Drinking Water Treatment Systems

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If your home water comes from a public water supply, it has been tested and meets EPA standards for drinking water. If you use a private well, however, you are responsible for assuring that the water is safe to drink. This means that you should periodically have your water tested, make sure your well is in proper condition without faulty well caps or seals, and identify and remove potential sources of contamination to your well such as leaking septic systems or surface contamination.

With a private well, you are also responsible for any treatment your water may need if it contains harmful pollutants or contaminants that affect the taste, odor, corrosiveness or hardness of the water. This fact sheet discusses different types of water treatment systems available to homeowners. Addressing the source of the problem is often less costly in the long run than installing and maintaining a water system. For more information on identifying pollutant sources, problems with your well, or help in testing your well water, see the references at the end of this fact sheet.

There are many types of water treatment systems available. No one type of treatment can address every water quality problem, so make sure you purchase the type of equipment that can effectively treat your particular water quality issue. The table below can help direct you to the right solution for your problem.

WATER QUALITY
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What type of water treatment is needed?

The table below lists common water contamination problems.

Contaminant or Problem	Possible Cause of Problem	Solutions
The following pollutants are health hazards and must be treated for the safety of your family. If you cannot successfully remove these pollutants, you should find an alternative source of water.		
Arsenic	Naturally occurring in water in some areas	Reverse osmosis; ion exchange
Bacteria	Well not sealed; sewage, manure or surface runoff	Remove source of bacteria; chlorination; ozonation; UV disinfection
Lead	Corrosive water, lead pipes or lead solder	Replace plumbing; reverse osmosis; distillation
Nitrate	Well not sealed; faulty septic system; animal waste; fertilizers	Remove source of nitrate; distillation; reverse osmosis; anion exchange (water softener)
Pesticides & Organic chemicals	Use of pesticides, chemicals near water source	Activated carbon filter; reverse osmosis; distillation
The contaminants below are not health hazards, but you may choose to treat because of aesthetic reasons.		
Bad odor, color, taste	Variety of sources	Ion exchange; activated carbon filter; chlorination
Cloudy or dirty water	Fine sand, clay, or other particles	Mechanical filter
Hardness	Naturally occurring minerals in water	Ion exchange (water softener)
Rotten egg odor	Hydrogen sulfide gas	Chlorination and activated carbon filter
Staining of sink and/or laundry, from iron or manganese	Naturally occurring in water, especially deep wells	Ion exchange or green sand filter (0-10 ppm); chlorination and filtration (if over 10 ppm)

Ion exchange (water softener)

Treats hard water (calcium and magnesium)

Removes barium, radium, dissolved iron, manganese

Removes some bad odors, colors and tastes

Anion exchange unit can remove nitrate, fluoride

System cost: $600 - $2200; can also rent

An ion exchange column is one of the most common water treatment systems found in the home. Also known as a water softener, a cation exchange system will remove calcium and magnesium compounds, barium, radium, and low concentrations of dissolved iron and manganese. An anion exchange unit can also be installed which will remove nitrate and fluoride.

Ion exchange works by passing water through resin beads. In cation exchange units, the beads are coated with positively charged sodium ions. These sodium ions exchange places with calcium, magnesium and other "hard" ions in the water. In anion exchange columns, the resin beads are coated with negatively charged chloride or hydroxide ions, which exchange with nitrate or fluoride in your water.

Ion exchange systems need to be periodically charged so that coating ions are available. Many water softener systems automatically recharge from a sodium storage tank. People with hypertension or high blood pressure should be aware that water treated with a water softener contains an elevated level of sodium.

Distillation

Removes lead, nitrate, sodium chloride, pesticides, organic compounds

System cost: $250 (counter-top) - $1200 (large tank), plus electricity to run

A distillation unit works by evaporating water and collecting the steam that is produced. Impurities in the water are left behind. Distillation can remove lead, nitrate, sodium chloride, and many pesticides and organic compounds. Distilled water often has a flat or bland taste, due to the removal of minerals.

The distillation process is slow and requires a lot of water – a typical distiller produces two to five gallons a day, and requires five gallons of water for every gallon of distilled water produced. A distiller must be cleaned frequently and consumes significant electricity to heat the water.

Reverse Osmosis

Removes radium, sulfate, calcium, magnesium, potassium, nitrate, fluoride, phosphorous

Removes some pesticides and organic compounds

System cost: $100 (under sink) - $800 (whole house)

In the reverse osmosis process, water passes through a semi-permeable membrane which removes inorganic minerals like radium, sulfate, calcium, magnesium, potassium, sodium, nitrate, fluoride and phosphorous. It also helps to remove some organic compounds including some pesticides. Often, reverse osmosis units are used in combination with a mechanical filter and an activated carbon filter. The water passes through the mechanical filter first, where sand and large particles are removed, then through the reverse osmosis unit, and lastly through the activated carbon filter which removes organic compounds.

Disinfection Methods

Chlorination

Kills bacteria and some viruses (Note – does not kill Cryptosporidium, Giardia and some other microscopic organisms)

Removes some bad odors, tastes and colors

System cost (continuous chlorinator): $500 - $1300

Chlorine added to water kills most bacteria and some viruses. Water can be chlorinated in two ways: a "shock" chlorination in which a strong chlorine solution is pumped through a well or plumbing system to kill bacteria on a one-time basis; or chlorine is added continuously through a chemical feed pump to constantly kill bacteria. Shock chlorination is usually used when a pump or well has just been installed to kill bacteria that may have been on the pipes or installation equipment, or if a well has become contaminated by a faulty cap or seal. Continuous chlorination is used when the source of the bacteria in the water cannot be eliminated.

Chlorination has a residual effect in water – it continues to disinfect for some time after treatment. If followed by mechanical or activated carbon filtration, chlorination can also remove hydrogen sulfide, and dissolved iron and manganese.

Chlorine can impart a disagreeable taste and smell to the treated water. Also, if the water being treated contains organic molecules, the formation of hazardous chlorinated organic compounds (trihalomethanes) is possible.

UV Radiation

Kills bacteria, some viruses

System cost: $250 (under sink) - $1000+ (whole house)

This type of water treatment uses a mercury arc lamp to kill pathogens in the water. UV radiation kills most bacteria and some viruses, but is ineffective against cysts (such as *Giardia*) and worms. Cloudy or turbid water can reduce the effectiveness of UV radiation. UV lamps should be replaced annually or as suggested by the manufacturer, as they become less effective with time.

Ozonation

Kills bacteria, some viruses

Removes some pesticides, can remove iron, sulfur, manganese

System cost: $250 (portable) - $2000 (whole house)

Ozone occurs naturally in our atmosphere; in fact the ozone layer in our atmosphere protects us from ultraviolet radiation coming from the sun. In ozonation of water, electrically generated ozone kills bacteria and some other pathogens, and removes some pesticides. In combination with an activated carbon or mechanical filter, ozonation oxidizes and precipitates out iron, sulfur, and manganese. Ozone does not produce any taste or odor in the water.

Ozone generators are relatively expensive to install. Ozonation does not have any residual effect in the water, unlike chlorination.

Filtration Methods

Activated Carbon

Removes organic compounds, pesticides, radon gas

Removes hydrogen sulfide, mercury, chlorine, some cysts

System cost: $50 (faucet mount) - $1500 (whole house)

Solid Block Activated Carbon filters can remove Cryptosporidium and Giardia cysts.

Activated carbon filters absorb organic compounds and remove them from the water. These filters can remove volatile organic compounds, some pesticides, radon gas, hydrogen sulfide, mercury, and residual chlorine. Activated carbon filters are often used in combination with other water treatments such as reverse osmosis, chlorination, and ozonation.

There are different types of activated carbon filters. Granular activated carbon (GAC), composed of loose granules of carbon, have some problems associated with their use. GAC filters accumulate the organic impurities they remove from the water, but these impurities can then become food for bacteria. Also, the filter can become saturated with organics, which are then released back into the water. Finally, channels can form between the granules in the filter, which reduces contact time between the water and carbon, resulting in less effective filtration.

Solid block activated carbon filters (SBAC) are a solid compressed block of activated carbon. In addition to removal of chemicals mentioned above, the carbon is so tightly compressed that it can filter out some cysts such as Giardia and Cryptosporidium. Because SBAC filters are so fine, they easily become plugged with particulate matter, and frequently need to be replaced. They are also more expensive than granular activated carbon filters.

Inadequately maintained carbon filters can become breeding grounds for bacteria, so the filters need to be kept clean and replaced as recommended by the manufacturer. If a carbon filter is unused for several days, run water through it for at least 30 seconds to flush any bacteria.

Mechanical

Removes sand, silt, clay, organic matter

System cost: $35 (single faucet) - $550+ (whole house)

Mechanical water filters remove suspended material from water, including sand, silt, clay and organic matter. This filtration system does not remove dissolved or very fine particles and is often used in combination with other water treatment equipment. Mechanical filters commonly consist of fabric, fiber, ceramic or other screening material. Mechanical water filtration system can be cartridge units, mounted in a single waterline or on a tap, or tank units, which treat an entire household water supply. The filters must be serviced periodically.

Filtration Methods – continued

Green Sand

Removes iron and manganese up to 10 ppm, prevents rotten egg smell (hydrogen sufide)

System cost: $500 - $900 (whole house)

Manganese green sand filters remove iron, manganese and hydrogen sulfide (rotten egg odor). As water is passed through the filter, soluble iron and manganese are pulled from solution and later react to form insoluble iron and manganese. Insoluble iron and manganese build up in the green sand filter and must be removed by backwashing. Backwashing should be done regularly twice a week or as recommended by the manufacturer.

Periodically, the green sand must also be regenerated by washing with a permanganate solution. Regeneration will leave the green sand grains coated once again with a manganese material that adsorbs soluble iron and manganese. Follow the manufacuturer's recommendations for frequency of regeneration.

If the level of iron and manganese in your water is over 10 parts per million (ppm), use chlorination followed by filtration for removal.

Before You Purchase Water Treatment Equipment...

National Sanitary Foundation

The National Sanitary Foundation (NSF) is an excellent resource for anyone who is considering a purchase of a water treatment system. It is an independent, non-profit group of scientists, engineers, technicians, educators and analysts who test and certify drinking water treatment (and other) equipment. At their Web site, www.nsf.org, you can find out if a particular product is certified to perform as advertise. When purchasing equipment, check to see if it has the NSF mark or listing on it.

Questions to ask a water treatment professional

If you have determined there is a water quality problem that needs treatment, here are some questions to ask a manufacturer or distributor of water treatment equipment.

1. What exactly does the water analysis show? Do more tests need to be done? Many water treatment companies will offer free water testing. Make sure you understand the results. In-home quick tests of hardness, pH, iron and sulfur are possible; tests for organic chemicals require laboratory analysis. Be wary if the quick testing results claim the presence of organics.

2. Are the products and manufacturer rated by the NSF (see above)?

3. Is there a list of referrals you can contact? How long has the company been in business?

4. Does the water quality problem require whole-house treatment, or will single-tap treatment be sufficient?

5. Is the water treating capacity of the system adequate? Will it produce enough treated water for daily needs?

6. Are there parts to be cleaned or filters to be replaced? Is there an indicator light on the unit in case of a malfunction? Make sure you understand the maintenance required, as many systems will not operate effectively without proper maintenance.

7. What is the total purchase price, including installation? What are the expected maintenance costs (filter replacement, cleaning, etc)? Will the system use significant amounts of electricity? What is the expected lifetime of the system?

References

Bach, Annette, and Darnell Lundstrom. 1988. Household Water Treatment. HE-430, North Dakota State University Extension Service, Fargo, North Dakota.

Pfeil, Adel. 2001. Buying Home Water Treatment Equipment. WQ-6, Purdue University Cooperative Extension Service, West Lafayette, Indiana.

Mesner, Nancy. 2005. How to Protect Your Well Water. WQFA 1. Fact Sheet 1, Utah State University Water Quality Extension, Utah State University.

Seelig, Bruce, Russell Derickson, and Fred Bergsrud. 1992. Treatment Systems for Household Water Supplies: Iron and Manganese Removal. AE-1030, North Dakota State University Extension Service.

University of Illinois Extension. 1995. Selective Effective Water-treatment Methods. In 57 Ways To Protect Your Home Environment. College of Agricultural, Consumer and Environmental Sciences, University of Illinois.

Utah State University. 2005. Water Quality Toolbox. www.extension.usu.edu/waterquality.

Wagenet, Linda, and Ann Lemley. 1988. Questions to Ask When Purchasing Water Treatment Equipment. Water Treatment Notes Fact sheet 1, Cornell Cooperative Extension, New York State College of Human Ecology.

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