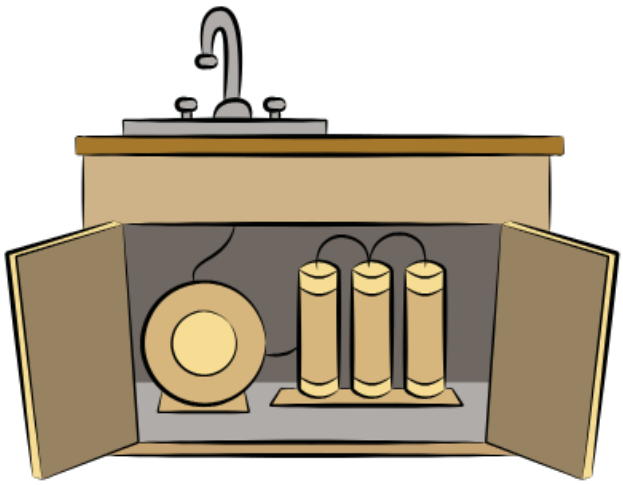
WQ-1047

It's All In Your Water
2013 EDITION

Reverse Osmosis



Roxanne Johnson
Water Quality Associate
North Dakota State University

Tom Scherer, Ph.D.
Extension Agricultural Engineer
North Dakota State University

How Reverse Osmosis Works

Reverse osmosis (RO) sometimes is referred to as ultrafiltration because it involves the movement of water through a membrane as shown in Figure 1. The membrane has microscopic openings that allow the relatively small water molecules, but not larger molecules such as dissolved minerals, to pass through. Some RO membranes also have an electric charge that helps in rejecting some chemicals at the membrane surface. Proper maintenance, especially routine backflushing and membrane cleaning, is essential to retain effectiveness through time. Some units are equipped with automatic membrane flushing systems to clean the membrane.

What Impurities Reverse Osmosis Will Remove

Reverse osmosis is a common method for treating household drinking water supplies. The effectiveness of RO units depends on the concentration of the contaminant and water pressure, given proper routine maintenance of the unit.

RO systems typically are used to reduce the levels of total dissolved solids and suspended matter, which may cause water supplies to be unhealthy or unappealing (foul taste, odor or color). The principal use of reverse osmosis for household water supplies is to reduce high levels of nitrate, sulfate, sodium and total dissolved solids (TDS).

Most home RO units have pre- and post-treatment filters to protect the membrane unit. The pre- and post-filters are commonly activated carbon filters, which are used to reduce the level of chlorine and some soluble organic compounds (SOCs), such as pesticides and dioxins, along with volatile organic compounds (VOCs), such as chloroform and petrochemicals.

An RO unit alone is not the best solution for these types of contaminants, but installing a properly designed RO unit to reduce the levels of other contaminants may provide a reduction in SOCs and VOCs.

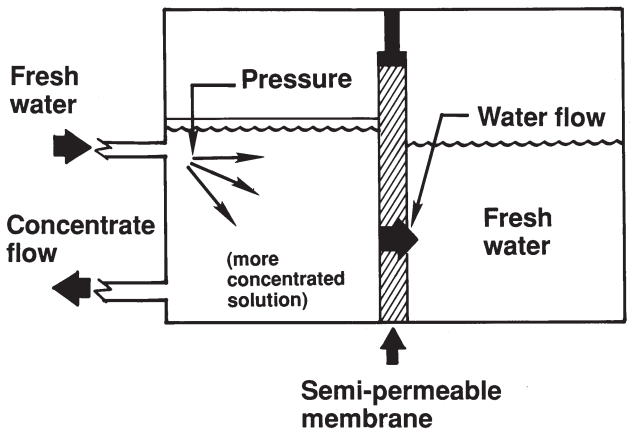


Figure 1.
Cross-section of a reverse osmosis unit

NDSU EXTENSION SERVICE

March 2013

How to Test Your Water

Having the water tested before installing any water treatment system is important. The test will identify the bacteria and level of minerals that are present. Interpretation of the test results will help determine whether treatment is needed and what type of system or systems to consider. The intended use of the water (drinking only, drinking and cooking, laundry or all household uses) also will help determine the extent of treatment needed and the type of system to select.

The water test analysis and interpretation will provide information about naturally occurring substances and those resulting from human activity. The treatment of contaminated water supplies should be considered only as a temporary solution. The best solution is to remove the source(s) of contamination and/or obtain a new water supply.

Note: Household-size RO systems normally are used to treat only drinking and cooking water supplies, so they may not be appropriate for treating larger flows of water. RO systems are not appropriate for treating water supplies that are contaminated with coliform bacteria.

How is Effectiveness Measured?

The effectiveness of RO units is characterized by the rejection rate or rejection percentage. The rejection rate is the percent of a contaminant that does not move through, or is rejected by, the membrane. Some typical rejection rates for common contaminants are shown in Table 1. These rejection rates are for single contaminants under testing conditions.

For water containing more than one contaminant, the rejection rate for each contaminant may be reduced, or one of the contaminants may be reduced in preference to the other contaminant. For example, water supplies containing high TDS levels or high sulfates in combination with nitrates may show no decrease in nitrates after treatment. (Nitrates in this publication refer to nitrate-nitrogen or NO_3-N.)

Rejection rates need to be high enough to reduce the contaminant level in the untreated water to a safe level in the resulting treated water. To determine the needed rejection rate, considering the initial concentration is necessary. For example, if a water supply contains nitrates at a concentration of 20 milligrams per liter (mg/l), an RO unit rejecting at a rate of 85 percent, which means 15 percent remains, would reduce the level to 3 mg/l (20 times 0.15 = 3).

Water with very high levels of nitrates (such as 100 mg/l) would remain near or above health standard levels even after treatment at this rejection rate. Nitrate levels this high are not normal and require special investigation and handling. The National Sanitation Foundation (NSF) recommends that special designs be used for RO units in which the NO_3-N level exceeds 40 mg/l.

Table 1. Reverse Osmosis Rejection Rates

Typical rejection rates for common contaminants			
Arsenic	94-96%	Nitrate	93-96%
Bacteria	99+%	Sodium	92-98%
Fluoride	94-96%	Sulfates	99+%
Lead	96-98%	% TDS	95-99%

From the Excel Water Directory at *www.excelwater.com/eng/b2c/rejection.php*

[1] Ave. Holiday, East Tower, Suite 501, Pointe-Claire, Quebec, CA H9R 5N3

Certification of Product

NSF International is a nonprofit organization that sets performance standards for water treatment devices. If a product meets its minimum requirements, the manufacturer is entitled to display the NSF listing mark on the product and literature for the product. To see a listing of manufacturers and models that meet NSF's standards, contact NSF at *www.nsf.org/certified/consumer/listings_main.asp*. A list of minimum contaminant-reduction requirements under NSF is posted at *www.nsf.org/consumer/drinking_water/dw_contaminant_protocols.asp?program=WaterTre*.

Disadvantages of Reverse Osmosis Units

RO units treat only a fraction of the water going into the RO unit. The usable amount of water from an RO unit is only 5 to 15 percent of the water entering the system. The remainder is discharged as waste water. Because waste water carries the rejected contaminants, methods to recover this water are not practical for household systems.

Waste water typically is connected to the house drains and will add to the load on the household septic system. An RO unit delivering 2 gallons of treated water per day may discharge 8 to 15 gallons of waste water per day to the septic system. North Dakota plumbing code states "waste must not be discharged into surface or subsurface water unless it has first been subjected to some acceptable form of treatment," so bypassing the septic system is not suggested.

For whole-house RO systems, the volume of discharge can be more than 500 gallons a day. Household septic systems are not designed to handle this volume of wastewater. Therefore, for whole-house RO systems, the wastewater must be discharged some other way than through the septic system.

Contact your local health unit for county-specific regulations. Depending on the volume of contaminants in your water supply, the useful life of the filters may require replacement more often.

Point of Use: Reverse Osmosis Equipment

A typical home reverse osmosis treatment system is shown in Figure 2. The system normally is beneath the kitchen sink and connected to the cold water inflow line because it is used to treat water for drinking and cooking. RO systems consist of the prefilter, RO membrane unit, a pressurized storage tank for the treated water, a post-filter and a separate delivery tap for the treated water supply.

The water supply entering the RO unit should be bacteriologically safe. RO units will remove all microorganisms, but they are not recommended for that use because of the possibility of contamination through pinhole leaks or deterioration of the RO membrane due to bacterial growth. Water softeners commonly are used to treat water before it enters the point of use RO system.

Figure 2.

A typical home RO system includes: (1) particle filter, (2) reverse osmosis membrane unit, (3) pressurized treated-water storage container, (4) carbon adsorption post-filter and (5) separate treated-water tap

- **Prefilter:** The prefilter sometimes is referred to as a sediment filter. It removes small suspended particles to extend the life of the membrane. Some membrane units are damaged by chlorine and others by bacterial growth. Where chlorine is present, a carbon prefilter also may be recommended.
- **RO membrane:** Several kinds of reverse osmosis membranes are available. Three types of membranes are used in RO systems: cellulosic, aromatic polyamide and polyamide thin film composite (TFC). Cellulosic filters come in two types: cellulose acetate or cellulose triacetate. The cellulosic membranes may contain dioxane from the manufacturing process and need a warning label. A cellulosic membrane does not offer the rejection rate of polyamide and TFC membranes. However, chlorine can break down polyamide and TFC membranes faster and cause premature failure of the system, so a carbon pretreatment is recommended to remove chlorine.

  Each product has certain advantages and limitations, and they need to be considered. Some of the factors that should be investigated are:

  - The contaminant(s) involved and their initial concentration(s)
  - The water supply rate, or whether the system will deliver enough water to meet normal daily drinking and cooking requirements
  - The rejection rate, or the percentage of contaminants to be removed by the membrane
  - The water pressure required to meet the supply and rejection rates. That is, can this unit be operated on the normal operating pressure of a home water system or will a booster pump be required?
  - How can the system's performance be monitored? That is, how can leaks or other problems be detected or how is the time for servicing or replacement determined? Most RO systems have built-in monitors that display their condition on the delivery tap, but some do not. Conductivity meters, pressure gauges and other devices can be used to detect problems where monitors are not included. Where coliform bacteria or other special contaminants are a known or suspected problem, periodic testing is recommended.
- **Storage tank:** Most RO units supply treated water at very low rates, so a storage tank of 2 to 5 gallons is used to provide a suitable supply. These units are pressurized to produce an adequate flow when the tap is open. Under-sink storage requires minimum pressure to deliver water. Other locations may require increased delivery pressure, which may reduce membrane performance.
- **Post-filter:** The main reason for post-filtration is to remove any undesirable taste and residual organics (this may include certain pesticides and organic solvents) from the treated water. Usually an activated carbon filter is used for this purpose. Some manufacturers will eliminate the post-filtration step if a carbon filter is used in prefiltration.
- **Delivery tap:** A separate delivery tap for the treated water is used so that treated and untreated water are available.
- **Other:** No special controls are required on most systems because they use household water pressure. Monitoring gauges or servicing lights are becoming increasingly common and assist in knowing whether the system is working properly. Be aware that many gauges are based on time expended, not on the amount of water that has passed through the filter.

Summary

Reverse osmosis is a proven technology. One of the better known uses of RO is the removal of salt from seawater. Household RO units typically deliver small amounts (2 to 5 gallons per day) of treated water and waste three to seven times the amount of water treated.

Reverse osmosis units remove many inorganic contaminants from household drinking water supplies. The removal effectiveness depends on the contaminant and its concentration, the membrane selected, the water pressure and proper installation. RO units require regular maintenance and monitoring to perform satisfactorily during an extended period of time.

Before purchasing an RO unit or any other water treatment equipment, test your water to be certain it needs treatment and the equipment you have selected is appropriate to the problem requiring treatment. You need to consider all costs when comparing competitive systems and making purchase or rental decisions.

References

NSF International
P.O. Box 130140
Ann Arbor, MI 48113-0140
877-8-NSF-HELP, (877) 867-3435
www.nsf.org
info@nsf.org

Underwriters Laboratories Inc.
333 Pfingsten Road
Northbrook, IN 60062-2096
(877) 854-3577
www.UL.com/water
mail to:water@us.ul.com

Water Quality Association
4151 Naperville Road
Lisle, IL 60632-3696
(630) 505-0160
www.wqa.org
info@mail.wqa.org

Further Information

For further information, contact your county Extension office or state health department. Additional information can be found in other publications in this series:

WQ1029	"It's All In Your Water, Filtration: Sediment, Activated Carbon and Mixed Media"
WQ1031	"It's All In Your Water, Softening"
WQ1032	"It's All In Your Water, Distillation"
WQ1046	"It's All In Your Water, Chlorination"
WQ1030	"It's All In Your Water, Iron and Manganese"

The printing and development cost of this publication was paid, in part, by the Northern Plains and Mountains Regional Water Program in partnership with the USDA-NIFA.

- The NDSU Extension Service is solely responsible for the content of this publication.
- This material is based upon work supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2004-51130-022848

For more information on this and other topics, see www.ag.ndsu.edu

250-3-13