Nanofiltration and Reverse Osmosis (NF/RO)

OVERVIEW

Reverse osmosis (RO) is a physical separation process in which properly pretreated source water is delivered at moderate pressures against a semi-permeable membrane. The membrane rejects most solute ions and molecules, while allowing water of very low mineral content to pass through (**Figure 1**). This process also works as a barrier for cysts and viruses. The process produces a concentrated reject stream in addition to the clean permeate product. Reverse osmosis systems have been successfully applied to saline groundwaters, brackish waters, and seawater, as well as for removal of inorganic contaminants such as radionuclides, nitrates, arsenic, and other contaminants such as pesticides, trace organics, and per- and polyfluoroalkyl substances (PFAS).

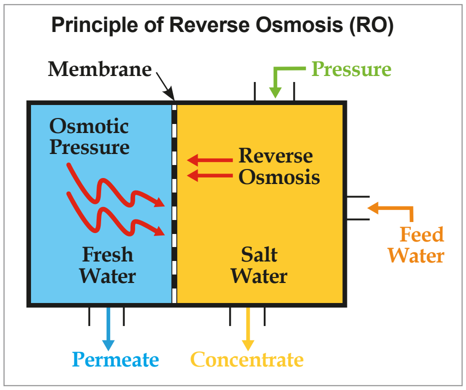

Figure 1: Principle of Reverse Osmosis

In an RO system, a higher concentration solution on one side of a semi-permeable, thin film composite membrane is subjected to pressure, causing low salinity permeate to diffuse through the membrane and leaving behind a more concentrated solution containing a majority of the dissolved minerals and other contaminants. The major energy requirement for reverse osmosis is to pressurize the source, or "feed" water. Depending on the characteristics of the feedwater, different types of membranes may be used. Because membranes are used for molecular level rejection, suspended solids and debris must be removed during the initial treatment phase (pretreatment) before entering the membrane elements.

A lower pressure RO technology called nanofiltration (NF), also known as membrane softening, has been successfully used to treat hard, high color, and high organic content feedwater. The NF membrane has lower monovalent ion rejection properties, making it more suitable to treat waters with low salinity and thereby reducing post-treatment and conditioning as compared with RO. The NF membrane also works as a barrier for cysts and most viruses. NF plants typically operate at 85 to 95 percent recovery. Brackish water RO plants typically recover 70 to 85 percent of the source water into permeate, and seawater RO recovery rates range from 40 to 60 percent.

Membrane elements are the building blocks of any NF/RO facilities. Elements are placed in pressure vessels in series, typically five to seven. Pressure vessels are then configured on skids, depending on the number of stages required. Multiple skids then make up the typical NF/RO facility (**Figure 2**).

SELECTING NF/RO MEMBRANE SYSTEMS

When selecting RO/NF systems, the following should be considered:

1. ***Membrane Selection:*** The majority of NF/RO membranes are polyamide composites in a spiral wound configuration. Materials are generally cellulose acetate (CA) based and polyamide thin film composites (TFC), with TFC more commonly used. Objectives for fluid separation will determine whether to use NF/RO in either CA or TFC and will also depend on the application, feedwater, pH range, operating conditions, and permeate quality and quantity desired. Operational conditions and useful life vary depending on the type of membrane selected, quality of feedwater, and process operating parameters.

2. ***Useful Life of the Membrane:*** Membrane replacement and power consumption represent major components in the overall water production costs. Feed water salinity is important; however, other constituents that foul and scale membranes need to be controlled to maximize useful life versus replacement. Well-designed and operated RO systems can yield a membrane service life of five to 10 years with proper maintenance. Many facilities have membrane elements over 12 years. Some facilities replace elements to take advantage of improvements in energy demand and improved rejection properties even though the original membranes still perform well.

Figure 2: A Plant With Multiple RO Skids

3. ***Pretreatment Requirements:*** Acceptable feedwater characteristics depend on the type of membrane chosen and operational parameters of the system. Without suitable pretreatment or acceptable feedwater quality, the membrane may become fouled or scaled, and consequently its useful life is shortened. Pretreatment is essential and pretreatment processes should be tested for Silt Density Index (SDI), turbidity reduction, iron or manganese removal, stabilization of the water to prevent scale formation, microbial control, chlorine removal (for certain membrane types), and pH adjustment. As a minimum pretreatment, one-to-five-micron cartridge filters (**Figure 3**) are used to protect membranes against particulate matter or source water upsets.

Figure 3: Cartridge Filter Housings for Pretreatment

4. ***Treatment Efficiency:*** Reverse osmosis is highly efficient in removing metallic salts and ions from feedwater. However, efficiencies vary depending on the ion being removed and the membrane utilized. For most commonly found ions, removal efficiencies will range from 85 percent to more than 99 percent. Organics removal is dependent on the molecular weight, shape and charge of the organic molecule, and the characteristics of the membrane utilized. Organic removal efficiencies may range from as high as 99 percent to less than 50 percent, depending on the membrane type and treatment objective.

For more information on pretreatment, post treatment and piloting, visit AMTA's Membrane Technology Fact Sheet Library.

5. ***Bypass Water:*** Reverse osmosis permeate will be virtually demineralized. The extent of demineralization depends on the type of membrane used. If the raw water does not contain pathogens, viruses and unacceptable contaminants, the design may provide for a portion of the raw water to bypass the unit and blend with RO permeate. Bypass/blend can maintain stable water within the distribution system, reduce equipment size and power requirements, and improve process economics.

6. ***Post-Treatment:*** Post-treatment typically includes degasification for carbon dioxide (if excessive) and hydrogen sulfide removal (if present); pH and hardness adjustment for corrosion control; and disinfection as a secondary pathogen control and for distribution system protection.

7. ***Desalting By-Product:*** By-product water—the concentrate—may range from 10 to 60 percent of the feedwater pumped to the RO unit. For most brackish waters and ionic contaminant removal applications, the by-product is in the 10 to 25 percent range, while for seawater, it could be as high as 60 percent. The by-product volume should be evaluated in terms of availability of source water and cost of disposal. Acceptable methods of by-product disposal typically include discharge to a municipal sewer system or waste treatment facility, to sea, deep well injection, or other environmentally acceptable methods, depending on the by-product concentration, available options, and regulatory requirements.

AMTA
American Membrane Technology Association

FOR MORE INFORMATION:
American Membrane Technology Association (AMTA)
PO Box 14918
Tallahassee, FL 32317
Phone: (772) 469-6797
Email: custsrv@amtaorg.com
www.amtaorg.com

@AmericanMembraneTechnologyAssociation

@amtaorg

8. ***Pilot Plant Study:*** Prior to initiating the design of an RO treatment facility, contact the regulatory agency to determine if a pilot plant study is required. In many cases, a pilot plant study is recommended to determine the best membrane to use, pretreatment and post-treatment requirements, bypass ratio, volume of reject water, system recovery, process efficiency, and other design and operational parameters.

9. ***Skid Design:*** Depending on the size of skid, they can be pre-fabricated, factory tested and shipped to the site (**Figure 4**), or fabricated on site, which is typical of larger facilities (**Figure 5**).

Figure 4: Example of Prefabricated Skids

Figure 5: Larger RO Facility Example

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.