American Membrane Technology Association
America's Authority in Membrane Treatment

Forward Osmosis (FO)

Overview

In recent years, significant advances in membrane technology, improved processes, and the need to treat more difficult waters has expanded the market potential of Forward Osmosis (FO). Initial uses of FO included the treatment of difficult waste streams, small-scale water reuse, and emergency/disaster recovery. These applications were well suited for the technology, given the main benefits of FO:

- Low propensity for fouling/scaling
- Potential to apply waste energy (i.e. salt/heat) om the effective separation/ concentration of solutions
- Ability to achieve very high concentrations of feed solutions
- Potential to convert stored chemical energy into hydrostatic pressure (e.g., pressure retarded osmosis)

FO is an osmotic membrane process, which takes advantage of osmotic pressure to drive water across a semi-permeable membrane, where two solutions of varying salinity are present. Unlike Reverse Osmosis (RO) where hydraulic pressure is required to overcome osmotic pressure, FO is not hydraulically pressurized. Water flows naturally and spontaneously from a lower salinity feed solution on one side of the membrane to dilute a higher salinity draw solution on the other side. Like RO, the semi-permeable membrane allows water to pass through it, but rejects nearly all suspended and dissolved solids.

During the FO process, the lower salinity feed solution is concentrated and the more concentrated draw solution is diluted. If fresh water is the goal of the process, a separate draw solute separation process must be included in the treatment scheme. Figure 1 illustrates Forward Osmosis and Reverse Osmosis Processes. Figures 2 and 3 show treatment scheme examples in which FO is used.

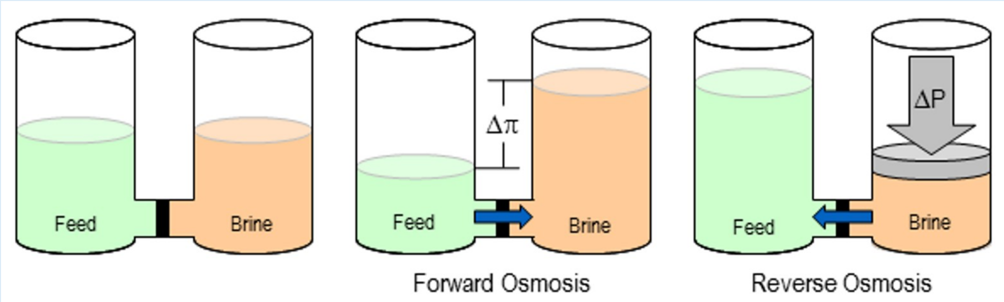

Figure 1: Osmotic Membrane Processes

Forward osmosis is used in the municipal, mining, oil and gas, and food and beverage industries in several ways:

- Clean water recovery
- Product concentration
- Waste concentration

FO is ideally suited to recover clean water from an impaired source. It can be used most efficiently where a high salinity draw solution is already being used to supply a desalination process, or where waste heat is available to increase the osmotic pressure driving the process. Clean water recovery treatment schemes that utilize FO require the downstream separation of the solute from the solution to produce fresh water, since it is the high concentration of the solute that is inducing the FO process. Technologies used for this downstream separation may include RO, membrane distillation (MD), thermal evaporation, thermal distillation, or the use of a specific draw solute that is removable by some other means. Alternative draw solutes that have been used include thermolytic salts (which volatilize when heat is applied) or magnetic nanoparticles. In some schemes, the FO process acts as a high-quality pre-treatment before the solute separation process. Because the FO membrane rejects nearly all foulants and other contaminants, the downstream desalination process can be designed more aggressively, targeting only the removal of the specific salt used to induce the FO process.

In other applications, FO is used for clean water recovery, but the draw solute is not separated from the diluting water. In one such process, a bag constructed of FO membrane contains a beverage concentrate (primarily sugar and flavoring). When the bag is placed in a potentially contaminated or saline water source, the beverage concentrate acts as a draw solution, pulling water across the membrane, creating a more diluted beverage. In this way, a safe, potable drink can be made using a contaminated feed water source, without applying outside energy. There are commercial products available using this scheme, marketed to back country hikers or for use as emergency hydration packs. Another use is “fertigation”, in which a fertilizer is used as a draw solution to recover clean water from seawater or brackish water. The fertilizer is then diluted to the desired strength and applied to crops.

associated disposal costs. Concentration factor is directly related to the osmotic potential of the draw solution being used in the system.

A sub-technology to FO, Pressure Retarded Osmosis (PRO), makes renew- able energy production possible by mixing freshwater and saltwater. In PRO, the saltwater is pressurized to some fraction of the osmotic pressure by the

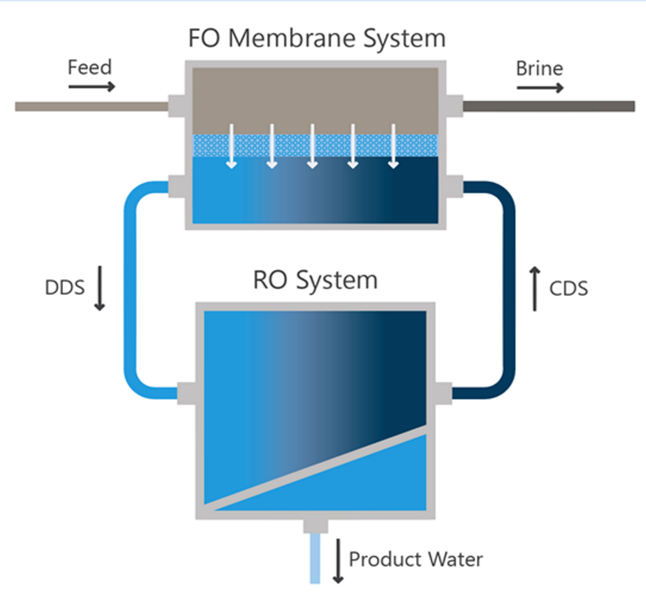

Figure 2: Typical FO system design with draw solution and product water separation by RO (ionic salt as osmotic agent)

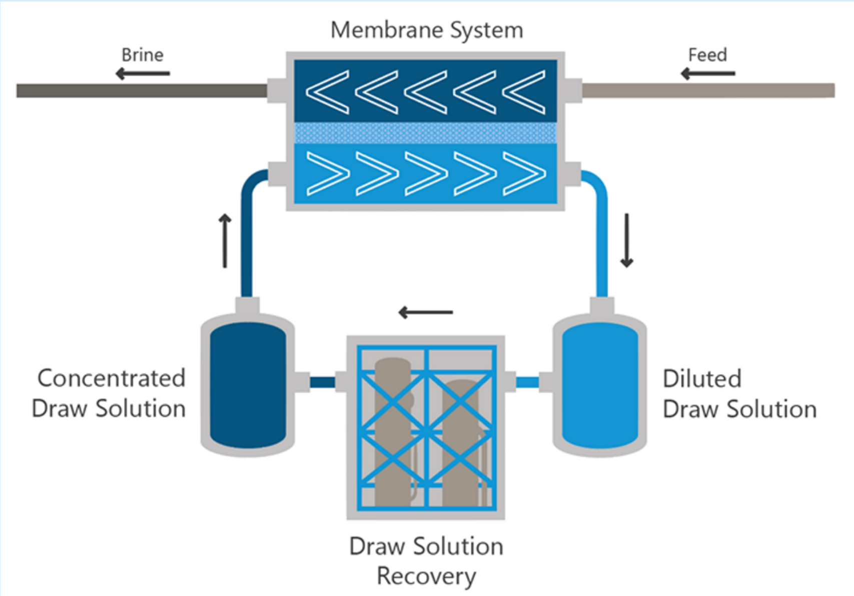

Figure 3: Typical FO system design with thermal draw solution and product water separation (thermolytic salt as osmotic agent)

The food and beverage industry uses FO for food product concentration. Saltwater or sugar water are used as a draw to remove excess water and subsequently concentrate juices, soups, and other food products. One significant benefit of using FO in this process is that the flavor and appearance of the food are not altered by the high heat or pressure required in other concentration methods.

In the mining, power, chemical, and oil and gas industries, FO is usually used to minimize and concentrate waste streams. In these industries, waste streams are often very difficult to concentrate due to their high salinities or high fouling or scaling potential. FO is able to highly concentrate these streams and effectively reduce the volume of waste and the

flux of water across the membrane. A portion of this high-pressure salt water is then relieved though a turbine, generating electricity. This technology makes it possible to generate energy from waste streams of freshwater, while reducing the volume of the waste stream.

The first FO membranes were cellulose acetate (CA) based, and contemporary CA membranes have been optimized and are still widely available for FO. The latest FO membranes, however, have adopted the thin-film composite structure of current RO membranes. FO membrane elements are commercially available in a variety of configurations, including flat sheet, spiral wound, and hollow fiber. Water fluxes in the FO process are a function of the salinities of the source water and the draw solution, but tend to be lower than other membrane technologies, including RO (on the order of 1 to 5 gallons per day per square foot). Because FO does not require high pressure, higher packing densities can be achieved in spiral wound and flat sheet FO membrane element configurations.

The Future of Forward Osmosis

Continued scarcity of pristine water sources, increased waste disposal costs, and continued improvements in FO technology will significantly expand the FO market in coming years. As water reuse becomes increasingly necessary, FO will be a viable technology in the water treatment arsenal to obtain high-quality pre-treatment for other separation processes. In situations where zero liquid discharge (ZLD) is mandated, for wastewater treatment, FO can reduce the cost of the energy intensive brine concentration step prior to crystallization, FO will also fill a critical void for mining and oil and gas companies that are looking for methods that minimize the volume and cost of waste disposal and increase the recovery and reuse of water and process fluids. Food and beverage companies will also look to FO as a desirable method of product concentration that protects the flavor and nutritional content of their products.

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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