October 2011

Water Treatment

A great percentage of the population, on a day-to-day basis, turns on the water faucets in their home without ever thinking about how the water gets there, let alone whether or not the water is safe to consume and use for cooking and other household needs. Therefore, this edition of Health and Safety News, as well as next month’s issue, will address the subject of water quality and supply. However, there is no way that a newsletter can do this topic justice, so there will be additional websites and links provided for more in depth information. The sources utilized for constructing this newsletter include the following: U. S. Environmental Protection Agency (EPA) (http://www.epa.gov), National Sanitation Foundation (NSF International) (http://www.nsf.org/consumer/drinking_water/dw_quality.asp?program=WaterTre), and Environmental Working Group (EWG) (http://www.ewg.org/tapwater/executive-summary).

The focus of this October issue is to highlight, according to the EPA, the history of drinking water treatment. The contents are educational and will, hopefully, cause an increased interest into the topic that will lead to a better understanding of how water was treated in the past as well as what goes into its preparation for today’s needs. The final topic of this month’s issue will address individual household considerations.
The History of Drinking Water Treatment

This fact sheet is based on information from the EPA report “25 Years of the Safe Drinking Water Act: History and Trends.” Please refer to the full report for details and references. You may order a copy of the report, as well as many other EPA drinking water documents, by calling the Safe Drinking Water Hotline at (800) 426-4791, or you may review the report online at http://www.epa.gov/safewater/sdwa25/sdwa.html

Ancient civilizations established themselves around water sources. While the importance of ample water *quantity* for drinking and other purposes was apparent to our ancestors, an understanding of drinking water *quality* was not well known or documented. Although historical records have long mentioned aesthetic problems (an unpleasant appearance, taste or smell) with regard to drinking water, it took thousands of years for people to recognize that their senses alone were not accurate judges of water quality.

Water treatment originally focused on improving the aesthetic qualities of drinking water. Methods to improve the taste and odor of drinking water were recorded as early as 4000 B.C. Ancient Sanskrit and Greek writings recommended water treatment methods such as filtering through charcoal, exposing to sunlight, boiling, and straining. Visible cloudiness (later termed turbidity) was the driving force behind the earliest water treatments, as many source waters contained particles that had an objectionable taste and appearance. To clarify water, the Egyptians reportedly used the chemical alum as early as 1500 B.C. to cause suspended particles to settle out of water. During the 1700s, filtration was established as an effective means of removing particles from water, although the degree of clarity achieved was not measurable at that time. By the early 1800s, slow sand filtration was beginning to be used regularly in Europe.

During the mid to late 1800s, scientists gained a greater understanding of the sources and effects of drinking water contaminants, especially those that were not visible to the naked eye. In 1855, epidemiologist Dr. John Snow proved that cholera was a waterborne disease by linking an outbreak of illness in London to a public well that was contaminated by sewage. In the late 1880s, Louis Pasteur demonstrated the “germ theory” of disease, which explained how microscopic organisms (microbes) could transmit disease through media like water.
During the late nineteenth and early twentieth centuries, concerns regarding drinking water quality continued to focus mostly on disease-causing microbes (pathogens) in public water supplies. Scientists discovered that turbidity was not only an aesthetic problem; particles in source water, such as fecal matter, could harbor pathogens. As a result, the design of most drinking water treatment systems built in the U.S. during the early 1900s was driven by the need to reduce turbidity, thereby removing microbial contaminants that were causing typhoid, dysentery, and cholera epidemics. To reduce turbidity, some water systems in U.S. cities (such as Philadelphia) began to use slow sand filtration.

While filtration was a fairly effective treatment method for reducing turbidity, it was disinfectants like chlorine that played the largest role in reducing the number of waterborne disease outbreaks in the early 1900s. In 1908, chlorine was used for the first time as a primary disinfectant of drinking water in Jersey City, New Jersey. The use of other disinfectants such as ozone also began in Europe around this time, but were not employed in the U.S. until several decades later.

Federal regulation of drinking water quality began in 1914, when the U.S. Public Health Service set standards for the bacteriological quality of drinking water. The standards applied only to water systems which provided drinking water to interstate carriers like ships and trains, and only applied to contaminants capable of causing contagious disease. The Public Health Service revised and expanded these standards in 1925, 1946, and 1962. The 1962 standards, regulating 28 substances, were the most comprehensive federal drinking water standards in existence before the Safe Drinking Water Act of 1974. With minor modifications, all 50 states adopted the Public Health Service standards either as regulations or as guidelines for all of the public water systems in their jurisdiction.

By the late 1960s it became apparent that the aesthetic problems, pathogens, and chemicals identified by the Public Health Service were not the only drinking water quality concerns. Industrial and agricultural advances and the creation of new man-made chemicals also had negative impacts on the environment and public health. Many of these new chemicals were finding their way into water supplies through factory discharges, street and farm field runoff, and leaking underground storage and disposal tanks. Although treatment techniques such as aeration, flocculation, and granular activated carbon adsorption (for removal of organic contaminants) existed at the time, they were either underutilized by water systems or ineffective at removing some new contaminants.

Health concerns spurred the federal government to conduct several studies on the nation’s drinking water supply. One of the most telling was a water system survey conducted by the Public Health Service in 1969 which showed that only 60 percent of the systems surveyed delivered water that met all the Public Health Service standards. Over half of the treatment facilities surveyed had major deficiencies involving disinfection, clarification, or pressure in the distribution system (the pipes that carry...
water from the treatment plant to buildings), or combinations of these deficiencies. Small systems, especially those with fewer than 500 customers, had the most deficiencies. A study in 1972 found 36 chemicals in treated water taken from treatment plants that drew water from the Mississippi River in Louisiana. As a result of these and other studies, new legislative proposals for a federal safe drinking water law were introduced and debated in Congress in 1973.

Chemical contamination of water supplies was only one of many environmental and health issues that gained the attention of Congress and the public in the early 1970s. This increased awareness eventually led to the passage of several federal environmental and health laws, one of which was the Safe Drinking Water Act of 1974. That law, with significant amendments in 1986 and 1996, is administered today by the U.S. Environmental Protection Agency’s Office of Ground Water and Drinking Water (EPA) and its partners.

Since the passage of the original Safe Drinking Water Act, the number of water systems applying some type of treatment to their water has increased. According to several EPA surveys, from 1976 to 1995, the percentage of small and medium community water systems (systems serving people year-round) that treat their water has steadily increased. For example, in 1976 only 33 percent of systems serving fewer than 100 people provided treatment. By 1995, that number had risen to 69 percent.

Since their establishment in the early 1900s, most large urban systems have always provided some treatment, as they draw their water from surface sources (rivers, lakes, and reservoirs) which are more susceptible to pollution. Larger systems also have the customer base to provide the funds needed to install and improve treatment equipment. Because distribution systems have extended to serve a growing population (as people have moved from concentrated urban areas to more suburban areas), additional disinfection has been required to keep water safe until it is delivered to all customers.

Today, filtration and chlorination remain effective treatment techniques for protecting U.S. water supplies from harmful microbes, although additional advances in disinfection have been made over the years. In the 1970s and 1980s, improvements were made in membrane development for reverse osmosis filtration and other treatment techniques such as ozonation. Some treatment advancements have been driven by the discovery of chlorine-resistant pathogens in drinking water that can cause illnesses like hepatitis, gastroenteritis, Legionnaire’s Disease, and cryptosporidiosis. Other advancements resulted from the need to remove more and more chemicals found in sources of drinking water.

According to a 1995 EPA survey, approximately 64 percent of community ground water and surface water systems disinfect their water with chlorine. Almost all of the remaining surface water systems, and some of the remaining ground water systems, use another type of disinfectant, such as ozone or chloramine.
FYI-----Household Considerations
(http://www.bae.ncsu.edu/programs/extension/publicat/wqwm/he419.html)

Water quality is the acceptability of the water for uses like drinking, cooking, bathing, and laundering.

Drinking water supplies may be contaminated by many sources. Hazardous household wastes, septic systems, lawn and garden chemicals, leaking fuel storage tanks, animal waste, agricultural chemicals, landfills, and leaching of metals from plumbing systems may contaminate water.

Contaminated water may have off-tastes, odors, or visible particles. However, some dangerous contaminants in water are not easy to detect. Accurate water testing is needed to determine safety and quality. Water testing also identifies the need for water treatment equipment.

When water is contaminated, it is best to eliminate the source of the contamination, if at all possible. If this cannot be done, then water may need to be treated. Treatment can reduce common contaminants such as sediment, calcium, iron, magnesium, sulfate, nitrates, arsenic, or lead. Water treatment can produce clearer, safer, better tasting, and better smelling water, better suited for household use. Some typical water quality problems and recommended treatment systems are listed in Table 1. There are eight general types of treatment systems available for household use. These include carbon filters, fiber filters, reverse osmosis units, distillation, neutralizers, chemical-feed pumps, disinfection, and softeners. These systems range in cost from a few dollars to several thousand dollars, depending on the type of system and the type of contaminants.

Before buying, consider:

- Type and amount of water contaminants
- Equipment cost
- Operating and maintenance costs
- Operating and storage space
- Ease of use

Some systems treat all the water in the house, while others primarily improve safety and quality of drinking water. Before buying water-treatment equipment, have your water supply tested by a recognized,
You need to identify the type and level of contaminants if you are to get the right system.

### Table 1. Typical Water Quality Problems and Recommended Treatment Systems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Recommended Treatment Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria and other microorganisms</td>
<td>Disinfection</td>
</tr>
<tr>
<td>Taste and odor</td>
<td>Carbon filter</td>
</tr>
<tr>
<td>Hydrogen sulfide gas (rotten egg odor)</td>
<td>Oxidizing filter followed by carbon filter; chlorination followed by sediment filter</td>
</tr>
<tr>
<td>Sediment (suspended particles)</td>
<td>Fiber filter</td>
</tr>
<tr>
<td>Hardness (calcium and magnesium)</td>
<td>Softener</td>
</tr>
<tr>
<td>Dissolved iron</td>
<td>Softener for up to 5 milligrams per liter; iron filter; chlorination followed by sand filter and carbon filter</td>
</tr>
<tr>
<td>pH (acid or alkaline conditions)</td>
<td>Neutralizing filter or chemical-feed pump</td>
</tr>
<tr>
<td>Organic chemicals (pesticides, fuel products)</td>
<td>Carbon filter</td>
</tr>
<tr>
<td>Metals (lead, mercury, arsenic, cadmium), and other minerals (nitrate, sulfate, sodium)</td>
<td>Reverse osmosis unit; distillation</td>
</tr>
</tbody>
</table>

**Carbon Filters**

Carbon filters remove most of the organic compounds that cause taste and odor problems. A filter’s effectiveness depends on the amount of carbon in the unit and how long the water stays in the unit. The longer the water is in contact with the filter medium, the more of the impurities are removed. Some carbon filters harbor bacteria. Flushing fresh water through the filter for at least 30 seconds may remove bacteria.

Carbon filter cartridges must be replaced when taste or odor problems reappear. Carbon filters and replacement cartridges range in price from a few dollars to several hundred dollars. Some units may require professional installation. Four types of carbon filters, based on their location in the plumbing system, are (1) faucet mount; (2) in-line; (3) line bypass; and (4) point of entry (POE). Other types of carbon filters are pour through (portable) and specialty filters.

**Faucet-mounted** carbon filters attach to the faucet where drinking water comes out. These filters contain only a small amount of carbon and are not as effective as other types of carbon filters. One design includes a bypass option, which diverts non-drinking water around the filter to prolong the life of the carbon cartridge.
In-line carbon filters are installed beneath the kitchen sink in the cold water supply line. This does not allow for bypassing the unit for non-drinking water uses.

Only the cold water from the tap is treated. Warm or hot tap water will contain untreated water.

Line bypass carbon filters also are added to the cold water supply line, but a separate faucet is installed at the sink to provide treated drinking water. The regular tap delivers untreated water. The carbon filter lasts longer because only water used for drinking is treated.

Point of entry (POE) carbon filters treat all water entering the home. This type of filter is recommended for treating volatile organic compounds (VOCs) that easily evaporate into the air. These are the most expensive filters to purchase and maintain.

Pour through carbon filters are similar to drip coffee makers and are the simplest and least expensive type. They are portable, require no installation, and are convenient for camping or similar uses. They treat only a little water at a time and are not as good at removing impurities as other types of carbon filters.

Specialty carbon filters attach to the cold water supply line to appliances. Ice maker filters are placed on the supply line to refrigerators, and scale filters are placed on the supply line to water heaters or humidifiers.

Fiber Filters

Fiber filters contain spun cellulose or rayon. They remove suspended sediment (or turbidity). The water pressure forces water through tightly wrapped fibers around a tubular opening leading to the faucet. These filters come in a variety of sizes and meshes from fine to coarse, with the lower micron rating being the finer. The finer the filter, the more particles are trapped and the more often the filter must be changed. Fiber filters may not remove all contaminants. If taste and odor problems remain, use a carbon filter after the fiber filter. Fiber filters and replacement cartridges range in price from a few dollars to several hundred dollars. Remember, filters do not purify or soften water - they only remove some suspended particles and dissolved organic compounds that cause disagreeable odors and tastes.

Reverse Osmosis Units

A reverse osmosis (RO) unit removes a variety of inorganic chemicals such as nitrates, calcium, and magnesium. A reverse osmosis unit is up to 95 percent effective. Unfortunately, reverse osmosis also removes beneficial chemicals (fluoride). Typically, this unit is used to treat only drinking and cooking water.

An RO system usually includes:

- A prefilter to remove sediment
- An activated carbon filter to remove odors and taste
- A semi-permeable membrane through which water flows under pressure
- A tank to hold the treated water
- A drain connection for discharging concentrated contaminants
Different sizes are available. They can be installed under the sink or in a remote location, depending on the size of the water-holding tank. Match its capacity to the number of gallons used per day. A household of four people normally finds 5 gallons per day enough.

A reverse osmosis unit is expensive (typically $600 to $900), and renting is an option. There are maintenance costs because the RO membrane needs replacing according to the manufacturer's recommended schedule. Weigh the cost of a unit against the type and amount of contaminants and your concern for safety. Also compare the cost of an RO unit to other alternatives, like bottled water.

**Distillers**

Distillers produce almost pure water. They remove minerals such as nitrate and sodium, many organic chemicals, and virtually all impurities. Distilled water is suitable for wet batteries and other household equipment requiring mineral-free water.

When the distiller is operating, tap water in a boiling tank (often made of stainless steel) is heated to boiling. Steam is produced, rises, and leaves most impurities behind. The steam enters condensing coils, where it is cooled and condensed back to water. The distilled water then goes into a storage container or is piped to a special faucet.

Consider:

- Capacity of the boiling tank
- Type and size of the water-storage container
- Rate at which distilled water is produced
- Presence of automatic features
- Location of unit for convenience of use and ease of maintenance
- Wattage rating (650 to 1,500-plus watts)
- Batch or continuous process mode of operation

Storage containers can be glass, metal, or plastic. Each type is satisfactory when cared for as the manufacturer directs.

Large distillers can distill about one-half gallon of water per hour. Smaller units produce less than one quart of water per hour. The cost of producing distilled water depends on the appliance and the local electric rate. Although the distiller has no parts to replace, it is not maintenance-free. Scale must be removed from the boiling tank. Frequency of cleaning the distiller varies with the quantity of impurities in the water and the amount of water distilled. White vinegar or a manufacturer's cleaner is used for cleaning.

It may cost $250 for a small unit to over $1,450 for a large unit. Electricity makes operating costs higher than alternative treatment systems. Consider how much water you need, how contaminated your water supply is, costs, and alternatives like bottled water before buying a distiller.

**Neutralizing Filters and Chemical-Feed Pumps**

Neutralizing filters and chemical-feed pumps adjust the pH of water. A pH of 7 is neutral, while a pH less than 7 is acidic, and a pH greater than 7 is alkaline. Water should be as close to pH 7 as possible. Very low or very high pH water is corrosive, which can cause leaching metals from plumbing systems or
forming scale in pipes. Signs of very low or very high pH water are blue-green stains from copper plumbing or red stains from galvanized plumbing.

Tank-type neutralizing filters or chemical-feed pumps that inject a neutralizing solution into the well neutralize acid water. If iron treatment is needed, the chemical-feed pump system is required. Tank-type neutralizing filters pass the water through granular calcite (marble, calcium carbonate, or lime) or magnesia (magnesium oxide). They treat water as low as pH 6. They must be installed after the pressure tank. These systems make the water harder.

For water less than pH 6, chemical-feed pumps inject a neutralizing solution of soda ash (sodium carbonate) or caustic soda (sodium hydroxide) into the well. This raises the sodium content of the water. Potassium can be substituted for sodium, but potassium is more expensive. Keep the solution tank full and adjust the feeder to provide the correct rate to result in a pH of near 7. For water between pH 4 and pH 6, use soda ash mixed at one pound of soda ash per gallon of water. Feed this solution into the well at a rate to raise the pH to near 7 at the faucet farthest from the well. For water less than pH 4, use caustic soda. This material is extremely dangerous. Wear gloves and goggles. Slowly feed a solution of one pound of caustic soda per gallon of water into the well at a rate sufficient to result in pH 7 at the faucet farthest from the well.

Neutralize alkaline water (greater than pH 7) by feeding diluted sulfuric acid in the same manner as soda ash. Use caution in making solutions from strong acids. Always add acid to water slowly. Never add water to acid: Use gloves and goggles when preparing solutions.

Disinfection

Disinfection kills bacteria and other microorganisms. Chlorination is the most common method. Other disinfection systems use ultraviolet light or ozone. These are not as readily available for home use.

Continuous chlorination systems consist of a chemical metering device that feeds chlorine in sufficient amounts to kill bacteria. Chlorine must be in contact with water at least 1 minute to kill all bacteria. A chlorine residual of about 3 to 5 parts per million should remain to indicate that disinfection is complete. Typical chlorine feed rates are about 1 cup of 5 percent laundry bleach per 300 gallons of water. This rate depends on water temperature, pH, and pumping rate. Use an inexpensive chlorine residual kit to determine if the feed rate should be adjusted up or down to obtain the proper chlorine residual. If chlorine taste is a problem, use a carbon filter to remove excess chlorine from drinking water.

Before investing in a continuous chlorination system, it is wise to try repeated shock chlorination. This simple process involves adding high concentrations of chlorine directly to the well to kill all existing microorganisms. Use this process to disinfect all new and repaired water systems. Shock chlorination can be done using ordinary laundry bleach (containing 5.25 percent sodium hypochlorite). The goal is to add enough chlorine to raise the concentration in the well to about 200 milligrams per liter to kill potentially harmful bacteria and viruses. If iron bacteria are a problem, concentrations of 800 milligrams per liter may be necessary.

Follow these safety precautions when using shock chlorination procedures:

- Do not chlorinate activated carbon or charcoal filters. Use the "bypass" valve on the filter if there is one. Otherwise, disconnect the filter temporarily during shock chlorination.
- Wear rubber gloves, goggles, and a protective apron when handling chlorine solutions. If chlorine gets on the skin, flush immediately with fresh water.
Never mix chlorine solutions with other cleaning agents, especially ammonia, because toxic gases may be formed.

Use plain laundry bleach. Do not use products such as "Fresh-Scent" bleach or other special laundry products to disinfect a well.

Water containing chlorine bleach is not safe to drink. Follow shock chlorination procedures carefully and be sure there is no chlorine odor before drinking the water.

Shock chlorination procedure:

Select a time when well water will not be used for at least 24 hours. Store enough drinking water for this period or do the procedure before leaving for a short trip.

Determine how much laundry bleach is needed. This depends on the diameter of the well and the height of standing water in the well. The height of standing water is the difference between the well depth and the distance from the top of the well down to the water level. For example, if the well is 250 feet and the water level is 150 feet down from the top, then the height of the standing water is 100 feet. If it is a 4-inch well, 2 quarts of laundry bleach are needed to raise the chlorine concentration to 200 milligrams per liter. Recommended amounts of laundry bleach are shown in Table 2.

Mix the proper amount of bleach with water in a 5-gallon or larger container and pour the solution directly into the well.

Turn on the outdoor faucet nearest the well and let the water run until a strong odor of chlorine is detected. Add more bleach if a strong odor is not present.

Turn the faucet off. Connect a garden hose to the faucet and attach a spray nozzle to the end of the hose. Thoroughly wash down the entire inside surface of the well casing with the spray nozzle for at least 15 minutes.

After washing the inside of the well casing, turn on all outdoor and indoor faucets one at a time until a strong chlorine odor is detected at each location. Turn each faucet off when the chlorine odor is detected.

Let the chlorinated water stand in the well and plumbing for at least 24 hours. Do not drink the chlorinated water during this period. You may flush the toilets, but try to minimize the number of flushes.

After 24 hours, completely flush the system of chlorine by turning on all outdoor faucets and running them until the chlorine odor is gone. Do not run the indoor faucets until the odor dissipates to prevent damage to the septic system.

Finally, turn on the indoor faucets until the chlorine odor is gone. You may notice a slight chlorine taste or odor in the water for a few days.

Test the water for bacteria two weeks after shock chlorination to see if you have a recurring problem.

<table>
<thead>
<tr>
<th>Height of standing water (feet)</th>
<th>4-inch well</th>
<th>6-inch well</th>
<th>8-inch well</th>
<th>12-inch well</th>
<th>24-inch well</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1 quart</td>
<td>2 quarts</td>
<td>1 gallon</td>
<td>2 gallons</td>
<td>8 gallons</td>
</tr>
<tr>
<td>100</td>
<td>2 quarts</td>
<td>1 gallon</td>
<td>2 gallons</td>
<td>4 gallons</td>
<td>16 gallons</td>
</tr>
<tr>
<td>200</td>
<td>1 gallon</td>
<td>2 gallons</td>
<td>4 gallons</td>
<td>8 gallons</td>
<td>32 gallons</td>
</tr>
</tbody>
</table>
**Water Softeners**

Hard water is caused by dissolved calcium and magnesium in the water. Hard water interferes with laundering, washing dishes, bathing, and personal grooming. It also affects appliances. For example, scale builds up in water heaters, increasing the costs of heating water and reducing the life of the appliance.

The calcium and magnesium that cause hardness are reported as grains per gallon, milligrams per liter (mg/L), or parts per million (ppm). Hard water, when used with soap, causes soap deposits that will not dissolve.

Water is softened by passing through a bed of ion-exchange resin. The softening process exchanges calcium and magnesium ions in the water for sodium ions in the resin. About 15 mg of sodium are added per gallon for each grain of hardness reduced.

When the sodium is used up, the softener needs to be regenerated. This is done by backwashing to clean the ion-exchange material, brining with salt (sodium chloride) to replace sodium ions, and rinsing to remove any excess salt.

A water softener removes small amounts of dissolved iron (5 to 10 ppm). However, if there is oxidized iron or iron bacteria in the water, the ion exchange resin becomes coated or clogged and loses its softening ability. In this case, use an iron filter or chlorination to remove iron.

The size water softener needed depends on the hardness of water, the quantity to be softened, and the length of time between recharging. There are three types of ion-exchange softeners for the home.

- **MANUAL.** Each step for recharging the unit must be activated by hand. Salt is added directly to the single tank of this softener.
- **SEMI-AUTOMATIC.** The homeowner sets the switches when the system needs recharging. The system completes the process by itself. A second tank is needed for the brine system.
- **AUTOMATIC.** All steps of the recharging process are controlled by a timing mechanism that the homeowner sets, based on water usage. Some models can measure water usage or remaining softening capacity and recharge themselves only when needed. Most water softeners have a fully automatic recharging feature. These softeners also require a second tank for the brine solution.

Water softeners can be installed in various ways. Most people soften hot and cold water but bypass outside water lines.

The increased sodium in softened water is a concern to people on a sodium-restricted diet. Therefore, some water softener installations bypass the cold water line in the kitchen only.

Water softeners can be rented or purchased. Renting a softener or ion-exchange resin tank is convenient since the user does not worry about maintenance or regeneration. The dealer regularly replaces the ion-exchange resin tank, so a second tank for the brine solution for recharging is not needed.

A water softener can cost $500 to over $41,500, but owning the equipment could be more economical in the long run than renting it. The cost of the water softener is balanced against the savings of soft water. Using soft water reduces the quantity of cleaning products needed by as much as 500 percent. The home's plumbing system and water-using appliances will last longer. Other benefits include the time saved in cleaning and removing scale and better results in laundry, dish washing, and personal grooming.
Selecting a Treatment System

Always test your water before purchasing water treatment equipment. This ensures that the system you purchase will adequately treat your problem. Consult with water quality professionals, health departments, and equipment manufacturers and suppliers to identify the best system to meet individual needs. Before purchasing expensive water treatment systems, consider lower-cost alternatives, such as bottled water or a new well.

For additional information on water testing and treatment, these are publications that may be useful:

- Should You Have Your Water Tested? AG-473-2/WQWM-2
- Health Effects of Drinking Water Contaminants HE-393
- Iron and Manganese in Household Water HE-394/WQWM-11
- Lead in Drinking Water HE-395/WQWM-8
- Metals in Drinking Water AG-473-1/WQWM-6
- Nitrate in Drinking Water AG-473-4/WQWM-5
- Radon in Drinking Water HE-396-WQWM-13
- Volatile Organic Chemicals (VOCs) in Drinking Water AG-473-5/WQWM-16
- Questions to Ask When Purchasing Water Treatment Equipment AG-473-3/WQWM-7
- Protect Yourself When Selecting a Home Water Treatment System HE-418/WQWM-135

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