America's Authority in Membrane Treatment

AMTA

American Membrane Technology Association

Improving America's Waters Through Membrane Treatment and Desalting

Water Desalination Processes

Water desalting, or desalination, has long been utilized by water-short nations world-wide to produce or augment drinking water supplies. The process dates back to the 4th century BC when Greek sailors used an evaporative process to desalinate seawater. Today, desalination plants worldwide have the capacity to produce over 11 billion gallons a day – enough water to provide over 36 gallons a day for every person in the United States. About 1,200 desalting plants are in operation in USA.

In the United States, water is relatively inexpensive compared to many other parts of the world. However, the vagaries of weather, population growth and subsequent increases in demand for water in arid, semi-arid and coastal areas are contributing to a heightened interest in water desalination as means to augment existing supplies. In addition, many communities are turning to desalting technologies as a cost-effective method of meeting increasingly stringent water quality regulations. Most potable water desalination plants in the United States utilize membrane processes for desalting brackish (moderately saline) water and for softening and organics removal in ground water (low saline) supplies. However there are several large seawater plants in the planning phase. Desalination is generally divided into two primary categories: Distillation Processes and Membrane Processes.

Thermal (Distillation) Processes

Nature, through the hydrologic cycle, provides our planet with a continuous supply of fresh, distilled water. Water evaporates from the ocean (seawater) and other water bodies, accumulates in clouds as vapor, and then condenses and falls to the Earth's surface as rain or snow (fresh water). Distillation desalting processes work in the same way. Over 60 percent of the world's desalted ocean water is produced by boiling seawater to produce water vapor that is then condensed to form fresh water.

Since thermal energy represents a large portion of the overall desalting costs, distillation processes often recover and reuse waste heat from electrical power generating plants to decrease overall energy requirements. Boiling in successive stages each operated at a lower temperature and pressure can also significantly reduce the amount of energy needed.

Vapor phase, or evaporative processes are used primarily for seawater conversion, and consist of the following well established methods:

- Multistage flash evaporation (MSF)
- Multieffect distillation (MED)
- Vapor compression (VC)

MSF and MED require thermal input in addition to electric power, and because they handle hot seawater, materials selection becomes a critical factor in design. VC uses only electric power, with the thermal input coming from heat of compression. VC is generally the most economical evaporative process, but the fan compressors that are used limit the output capacity of the equipment.

Depending on the plant design, distilled water produced from a thermal desalination plant typically has salt concentrations of between 5 to 50 parts per million (ppm) of Total Dissolved Solids (TDS). Between 25 and 50 percent of the source water is recovered by most distillation methods.

Membrane Processes

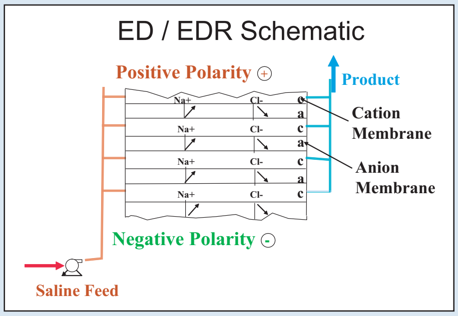
In the late 1940s, researchers began examining ways in which pure water could be extracted from salt water. Significant research was done in the 1950's at the University of Florida to demonstrate semi-permeable (desalination properties) of cellulose acetate (CA) membranes. During the John F. Kennedy administration, saline water conversion to fresh water was a high priority technology goal, "go to the moon and make the desert bloom", was the slogan. Supported by federal and state funding, a number of researchers advanced the science and technology of saline water conversion, but UCLA made a significant breakthrough in 1959 and became the first to demonstrate to be practical a process known as reverse osmosis (RO).

Professor Sidney Loeb and engineer Ed Selover remove newly manufactured reverse osmosis membrane from plate-and-frame production unit circa 1960.

About the same time, some researchers were investigating a non-permeable membrane technology known as electrodialysis. Both the electrodialysis (ED) and Reverse Osmosis (RO) processes use membranes to separate dissolved salts from water.

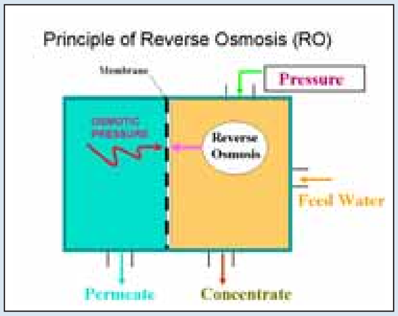
Electrodialysis

Electrodialysis is an electrochemical process in which the salts pass through the cation and anion membranes, leaving the water behind. It is a process typically used for brackish water. Because most dissolved salts are ionic (either positively or negatively charged) and the ions are attracted to electrodes with an opposite electric charge, membranes that allow selective passage of either positively or negatively charged ions accomplish the desalting. Freshwater recovery rates for this type of process range from 75 to 95 percent of the source water.



Reverse Osmosis

When two solutions with different concentrations of a solute are mixed, the total amount of solutes (i.e. salts) in the two solutions will be equally distributed in the total amount of solvent (i.e. water) from the two solutions. In the natural occurring phenomenon of osmosis this is achieved by *diffusion*, in which solutes will move from areas of higher concentration to areas of lower concentrations until the concentration on both sides of a membrane and the resulting mixture are the same, a state called *equilibrium*. Equilibrium occurs when the hydrostatic pressure sifferential resulting from the concentration changes on both sides of the semi-permeable membrane is equal to the osmotic pressure of the solute.



In Reverse Osmosis, salt water on one side of a semi-permeable plastic membrane is subjected to pressure, causing fresh water to diffuse through the membrane and leaving behind a more concentrated solution than the source supply containing the majority of the dissolved minerals and other contaminants. The major energy requirement for reverse osmosis is for pressurizing the source, or "feed" water.

Depending on the characteristics of the feed water, different types of membranes may be used. Because the feed water must pass through very narrow passages as a result of the way the membrane packaged, fine particulates or suspended solids must be removed during an initial treatment phase (pretreatment). Brackish water RO plants typically recover 50 to 80 percent of the source water and seawater RO recovery rates range from 30 to 60 percent.

A "loose" version of RO nanofiltration (NF) plants typically operate at 85 to 95 percent recovery, which is typically used for organic removal and softening (reducing calcium and magnesium hardness).

Applying the Technology

No one desalting process is necessarily "the best." A variety of factors come into play in choosing the appropriate process for a particular situation. These factors include the quality of the source water, the desired quantity and quality of the water produced, pretreatment, energy and chemical requirements, and methods of concentrate disposal.

Uses of Desalting

The conversion of seawater to drinking water is the most publicly recognized use of desalination. Desalination is also used for improving the quality of drinking water from marginal or brackish sources. Membrane desalting technologies are also used in home or tap water treatment systems, in industrial wastewater treatment to reclaim and recycle, to produce high-quality water for the semi-conductor and pharmaceutical industries and for the treatment and recycling of domestic wastewater.

Membrane desalting technologies are not only used to remove salt and other dissolved minerals from water but in addition contaminants, such as dissolved heavy metals, radionuclides, pathogens, arsenic, bacterial and dissolved organic matter may also be removed in a variety of methods.

In the last twenty years, there has been a significant reduction in power requirements of membrane desalination technologies, with improvements in membrane salt rejection and flux properties. As an example Island Water Association's 5 MGD Brackish RO WTP originally installed in 1980 with CA membrane elements operating at 550 psi and 75% recovery with 10% salt passage currently operates non-CA membrane thin-film composite polyamide (TFCPA) at 170 psi with only 5% passage. In fact this plant was a pioneer initially converting to TFCPA membrane elements in 1984. In charted performance from December 1986 to October 1998, this plant experienced a decrease from 3.9 KWH / Kgal to 2.7 KWH / Kgal.

Desalination Future

Water from desalination is not bound by many of the conditions that plague traditional fresh water development. The increase in the public awareness of the environmental problems associated with fresh water sources coupled with the new, more stringent drinking water quality regulations make development of new traditional water resources more difficult and costly. Unlike traditional water supplies, alternative desalted water supplies are not vulnerable to weather (droughts).

Membrane desalting technologies also allow plants to be built in stages to meet demand, unlike traditional water development with its high initial capital outlay. Finally, membrane desalted water is in many cases comparable in cost to water from traditional water supplies, especially if utilized to augment current supplies.

From initial experiments conducted in the 1950's which produced a few drops per hour, the reverse osmosis membrane industry has today resulted in combined worldwide production in excess of 6.8 billion gallons per day. With demand for pure water ever-increasing, and water shortages world-wide, the growth of the reverse osmosis industry is poised well into the next century.

In the early 1980's, research in US Government Labs resulted in the first Composite PolyAmide membrane. This membrane had significantly higher permeate flow and better salt rejection than CA membranes. Today, with the advancement of non-CA thin-film composite polyamide membrane elements, the industry has attained a 20-times increase in energy efficiency over the original CA membrane elements, with a similar order of magnitude decrease in salt passage.

Experts around the world continue to research better membranes for desalination, as well as membranes for contaminant removal, water reclamation, re-use, and industrial applications. The primary focus of the research is on reduction in energy requirements and making elements with higher and selective rejection properties, while minimizing fouling tendencies.

This material has been prepared as an educational tool by the American Membrane Technology Association (AMTA). It is designed for dissemination to the public to further the understanding of the contribution that membrane water treatment technologies can make toward improving the quality of water supplies in the US and throughout the world.

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