “conventional treatment,” this trend is expected to continue.