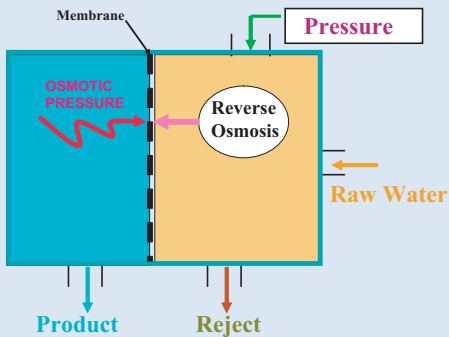


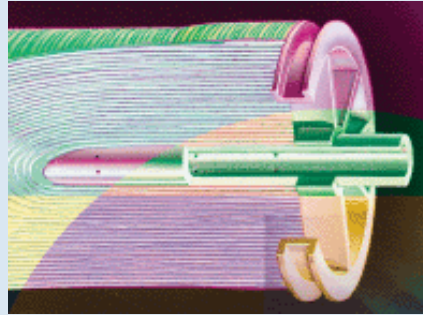
# Nanofiltration and Reverse Osmosis (NF/RO)

Reverse osmosis (RO) is a physical separation process in which properly pretreated source water is delivered at moderate pressures against a semipermeable membrane. The membrane rejects most solute ions and molecules, while allowing water of very low mineral content to pass through. This process also works as an absolute 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.

## Principle of Reverse Osmosis (RO)



In an RO system, a higher concentration solution on one side of a semi-permeable plastic membrane is subjected to pressure, causing freshwater to diffuse through the membrane 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 the feedwater has to pass through very narrow passages in the membrane module, larger suspended solids must be removed during the initial treatment phase (pretreatment).

A lower pressure RO technology called nanofiltration (NF), also known as “membrane softening,” has been successfully used for treatment of 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, thereby reducing post-treatment and conditioning as compared with RO. The NF membrane also works as an absolute barrier for cysts and most viruses. Nanofiltration plants typically operate at 85 to 95 percent recovery. Brackish water RO plants typically transfer 70 to 85 percent of the source water into permeate, and seawater RO recovery rates range from 40 to 60 percent.

## When Selecting RO/NF Systems, the Following Should Be Considered:

1. *Membrane Selection:* Two types of membranes are most commonly used. These are cellulose acetate based and polyamide composites. Membrane configurations typically include spiral wound and hollow fiber. Operational conditions and useful life vary depending on the type of membrane selected, quality of feedwater, and process operating parameters. Most current manufacturers only have the spiral wound option.
2. *Useful Life of the Membrane:* Membrane replacement and power consumption represent major components in the overall water production costs. The relative contributions depend primarily on feedwater salinity. In well designed and operated RO systems, membranes have lasted 5 to over 10 years in suitable applications.



3. *Pretreatment Requirements:* Acceptable feedwater characteristics are dependent 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 usually needed for 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, cartridge filters are used for protection of the membranes against particulate matter.
4. *Treatment Efficiency:* Reverse osmosis is highly efficient in removing metallic salts and ions from raw water. Efficiencies, however, do vary depending on the ion being removed and the membrane utilized. For most commonly found ions, removal efficiencies will range from 85% to over 99%. 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% to less than 50%, depending on the membrane type and treatment objective.
5. *Bypass Water:* Reverse osmosis permeate will be virtually demineralized. If the raw water does not contain unacceptable contaminants, the design may provide for a portion of the raw water to bypass the unit and blend with RO permeate in order to maintain a stable water within the distribution system and improve process economics. Bypass/Blend will reduce equipment size and power requirements.
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 or the “concentrate” may range from 10% to 60% of the raw water pumped to the reverse osmosis unit. For most brackish waters and ionic contaminant removal applications, the by-product is in the 10-25% range while for seawater it could be as high as 60%. 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 municipal sewer system or to waste treatment facilities, discharge to sea, or by deep well injection, depending on the by-product concentration and availability of the discharge option being considered.
8. *Pilot Plant Study:* Prior to initiating the design of a reverse osmosis treatment facility, the state reviewing agency should be contacted to determine if a pilot plant study will be required. In many cases, a pilot plant study will be necessary to determine the best membrane to use, type of pretreatment as well as post-treatment, bypass ratio, amount of reject water, system recovery, process efficiency, and other design and operational parameters.



*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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