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A Guide To Home Water Treatment

This bulletin provides a guide for consumers who want to know about home water treatment options. The first step for homeowners or renters with suspected water quality problems is to have their water chemically analyzed by their local health department or a private laboratory. Public health professionals can then help interpret the results. It is important to remember that the presence of a contaminant does not always mean that the water needs to be treated. A water quality professional will use the chemical and microbiological analyses to determine which, if any, water treatment option is appropriate.

Although there are strict regulations for public water supplies in the United States, there is increasing concern about the quality of drinking water. In addition, private water supplies (generally supplied by wells) are not regulated in the same way. Concern about possible health problems from contamination in these water supplies is causing consumers to wonder what they can do to ensure the quality of either their own private water supply (e.g., a private well) or the water that enters their homes from a public system.

One option for treating water is to install a home water treatment system; however, home treatment options can be expensive, require regular monitoring and maintenance, and no single system can be used alone to treat all contaminants. They may also become less effective over time or if the concentration or type of contamination changes.

Some water quality problems, such as bad odor or taste, may be only aesthetic, not health-related. Although these types of problems are important and may be resolved using home water treatment systems, the information in this bulletin focuses on contaminants that may cause adverse health effects.

A variety of water treatment processes are available to the homeowner. The systems differ in the types

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of chemicals removed, location within the home and operating and maintenance requirements. Two broad categories of home water treatment units are point-of-use (POU) and point-of-entry (POE) systems. POU systems are installed close to where the water is used in the home, normally in the kitchen at the end of a faucet, in the plumbing line under the sink or on a countertop. These systems typically treat the three to five gallons per day that the average family uses for drinking and cooking. POE units are larger, more expensive to purchase and usually placed in the basement or utility area. They treat water as it enters the home, generally excluding water to outdoor taps.

Home water treatment systems are the most economical if they are sized and operated to supply treated water only in quantities needed. POU devices are generally less expensive to operate and are often preferable when water is hard or contains iron or copper. These conditions can discolor fixtures and clothes or lead to buildup of scale in water pipes.

Several treatment systems are available for home water purification. These include granular activated carbon, ion exchange, reverse osmosis, membrane filtration, distillation, chemical oxidation and ultraviolet radiation treatment.

To determine the effectiveness of any water treatment system, appropriate testing must be done. Testing before and after the installation of a treatment system will help determine the effectiveness of a water treatment process.

Certification and Validation

Certification of treatment products is available to manufacturers through independent testing laboratories, one of the most prominent of which is NSF International. Results from NSF tests provide measures of the effectiveness of devices designed to treat water for both aesthetic and health reasons. Homeowners interested in particular systems can contact NSF to determine if these devices have been certified for the use intended.

Treatment Processes

GRANULAR ACTIVATED CARBON

Granular Activated Carbon (GAC) is commonly used to remove organic contaminants from water, such as pesticides, industrial solvents, chlorine and chlorine reaction products and components of gasoline, such as benzene. The contaminants interact with the large surface area of the GAC in a process called adsorption. GAC also effectively removes radon and many natural organic compounds that can cause unpleasant tastes and odors. GAC filters may not effectively remove heavy metals, such as lead, unless they are specifically designed to do so. Check for NSF certification or the manufacturer's information for verification.

Table 1. Typical Home Water Treatment Systems

Treatment Type	Contaminants Reduced or Removed
Granular Activated Carbon	Volatile organic compounds, pesticides, radon, some metals, chlorine
Ion Exchange Water Softeners	Hardness (calcium and magnesium), some additional metals
Reverse Osmosis/Membrane Filtration	Microorganisms, metals, nitrate, some inorganic and organic substances
Distillation	Microorganisms, metals, nitrate, some organic substances
Chlorination and Chemical Oxidation	Microorganisms, some organic substances
UV Radiation	Microorganisms
Note: Metals include lead, mercury, cadmium and iron. Microorganisms include bacteria, viruses and protozoans. Organic substances include trihalomethanes and organic halides. Inorganic substances include arsenic, calcium, sodium and magnesium.	

Activated Carbon – Faucet Model

GAC treatment systems use replaceable cartridges containing granular block carbon. In general, cartridges with higher amounts of carbon are more thorough at removing contaminants and last longer, thus increasing the life of each cartridge. Under-the-sink models typically contain more carbon, are more convenient and perform better than faucet and countertop models. A system that can also dispense unfiltered tap water for purposes other than drinking and cooking will extend the life of the cartridges.

It is important to change filter cartridges regularly because of the potential for bacterial growth. Follow the manufacturer's recommendations regarding filter replacement.

The following considerations are important when purchasing GAC filters:

- Ability to bypass for nonfiltered water
- Ease of replacing cartridges
- Availability and cost of replacement cartridges
- Amount of pressure loss at the faucet caused by the filter

WATER SOFTENERS (ION EXCHANGE)

Water Softeners are the best known examples of ion exchange systems. These systems soften water by removing the calcium and magnesium that make water hard. With home units, hardness ions in water are exchanged for sodium ions that are attached to a resin surface. This type of treatment is usually used for aesthetic concerns, such as taste, odor and discoloration, rather than for health concerns.

When most of the sodium ions on the resin have been replaced by hardness ions, the used resin must be replaced with fresh resin or, in most cases, recharged using a concentrated brine solution. Recharging is accomplished by flushing the resin with high concentrations of salt (sodium chloride) to discharge the attached calcium and magnesium ions into a waste brine solution and restore the resin sites to their sodium state.

For people with high blood pressure and heart disease, consuming water from home water softeners that contain the exchanged sodium ions may pose some health risks. These individuals should check with their doctor to determine whether consuming water from a home softener will exceed the amount of sodium they are allowed. Water softeners can use potassium chloride instead of sodium chloride, but more potassium chloride is needed.

REVERSE OSMOSIS AND MEMBRANE FILTRATION

Reverse Osmosis (RO) uses semipermeable membranes that allow water to pass across them. The contaminants collect on one side of the membrane, where they are flushed to the sewer or septic system. RO membranes operate at high pressure, with most home units designed to recover about 20 to 30 percent of the water, although some can recover substantially more (Kneen et al. 2005). Generally, for every 10 gallons that pass through the RO unit, about two to three gallons are produced for use. However, some whole house (POE) systems are capable of recovering 50-74 percent of the filtered water. These systems can be used to remove or reduce the concentration of major chemicals and impurities, including sodium, chloride, copper, chromium, lead, arsenic, fluoride, radium, sulfate, calcium, magnesium, potassium, nitrate and phosphorus. They can also remove bacteria, viruses and protozoans. The range of removal varies with each chemical or organism and membrane type. RO systems do not remove gases or volatile organic chemicals.

Reverse osmosis systems incorporate pre-filtration and post-treatment. The pre-filters are necessary to protect the RO membranes by removing sand, grit, particulates and dirt that could clog the membrane. Pre-treatment using activated carbon may also be required to remove chlorine, which can degrade the RO membrane. Tastes and odor-causing compounds that are not rejected by the membrane can be removed by post-treatment, which is typically activated carbon. In cases where the water is extremely hard, a water softener may be needed before the water is treated by the RO unit.

Another issue related to the RO system is that the water produced is corrosive. Corrosive water can damage pipes and leach metals from the pipes, such as lead, into the water. Post-treatment to reduce the corrosiveness of the water is necessary with POE systems. The post-treatment usually involves a chemical addition or passing the water through a bed of limestone to add minerals back into the water. Additionally, POE systems require plastic piping.

RO systems, like all other home water treatment devices, require regular maintenance and replacement of filters. RO membranes and filters should be replaced according to the directions that came with the filter. Verification of any treatment system's performance can only be determined by water testing.

Membrane Filtration

In addition to RO, other types of filtration are nanofiltration (NF), ultrafiltration (UF) and microfiltration (MF). The main differences among these membrane filtration types are the membranes' pore size (see figure 1) and the pressures utilized. In addition, since salt removal is not as effective as that from RO systems, the treated water is noncorrosive. Nanofiltration is capable of removing salts, such as calcium and magnesium, and therefore can be used as an alternative to ion exchange for softening water. Nanofiltration is only moderately effective for removing chemical contaminants but is very effective at removing protozoans, bacteria and viruses. Operating pressures for residential nanofiltration systems range from 50-120 pounds per square inch (psi).

Ultrafiltration is designed to reduce turbidity, particulates as small as 0.025 microns (µm), bacteria, protozoan cysts and viruses. It is not effective at removing salts and therefore cannot be used to remove nitrates, arsenic, uranium, fluoride and other dissolved chemicals. It is most effective for treating uncontaminated well water or treated drinking water to ensure pathogen removal. Operating pressures for residential ultrafiltration systems range from 30-100 psi.

Microfiltration is most often used as a pre-treatment before ultrafiltration, nanofiltration or reverse osmosis. It can remove particulates ranging from about 0.1 to 5 microns. As such, it is very effective at removing protozoan cysts, moderately effective at removing

Reverse Osmosis

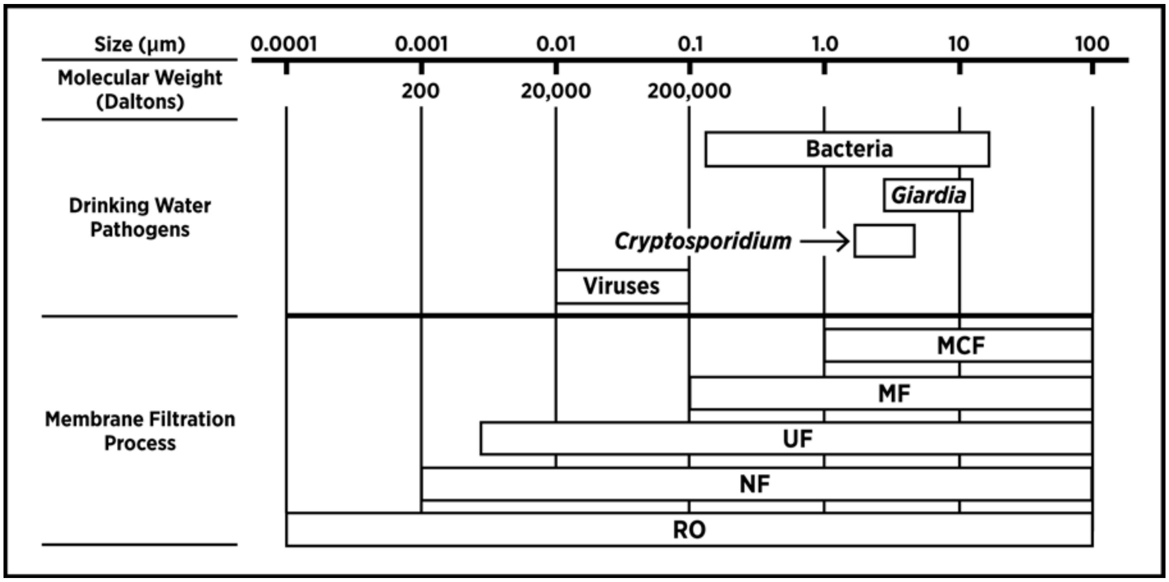


Figure 1. *Removal of various drinking water pathogens of interest on the basis of size. USEPA 2005.(Membrane Filtration Guidance Manual. EPA 815-R-06-009). (Note: MCF (membrane cartridge filtration) is not typically used for water filtration).*

bacteria and ineffective at removing viruses. Operating pressures for residential microfiltration systems range from 15-60 psi.

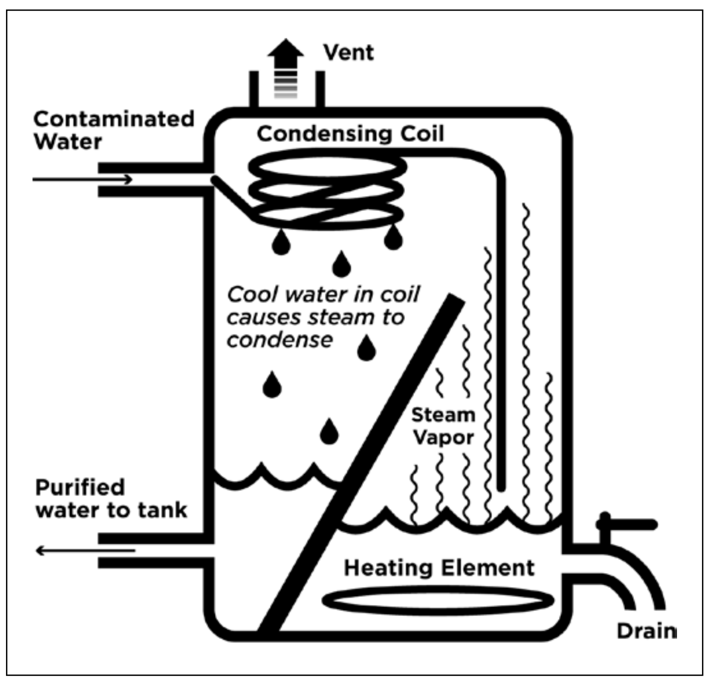
As previously stated for reverse osmosis, pre-treatment with carbon filters for these membrane filtration systems should be used to remove chlorine because it can degrade the membrane filter.

DISTILLATION

Distillation relies on evaporation for water purification. It removes inorganic compounds, such as lead, nitrate, mercury and arsenic as well as microorganisms, such as bacteria and some viruses. It also removes some organics that do not easily evaporate.

During distillation, the water is heated to form steam. The steam then cools and condenses to form purified water. Contaminants that easily become gases at or near the boiling point of water, such as some gasoline components and radon, may remain in the distilled water. More advanced distillation systems are needed to remove them. The unevaporated pollutants remaining in the heating chamber need to be cleaned periodically depending on the amount and type of dissolved minerals in the water.

One of the advantages of distilling nonchlorinated water supplies is that the boiling process naturally disinfects the water; however, care must be taken to avoid bacterial recontamination of the condensed purified water in the storage container.



Operation of a distillation system.

Problems associated with distillation include loss of beneficial minerals from the water, such as calcium and iron, and a bland or flat taste. Operating costs may be higher than other forms of home treatment. The heat produced by a distiller may be beneficial in the winter but can be a disadvantage in the summer. Due to the amount of time needed for the distillation process, these systems are best used to treat smaller amounts of water, such as for drinking and cooking.

Distillation systems are usually installed as POU systems and may be countertop or wall mounted. Distilled water is corrosive to copper, brass and galvanized iron. It is not a very common method for home water treatment.

CHLORINATION AND OZONATION

While chlorine is a common chemical added to most public water supplies for disinfection purposes, it is typically not used in home water treatment systems. Chlorine acts as a disinfectant by deactivating bacteria and is available either as a dry powder or pellet (calcium hypochlorite) or as a liquid (sodium hypochlorite). The effectiveness of chlorination is influenced by water temperature, pH and the amount of time that the chlorine is in contact with the untreated water. Pre-treatment may be required for water that contains high amounts of sediment. Under certain circumstances, chlorination may produce potentially harmful by-products, such as trihalomethanes, which can be carcinogenic, by reacting with natural organic materials in the water. Additionally, both the solid and liquid forms of chlorine can irritate the skin. When concentrated, they are poisonous. Careful handling and storage is necessary.

Ozonation, which uses ozone gas to treat water, is another process that may be used for home water treatment. However, it is not often used because it is difficult to control and monitor. Ozonation can destroy bacteria in drinking water without creating the taste and odor problems common with chlorine. It will also precipitate iron, sulfur and manganese, which can then be filtered from the water. Many organic compounds can be partially or completely oxidized by ozone without the formation of chlorinated compounds. Because its disinfection process is short-lived, ozonation does not inhibit or prevent bacterial regrowth.

ULTRAVIOLET RADIATION

Ultraviolet (UV) Radiation treatment provides a chemical-free option for killing microorganisms by using special lamps that destroy bacteria, viruses and protozoa. Exposing water to UV light can destroy most harmful microorganisms. It can also destroy organisms that are resistant to chlorine, such as *Giardia* and *Cryptosporidium*. However, UV technology will not remove heavy metals, petroleum products or pharmaceuticals from water. Additionally, a pre-filter is usually necessary to ensure that the water is clear enough for an effective UV light treatment.

UV water treatment can include single-tap or whole-house systems. Some units have a UV sensor to monitor the light's intensity, an automatic shutoff valve that activates if the system malfunctions and a flow meter, which calculates the UV dose.

UV light is a cost-effective water treatment technology that does not require the addition of disinfecting chemicals, eliminating taste and odor issues that may occur from them. UV does not, however, provide any residual disinfection. If treated water is to be stored,

Example of a system that has separate filtered and unfiltered water options.

then chemical disinfection using chlorine or iodine is also necessary. UV systems may come with their own pre-treatment filters. Regular replacement of these filters as well as the lamp is necessary to ensure proper water treatment.

BOTTLED OR BULK WATER

Bottled or ***bulk water*** may be a viable alternative to home water treatment. Bottled water may be necessary when a homeowner is pursuing a new source of water, installing a home water treatment system or during a temporary lapse in municipal treatment. Homeowners may choose to use bulk water when the quality of distributed water is questionable or when taste and/or odors make the water undesirable for drinking.

Bottled water is regulated as a food by the U.S. Food and Drug Administration (FDA). The FDA is responsible for monitoring and inspecting water bottling plants similarly to how they inspect other beverage facilities. The FDA has set standards that they require bottled water manufacturers to follow.

In Michigan, companies that sell bottled water must be registered, even if they are out-of-state. The Michigan Department of Environmental Quality (MDEQ) evaluates the water source. The Michigan Department of Agriculture and Rural Development (MDARD) regulates Michigan-based bottled water companies as a food processing facility. Bottled water is typically more expensive than tap water. Public water supplies are typically tested for contaminants more frequently than bottled water. Bottled water is available in many sizes, from a few ounces to several gallons.

Water cooler services are also available in some areas of Michigan and are regulated as bottled water. These services may involve rental of a water cooler and payment for the delivery of water refills.

Bottled water can be purchased in multi-gallon containers.

Summary

There are many strategies for dealing with a drinking water problem. The best approach for each situation depends on the type and level of contaminants present, based on a current water test. Budget constraints and willingness to maintain a system should also be considered. Homeowners should remember that no one system can work for all contamination problems, and none are maintenance free. Homeowners or renters should learn about their water source and the treatment systems available in order to intelligently and appropriately address their water quality issues.

For questions about water testing, test interpretation and treatment systems, contact your local health department. A directory of local health departments is available at **www.michigan.gov/mdhhs/0,5885,7-339--96747--,00.html**.

When you contact your health department, ask for the Environmental Health Division.

BUYER'S CHECKLIST

1. Have a water analysis performed by a qualified laboratory. A listing of DEQ certified labs is available from **www.michigan.gov/documents/deq/deq-rrd-Lab-ChemistryLabsListCertifications_429759_7.pdf**
2. If you have concerns about how your water might affect your health, contact a health professional to obtain their recommendations.
3. Research different products on the market. Compare initial, operating and maintenance costs, contaminant removal efficiency and company reputation and service record. One information source is NSF International. Go to **www.nsf.org** and search for home water treatment systems.
4. Read manufacturer's claims and warranties carefully to make sure that the capacity and life expectancy of a given system meet your needs.
5. Understand the operation and maintenance requirements when the system is installed. Find out where to obtain replacement filters and who will service the equipment when problems arise.

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