Virginia Cooperative Extension
Knowledge for the CommonWealth

Household Water Treatment

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Introduction

Foul taste, smell, or color of your household water may prompt you to investigate water treatment equipment. The publicity about water pollution problems may make you question the safety of your water supply. Or mineral scale buildup may cause you to invest in early replacement of plumbing fixtures and water-using appliances.

Before you attempt a quick and possibly costly remedy, take a first important step. Have your water analyzed. A water analysis will help identify bacteria, minerals, or other pollutants that are present. Interpretation of the test results will help you determine whether the water needs to be treated and, if so, the type of treatment needed.

The intended use of the water (whether for drinking, laundry, or all household uses) will also help determine the extent of treatment required.

Keep in mind that no single water treatment device treats all problems, and that all devices have limitations. See table for common water quality problems and suggested corrective procedures.

Do not assume that installation of water treatment equipment similar to that of your neighbors will be the answer to improving your household water quality. Different water supply sources, amounts and types of household uses, and many other variables affect the selection of the proper water treatment system.

See Quick Reference to Common Water Treatment Devices

Types of Water Treatment

Problem	*Typical corrective procedures*
Fine sand, clay, other particles	Remove using a mechanical filter
Bacterial contamination	Remove the source of contamination or treat using chlorination or other forms of disinfection
Hydrogen sulfide gas (rotten egg odor)	Remove using chlorination and a sedimentation filter or an oxidizing filter followed by activated carbon filter
Suspended iron and manganese particles	Remove using a mechanical filter
Small amounts of dissolved iron	Remove using a water softener
Higher amounts of dissolved iron and manganese	Remove using a potassium permanganate regenerated oxidizing filter
Very high amounts of dissolved iron	Remove using a chlorinator followed by a mechanical filter
Hardness	Treat using a water softener
Acidity	Treat using a neutralizing filter
Volatile organic chemicals, trihalomethanes, certain pesticides and radon	Remove using an activated carbon filter
Heavy metals (lead, mercury, arsenic cadmium)	Remove using a reverse osmosis unit or a distiller
High total dissolved solids, sodium, sulfates, nitrates	Remove using a reverse osmosis unit or a distiller

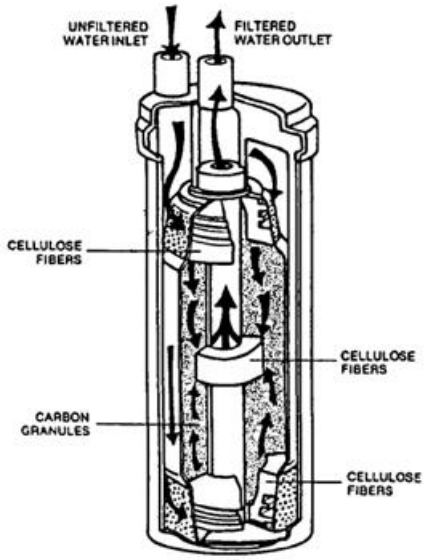
Quick Reference to Common Water Treatment Devices

Device	*Primary Use*	*Limitations*
Carbon Filter	Removes chlorine, some organic chemicals, resin, general taste and odor problems	Does not remove nitrate, bacteria, or metals. Periodic replacement of activated charcoal required
Mechanical Filter	Removes sand dirt, and other causes of turbidity	Requires regular cartridge replacement or backwashing (depending on type) to maintain effectiveness
Water Softener	Replaces water hardness minerals (calcium, mangesium) with sodium	Removes calcium and magnesium, replacing with sodium (consult physician if sodium is a health concern)
	Improves cleaning action of soaps, detergent	Softened water can be more corrosive than unsoftened water
	Prevents scale deposits in pipes, equipment	Periodic backwashing and regeneration required
Iron filter	Removes iron and manganese that can cause staining of clothes and plumbing fixtures Prevents ordor caused by iron, manganese	Periodic backwashing, addition of potassium permanganate required (frequency dependent on water usage, iron content)
Neutralizer	Treats corrosive or acidic water	May increase sodium or alter water hardness

Activated Carbon and Mechanical Filters

Activated carbon filters (also called carbon filters) treat general taste and odor problems, including chlorine residue. When water flows through carbon filters, contaminants adsorb or stick to the surfaces of the carbon particles. Activated carbon filters are reported to be the best method available for removing specific organic chemicals, including some pesticide residues. Studies have also shown that GAC (granular activated carbon) adsorption is an effective method for radon removal. Mechanical filters trap, through a straining process, sand, dirt, and other suspended particles to reduce turbidity in water.

Activated Charcoal Filter



Water passes between inner and outer cylinders, then through cellulose fibers.

General Description

Carbon filter devices are available in several sizes and designs. Small units fit on kitchen taps and treat only 100 to 300 gallons effectively before a filter change is necessary. Large under-sink units, often called in-line filters, are designed to treat up to 1500 gallons. On such a unit the canister is connected to the cold water line. Other styles are available that treat all household water. An extra filter cartridge or canister is often included with the initial purchase. Check on availability of filters and cost of replacement filters at time of purchase; they may be available from the same dealer, at plumbing supply stores, or by mail order.

Design greatly influences efficiency. Variations include use of powdered carbon or blocks of carbon instead of granular carbon. Those filters containing more carbon will usually treat more water before replacement is necessary.

Mechanical filters are frequently combined with activated carbon filters. Small mechanical filters, using spun cellulose, attach to a tap or can be installed under a sink. Filters to treat all the water supplied to the house may use sand or gravel.

Limitations

Activated carbon filters do not remove nitrate, bacteria, or metals. Concern about the growth of harmful bacteria in these filters has been raised in the past. However, recent research by the U.S. Environmental Protection Agency indicates that the types of bacteria found in water samples obtained from this type of filter create no health hazard if the filter is properly maintained. As a precaution, however, activated carbon filters are recommended for use only on microbiologically safe water.

Maintenance

Setting up a regular maintenance schedule for filter replacement is necessary, because there is no easy method for detecting that a filter is no longer working effectively. The frequency of filter cleaning or replacement depends largely on the level of pollutants in the water supply and the quantity of water flowing through the filter.

A mechanical filter may become clogged if not cleaned or replaced periodically, resulting in loss of water pressure and a reduction in flow. Filters using sand or gravel require automatic or manual backwashing to remove trapped particles.

Water Softeners

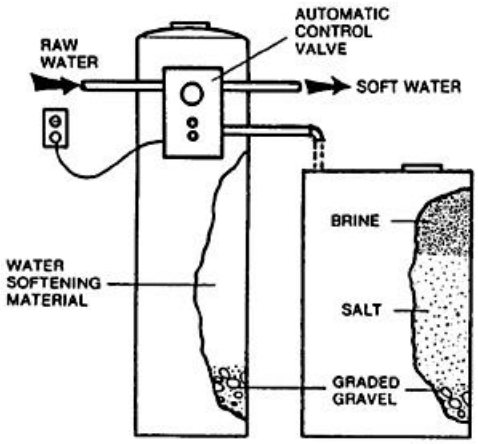
Water softeners remove the hardness minerals calcium and magnesium. Water exceeding about 7 to 8 grains per gallon hardness may interfere with the cleaning action of soaps and detergents, and cause scale buildup in hot water pipes, water heaters, and plumbing fixtures.

General Description

The most common way to soften household water is to use a cation exchange water softener. A synthetic resin with a strong attraction for calcium, magnesium, and other positively charged metal ions (cations) is first saturated with sodium cations from a salt (sodium chloride) solution. As the water passes through the resin, the sodium exchanges with calcium and magnesium.

Softeners are automatic, semi-automatic, or manual depending on the system for regeneration of the resin. Each type is available in several sizes and is rated on the amount of hardness it can remove before regeneration is necessary.

Automatic Water Softener



The unit completes all regeneration steps automatically. The salt in the brine tank must be replenished periodically.

Limitations

Individuals on a sodium-restricted diet should consult a physician before using softened water. A possible solution is to have drinking and cooking water lines bypass the water softener. Water softening units also remove small amounts of iron. However, using a softener to remove iron in naturally soft water is not advised. Refer to the iron filter section of this publication.

Maintenance

When the resin is filled to capacity with calcium and magnesium, it must be recharged. Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a time clock, although some units start regeneration by water-use meters or hardness detectors.

Semi-automatic softeners have automatic controls for everything except for the start of regeneration. Manual units require manual operation of one or more valves to control backwashing, brining, and rinsing.

In many areas, there are companies that provide a water softening service. For a monthly fee,the company installs a softener unit and replaces it periodically with a freshly charged unit. The replacement schedule depends on the water hardness and the amount of water used.

Iron Removal Equipment

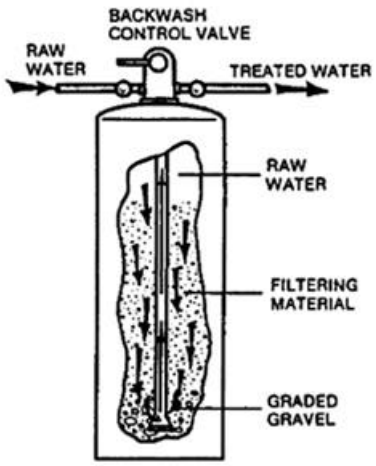
Iron filters remove iron and manganese that can cause staining of clothes and plumbing fixtures. Ferric iron usually appears as rust colored particles floating or settling in the water. Ferrous iron is in the dissolved form and cannot be seen in water. When water containing ferrous iron is exposed to air, the iron oxidizes and ferric iron is formed.

Water with a high iron or manganese content is not considered a health problem, but can be very objectionable in taste, odor, or appearance if iron is present in amounts greater than 0.3 milligrams per liter or manganese is present in amounts greater than 0.05 milligrams per liter.

Iron bacteria are nuisance organisms often associated with soluble iron in water. Because they cause a slime buildup, they can be quite objectionable with iron concentrations as low as 0.1 milligrams per liter ferrous (soluble) iron.

The presence of iron bacteria is indicated by a gelatinous slime on the inside wall of the toilet flush tank and gelatinous "rusty slugs" being discharged at the tap. High dosages (200 to 500 milligrams per liter) of chlorine (known as shock chlorination or disinfection) are required to control iron bacteria. Shock chlorination must include the well and pumping system.

Iron filter, backwash type



The unit can be used for the removal of iron, sulfur, sediment, tastes, and odors, depending upon the filtering material used in the tank.

General Description and Maintenance

Five types of iron-removal equipment are available:

1. **Iron Filter.** Iron filters are only useful for removal of ferrous (soluble) iron and manganese; ferric iron will plug them. They look like water softeners but contain a bed of natural or synthetic manganese green sand. Manganese dioxide oxidizes iron and manganese and the oxidized particles are then filtered out in the lower part of the bed.

   The filter bed must be backwashed frequently to remove the accumulation of iron particles. For backwashing, a flow rate more than double the normal service flow rate is usually required. The exhausted manganese must be recharged by adding potassium permanganate.

   Acid water below a pH of 6.8 will pick up manganese from the green sand and cause loss of oxygenexchange capacity. Therefore, neutralization treatment may be necessary. Also, the slime produced by iron bacteria will clog the filter.

2. **Water softener.** Water softeners contain a zeolite mineral in the resin that will remove soluble iron on an ionexchange basis (the same way calcium and magnesium are removed in water softening). Depending on the kind of zeolite used and the regeneration process, up to 5 milligrams per liter of soluble iron can be removed. The slime produced by iron bacteria will clog the zeolite and reduce its effectiveness.

3. **Polyphosphate feeder.** These units can handle up to 3 milligrams per liter of iron in solution. They contain a phosphate compound which coats the soluble iron and prevents its oxidation when the water is exposed to air. The compound is not effective against ferric iron that has already oxidized.

   Polyphosphate is only effective in cold water. Heating the water will release the iron so that oxidized iron accumulates in the waterheater. The heated water will be rusty and unsatisfactory for home use.

4. **Chlorinator and filter.** Chlorination followed by filtration through a sand filter can remove any quantity of iron in any form. The chlorine oxidizes and precipitates the iron and the filter strains out the particles. Carbon filtration may be required to remove excess chlorine residue.

   This method also destroys iron bacteria. When the bacteria cannot be permanently

eliminated by shock chlorination, continuous chlorination is required.

5. **Aerator and filter.** An alternative to chlorination for iron removal is that of aeration followed by filtration. An aerator introduces oxygen into the water, thereby causing ferrous iron to precipitate through oxidation. Aeration equipment for household use has become more available in recent years.

Limitations

Iron removal from your water supply can involve complex choices. Careful planning is needed when iron removal equipment is used in conjunction with other water treatment equipment. The type of iron removal equipment chosen depends on the type and quantity of iron in the water, the characteristics of the water supply, other water treatment equipment in use, and the user's requirements for cost, ease of use, and maintenance.

Neutralizers

This system treats corrosive (acidic) water by increasing alkalinity, resulting in a pH near 7.0. Reducing corrosivity may also lower the concentration of harmful metals, such as copper and lead, that may be dissolved from pipe walls and fittings.

General Description

Passing the water through granular calcite (marble, calcium carbonate, or lime) is the most common method of home treatment. A mix of calcite and magnesium oxide also is used. If the water is very acidic or if a high flow rate is needed, a system to chemically feed soda ash, sodium carbonate, or caustic soda (sodium hydroxide) may be necessary.

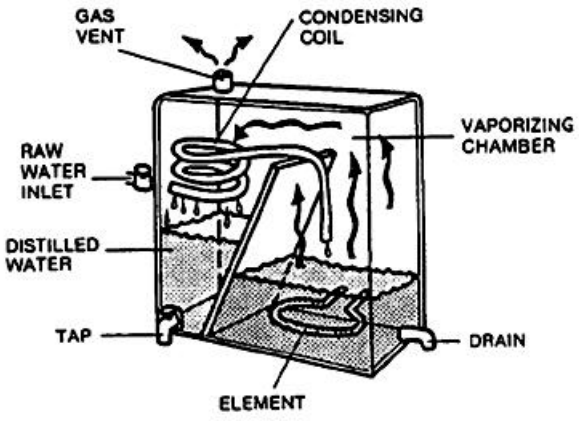
Limitations and Maintenance

Neutralizers using soda or sodium compounds increase the sodium content of water which may be a health concern. Using calcite to neutralize water increases calcium, which increases water hardness. These factors must be considered in your treatment choice. All systems require routine maintenance to replenish the chemical used to neutralize the water.

Distillation Units

Distillation removes most impurities from water, including minerals such as nitrate, sodium, and sulfate, and many organic chemicals.

Distiller, rectangular cart style



General Description

Distillation units boil water to create steam which is then condensed and collected as purified water. Most impurities remain in the heating chamber and must be periodically removed. Units vary from the kitchen countertop size to larger units.

Limitations

Removal of minerals produces water that can have a bland taste. Because a kitchen location close to point of use is preferred for smaller units, counter or cabinet space must often be given up. Also, distillers are expensive to operate.

Some distillers allow contaminants with a boiling point lower than water (e.g. some pesticides and volatile solvents) to vaporize with the water and recondense with the treated water, which means they remain in the treated water. Others have a volatile gas vent that releases these products to the atmosphere.

Maintenance

Design of the unit is important because minerals and other contaminants accumulate in the boiling chamber and can interfere with the operation of the unit. Hard water can cause scaling in a distiller. Some units are easily cleaned by hand while others require washing with a strong acid.

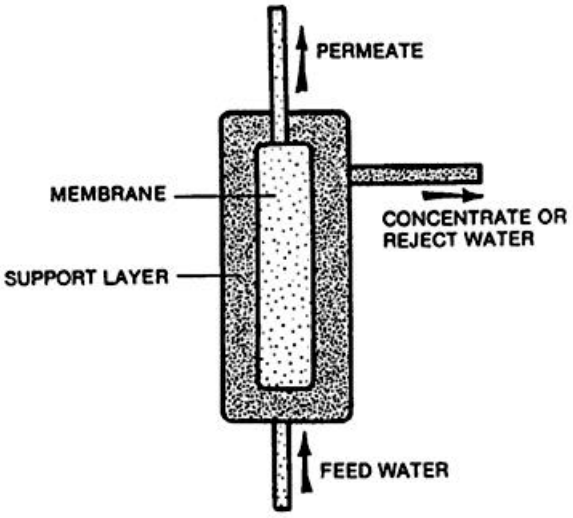
Reverse Osmosis

A reverse osmosis unit substantially reduces most suspended and dissolved matter from water.

General Description

Contaminants are removed by forcing water through a membrane having microscopic holes that allow water molecules, but not larger compounds, to pass through. Water flushes away the contaminants held by the membrane.

The Reverse Osmosis process



Membranes are made of a variety of materials that differ in effectiveness for different chemicals. Be sure to study water test data and identify the chemicals to be removed.

Limitations and Maintenance

Although reverse osmosis removes many organic chemicals, it does not remove all. For instance, it will not remove chloroform. And it does not remove 100 percent of most chemicals.

These units waste large amounts of water. Most units will discharge up to 50% or more of total water as waste.

The membrane can develop problems from precipitate buildup and scaling. A softener must be installed ahead of the reverse osmosis unit if hard water is used. Otherwise, the minerals will quickly plug the membrane filter.

Frequently, mechanical and/or activated carbon filters are installed before the reverse osmosis unit to remove turbidity and improve taste and odor. This can result in improved overall water quality and extend the life of the reverse osmosis membrane.

The reverse osmosis membrane will need periodic replacement according to the manufacturer's recommended schedule. Occasional cleaning and flushing of the whole reverse osmosis unit may be required.

Disinfection Methods

Chlorination

Both municipal systems and households can disinfect water by adding chlorine. Household systems commonly use liquid chlorine bleach injected into the water by one of several types of pumps.

Chlorination does not remove nitrate or other chemicals, but may oxidize organics and some minerals such as iron Chlorine metering pumps must be calibrated and maintained carefully Using a carbon filter after chlorination will remove any excess chlorine and chlorinebased chemicals that may form

Other Methods

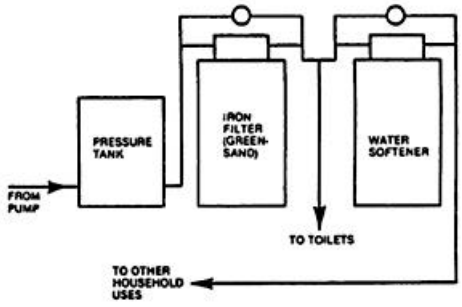
Other methods of disinfecting water include boiling distilling pasteurizing treating with ultra-violet light, and treating with ozone Chlorination distillation or boiling for 15 minutes are the usual methods used to purify water for household use. Disinfection by ozonation or ultraviolet light methods are replacing chlorination in some water treatment plants, and are becoming more popular for home uses

Some filtration units with silver-coated activated charcoal blocks are being sold for removal or killing of bacteria Before purchasing such a unit, evaluate it carefully and check for sufficient test data and certification to assure its effectiveness.

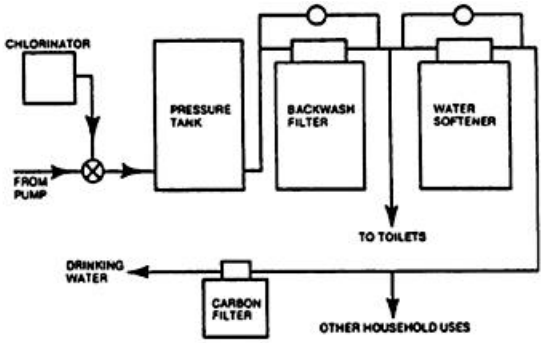
Household Water Treatment Systems

When single water quality problems are identified, one water treatment device may be adequate. In many cases, however, more than one problem is present, requiring a combination of water treatment devices. A household treatment system should take into account the most practical and effective device to treat each problem, the order these devices should be placed in the system, and the intended use of the water-- for drinking, laundry, or all household uses. See diagrams for typical illustrations of household water treatment devices in combination.

Household Water Treatment Systems



Proper installation when both an iron-filter and water softener are utilized.



Installation when chlorination is used for iron removal and water is softened.

Definition of Terms

ACIDITY - A condition of water when the pH is below 7. See pH.
ALKALINITY - A condition of water when the pH is above 7. See pH.
BACKWASHING - The process of reversing the flow of water to restore or clean a filter.
FLOW RATE - The quantity of water available or needed commonly measured in gallons per minute, per hour, or per day.
GRAINS PER GALLON - The weight of a substance, in grains, in a gallon. Commonly, grains of minerals per gallon of water is a measure of water hardness. 1 grain per gallon = 17.1 milligrams per liter.
HARDNESS MINERALS - Minerals dissolved in water that increase the scaling properties and decrease cleansing action usually calcium and magnesium.
ION EXCHANGE - Process whereby one mineral is substi tuted for another.
NEUTRALITY - A condition of water when the pH is at 7. (neither acid or alkaline) See pH.
OXIDATION - Causes the impurities to precipitate, and this reduces water impurities, such as iron, manganese, hydrogen sulfide, and many organics.
PEAK USE RATE - The flow rate necessary to meet the expected maximum water demand in the system.
pH - A measure of the acidity or alkalinity of water. Below 7 is acid, above 7 is alkaline.
REGENERATION - Process which restores the ion-exchange material (zeolite or resin beads) to useable condition.
SHOCK CHLORINATION - Using high dosages of chlorine (200 to 500 milligrams per liter)
SOFTENING - The process of removing hardness caused by calcium and magnesium minerals.

Adapted from a publication by Annette Bach and Darnell Lundstrom, North Dakota State University Extension Service by: Kathleen Parrott, Blake Ross, and Janice Woodard.

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