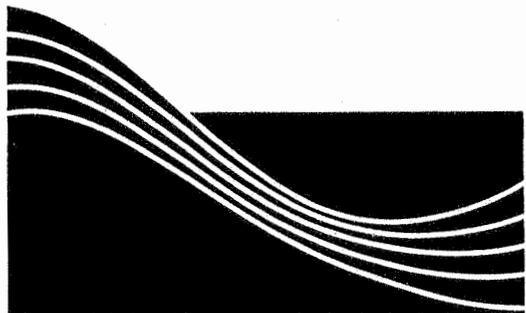


# HOUSEHOLD DRINKING WATER PROTECTION AND TREATMENT

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**WATER QUALITY**

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## PREFACE

When you fill a glass with water, you expect to drink water that is safe and pure. However, gases, minerals, bacteria, metals or chemicals suspended or dissolved in your water can affect your health and influence the quality of your water. For many Montana private water wells, water treatment systems are imperative to maintain usable water for human and animal consumption. But selecting a water system can be complex—there are many treatment devices available and since they are not regulated, quality control can be a problem.

The purpose of this publication is to help consumers sort out the many treatment options available, define treatment terms used by the industry and help choose a reliable treatment dealer. For those already familiar with water treatment systems, this publication provides a closer look at treatment devices—how they function, contaminants they reduce, treatment limitations and sizing considerations.

*This information is for educational purposes only.  
Reference to commercial products or trade names  
does not imply discrimination or endorsement by the  
Montana State University Extension Service.*



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## Household Drinking Water Protection and Treatment

**W**hen we go to the faucet for a drink of water, we expect a glass of clear, safe water. When bathing, doing laundry or using water for cooking, we also expect clean, fresh water. Although most groundwater is safe to drink and suitable for household tasks, there is growing concern about contamination of public and private water supplies.

Due to poor techniques in applying and disposing of household, agricultural and industrial chemicals, more synthetic and volatile organic chemicals are showing up in water supplies. In mining and petroleum drilling areas, dangerous levels of metals have been detected in groundwater and surface water supplies. In a private well water testing program<sup>1</sup> conducted by the Montana State University Extension Service in 1989, 43 percent of 1400 water samples taken from private wells exceeded the federal limit of coliform bacteria. Other studies<sup>2</sup> have revealed the presence of seven pesticides in Montana groundwater. These include the herbicides atrazine, 2,4-D, dicamba, MCPA, picloran, simazine and the insecticide aldicarb. Fortunately, the levels detected were below established guidance levels that indicate cause for health concern. On the other hand, in 1989, dry-cleaning solvents and de-greasing agents—perchloroethylene (PCE) and trichloroethylene (TCE)—were found in wells near Bozeman, Montana, at levels 30 to 50 times the safe level.

Even if you're on a public water supply, potential problems exist. While municipal water supplies must comply with federal drinking water standards,

<sup>1</sup>Bauder, James W., "Extension Water-Well Test Program," Montana AgResearch, Montana State University, Summer/Fall 1990.

<sup>2</sup>Jeffrey S. Jacobsen, and Gregory D. Johnson, Water Quality and Agrichemicals in Montana, Montana State University Extension Service, EB 51, September, 1989.

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there may still be health-related water problems. In areas with naturally soft, acidic waters, lead may leach from piping and solders. Cadmium and zinc may enter drinking water as a result of corrosion of galvanized pipe.

Small communities and individuals with private wells often face difficult decisions about costly drinking water treatments. Economics often prohibit construction of a central treatment system for small communities. Construction of new wells or piping water from neighboring supplies of better quality may not be feasible. For these small community water systems and for homes with private wells, in-home water treatment may be more cost effective in removing undesirable contaminants from the water.

### Should Treatment Be Considered?

Many types of water treatment and conditioning systems are available. Their effectiveness depends on the contamination to be treated. Before considering any water treatment you should follow these recommendations:

#### 1. Have the water tested by a certified laboratory.

The only way to determine contaminant levels is to have your water tested by a certified laboratory or qualified water specialist with reliable field test equipment. If there is any doubt about how any water sample was taken or tested, re-sample the water before investing in a treatment system.

#### 2. If possible, locate contamination sources.

Treatment of water should only be considered after every effort has been made to locate and control the source of contamination. Diverting surface water drainage away from the well may help. In other cases this may not be possible due to geological formations. If the water supply is being contaminated by feed lot runoff, septic tank seepage, or improper use, storage or disposal of household and agricultural chemicals, controlling these sources may eliminate the need for continuous treatment.

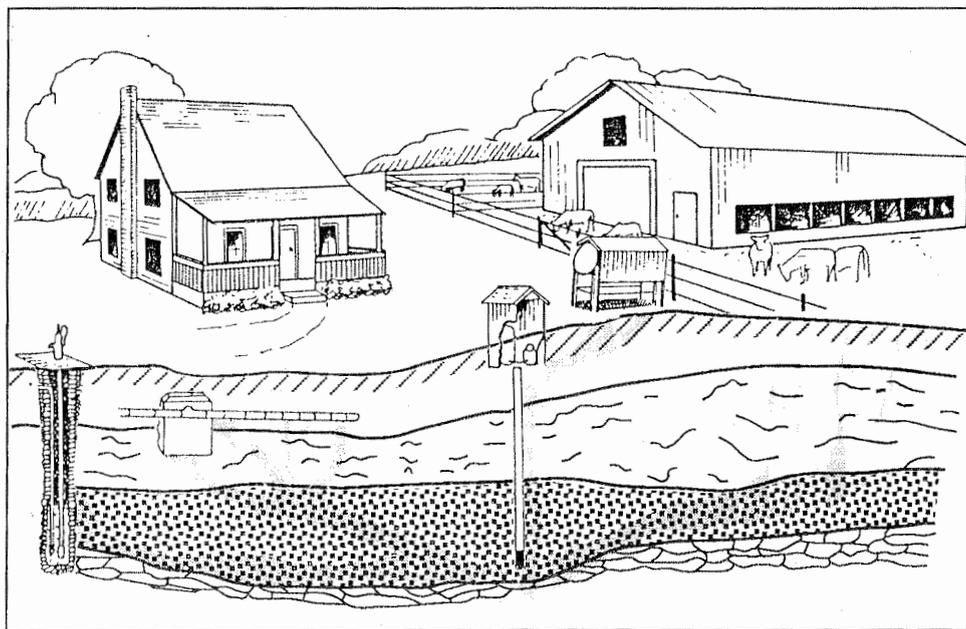


Figure 1. Concentrated sources of pollution can overload the natural filtering capacity of the soil. Source: Adapted from Iowa State University, Pm-840, 1989.



### 3. Check well construction.

Often water contamination leads back to the well itself (Figure 1). Due to improper construction, placement or neglect, surface or ground contamination can enter the water supply (Figure 2). Persistent bacterial contamination or turbid water may indicate a cracked well casing, poor grout or bad seals. Good well construction incorporates protective features that block contamination pathways.

Well water may become contaminated by coliform bacteria from:

- Loose or worn adapter seals to discharge line.
- Defective or inadequately sealed casings in a drilled or driven well.
- Cracked or loose-fitting well cover.
- Defective wall lining or cracked concrete apron of a dug well.
- Repair to well structure or submerged pump.
- Flooding of the well by heavy rainfall.
- Defective septic tank.
- Well drilled into fractured rock formations without adequately sealed casing.
- Well located where ground waters are subject to continuous contamination.
- Well located close to septic system, feed lot, abandoned well, or chemical and petroleum storage area.

Since soil is nature's medium for filtering pollutants from groundwater, it is important to maintain adequate distance between wells and potential sources of contamination. Table 1 shows the minimum recommended distance between wells and common sources of groundwater pollution.

When locating a well, consider relative elevations and locations of septic tanks, drain fields, stockyards, and other sources of contamination. Where geological and/or well construction conditions are marginal, even greater distances should be allowed. In well construction, plastic or metal casing serves as a structural support to prevent caving of the hole and to shut out seepage of undesirable water. If plastic casing is used, it must have a metal transition section extending at least 18 feet below ground level and extending at least 18 inches above ground. The metal casing is an important guard against contamination

## CONTAMINATION

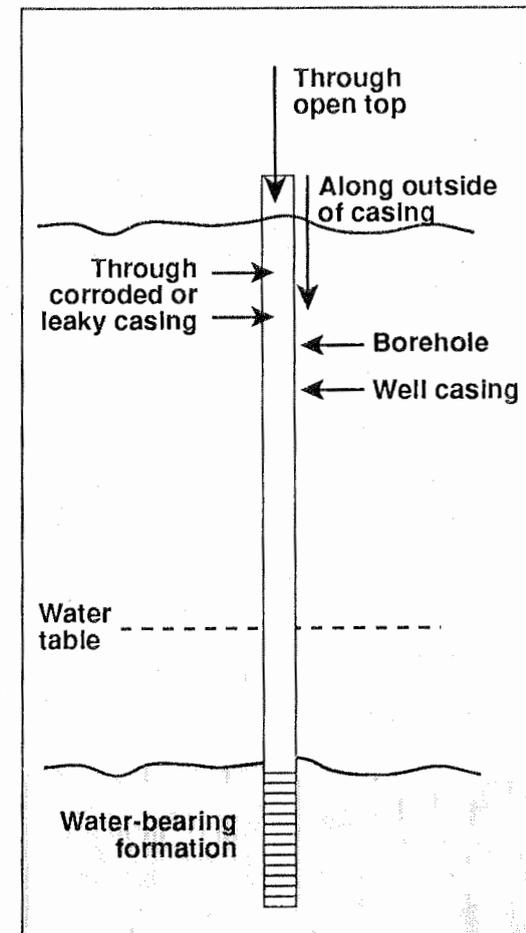


Figure 2. Pathways for contaminants into an unprotected well. Source: Iowa State University, Pm-840, 1989.



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because it prevents breakage. It also allows adequate space between the side of the casing and the earth. A tightly fitting cap should be installed at the top of the casing to prevent foreign material from entering the well (Figure 3).

Grouting is also an important step because it prevents seepage of contaminants from the surface along the casing walls. Grouting seals the space between the side of the casing and the hole with an impermeable material — usually bentonite or concrete. Generally, every well must be sealed in this manner to at least 18 feet below ground level.

Back siphonage of contaminants into a well from stock tanks and other contaminated water sources can occur when a domestic water supply system shares a common distribution system with these facilities. If sharing a common distribution system is unavoidable, it is important to use equipment with proper backflow preventers to guard against back siphonage.

#### 4. Check septic system.

Since septic systems are a major source of bacteria contamination, it is important the system be properly designed, installed and maintained. A few tips to assure a safe system:

- Inspect the tank yearly for scum and sludge levels.
- Have the septic tank pumped and flushed regularly. How often depends on the size of tank and the amount of discharge.

- Do not irrigate above the absorption drain field. Irrigation causes leaching of waste water into shallow groundwater sources.

- Make sure there is a 100 foot separation between septic systems and any surface water or floodplain.

#### 5. Eliminate sources of contamination.

Sometimes the source of contamination is local, such as a septic system, chemical spill, leaking storage tank, or drainage into a sinkhole or seepage from a feedlot. Once the source of the contamination is eliminated, groundwater will eventually cleanse itself through filtration, natural breakdown of the contaminants, dilution and movement of the contaminants away from the well.

Table 1. Minimum distance recommended between wells and potential contamination sources

Sources of Contamination	Minimum Lateral Distance
Preparation or storage area for spray materials, commercial fertilizers or chemicals that may result in groundwater pollution	150 ft
Soil absorption field, pit privy or septic drain fields	100 ft
Confined livestock feeding facilities; accumulations of manure	100 ft
Septic tank, concrete vault privy, sewer of tight joined tile or equivalent materials	50 ft
Cast iron sewers, independent clear water drains or cisterns	25 ft
Lagoons and sanitary landfills	1,000 ft
Abandoned wells not properly plugged	100 ft
Sewers from public water supply wells	50 ft



Obtaining water from another safe source may be inconvenient, but can provide a temporary alternative while the contamination is being corrected. Depending on the local geology and the nature of the pollutants, however, natural cleansing may take far too long — years or decades — for a temporary solution to be practical.

### 6. Consider installing a new well.

Constructing a new well is often the surest way to get safe water. You may have to change the well location. Or, you may be able to drill or drive the existing well to a different depth where the aquifer is less contaminated, or into a different, uncontaminated aquifer.

### 7. Use caution when disposing of household hazardous waste.

When people think of ground and surface water contamination, they generally visualize an irresponsible industry spewing gallons of hazardous waste into lakes or an agricultural field needlessly sprayed with chemicals that run off into nearby streams. However, many household wastes find their way into water supplies.

The U.S. Environmental Protection Agency (U.S. EPA) defines hazardous waste as materials that exhibit “corrosivity, flammability or toxicity.” Many ordinary products found in the home have one or more of these properties. Paints, solvents and refinishing supplies are among the most common, along with automotive motor oil and transmission fluid. Caustic cleaning supplies, arts and crafts materials, some cosmetics and certain medications can pose an environmental threat.

### Disposing of Household Wastes

Protecting human health and the environment through safe disposal is largely a matter of common sense. Before disposing of household wastes, read the product label. Substances which are poisonous, corrosive, or flammable, or packages that should not be incinerated or punctured will be clearly labeled for consumer safety. The best disposal method for any product, household or otherwise, is to use it up or give it to someone who can. This is not only efficient disposal but good use of our natural resources. Table 2 lists other disposal practices for household wastes.

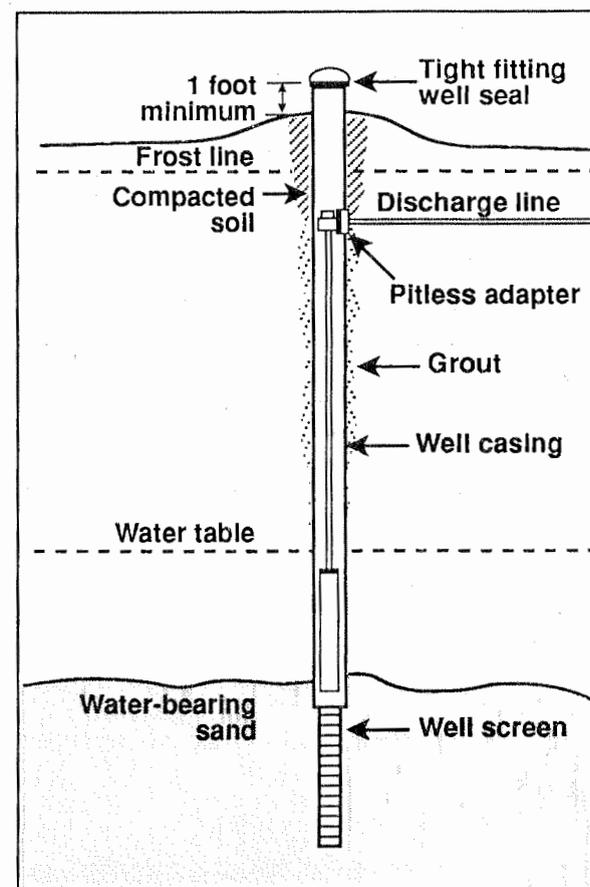


Figure 3. Proper drilled well construction.  
Source: Iowa State University, Pm-840, 1989.



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**Table 2. Disposal Do's and Don'ts**

Follow this list of DO's and DON'Ts when disposing of any leftover substances in the home.

DO's WHEN DISPOSING	DON'Ts WHEN DISPOSING
<p><b>DO</b> buy the right amount of product for the job. Read the label carefully before you purchase. It is your responsibility to use and dispose of household products and materials safely.</p> <p><b>DO</b> use up any product that you buy. If you can't, give it to someone who can. Make sure that any product you give away is in its original container with its label intact and any use and disposal instructions included. Give leftover paint to a local community or theater group; donate leftover pesticides to the local garden club; etc.</p> <p><b>DO</b> recycle wastes if you can. Take used or contaminated motor oil, transmission fluid, kerosene and diesel fuel to an automotive service center, oil recycling station, or authorized collection site; turn in your old car battery.</p> <p><b>DO</b> wrap the container in newspaper before placing it in the trash if the label carries a warning not to get the contents on your skin.</p> <p><b>DO</b> dispose of products that are meant to go down the drain during normal use by pouring them down the drain with plenty of water. Dispose of each product separately, small amounts at a time. This includes sink and drain cleaners, laundry products, soaps, etc.</p> <p><b>DO</b> empty all aerosol cans by depressing the button until no more product comes out before putting in the trash. Never throw empty aerosol containers into an incinerator or trash compactor.</p> <p><b>DO</b> follow all label directions.</p> <p><b>DO</b> call the product manufacturer or your local environmental or public health agency with questions about any material which you think may pose a disposal problem.</p> <p><b>DO</b> contact your community government to find out what kind of disposal systems (solid waste and sewage) your community has, and whether there are any materials which should not go through normal municipal disposal.</p>	<p><b>DON'T</b> dispose of any materials by pouring them into your backyard or into a storm sewer.</p> <p><b>DON'T</b> bury any containers, empty or full, in your backyard.</p> <p><b>DON'T</b> attempt to use a fireplace or a backyard barbecue as an incinerator.</p> <p><b>DON'T</b> dispose of anything in dumps by the side of the road.</p> <p><b>DON'T</b> remove product labels.</p> <p><b>DON'T</b> remove products from their original containers for storage or future use.</p> <p><b>DON'T</b> refill empty containers, even with the same material, unless the label recommends it. Once a container is empty, dispose of it. Follow label instructions about rinsing the container or wrapping it in newspaper.</p>

## FEDERAL DRINKING WATER QUALITY STANDARDS

**G**roundwater is never simply a pure combination of hydrogen and oxygen atoms (H<sub>2</sub>O). Water contains many elements, reflecting the composition of the soils, sand and rock formations through which it has moved.

Groundwater may contain: 1) dissolved minerals such as iron, calcium, magnesium, bicarbonate, chloride, and sulfate; 2) gases such as carbon dioxide, oxygen, hydrogen sulfide, and nitrogen; and 3) dissolved organic compounds. Typical concentrations of these substances are often beneficial to health and give water its characteristic taste. However, different levels may create undesirable water conditions. Too much iron can discolor laundry; too much calcium can cause a buildup of scale in water heaters and plumbing.

Contamination is most serious if the groundwater contains substances that pose a health risk — bacteria, viruses, nitrate, metals such as mercury or lead, pesticide residues and other synthetic organic compounds.

The Federal Safe Drinking Water Act (P.L. 93-253) was signed into law in 1974 and amended in 1986. The act directs the U.S. Environmental Protection Agency to establish minimum national drinking water standards.

Regulators have determined an “Acceptable Daily Intake,” or ADI, for chemicals that cause adverse health effects. The ADI is the daily dose of a substance that a person can drink safely over a lifetime without suffering adverse health effects. ADIs allow a generous safety margin.

The ADI is used to establish a “Maximum Contaminant Level Goal,” or MCLG, for a contaminant. The MCLG is the concentration of a contaminant that experts believe a person can drink safely over a lifetime. It is based entirely on health considerations and is set at a level where no adverse health effects should occur.

The “Maximum Contaminant Level,” or MCL, is the highest allowable concentration of a contaminant in drinking water supplied by municipal water systems. (Public water systems have been defined in Montana as systems that serve 10 or more service connections — the federal rules say 15 — or 25 or more



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Table 3. Primary drinking water standards as of July 1990

Contaminant	Maximum (MCL) (mg/L) <sup>1</sup>	Contaminant	Maximum (MCL) (mg/L) <sup>1</sup>
<b><i>Inorganics</i></b>		<b><i>Volatile Organic Chemicals</i></b>	
Arsenic	0.05	Benzene	0.005
Barium	1	Carbon Tetrachloride	0.005
Cadmium	0.010	Para-dichlorobenzene	0.075
Chromium	0.05	1,2-dichloroethane	0.005
Fluoride	4.0	1,1-dichloroethylene	0.007
Lead	0.05	1,1,1-trichloroethane	0.20
Mercury	0.002	Trichloroethylene	0.005
Nitrate (as N)	10.	Vinyl Chloride	0.002
Selenium	0.01	<b><i>Radionuclides</i></b>	
Silver	0.05	Radium 226 and 228	5pCi/L <sup>2</sup>
<b><i>Organics</i></b>		Gross Beta Particles 4 mrem/yr or	50pCi/L
Endrin	0.0002	Gross Alpha Particles	15pCi/L
Lindane	0.004	<b><i>Microbiological Contaminants</i></b>	
Methoxychlor	0.1	Total Coliform	1/100 ml <sup>3</sup>
2,4-D	0.1	<i>Giardia Lamblia</i>	TT <sup>4</sup>
2,4,5-TP (Silvex)	0.01	HPC	TT <sup>4</sup>
Total Trihalomethanes	0.10	<i>Legionella</i>	TT <sup>4</sup>
(Chloroform, Bromoform, Bromodichloromethane, Dibromochloromethane)		Virus	TT <sup>4</sup>
		<b><i>Turbidity</i></b>	1-5 units

<sup>1</sup>mg/L = parts per million (ppm)

<sup>2</sup>Concentrations of radioactive elements are measured in picoCuries per liter (pCi/L)

<sup>3</sup>Coliform bacteria count in 100 milliliter sample of water

<sup>4</sup>Treatment Technique requirements established in lieu of MCLs: effective beginning December 1990.

people). The MCL is set as close as possible to the MCLG. In setting an MCL, EPA considers, in addition to health effects, the feasibility and the combined cost of analyzing water for a contaminant and for treating water to remove the contaminant.

Contaminants that affect the safety of drinking water and may cause health risks are regulated by Primary Drinking Water Standards. These standards (Table 3) only apply to public drinking water systems which means that every public water supply in the country serving at least 15 service connections or 25 or more persons must ensure that its water meets these minimum standards. Even non-community supplies, such as campgrounds and roadside motels with their own water supplies, are covered by the regulations. The standards do not apply to individual private wells, but, they serve as a guide for assure safe drinking water for these systems. Table 3 lists contaminants currently regulated by EPA.

Secondary Drinking Water Standards, Table 4 are concentration limits for aesthetic contaminants that affect the taste, odor, color of drinking water and which do not present health risks. Secondary Standards are not enforced by state or Federal agencies. Municipal water systems are not required to test for nor remove secondary contaminants but very often do. These are useful guidelines for water suppliers and well owners who wish to ensure that their water will be suitable for all household uses, including drinking, bathing, washing, and cooking. Table 4 lists National Secondary Drinking Water Standards.

Many public and private laboratories analyze drinking water for seven parameters in a routine testing procedure referred to as a "partial chemical analysis." Except for fluoride and nitrate, the levels listed in Table 5 are general guidelines. The results are reported in milligrams per liter (mg/L) for all parameters except conductivity.

For answers to questions about drinking water contaminants the U.S. EPA has a toll-free hot line. The toll free telephone number is (800) 426-4791.

## PRIMARY AND SECONDARY

**Table 4. National secondary drinking water standards\* (U.S. EPA)**

Contaminant	Maximum Level (MCL)
Chlorid	250 mg/L
Color	15 color units
Copper	1 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 TON**
pH (acidity)	6.5 - 8.5 on scale
Sulfate	250 mg/L
Total Dissolved Solids (TDS)	500 mg/L
Turbidity	5.0 NTU
Zinc	5 mg/L

*\*Secondary Maximum Contaminant Levels (SMCLs) are federally non-enforceable and establish limits for contaminants in drinking water which may affect the aesthetic qualities and the public's acceptance of drinking water (e.g. taste and odor).*

*\*\*Threshold odor number*

*Source: Water Technology, August 1990.*



## PROTECTION AND TREATMENT

## TREATMENT VERSUS CONDITIONING

In treating water, first priority should be given to eliminating water contaminants that can threaten health. When evaluating the need for a treatment system, it is important to remember that "impurities" in water aren't always bad. The much-praised "clean, delicious" taste of bottled spring waters often comes from the minerals they contain, such as calcium and magnesium. Anyone who has tasted distilled water know that water without most minerals is insipid. It may not be

necessary to remove all mineral contaminants simply because a water sample indicates a high level.

Methods that improve the quality of water are variously referred to as "treatment" and "conditioning." What is the difference? While these terms are often used synonymously, water treatment refers to systems that reduce harmful contaminants in the water and therefore deal with health and safety of the water. High levels of coliform, nitrates, arsenic, lead and pesticides are examples of harmful contaminants that must be treated before water is safe to drink.

Water conditioning alleviates problems that affect water taste, color, odor, hardness and corrosivity rather than health and safety. Water with high levels of magnesium, calcium, iron, manganese and silt commonly requires water conditioning. It is not uncommon to use both treatment and conditioning methods to improve water quality.

**Table 5. Partial chemical analysis parameters. Test results in milligrams per liter (mg/L)**

Test	Excellent	Satisfactory	Objectionable	Problem
Iron	0.05-0.2	0.2-0.5	over 0.5	Staining, rust, taste.
Sodium	0-20	20-250	over 250	Taste. Special diets may require water of low sodium content.
Nitrate N-No <sub>3</sub>	0-1	1-10	over 10 (state) drinking water standard	Nitrate above 10.0 considered health risk for infants.
Hardness as CaCO <sub>3</sub>	25-60	60-120	over 120	Scaling of water heater and fixtures, soap scum
Chloride	0-20	20-250	over 250	Taste, corrosion.
Fluoride	*0.8-1.7	*0-0.8 or 1.7-2.4	over 2.4 (state) drinking water standard	Low levels beneficial in preventing tooth decay. High levels cause mottling of teeth.
pH value	7.0-8.0	down to 6.5 up to 8.5	below 6.4 above 9.0	Below 6.4, corrosive. Above 8.5, taste.
Conductivity	0-0.4	0.4-0.85	over 0.85	

\*Levels apply where fluoride supplements are not used.

## Treatment and Conditioning Systems Available

In-home water treatment systems should be considered only after water has been tested by a reputable laboratory, and after you have attempted to control any source of water contamination. Many treatment systems are available and effective, depending on water conditions. However, water treatment devices are not subject to U.S. EPA regulation, so shop wisely. Table 6 is a list of possible treatment processes.

In-home water treatment systems fall into two categories: "point-of-entry" or "point-of-use" systems.

Point-of-entry systems treat all of the water entering the home. Sedimentation filters, iron control treatment, water softener and a chlorination system used to control bacteria are all considered point-of-entry systems. Point-of-use water treatment systems, on the other hand, treat part of the water in the home water distribution system — usually at one faucet. Reverse osmosis, distillation, and cartridge activated carbon filtration are examples of point-of-use water treatment systems. Typically, the treated water is only used for drinking and cooking.

Table 7 illustrates common water problems and treatment which may be used to improve water quality.

## Water Treatment Limitations

Choosing an in-home water treatment device can be complex if more than one water quality problem exists. In many cases, you cannot treat one problem without treating another first. For example, it is impractical to install a distiller to remove lead from drinking water if the water is corrosive and continues to leach lead from the piping system. Sometimes several problems can be eliminated with one treatment. Activated carbon filters can remove taste, odor, chlorine, some pesticides and filter out particles. Occasionally, the treatment itself may cause other problems. For example, chlorination may form toxic trihalomethanes organic compounds requiring the installation of an activated carbon filter.

In some cases, two or more systems may be needed to satisfactorily treat the water. Chlorination will kill bacteria. However, to remove the taste of chlorine, an activated carbon filter is typically used. To remove particles of silt and sand, a mechanical filter should be included in the system.

**Table 6. Household water treatment processes**

- ✓ Mechanical or sedimentation filtration
- ✓ Activated carbon filtration/adsorption
- ✓ Oxidation/filtration
- ✓ Neutralizing filtration
- ✓ Reverse osmosis filtration
- ✓ Distillation
- ✓ Ultra-violet disinfection
- ✓ Water Softener — cationic ion exchange
- ✓ Chlorination disinfection/oxidation





<b>Problem</b>	<b>Symptom</b>	<b>Cause</b>	<b>Treatment</b>
Hardness	Soap curd & lime scum in bath, white scale in pipes	Excessive magnesium & calcium salts	Water softener (cationic ion exchanger)
Grittiness	Feels abrasive when washing, leaves residual in bath	Silt passing through well screen	Sand trap, membrane filtration
Odor	Grassy or musty	Organic matter	Activated carbon
	Chlorine	Excessive chlorination	Activated carbon
	Rotten egg	Hydrogen sulfide	Manganese greensand, chlorination, aeration
		Sulfate bacteria	Disinfect pipe system
Chemical (phenol)	Industrial waste seeping into water supply	Stop seepage, use activated carbon	
Taste	Salty or brackish	High sodium or magnesium content	Cation/anion exchange, reverse osmosis, distillation
	Metallic	Low pH	Acid neutralization
		High iron content	Oxidation and filtration
Stainless steel corrosion	Blackening or pitting of sinks and dishwashers	Excessive chloride content	Alternative materials, partial reverse osmosis
Turbidity	Mud, silt & clay	Suspended matter in water supply	Filtration
Acid water	Green stains on plumbing fixtures	Low pH reacting with copper & brass piping, fittings	Acid neutralization
Red water	Stains dishes and laundry	Dissolved iron	Oxidation and filtration
	Red sediment when water is left standing	Precipitated iron	Filtration
	Red color even after standing for 24 hours	Colloidal iron	Oxidation and filtration
Milky water	Cloudiness when drawn	Entrained air from faulty pump	Water will clear quickly
		Sludge pickup in hot water heater	Clean heater periodically
		Methane gas	Aeration with proper venting (volatile gas)
Excess fluorides	Yellowish, mottled teeth in children	Excessive fluorides	Activated alumina, reverse osmosis, deionization, distillation
Heavy metals	No color, taste or odor signs. Possible health effects	Industrial pollution, corrosion products	Softening, deionization, reverse osmosis
Nitrates	No color, taste or odor. May be a health hazard for infants	Human or animal waste and fertilizers seeping into water supply	Anionic ion exchange, reverse osmosis, distillation, deionization
Pesticides and herbicides	Chemical taste	Excessive agricultural spray applications	Activated carbon
Radioactive contaminants	No color, taste or odor signs. May be a health risk	Natural radium radioactivity, atmospheric fallout, nuclear waste	Water softening, deionization, reverse osmosis
		Radon gas	Aeration at faucet, carbon absorption

Source: Condensed from Water Processing for Home, Farm & Business, pgs. 61-68, Water Quality Association, 1988.

## DISINFECTION OF HOME WATER SUPPLIES

**D**rinking water should be essentially free of coliform bacteria. The U.S. EPA drinking water standards (Table 3) indicate water should contain less than one coliform organism in 100 milliliters. If the coliform test indicates contamination, these steps should be taken:

1. Disinfect the well equipment and water by "shock chlorination";
2. Re-sample the well and have a second coliform test run; and,
3. If possible, locate and correct the source of contamination.

There are a number of ways to disinfect water. Before installing a permanent means of disinfection, the homeowner should be sure that the contamination originates from the ground water and is not a temporary condition. This is determined by tests that show the presence of coliform bacteria even after the well has been disinfected and the owner has ascertained that the well is properly located, constructed, protected and maintained.

Most disinfecting systems for home water supplies use chlorine, heat (distillation), or ultra-violet light. Iodine is also effective in germicidal water treatment. Another method currently gaining prominence is ozone treatment.

### Boiling

The simplest disinfection method for small quantities of water is boiling. Because it does not provide treatment to all the water in the well or in the distribution system, boiling should be considered an emergency disinfection procedure. Disinfecting water requires continuous vigorous boiling for at least 15 minutes. Caution: Excessive boiling concentrates chemical impurities such as nitrates, which increases the probability of nitrate toxicity.

### Chlorination

Chlorine is the most common disinfectant for private water supplies. Chlorine is inexpensive, reliable and readily available. It is easy to use and to monitor against most pathogenic bacteria, virus, and cyst organisms. It oxidizes non-pathogenic iron, manganese, and sulfur bacteria. Chlorine is also a strong oxidizing agent that causes soluble iron and manganese to change to an insoluble precipitate that can be filtered from the water.



## PROTECTION AND TREATMENT

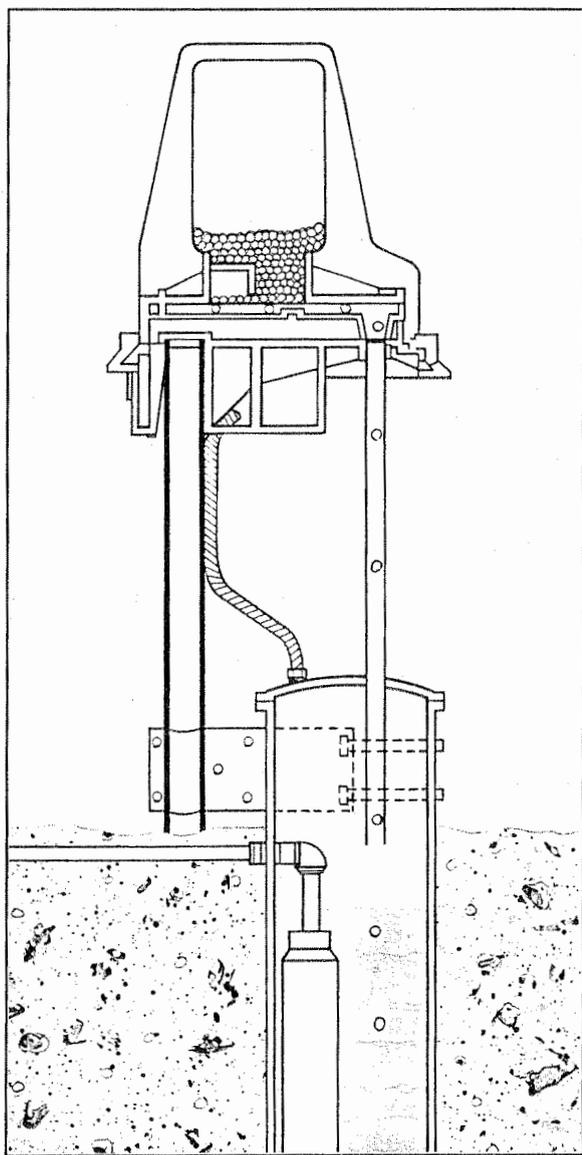


Figure 4. Typical dry chemical chlorinator installation at well head. Courtesy of Sentry I, Better Water Industries, Inc.

For home-size chlorination units, chlorine is available in the form of "hypochlorites" — diluted or low-grade forms of chlorine. There are two: sodium hypochlorite and calcium hypochlorite.

Sodium hypochlorite ( $\text{NaOCl}$ ) is a water-chlorine solution commonly used for household laundry bleaches (Clorox, Hi-Lex, Purex — use only non-scented products for water treatment). It is available in two strengths — domestic or commercial. Domestic laundry bleach is by far the most popular. It contains only about 5.25 percent available chlorine. Bleach that contains other cleaning agents should not be used for disinfecting water. It is not considered a health risk but it can give water an off-taste.

Commercial laundry bleach can be purchased from chemical supply houses, pool suppliers, and some hardware stores. It contains from 10 to 19 percent available chlorine, so requires smaller quantities for treatment than domestic laundry bleach. Commercial-strength bleach is normally used for swimming pool disinfection but is also suitable and economical for larger home, farm and ranch water systems.

Calcium hypochlorite ( $\text{CaOCl}_2$ ) is available in powder and tablet form and contains 30 to 75 percent active chlorine by weight (65 percent - 75 percent free chlorine). This form of chlorine can form deposits that interfere with chlorinator operation so has limited use. It can be purchased under various trade names.

Chlorine may be used continuously in a dry or liquid form that is dropped or injected into the well water using a chemical feed pump.

### Chlorination Equipment

Chlorinator units on the market are designed to meter (feed) small quantities of chlorine into a water supply as the water is being used. These liquids are normally injected into the water supply with an adjustable, positive displacement pump. Tablets are dispensed by feeder directly into the well (Figure 4). In either case, chlorine is introduced only when the water pump is running. The dispensing equipment should not run when the water pump is off. For safety reasons, if the chlorinator pump/feeder fails to operate or if the chlorine supply is empty, the water pump should not be able to run.

The positive-displacement chlorinator is considered the more reliable type. It consists of a small, electric, diaphragm-type pump. With each discharge stroke, it injects a fixed volume of chlorine solution into the water. The amount of chlorine can be increased or decreased during pump operation with a simple

adjustment of a control knob. Operation of an electric chlorinator should be synchronized with that of the pump, so that both start and stop at the same time. Positive-displacement chlorinators are not desirable in systems where water pressure is low and fluctuating.

Flow-actuated positive-displacement chlorinators or water-meter chlorinators dispense the chlorine solution in proportion to the actual flow rate of the water. Thus, where there is a wide variation in the pumping rate, they will maintain a more uniform dosage than the other type of positive-displacement unit.

Aspirators or suction-type chlorinators generally are not as reliable, because the chlorine dosage varies with the pressure and flow rate in the pipeline to which it is attached. Minerals precipitating from the chlorine solution may clog the small jets in the aspirator, and prevent the chlorine from being drawn into the system.

Figure 5 illustrates a typical equipment set-up for continuous chlorination using a chemical feed pump. The chlorine solution is injected into the water supply and then held in a contact tank for mixing and retention time. Suspected carcinogenic compounds, called trihalomethanes, can actually be formed during chlorine disinfection when organic substances are present. To remedy this, an activated carbon filter should be placed after the contact tank and just before the point of use faucet. The activated carbon filter will also remove chlorine taste.

### How Much Chlorine Is Enough?

Continuous disinfection requires equipment to add chlorine to all water drawn from the source. The chlorine must be thoroughly mixed with the water and have sufficient contact time to kill all disease-causing and nuisance organisms. Enough chlorine must be added to produce a certain amount of chlorine residual. Use a chlorine test kit to adjust the feeder to the level needed.

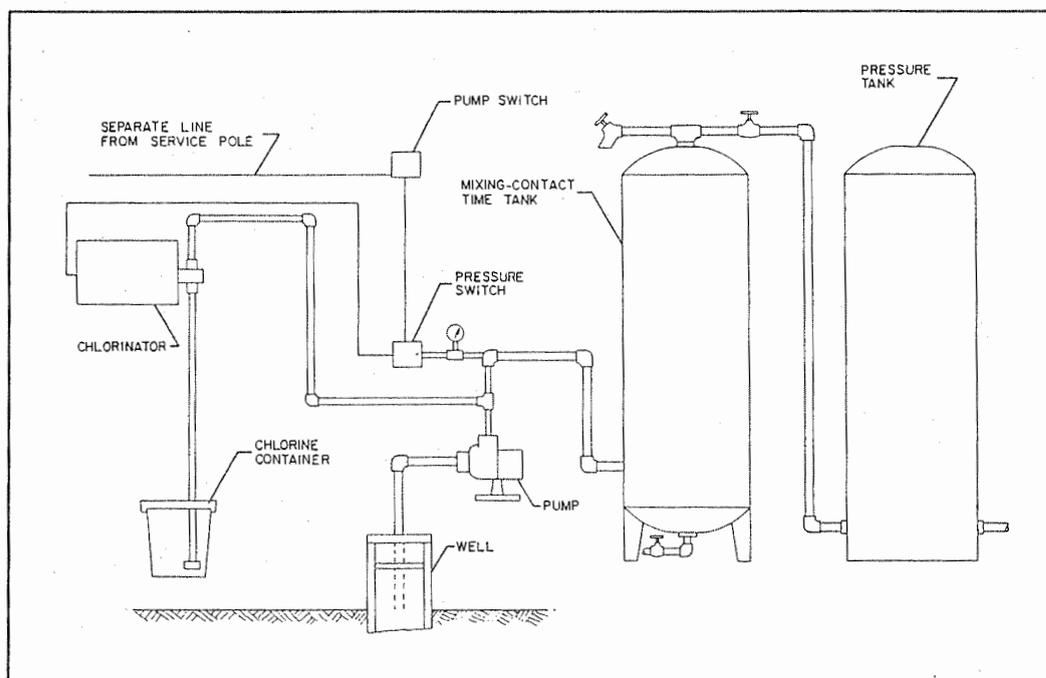


Figure 5. Recommended Installation of a chlorination system for disinfecting water from a well. Source: USDA 2274, 1984.



## PROTECTION AND TREATMENT

### Action of chlorine in water

When added to water, chlorine first reacts with any hydrogen sulfide, manganese, iron, and nitrites in the water (Figure 6). The amount of chlorine that reacts with these reducing agents is called the initial chlorine demand. This chlorine does no disinfecting — it is “reduced” or “used up.”

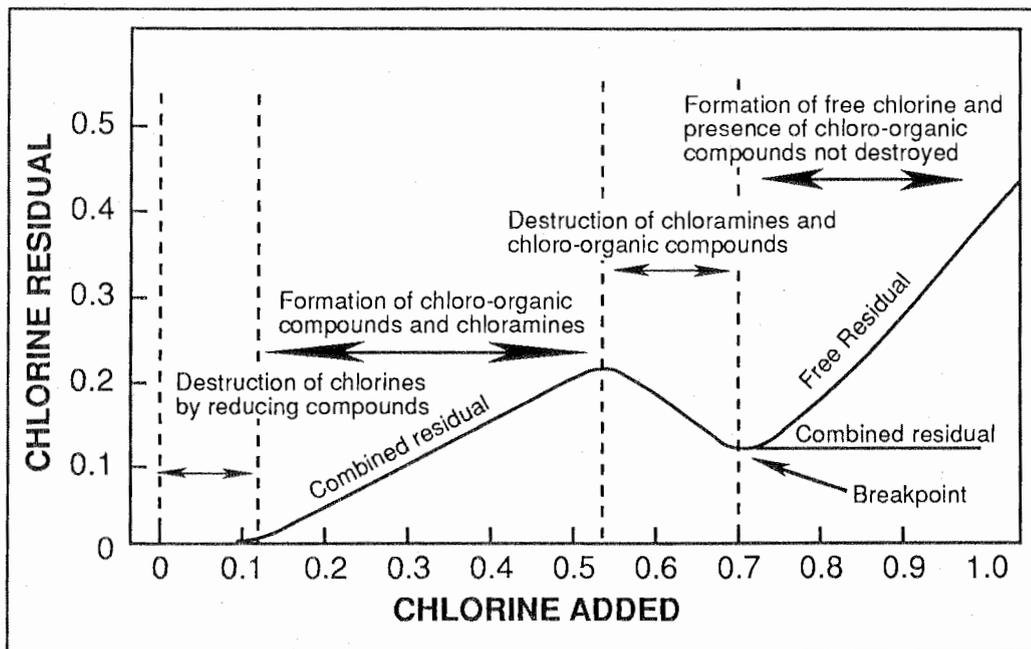


Figure 6. The action of chlorine in water as the amount of chlorine added is increased. For safe water, enough chlorine must be added to maintain a free-chlorine residual at all times. Source: USDA 2274, 1984.

The unreduced chlorine that remains then reacts with any ammonia and organic matter in the water to form chloramines and chloro-organic compounds. The reaction with ammonia is nearly instantaneous, while the reaction with organic matter is time-dependent.

The chloramines and the chloro-organic compounds together form what is called combined-chlorine residual. This residual does some disinfecting, but many hours of contact (exposure) time would be required for complete disinfection by it alone.

The combined-chlorine residual builds up to a certain level and then decreases as the chloramines and chloro-organic compounds are destroyed. The point at which the minimum amount of combined-chlorine residual occurs is called the breakpoint. Beyond this breakpoint, as more chlorine is added, a free-chlorine residual builds up. Combined-chlorine residuals are sometimes associated with unpleasant chlorine or medicinal tastes and odors.

Free chlorine is a much more effective disinfectant than combined chlorine. Only it can provide the fast, effective disinfection required in smaller water systems. To be completely safe, the water should contain a free-chlorine residual at all times.

### How Much Chlorine?

A little chlorine will go a long way — usually about one to five parts of chlorine to 1,000,000 parts of water. This is commonly referred to as parts per million, or “ppm.” If water contained no impurities, such as sulfur, iron, or organic particles that “use up” chlorine, the same amount could be used for treating all water supplies. But water is almost certain to contain one or more



impurities. For this reason, it is necessary to adjust the amount of chlorine to meet the needs of each water supply. The normal recommendation for chlorine treatment of a private water supply is three to five parts per million. Using household laundry bleach of 5.25 percent solution, five ppm is about six drops per gallon or 12 cups in 1,000 gallons of water. Continuous chlorination requires regular monitoring to assure adequate disinfection. The amount of chlorine should be checked by "residual" tests — simple, do-it-yourself test kits are available. A residual of 0.1 to 0.5 ppm at the point of use normally indicates that adequate disinfection has taken place.

### How Much Contact Time?

Chlorine requires time to completely disinfect water. Adequate "contact time" between the time of chlorine injection and water use is necessary. A practical contact time for private water systems is usually five minutes. At the end of the contact time, there must be an adequate detectable free-chlorine residual in the water to show that disinfection is complete.

The actual time required for disinfection depends on the dosage and concentration of chlorine, temperature and pH (acidity) of the water, the amount of organic matter in the water, and the discharge rate of the pump. Chlorine becomes less effective as water temperature lowers and as water increases in pH. For example, if water has a pH of 5 to 6, a chlorine residual of 0.2 ppm may be satisfactory. If the pH is 7.5 to 8, a residual of 0.8 ppm may be needed. Procedures for calculating chlorination contact time are found in Appendix A.

Contact time can be provided by holding the chlorinated water in a mixing or aggregate-filled storage tank. Pressure tanks and unbaffled tanks are not acceptable for providing contact time as there is nothing to prevent part of the water from taking a straight path from the tank inlet to the outlet, remaining untreated. Contact time can also be provided by using an extended length of supply-pipe between the water pump and the first water outlet. Appendix B provides formulas and tables for calculating pipe and tank storage.

Tank and extended-pipe storage may require a significant amount of space. If space is a consideration, altering the treatment conditions may be an option. A higher chlorine concentration could be used to reduce the contact time and volume but the contact time should never be less than two to three minutes.

Another method to increase the contact time is to feed the chlorine solution into the well at a point near the pump intake (Figure 7). When the pump starts, the chlorinator starts automatically. Chlorine solution in this arrangement enters

## PROTECTION AND TREATMENT

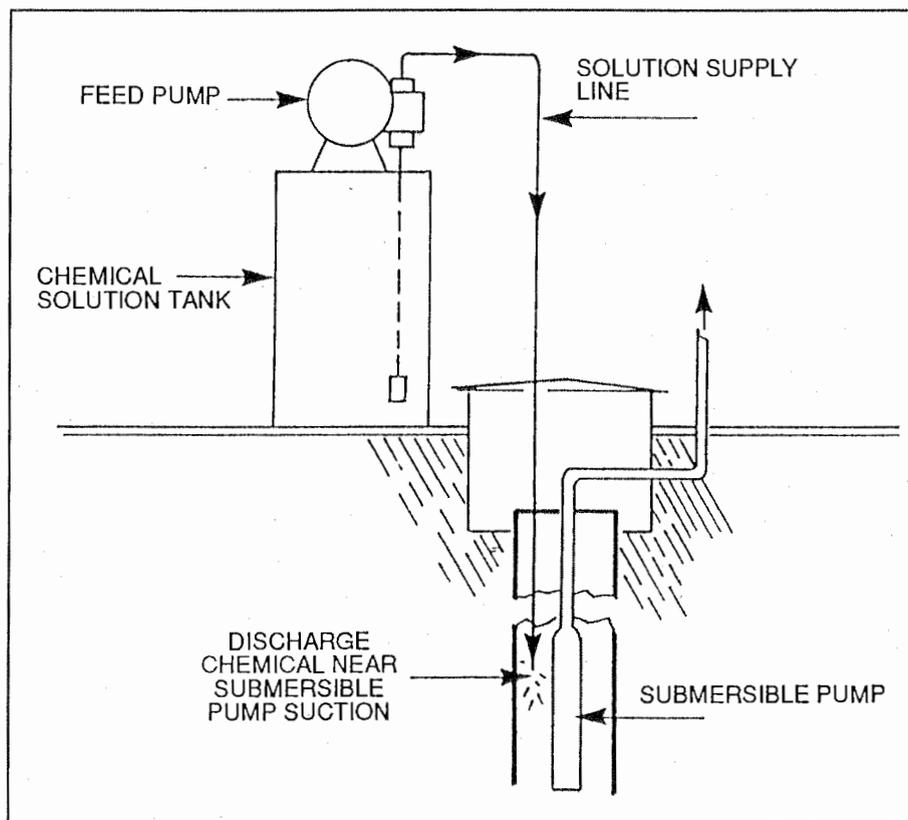


Figure 7. Chlorine solution feed direct to well. Source: McGowan, Water Processing, Water Quality Association, 1988.

the water in the well and is drawn into the pump suction along with the well water. The end of the feeder tube must be close to the pump intake for this arrangement to be effective. The flow of chlorine solution stops when the pump stops.

Another method is to use an automatic chlorine pellet dispenser (Figure 4). It feeds pellets directly into the well casing at a predetermined rate, depending on the water use.

### Shock Chlorination

New water wells, wells where the pump has been pulled for service, and wells that are occasionally contaminated should be treated by "shock chlorination." This involves pouring a strong solution of chlorine into the well, usually in excess of 50 parts per million, and pumping it through the equipment and piping. Let the chlorine solution stay in the system overnight. The amount of chlorine needed will depend on the volume of water and the persistence of the contaminants. As an example, doses of chlorine as high as 1500-2000 ppm have been necessary for persistent iron bacteria problems found in Montana. For determining chlorine amount for shock chlorination see Appendix C.

#### Shock Chlorination Procedure for a Private Well

1. With a solution of  $\frac{1}{2}$  cup of laundry bleach in five gallons of water, clean up the work area around the well, pumping equipment and piping. All concentrated chlorine solutions are corrosive, and care should be taken to avoid splashing them onto skin or into eyes. Rubber gloves, goggles, and protective aprons are recommended when handling chlorine solutions. Never mix chlorine solutions with compounds containing acids or ammonia to improve their cleansing ability because toxic gases will form.
2. Calculate the amount of water in the well casing or pipe using Table C-3 in Appendix C.
3. Using Table C-1 or Table C-2 in Appendix C, calculate the amount of chlorine needed.
4. If present, remove carbon filter from system.

## SHOCK CHLORINATION

5. Introduce recommended chlorine dose into the well. Liquid sources of chlorine can be poured directly into the well. Powdered chlorine compounds can be introduced in two ways:

a. Mix the required amount of dry compound with a small amount of water and stir thoroughly to dissolve. Let the undissolved calcium carbonate particles settle. Pour off the clear chlorine solution and use this to disinfect the well.

b. Place the required amount of chemical in a weighted cloth sack or in a section of perforated pipe that has been capped on both ends. Attach a rope and alternately raise and lower the chemical throughout the water-bearing portion of the well to dissolve the compound and distribute the disinfectant.

6. Mix the chlorine in well water. It is recommended that each quart of chlorine bleach be mixed with three to five gallons of water to force the chlorine mixture deeper into the well. This also is true for calcium hypochlorite mixtures. More water can be added later if needed. Without this step, the disinfectant may tend to stay in the upper area of the well, especially if the well is deep and/or has no perforations that stimulate mixing within the casing.

Pumping will also help to mix the disinfectant with water standing in the well. Use a garden hose to recirculate the strong chlorine solution directly into the well. Direct the return flow onto the pump piping and interior portions of the well casing that are above the water level.

7. To disinfect the distribution system, open the faucets on each water line, one by one. Allow water to flow until a strong chlorine odor is detected. If a strong chlorine odor is not detectable, add more chlorine at the well. This will be necessary if the water contains substantial amounts of iron, hydrogen sulfide, or organic materials that deplete the chlorine.

8. Drain the water heater and bleed the air from the pressure tank (except for tanks with a permanent air cushion) so that chlorinated water can completely fill and sanitize them. Caution: A rubber air-water separator in the pressure tank may be damaged by a strong chlorine solution. Water softeners, sand filters, and iron filters should be backwashed with the chlorinated water.

9. Allow the chlorine to remain in the well and distribution system for at least two hours — overnight if possible.

10. After at least two hours, flush the chlorinated water from the system. Since vegetation may be harmed by the chlorinated water, it is wise to dilute the water with fresh water if used for irrigation. Do not pump the chlorinated water



## PROTECTION AND TREATMENT

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to road ditches and waterways leading to streams, rivers or other bodies of water. High chlorine content can lead to fish kills and hefty fines. Also do not let more than 100 gallons flow into drains that lead to a septic tank.

11. After the well has been thoroughly pumped, use the water (except for drinking) for a week and then have another sample tested. If tests show continued presence of bacteria, repeat the process. Test again after a second chlorination. If several shock treatments do not remove bacteria, identify and stop the source of contamination, abandon the water source and develop a new source, or continuously chlorinate the water system.

### Ultraviolet Light Disinfection

Ultraviolet (UV) light provides another method to disinfect private well water systems. Most often, UV units are used for one or two faucet treatment to provide safer drinking water only, not whole-house treatment. Although ultraviolet light has long been known to have germicidal properties, it is more difficult to monitor than chlorination. Ultraviolet radiation disinfects without the use of heat or chemical additives and usually does not produce any by-products.

The UV light is produced by a mercury vapor lamp. An electric arc is struck through an inert gas carrier in a sealed quartz glass tube. Heat from the arc causes vaporization of the small amount of mercury contained in the sealed tube. The mercury, when vaporized, becomes ionized and the electric arc gives off UV radiation.

The construction of an ultraviolet water treatment device is quite simple. The most common design consists of a stainless steel cylindrical chamber with a cylindrical mercury arc lamp in it. Lamps vary in length from 12 to 48 inches and vary in energy output. Water enters one end of the chamber, flows through the chamber around the lamp and exits from the other end within a few seconds. (Figure 8)

In order to be effective as a disinfection treatment, ultraviolet radiation must pass through every particle of water. The thinner the water film and the slower the water flow the more effective the system. Also, the water cannot be turbid or have high iron content, suspended particles, or organic matter. These contaminants will foul the quartz tubes and reduce the transmissibility of the UV light. For this reason, ultraviolet light treatment should only be attempted on clear water. A pre-filter is recom-

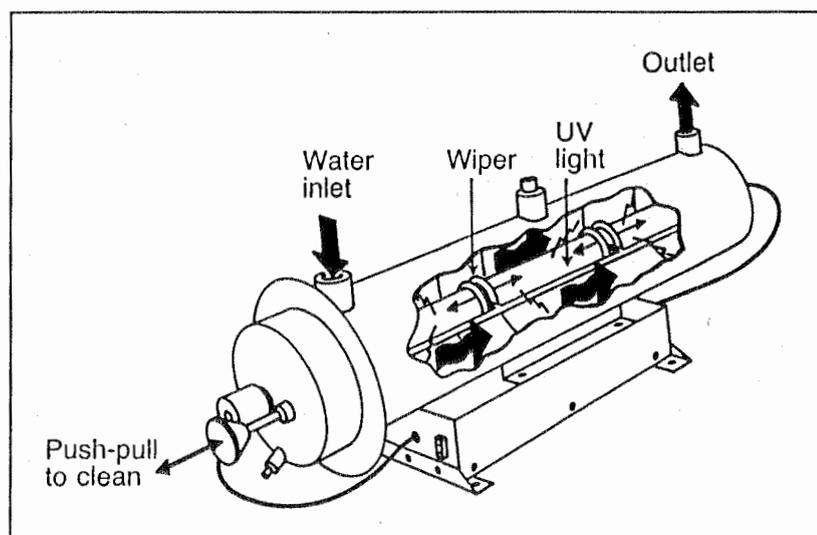


Figure 8. Schematic diagram of an ultraviolet water treatment device. Courtesy of Atlantic Ultraviolet Corp., Bay Shore, NY.

mended on ultraviolet systems as is periodic inspection and lamp cleaning. Also, a UV treatment system should have a UV intensity monitor to measure the output of the mercury-vapor bulb — as the bulb(s) age, less energy is produced. Due to these factors, if there is not regular inspection and maintenance, water treated by UV cannot be guaranteed to be bacteria free. In fact, one major distributor of the system adds this disclaimer of liability to its literature:

“This product is designed for use only on water known to be of acceptable bacterial quality. Its intended use is as a safety device on private and non-municipal potable supplies already identified as safe to drink. If you think your water may be unsafe, please contact your local public health agency.”

The UV bulb should be removed and cleaned regularly along with the quartz sleeve so the UV rays achieve maximum exposure through the water film. Bulbs are usually rated for about 9,000 hours of constant operation, and should be replaced yearly, or as recommended by the equipment manufacturer. A small, one faucet device (less than one U.S. gallon per minute flow) will use from 10 to 35 watts of electricity. Typical flow rate specifications of UV devices for home use range from one to 10 gallons per minute.

**UV Dosages.** Effective UV systems depend on the amount of UV radiation reaching the bacteria and on how long the bacteria are exposed to the radiation. A short exposure time at high intensity is as effective as a long exposure time at low intensity, provided the product of the time and intensity remains the same. The dosage or the amount of power delivered by the lamp is expressed in microwatt-seconds per square centimeter. There will be a higher probability of killing bacteria as the power rating goes up. Values of 20,000 microwatt seconds per square centimeter will kill most types of pathogenic bacteria. UV dosages required to kill various bacteria are shown in Table 8.

While UV is effective on pathogens, viruses are more resistant and may require 45,000 MWS/cm<sup>2</sup>. Also, UV will not deactivate protozoan cysts such as *Giardia lamblia*. Because of the possible presence of protozoan cysts, a sub-micron filter must be added to the system.

**Table 8. Ultraviolet dosages needed to de-activate different bacteria.**

Bacteria Type	Disease Caused	Dosage* MWS/cm <sup>2</sup>
Escherichia coli	Gastrointestinal distress	6,600
Legionella pneumophila	Legionnaire's disease	2,760
Mycobacterium tuberculosis	Tuberculosis	10,000
Pseudomonas aeruginosa	Opportunistic pathogen	10,500
Salmonella enteritidis	Salmonellosis	7,600
Shigella paradysenteriae	Dysentery	3,400
Staphylococcus aureus	Opportunistic pathogen	6,600
Clostridium tetani (spore)	Tetanus	22,000

*Source: Consumer Reports, 1988.*



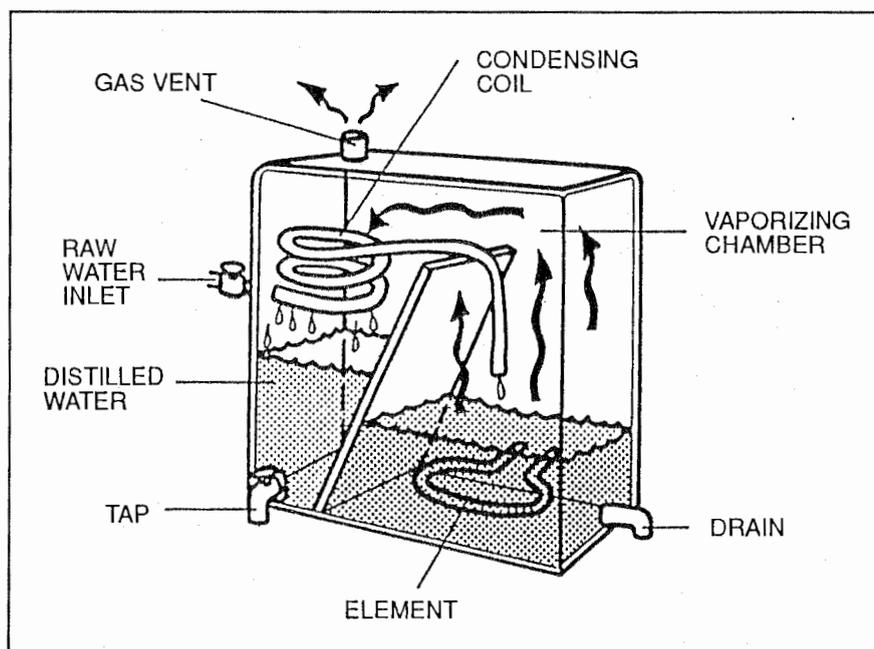


Figure 9. Typical home distiller. Source: Household Water Treatment, NDSU Extension Service, 1988.

### Distillation Disinfection

Distillation offers another method of water disinfection. However, distillation units are considered “point-of-use” systems and provide limited treated water. Distillers are also used to reduce nitrates, remove dissolved salts including chlorides, sulfates, and carbonates of sodium, potassium, and magnesium, organic matter and other soluble volatile substances.

Distillation units boil water, creating a steam vapor that is then condensed and collected as purified water. Water is introduced into a chamber and heated until it begins to boil. At this point, dissolved solids and unwanted contaminant liquids, with a boiling point above that of water, remain in the boiling chamber — chloroform, phenol, and trichloroethylene have been reported found in the finished water. The steam vapor rises through a series of baffles. When the vapor comes into contact with the baffles, some of it condenses on the baffles and runs back to the boiling chamber to repeat the process. The vapor that exits the baffles enters the condensing chamber of the distiller. Here, the vapor either comes in contact with a cold water chiller tube or air circulates around a tube carrying the vapor, changing it from a vapor to liquid much as water vapor condenses on the outside of a cool glass on a hot day. Finally, the water vapor falls and collects in a reservoir for use upon demand. (Figure 9).

Home distillers vary in design but the counter-top single-batch version is most common. All home electric distillers use 100-120 volt a.c. current. The water output of home distillers range from three to 12 U.S. gallons per day. Power consumption of these systems varies from three to five kilowatt hours of electricity per gallon of distilled water produced.

The minerals and other contaminants left behind in the boiling chamber can build up, interfering with the operation of the unit. Hard water can clog a distiller. Some manufacturers recommend cleaning the distiller after every third distillation. White vinegar may be used by leaving it in the boiling tank overnight, or a special cleaner made by the distiller manufacturer may be used.

### Ozone Disinfection

Ozone is a chemically active form of oxygen and, like chlorine, is a strong disinfectant and oxidizing agent. It is also used in much the same manner as chlorine. The major difference is that ozone cannot be purchased and must be generated at the point of use.

Municipal systems in Europe have used the ozone process for many years but only recently has the technology been applied to public systems in the United States. Now small units are available for the homeowner. The benefits of ozone are the strength of the disinfection and the lack of potentially harmful by-products like trihalomethanes. Ozone is also effective over a very broad pH range where chlorine is not. Like chlorine, ozone may not kill cysts and some other organisms so these should be eliminated by filtration or other procedures prior to treatment.

For water treatment, ozone is produced by two methods: by an electrical corona discharge in a box or by ultraviolet irradiation of dry air or oxygen. Corona discharge generally provide higher concentrations of ozone. Home ozone devices are installed in the plumbing system and connected to the electrical power supply. Raw water enters one opening and treated water emerges from another. Inside, ozone is produced and mixed with the water whenever the water pump is running. At present, all home systems use dry air to produce the ozone. A system to clean and remove the humidity from the air must be included, and such a system requires routine maintenance. The manufacturer's recommendations should be followed carefully. The only way to know if the unit is working is to test for ozone residual or have bacterial tests conducted on the treated water. However, it may be difficult to test the residual due to short life of ozone (half-life, depending on what is in the water, is between three and 20 minutes.) Test equipment for residual ozone is now available and should be purchased with the unit.

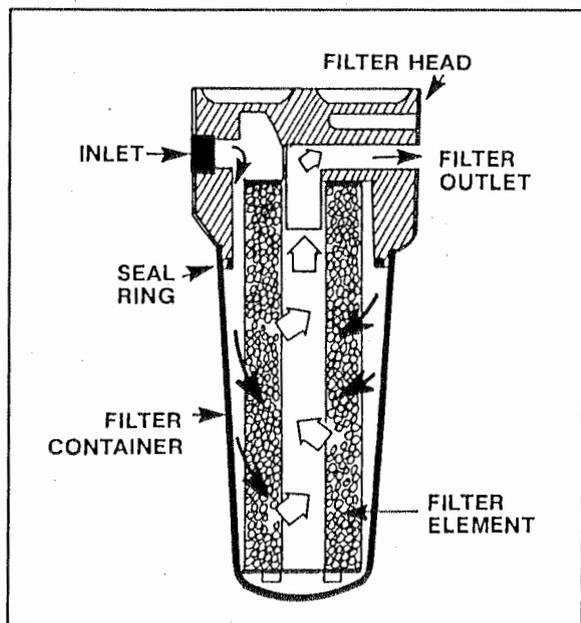




## PROTECTION AND TREATMENT

**Table 9. Water filtration-separation processes**

Mechanical Filtration
Activated Carbon Filtration/Adsorption
Oxidation Filtration
Neutralizing Filtration
Reverse Osmosis or Membrane Separation



**Figure 10. Typical single faucet cartridge filter.**  
 Source: McGowan, Water Processing, Water Quality Association, 1988.

## WATER FILTRATION SYSTEMS

**F**iltration represents a broad category of treatment systems used to remove particles, taste, odor, some organics and minerals and some bacteria from the water. In addition, mineral content can be removed from water by membrane separation or what is called “reverse osmosis.” Filtration systems depend upon several water filtration and separation processes. (Table 9)

### Mechanical Filtration/Turbidity Control

Mechanical filters simply catch debris or “turbidity” as water passes through the filter medium. Turbidity is suspended matter — clay, silt, algae and organic material — that causes water to have an objectionable cloudy appearance. Turbidity is measured in Nephelometric turbidity units (NTUs). The units are determined by a system which measures the scattered light from a sample of turbid water. The maximum level of turbidity, set by U.S. Environmental Protection Agency, is 5 Nephelometric turbidity units for potable water. Turbidity is objectionable because it interferes with disinfection. If the turbidity is due to inorganic minerals, it can have an abrasive effect on the plumbing system, causing physical wear or erosion of pipe and fittings. If the turbidity is due to suspended organic matter, it can stain sinks and fixtures and discolor laundered fabrics, much as iron does. Organic matter in water may contribute to unpleasant tastes or odors.

Mechanical filters are most effective for removing particles of sand, silt, solid organic matter, plant debris, precipitated iron and some bacteria. Filter effectiveness depends on the particle size and the exit clearance of the filter. The finer the filter medium, the more completely solid particles will be removed, but also the higher will be the resistance to flow and the greater the water pressure drop.

The cartridge filter is the most common mechanical filter device. Some cartridge filters are also referred to as “depth” filters that entrap particles deep within the filter medium. A typical home water system cartridge filter (Figure 10) is about four inches in diameter and 12 inches long and is installed to treat the water in a single water line.

Cartridge filters generally consist of a formed random array of fibrous, granular, or sintered material that is pressed, wound, or bonded together in a tortuous maze of flow channels. Other materials used to construct cartridge filters include cotton, fiberglass, paper, and polypropylene. Although some of the cartridges are designed for mechanical cleaning and re-use, most are designed for replacement when they become clogged with accumulated solids.

Most filter cartridges are available in nominal ratings called "microns," based on the sizes of particles to be removed. Cartridges with extremely small filtering pores have higher resistance to water flow and can become clogged quite rapidly. Table 10 illustrates cartridge ratings. Figure 11 illustrates the relative sizes of small particles.

Filter tanks are available for large volumes of water — to filter the entire household supply. These filters, referred to as "granular media" filtration, use specially graded sand or granular synthetic material as the filter media. Filter tanks are about the size of a household water softener. In addition to filtering suspended solids, some of these filters may be used to reduce iron, manganese, hydrogen sulfide, fluoride, arsenic content and to correct acid water.

To remain effective, a granular media filtration system must be back-washed periodically. Table 11 shows the properties of typical granular filter media.

### Activated Carbon Filtration/Adsorption

Activated carbon filtration is a common treatment to reduce offensive tastes and color, musty, earthy odors, chlorine odor or taste, volatile organic chemicals (benzene, lindane, trichloroethylene, vinyl chloride, etc.), synthetic organic chemicals (pesticides and herbicides), trihalomethanes (a group of suspected carcinogens) and radon. Activated carbon will not remove bacteria, dissolved metals such as iron, lead, manganese, or copper or chlorides, nitrates, and fluorides.

Cartridge activated carbon filters, usually made up of granules, powdered or block carbon, adsorb organic compounds frequently responsible for bad tastes, odors and colors. Adsorption is the process by which a vapor, dissolved material or very small particle adheres to the surface of a solid. The large, rough carbon surface also absorbs particles of debris flowing through the filter unit.

Activated carbon is made from various carbonaceous materials such as bituminous or lignite coal, coconut shells, nutshells, wood products, and fruit

**Table 10. Cartridge Filtration Ratings**

Filter size*	Micron rating**
Course Filter	50 and greater microns
Medium Filter	20-30 microns
Fine Filter	5-10 microns
Very Fine Filter	.5-5 microns

\*The size designation varies by manufacturer.  
\*\* 25,000 microns to the inch, 1 = 1 millionth of a meter (meter = 39.4 inches)



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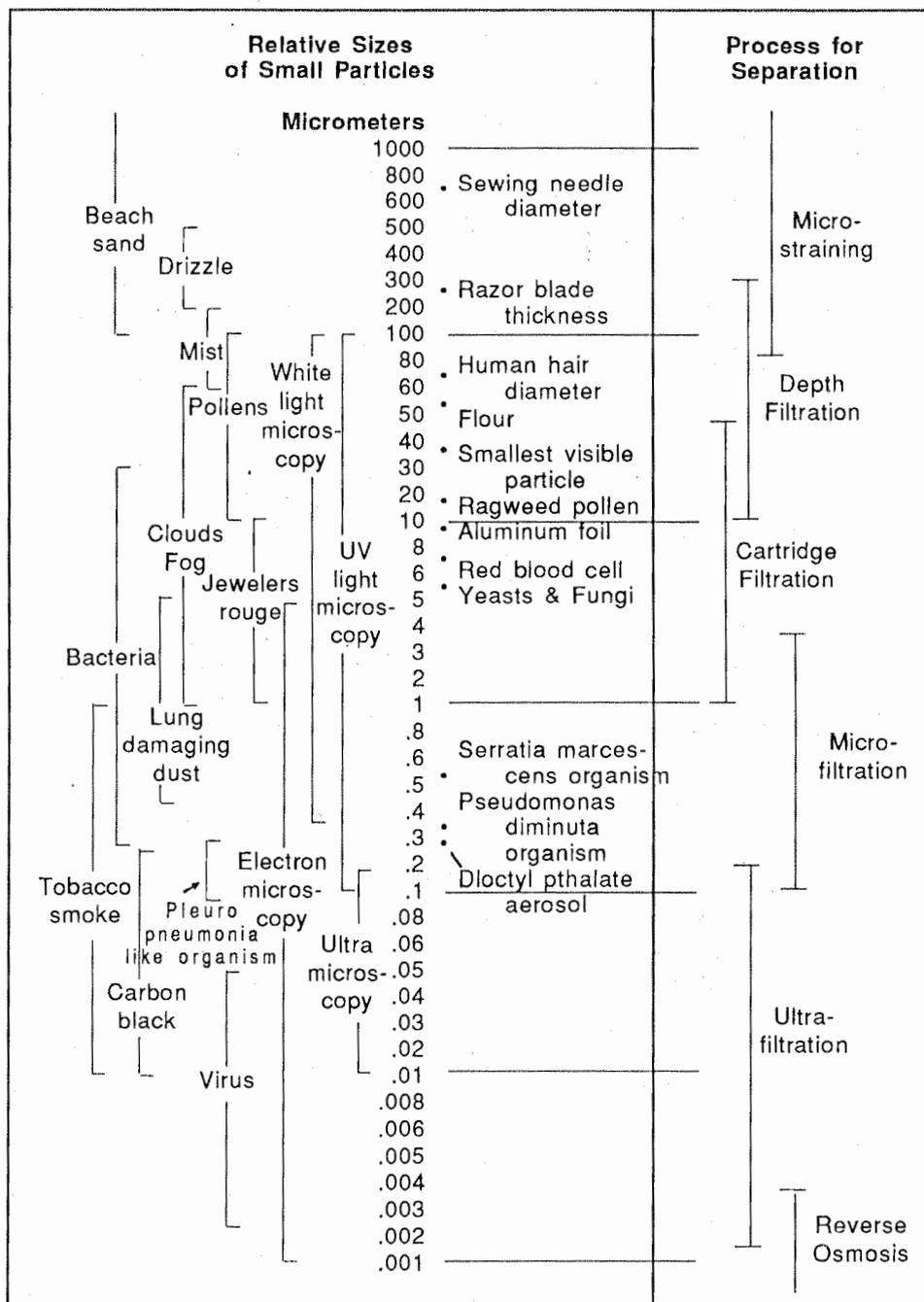


Figure 11. Particle sizes and filtration/separation processes. Source: Water Filtration, Water Quality Association, 1989.

pits. It has a tremendous surface area — as much as 125 acres per pound of carbon (Figure 12). These materials are “activated” by subjecting carbon to high temperatures (2300 degrees F) in a low oxygen atmosphere to reduce the raw materials to carbon and ash. The final activation step is usually performed with live, high pressure steam, carbon dioxide or acid which etches away the soft material in the carbon and leaves behind a complex pore structure which has an affinity for organic molecules.

The efficiency of an activated carbon filter is dependent on the amount of carbon (surface area) in the filter, the carbon’s adsorption rate (referred to as the “iodine” or “phenol” number), and the flow rate of water through the filter. Generally the more carbon and slower the flow rate, the more effective the filter.

For residential use, activated carbon filters are available as point-of-entry (POE) granular tank-type filters and as point-of-use (POU) cartridges. The granular POE device treats all water coming into the home and must be backwashed periodically. The POU cartridge units (Figure 10) are installed at a single faucet (usually the kitchen tap) for cooking and drinking needs. They must be replaced from time to time. The typical carbon filter cartridge will treat about 1000 gallons of water before replacement is necessary.

Domestic activated carbon cartridges are either faucet-mounted, in-line or line-bypass systems (Figure 13). In-line and stationary systems are connected directly to a cold water faucet. With an in-line system, treated water is assured only when using that faucet for drinking and cooking. The line bypass system has a separate faucet, but taps into the cold water pipe for its water supply. In this case, the regular faucet delivers untreated water. This installation increases the life of the carbon, allowing a choice of treated or untreated water — depending on the intended use. However, the line bypass system may be more susceptible to non-pathogenic bacteria growth if the filter faucet does not receive frequent use.

Pour-through carbon filters are also available. They are similar in design to the drip-through coffee maker, and are not connected to the water supply. They are portable, require no installation and are great for activities that require small quantities of water. However, due to the small amount of carbon and minimal contact time with the carbon, pour-through filters have limited effectiveness.

**Table 11. Properties of typical granular filter media**

Medium*	Primary Function
Silica sand	Suspended solids removal
Manganese greensand	Iron, manganese, hydrogen sulfide reduction
Calcite (calcium carbonate)	Acid neutralization
Magnesia	Acid neutralization
Aluminum silicate (pumicite)	Suspended solids removal
Granular activated carbon	Adsorption of chlorine, other taste and odor, some organic reduction and hydrocarbons
Anthracite coal	Filtration, suspended solids removal
Pumicite, manganese dioxide coated	Iron, manganese reduction
Activated alumina	Fluoride, arsenic reduction

*Source: adapted from Gellman Sciences, 1986.  
\* media are available under various trade names.*



## PROTECTION AND TREATMENT

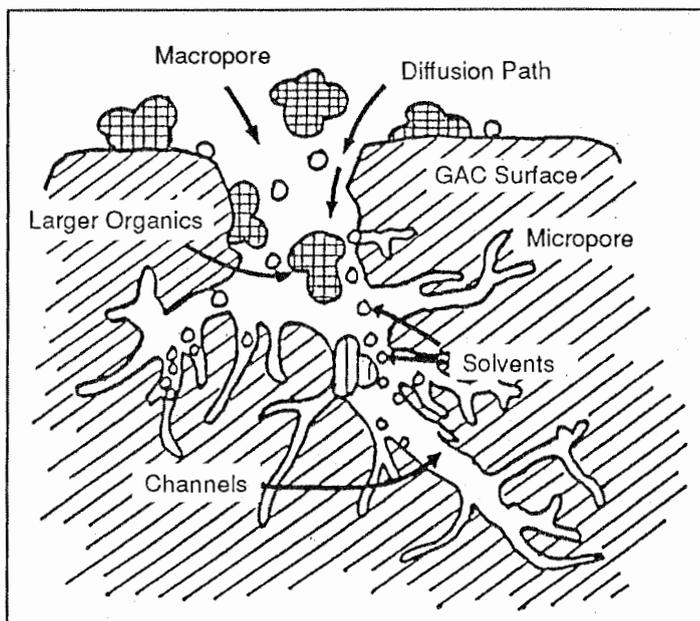


Figure 12. Activated carbon surface area. Source: *Water Conditioning and Purification*, June 1988.

Faucet-mounted filters are attached directly to the faucet spout and can be purchased in two designs — bypass or non-bypass. The bypass filter has a valve that, when turned, bypasses the filter and draws untreated water from the water supply, thus prolonging the life of the carbon cartridge. The non-bypass option filters all water passing through the faucet.

Without regular use and periodic replacement, carbon filters may provide a breeding ground for bacteria. To assure maximum effectiveness, a carbon filter should be replaced frequently, following the manufacturer's recommendations. Also, if the treatment device has not been used for five days or longer, running the water several minutes will help flush bacteria from the filter. As a precaution, activated carbon filters are recommended only for use on microbiologically safe water.

Some carbon units contain silver-impregnated activated carbon which manufacturers claim acts as a bacteriostatic agent. These units are registered with the U.S. EPA as bacteriostatic units. The main requirement of the registration is that the units do not release excessive amounts of silver. Registration does not imply that U.S. EPA has examined the effectiveness of the units or endorsed these methods for reducing bacteria in the filter or in the water.

### Oxidizing Filtration Systems

Oxidizing filters are used mainly for the removal of iron, manganese and hydrogen sulfide. The name comes from processes which oxidize (transform by exposure to oxygen) soluble forms of these elements into insoluble forms. To be effective, oxidizing filtration involves three steps: oxidation, precipitation and filtration.

**Oxidation.** In the first step, the water, with soluble contaminants, is brought into contact with an "oxidant." Oxidants commonly used include oxygen (air), and chlorine (household laundry bleach). Manganese greensand (natural zeolite-glaucanite), and manganese zeolite (silica gel zeolite), regenerated with solutions of potassium permanganate, also provide excellent oxidizing capacity and are commonly referred to as "oxidizing catalyst filters."

**Precipitation.** During this step, adequate contact time is allowed in the filter to complete the oxidation reaction. The oxidant converts the dissolved element, such as iron or manganese, to a non-soluble precipitate. The reaction

time will depend on factors such as water temperature, presence of organic material and pH. Generally, the higher the pH, the faster the rate of reaction.

**Filtration.** In this step the precipitates are entrapped in the filter medium as they are formed. The filter will eventually become clogged or the medium will reach its limit of effectiveness. Periodically the filter medium will have to be backwashed and regenerated with a potassium permanganate solution. Backwashing is the process reversing the flow of the water through the filter medium bed to loosen and expand the medium and allow the precipitant which has accumulated to be flushed out of the filter. For more information on removing iron from water, see page 40.

### Neutralizing Filters

Ground or surface water may be acidic in composition. The chief influence is the presence of dissolved carbon dioxide (carbonic acid). This gas may come from decaying organic matter or it may be brought down from the atmosphere by rainwater. Acid water can also be caused by weak concentrations of leaching mineral acids (sulfuric or nitric), particularly in mining areas. Low pH values can cause water to be corrosive and destroy pumps, pipes, and metallic plumbing fixtures. This condition is characterized by blue or green stains on plumbing fixtures when the piping is copper.

Neutralizing filters are typically used for pH value modification, that is, treating acid water (low pH). Acidity is indicated by the pH of water on a scale of 0 to 14. Neutral water has a pH of 7. Less than 7 is acid and greater than 7 is basic or alkaline. The ideal pH for household water is between 6.8 to 7.5. The pH scale is logarithmic, and a difference of 1.0 indicates a factor of 10. For example, a pH of 5 is 10 times as acid as a pH of 6.0. (Figure 14).

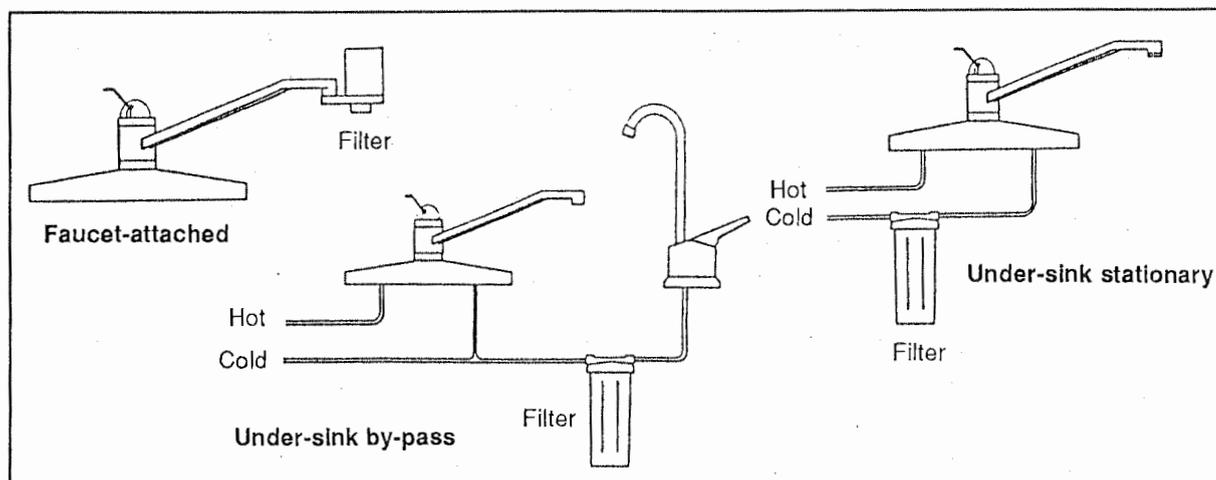


Figure 13. Activated carbon filtration installations. Source: Kansas State University.



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pH SCALE		
	14.0	
Extremely Alkaline	13.0	Household Lye
	12.0	Bleach
Extremely Alkaline	11.0	Ammonia
Strongly Alkaline	10.0	Milk of Magnesia
Moderately Alkaline	9.0	Borax
Slightly Alkaline	8.0	Baking Soda Sea Water
Neutral	7.0	Blood Distilled Water Milk Corn
Slightly Acid	6.0	
Moderately Acid	5.0	Boric Acid
Strongly Acid	4.0	Orange Juice
Extremely Acid	3.0	Vinegar
Excessively Acid	2.0	Lemon Juice
Very Extremely Acid	1.0	
	0.0	Battery Acid

Figure 14. pH scale. Source: McGowan, Water Processing, 1988.

For home water treatment, carbon dioxide can be readily removed by passing the acid water through a neutralizing filter containing a bed of calcite granules. A neutralizing filter is normally a pressure filter tank, similar in appearance to a water-softener tank, filled with marble or limestone chips. As the water passes through the filter bed, calcium carbonate is dissolved into the water and the water's pH value is increased, reducing its acidity. Through this process some calcium hardness is added to the water. (Figure 15)

For proper performance, it is critical that flow rate of the water through the calcite granules does not exceed the rate at which the chemical reaction can take place. The Water Quality Association suggests that best results for pH correction reduction are obtained when the flow is limited to 3.0 gallons per minute per square foot of bed area. Likewise, the bed depth of the neutralizing filter should be at least 30 to 36 inches. Because neutralizing filters also serve as mechanical filters, they must be backwashed periodically (perhaps weekly) to remove solid particles and loosen the neutralizing bed. Also, since the limestone neutralizing bed dissolves with use, it must be checked each year, and a portion replaced.

### Soda Ash Chemical Feed for pH Modification

An alternate method of neutralizing acid water is to treat the water with a solution of soda ash (sodium carbonate) or caustic soda (sodium hydroxide). The soda is added to the water using a chemical feed pump. Each ppm of carbon dioxide in the water requires a minimum of 2.5 ppm of soda ash or 0.85 ppm of caustic soda for neutralization. Where acid water also contains much iron, or where disinfection is desired, the chemical feed pump is often used since hypochlorite bleach and soda ash may be mixed in a single solution and fed into the water system with the same pump unit. The feed pump can be wired to operate in conjunction with the well pump. By introducing the soda ash solution ahead of the pressure or holding tank, good mixing and pH neutralization are achieved.

An advantage of soda ash feed is that it does not add hardness to the water as calcite pH correction does. Soda ash is also safer and less hazardous to handle in a home. However, the major disadvantage of soda ash or caustic soda is that they add sodium to the drinking water.

All tank-type filter systems require minimum pressure of 25 pounds per square inch (psi) and enough pumping capacity to fully backwash the medium.

## Reverse Osmosis

Where the only water available is highly mineralized, treatment to reduce the minerals may be the only economical solution. Reverse osmosis (RO) membrane separation for home water treatment is relatively new, although the process has been used extensively for industrial processes. Reverse osmosis treatment removes dissolved minerals in the water. It successfully treats water with high salt content and removes dissolved minerals such as nitrates, sulfates, calcium, magnesium, potassium, manganese, aluminum, fluoride, silica and boron.

Most minerals in water are beneficial to health. Because RO systems remove so many minerals from the water, consult your doctor about using such a system. Reverse osmosis systems also are effective with some taste and odor-producing chemicals, certain organic contaminants, and certain pesticides. Table 12 illustrates the rejection performance range of a properly operating under-sink RO drinking water system at 50-80 psi feed pressure.

Although the RO membrane is capable of rejecting virtually all micro-organisms, it can develop pinholes or tears that allow bacteria or other micro-organisms to pass into the treated water. Therefore, reverse osmosis is recommended only for bacteriologically safe water.

RO systems are based on the principal of osmosis (Figure 16). If two solutions containing different quantities of dissolved impurities are separated by a semi-permeable membrane, pure water with a low concentration of salt or dissolved chemicals will flow toward water with a high chemical concentration. Since fresh water is able to move through the membrane while the water containing impurities is not, the membrane is an ideal medium for microfiltration.

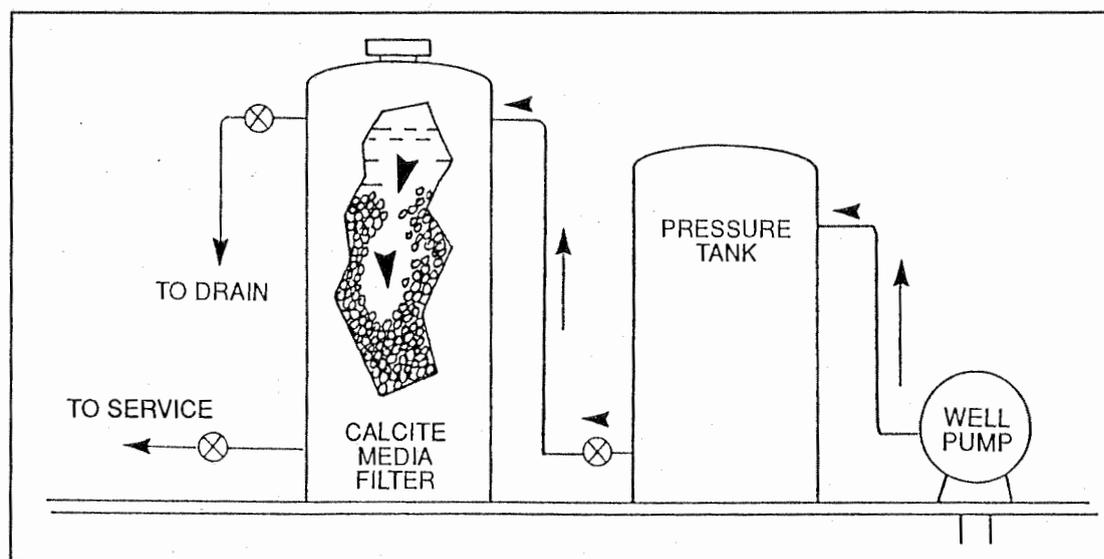


Figure 15. Calcite carbonate media bed, neutralizer-filter for pH modification or turbidity filtration. Source: McGowan, *Water Processing*, 1988.



**TABLE 12. Rejection performance range of under sink reverse osmosis system**

Inorganic Contaminant	RO System CTA* (No post filter)	RO System TFC** (No post-filter)
Aluminum	85-95%	88-98%
Arsenic III	30-50%	50-70%
Arsenic V	70-90%	80-95%
Barium	80-90%	85-95%
Cadmium	75-90%	85-95%
Calcium	85-95%	88-98%
Chloride	80-90%	83-95%
Chromium III	85-95%	88-98%
Copper	85-95%	88-98%
Fluoride	80-90%	83-95%
Iron	85-95%	88-98%
Lead	85-95%	88-98%
Magnesium	85-95%	88-98%
Manganese	85-95%	88-95%
Mercury II	50-70%	60-80%
Nitrate	30-50%	80-90%
Potassium	80-90%	83-95%
Selenium IV	80-90%	83-95%
Silver	75-85%	88-98%
Sodium	80-90%	83-95%
Strontium	85-95%	88-98%
Sulfate	85-95%	88-98%
Zinc	85-95%	88-98%
Total Dissolved Solids	85-95%	88-98%
Asbestos	> 99%	> 99%
<b>Organic Contaminant</b>		
Endrin	> 85%	> 90%
Methoxychlor	> 80%	> 90%
Lindane	> 30%	> 40%
PCB	> 80%	> 90%

*Source: Water Technology, October 1989.*  
 \*CTA — Cellulose Tri-Acetate membrane  
 \*\*TFC — Polyamide membrane  
 This is a chart of the nominal rejection performance range of a properly operating under-sink RO drinking water system at 50-80 psi feed pressure.

In reverse osmosis, normal household water pressure makes osmosis function in reverse (Figure 17). In this process, the water to be treated is forced against a cellulose or polyamide (non-cellulose) semi-permeable membrane. The force exerted on the contaminated side of the membrane squeezes pure water through the membrane, leaving rejected impurities behind to flow out as waste. Thus one flow of water enters the unit, and two streams come out; one a stream of drinkable water with most of the impurities removed, and a second containing the concentrated impurities. One drawback of RO systems is that they waste water. Only 10 to 25 percent of the influent water passes through the membrane; the rest goes down the drain along with the contaminants.

Domestic RO systems treat three to nine gallons per day — only enough water for drinking, beverage preparation and cooking. To operate properly, they need a minimum line pressure of 35 psi and will be much more efficient at 50 psi. When reviewing RO test results, be aware they may show the percentage of specific contaminants removed at water pressure that may exceed that of your water system.

The simplest home RO system consists of a faucet-mounted or countertop unit where installation of a permanent under-sink system is not feasible. Large RO equipment is available to use as a point-of-entry system to treat all of the water in a home but is relatively expensive.

The most common RO installation is located under the sink and includes a membrane, a pre/post filter, storage tank, and a flow regulator for the reject water (Figure 18). The pressure for RO is usually supplied by the line pressure of the water system in the home. An increase of line pressure will directly increase the amount of treated water delivered. For this reason, most RO suppliers now offer systems with small booster pumps. When pressure is increased 50 percent, an average drinking water RO unit will produce 60 percent more treated water.

Operating home RO systems at their best level calls for careful pretreatment and a safe, potable water supply. Much of the difficulty in getting good performance from an RO is attributed to inadequate pre- and post-treatment. Often, the RO systems are expected to do more than they are designed to handle. The water supply may need disinfection and filtering before being fed to an RO system. A pre-mechanical filter to remove sand, silt and sediments and an activated carbon post-filter to remove chlorine and organic materials and dissolved gases not treated by the RO membrane are usually included with the system. Water softeners are used in advance of the RO system when house-

hold water is excessively hard (over three grains per gallon). Softening will make the membrane more permeable and extend membrane life.

The more sensitive nature of the RO process calls for an after-sale testing and service program to assure the system is providing efficient performance. When purchasing an RO system, ask about service contracts that may include change of the prefilter element as preventative maintenance, replacement of membrane based on rejection ability, annual change of post-carbon filter and sanitizing the entire system (storage tank, too) yearly.

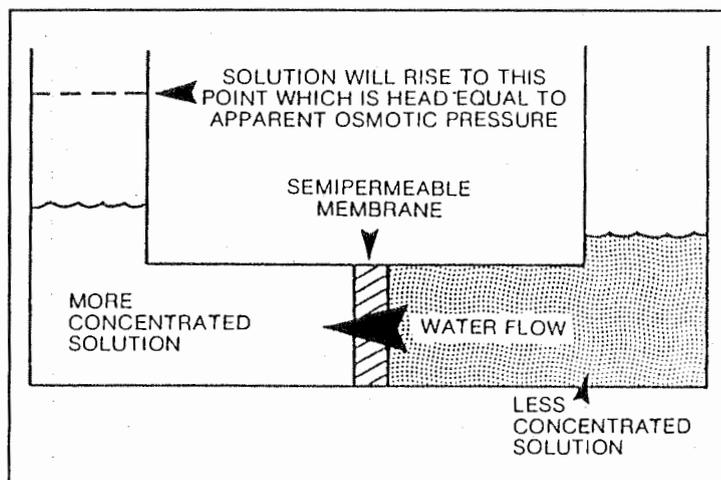


Figure 16. Osmosis

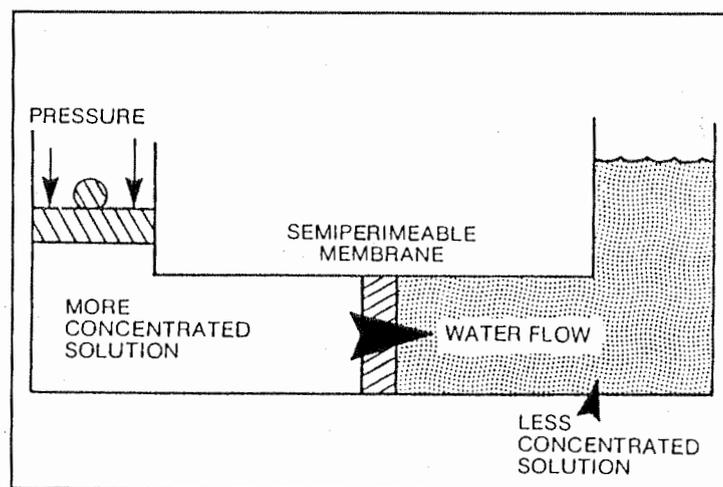


Figure 17. Reverse osmosis

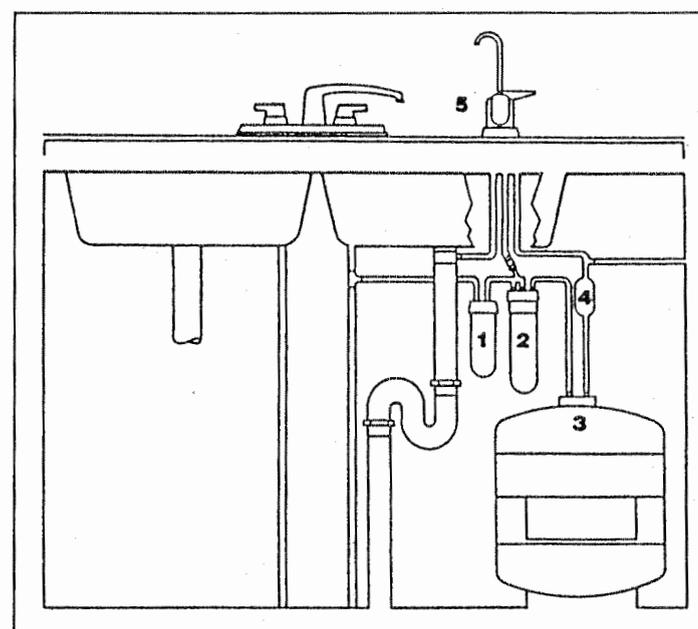


Figure 18. Typical home reverse osmosis system includes: 1) particle filter, 2) reverse osmosis membrane unit, 3) pressurized treated-water storage container, 4) carbon absorption post-filter, and 5) separate treated-water tap. Source: Cornell Cooperative Extension Service.





## IRON AND MANGANESE REMOVAL

Iron and manganese also cause problems in household water supplies. These minerals are not considered health risks but are a nuisance to consumers.

There is little doubt when a water supply contains too much iron or manganese because of the brown to black stains which these minerals cause. Even in water with small amounts, stains may show up rapidly in sinks and appear on laundered fabrics. Water that is high in these elements can have a metallic taste and affect both the flavor and color of foods. Iron-rich groundwater also promotes growth of iron bacteria slimes in plumbing systems. The U.S. EPA standard for iron is set at 0.3 ppm, and 0.05 ppm for manganese.

Since iron in nature accounts for at least five percent of the earth's crust, many water supplies contain some iron. Iron may be picked up or dissolved by the water as it passes through underground deposits or from contact with metal parts of the well casing, pump, and piping. Many types of rocks in Montana contain iron, including sandstone, shales, some coal beds, igneous rocks like granite and volcanic rocks such as basalt. Manganese is rarely found alone in a water source but is generally found in conjunction with dissolved iron.

Iron may be present in water in three forms:

**Ferrous Iron.** Ferrous iron in water is dissolved and is clear and colorless.

**Ferric Oxide or Oxidized Iron.** When ferrous iron in water is brought to the surface and exposed to air, it oxidizes readily, creating brown or rust-colored solid particles which are then precipitated as ferric oxide. Ferric iron is easily seen and usually will settle after water stands. Ferric iron is also the form of iron that stains clothes and water fixtures. Similar reactions occur more slowly with manganese, creating black stains.

**Iron and Manganese Bacteria.** Iron and manganese bacteria are two special forms of organic growths sometimes found in water. Although they do not cause disease, these organisms utilize energy obtained from the oxidation of iron and manganese in their metabolism, and may even attack steel pipe to obtain iron. As the bacteria grow, they form masses of rusty, gelatinous organic matter that trap the iron and manganese they use. Heavy growths cause pipe incrustation, can completely plug pipes, and can produce foul-tasting water. A brown, slime-like growth in a toilet flush tank is an indication of the presence of such organisms in a water system.

The methods for treating iron/manganese water conditions are:

- Sequestering ferrous iron by phosphate feeders
- Ion-Exchange units for ferrous iron
- Oxidizing filters for ferrous iron
- Chlorinator-and-filter units for ferrous and iron bacteria
- Oxidization by aeration followed by filtration

### Sequestration By Phosphate Feeders

For iron and manganese in the ferrous form, a process known as sequestration will treat water up to two ppm of iron. This process does not actually remove the iron from the water but prevents oxidization from taking place. The sequestration process uses food grade polyphosphate compounds (commercial names include "Zeotone," "Micromet" and "Nalco M-1") that are fed into the water by a chemical feed pump. These compounds react chemically with the dissolved iron and manganese to encapsulate them and keep the water clear and satisfactory for drinking. It also reduces staining and deposition in pipes.

Polyphosphates become less effective in high water temperature and thus, oxidized (ferric state) iron water may accumulate in the water heater and end up in the laundry water where it will stain clothing.

An injector chemical feeder similar to those used for adding chlorine to water can be used to feed polyphosphate compounds into water. The chemical feed injector pump can be set to inject a specific amount of solution into the water at regular intervals. Chemical feeders are generally of a tank-type design utilizing one or both of the feed-rate control factors of solubility of the chemical compound and flow rate through the dispenser. For greater feed-rate control, some chemical feeders incorporate pressure-differential devices and/or precision orifices or regulator valves within the feeder itself or installed in the water line. In water systems with a pressure tank, the feeder must be connected to the piping ahead of the tank. Once the ferrous iron water has been exposed to air in the pressure tank, ferric iron particles start to develop and the phosphate compound will not control it. The iron will then continue to produce stains.

### Ion-Exchange for Iron and Manganese Removal

In addition to removing calcium and magnesium in exchange for sodium, water softeners (ion-exchange systems) can also remove dissolved iron and manganese. When the water softener is regenerated, the iron, manganese, and



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hardness will be flushed down the drain. While the amount of iron removal varies with every manufacturer, water softeners generally are able to handle low to moderate amounts of dissolved iron — up to five ppm. If ferrous iron oxidizes before reaching the softener or during the softening process and some of the iron or manganese is precipitated, it will still be filtered out of the water by a softener. However, the precipitate tends to stick to the water softening resin, gradually building up in the bed. To remove the iron precipitate, the backwashing cycle of the softener usually is effective, but some may remain behind. In time, ferric iron precipitate can coat the softening material, gradually reducing the ability of the softener to remove the hardness. To prevent fouling of the softening resin, the softener should be set to regenerate more frequently than necessary for simple hardness removal and to regenerate before actual softening capacity exhaustion. For good iron and manganese exchange to take place, the pH of the water should be at 6.8 pH or higher. Where lower pH is encountered, pre-treatment for pH correction can be achieved with a calcite filter.

In situations where ferrous iron has oxidized and fouling occurs, the water softening media can be cleaned periodically with a commercial product made for this purpose. Some of these products are also designed to be mixed with the softener salt so that a mild cleaning occurs with every regeneration.

### Oxidizing Filters for Ferrous Iron

Oxidizing filters for removing ferrous iron may also be referred to as “iron filters” or “greensand filters.” These filters are often used for moderate levels of iron or manganese (concentration no greater than 10 ppm) where only iron removal without softening is desired. Manganese greensand can also be effective in removing hydrogen sulfide (rotten egg smell) in concentrations up to about five ppm. Iron filters do not tolerate iron bacteria because the slimy material that is produced coats the medium and fouls it.

An iron filter looks much like a water softener. The key is the media — manganese greensand — which is capable of oxidizing dissolved iron (ferrous iron) or manganese to the insoluble state (ferric iron). The greensand will also act as a filter and catch iron and manganese precipitates in the same tank. The unit works by providing oxygen to the iron and manganese. As a result, these minerals change from soluble to insoluble form. The precipitated minerals become trapped, especially in the lower section of the filter. To remain effective, manganese greensand filters must be backwashed weekly, regenerated, and rinsed to thoroughly flush iron precipitate from the bed. Backwashing consists of passing water through the filter in the opposite direction from the regular flow. Considerable water is needed if the backwash is to remove the iron particles. Flow rates of double the incoming rate is recommended. If backwashing is not

thorough, the precipitated iron and manganese will not be expelled from the filter and may ruin a washer-load of clothes.

When the oxygen from the manganese greensand is exhausted, it must be regenerated with a new solution of potassium permanganate. This process is similar to regenerating a water softener and is done at intervals from weekly to monthly depending on the amount of iron, filter size, water pH and water usage. Acid water below a pH of 6.5 is not recommended for this treatment.

### Chlorinator-and-Filter Units for Ferrous and Bacterial Iron

Water softeners and iron filters will not work well for high levels of ferrous iron and manganese and for iron bacteria. Chlorination with filtration removes practically all forms of iron and reduces iron bacteria to reasonable levels. Chlorination also will destroy sulfate-reducing bacteria and oxidize hydrogen sulfide, as well as inactivate some disease-causing organisms.

As in disinfection, a chemical feed pump can be used to introduce a solution of household bleach into the water supply, or at the pump ahead of the pressure tank. The feed rate of the chlorine is usually adjusted to produce a chlorine residual of 1.0 to 1.5 ppm at the outlet of the pressure tank. The chlorine will cause oxidation of iron, manganese, and organic matter — usually in the time it takes for the water to flow through the pressure tank. In some cases, additional contact time is necessary to obtain complete destruction of the organic matter present. (Refer to “chlorination,” pages 19-24, for details.)

Following chlorination, one or two filters are used to remove the excess chlorine and any precipitate that carries over. Ideally, a depth filter should be used, followed by an activated carbon filter. Depth filters must be backwashed periodically to flush the accumulated solids into a drain. For activated carbon filters, small amounts of carbon must be added from time to time to replace the spent carbon that has absorbed chlorine.

Where iron bacteria is a temporary situation, it can be eliminated from a well and water system by shock chlorination. However, most infected systems require periodic shock, or continuous, chlorination. (Refer to “shock chlorination,” pages 24-26 for details.)

### Oxidization by Aeration

Aeration is simply the process of bringing the water into contact with air, or more specifically, oxygen. Aeration followed by filtration can remove ferrous and ferric iron from well water. One method involves forcing air into a pressure tank by means of a compressor. The oxygen in the air reacts with iron or hydro-



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gen sulfide, causing it to precipitate. The precipitate is then removed with a filter. The filter requires periodic backwashing to remove accumulated sediment.

Another method involves the spraying of water into a cistern or other non-pressurized storage tank and letting the precipitated iron settle to the bottom where it is removed periodically. Automatic chlorination is needed following aeration and settling to destroy organisms that may enter the water during the aeration process.

### DEALING WITH HIGH pH WATER — ALKALINE WATER

The acidity of water is indicated by its pH value (Figure 14). The scale for pH ranges from 0 to 14 with 7 being neutral. Below a pH of 7, water is acid and above 7 it is alkaline. Both low pH or acid water and high pH or alkaline water can be corrosive and damaging to metals. Highly alkaline waters (9.0 pH and higher) are corrosive to brass, zinc, copper as well as aluminum.

While not often addressed as a critical matter in water treatment, the correction step for high pH is to acidify the water. With the use of a simple chemical feed pump, a five percent solution of acetic acid (kitchen white vinegar) can modify the alkalinity and bring down the pH to acceptable levels. Citric acid and alum can also be used to reduce pH in water. If alum is used to reduce pH, a precipitate will likely form which may be undesirable.

## ION-EXCHANGE — WATER SOFTENING

**W**ater softening to condition hard water is perhaps the most familiar water conditioning system known to consumers. Hard water is caused by calcium and magnesium which are dissolved in the water.

This causes the formation of scale in hot water pipes and water heaters. It interferes with the cleaning action of soaps and detergents, and forms a film on skin, clothing, and plumbing. Hardness is measured either as milligrams per liter or parts per million; however, it is normally expressed in grains of hardness per gallon of water. To establish uniform degrees of hardness, the Water Quality Association and the American Society of Agricultural Engineers have adopted the hardness levels of Table 13.

Softeners also will remove small amounts of iron and manganese if they are in a soluble or ferrous form.

The most common way to soften water is the cation-exchange water softener. A synthetic resin with a strong attraction for calcium, magnesium, and other positively charged metal ions called cations is saturated with sodium from a salt solution. As water passes through the resin, the sodium exchanges with the calcium and magnesium. Eventually, so much hardness collects on the resin that the unit can no longer soften the water and recharging is necessary. The softening material is backwashed with a brine solution to replace the sodium and enable the ion exchange process to continue. (Figure 19)

### Types and Components of Water Softeners.

Water softening tanks can be rented or purchased. Buying a water softener requires comparison shopping and investigation into the various types and options. An ion exchange water softener is made up of four basic components (Figure 20):

Term	Grains/Gallon	Mg/Liter
Soft	Less 1.0	Less 17.0
Slightly Hard	1.0 to 3.5	17.1 to 60
Moderately Hard	3.5 to 7.0	60 to 120
Hard	7.0 to 10.5	120 to 180
Very Hard	10.5 and over	180 and over

## ALKALINE WATER

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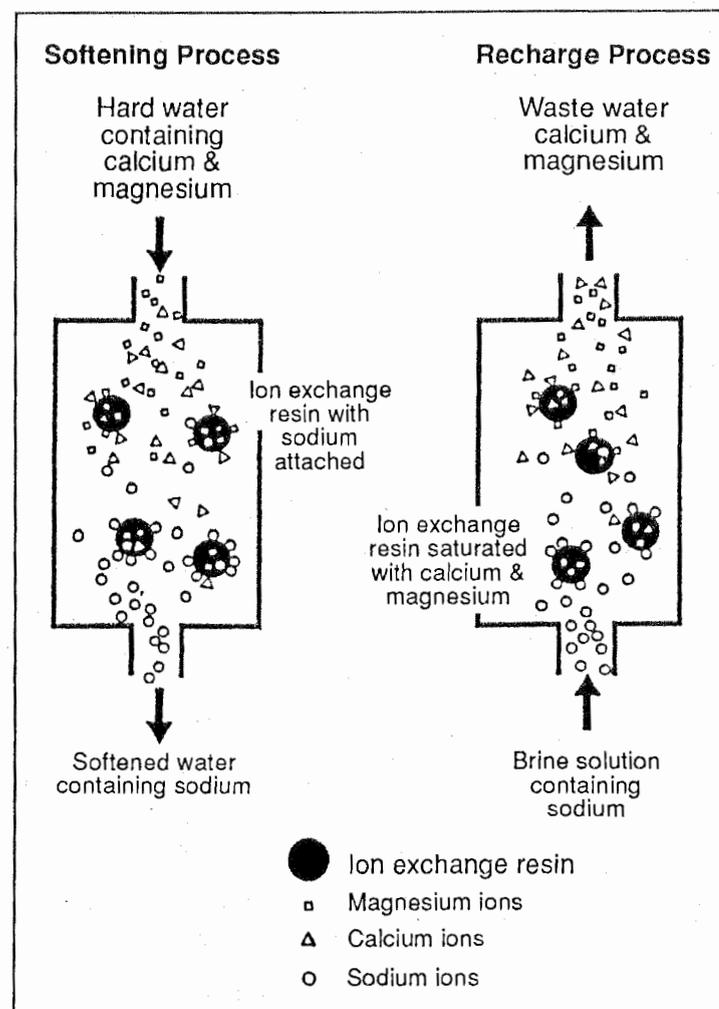


Figure 19. The water softening or ion exchange process.



## PROTECTION AND TREATMENT

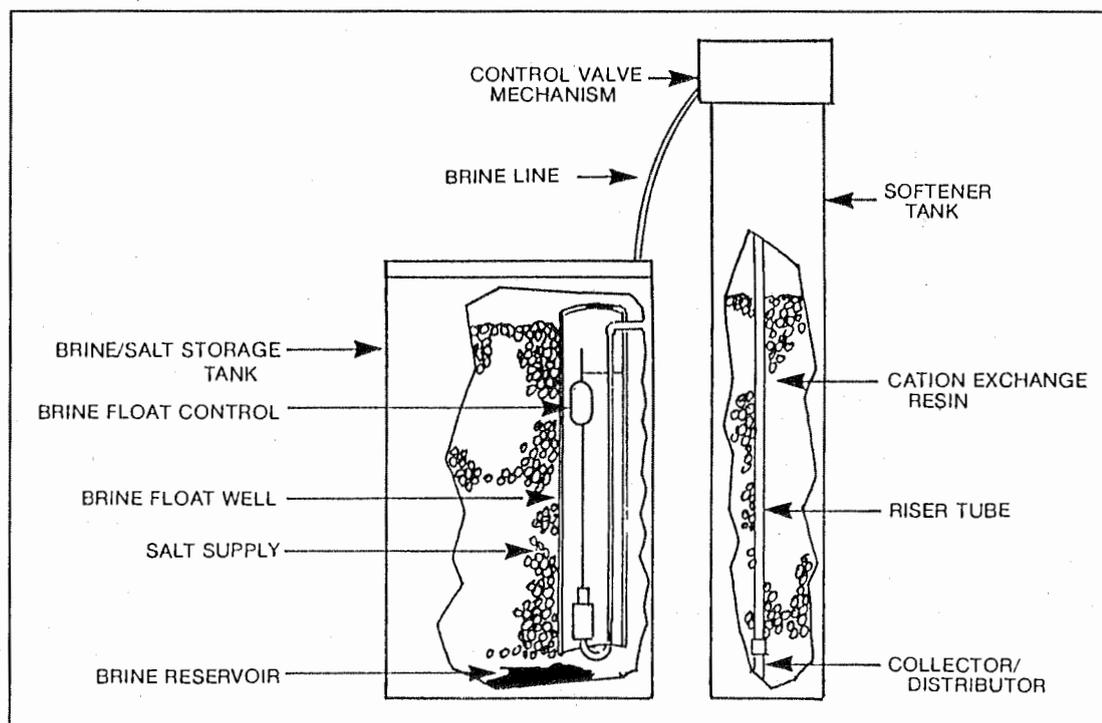


Figure 20. Home water softener, with automatic controller for regeneration and service. Source: McGowan, Water Processing, Water Quality Association, 1988.

**Resin Tank.** This tank contains the resin bed.

**Resin Bed.** This is where the exchange process takes place. The resin bed is made up of tiny beads (less than  $\frac{1}{32}$  inch in diameter) composed of styrene and divinylbenzene. The resin beads attract and hold positively charged sodium ions, but will exchange them whenever the bead encounters another positively charged ion, like calcium and magnesium, for which it has greater attraction.

**Brine Tank.** This tank holds the water and dissolved sodium chloride salt solution (brine) that is necessary to perform the ion exchange.

**Control Valve.** The valves determine the direction of the flow of water through the resin tank or from one location to another during the various softening cycles.

Mechanical water softeners are classified in four different categories as follows:

**Manual.** All manual units require the owner or operator to initiate some or all of the steps in the softener operation. The most basic unit requires the operator to initiate all the functions: backwash, brining, rinsing and the return to service.

**Semi-automatic.** The more complex semi-automatic units require only the initiation by the operator of the regeneration cycle. All necessary steps of regeneration and return to service are then handled by the softener controls.

**Fully Automatic.** The fully automatic softener is usually equipped with a timer which automatically initiates the regeneration cycle and every step in the regeneration process. The regeneration of the unit is usually done during periods of low water usage.

**Demand Initiated Regeneration.** With a demand initiated regeneration unit, all operations are initiated and performed automatically in response to the demand for treated water. The need for regeneration is determined by measuring gallons of water used, or by measuring the change in the electrical conductivity of the resin bed, or by sensing a change in water hardness.

## Softener Size

The softener size to install depends on:

- the amount of hardness and other dissolved minerals in the water;
- the peak flow rate of water required in the home;
- water use per day — number of persons in the home; and,
- the desired interval between regenerations.

Water softener capacities are given in terms of the number of grains of hardness they will remove between successive regenerations. The number of gallons softened between regenerations is calculated by dividing the rated capacity (in grains) by the number of grains of hardness in one gallon of water. For example a softener rated at 20,000 grains of hardness exchange capacity softens 1,000 gallons of water with 20 grains per gallon between regenerations. For other examples, Table 14 illustrates the rated capacity of softeners in grains of hardness removed.

To apply the above factors, let's select a softener for a family of four with a hardness of 20 grains per gallon:

An average family uses about 70 gallons per person day for all water used in the home, or about 50 gallons per person if hard water is supplied to toilets.

1. Multiply 70 gallons per day by four people living in the home.

$$70 \text{ gallons} \times 4 \text{ persons} = 280 \text{ gallons per day}$$

2. Multiply 280 gallons per day by the hardness (grains per gallon = 20 GPG in our case).

$$280 \text{ gallons/day} \times 20 \text{ grains per gallon} = 5,600 \text{ grains per day}$$

Water softener capacities are given in terms of the number of grains of hardness they will remove between successive regeneration. The typical household softener's capacity is between 20,000 and 30,000 grains. It's recommended that a softener have enough capacity to last as least three days between regeneration.

3. Using the example of 5,600 grains per day hardness, three-day capacity means 16,800 grains. Thus, a softener with a 20,000 resin bed capacity would be needed.

A disadvantage of water softeners is that they remove calcium and magnesium and substitute sodium. People who are on a restricted sodium diet may be advised not to drink softened water. Softening only the hot water tank lines, leaving the major cold water line unsoftened for drinking water can overcome this problem.

## WATER SOFTENING

Table 14. Gallons of water softened between regenerations\*\*

Hardness of water supply in grains per gallon	Rated capacity of softener in grains of hardness removed		
	10,000	20,000	30,000
	Gallons Between Regeneration*		
5	2000	4000	6000
10	1000	000	3000
15	667	1333	2000
20	500	1000	1500
30	333	667	1000
50	200	400	600

\* It is recommended that a softener have enough capacity to last at least three days between regeneration.  
\*\* Source: Water Quality Association, 1989.



## PROTECTION AND TREATMENT

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## DEALING WITH HEALTH RISK WATER CONTAMINANTS

### Focus on Pesticides and Synthetic Organic Chemicals

In rural areas, pesticides and synthetic organic chemicals are often major contributors to ground water contamination. Although no one water treatment will solve all problems, removal of pesticides and synthetic organic chemicals can be accomplished using point-of-use treatment systems.

Pesticides include volatile compounds like ethylene dibromide and dibromochloropropane; organochlorine compounds like lindane, DDT, alachlor, endrin and chlordane; nitrogen and/or phosphorous compounds, malathion, carbaryl; organonitrogen compounds and their many decomposition products.

The list of synthetic organic chemicals is even broader and also includes volatile organic compounds such as compounds from dry cleaning and metal cleaning including 1,1,1-trichloroethane, tetrachloroethylene and trichloroethylene. Leaking underground fuel tanks contribute gasoline, diesel or fuel oil which contain hydrocarbon, benzene, toluene, xylenes, ethylbenzene and other chemicals.

The synthetic organic chemicals include phthalates, organic ethers and polynuclear aromatics (naphthalene) and dioxin.

Three common household drinking water treatments are typically used to treat water contaminated by pesticide and synthetic/volatile organic compounds: granular activated carbon, reverse osmosis and distillation. Table 15 compares each of these technologies and their ability to remove pesticides, synthetic and volatile organic chemicals.

To provide a national assessment of pesticide contamination of drinking water wells, the U.S. Environmental Protection Agency surveyed the quality of 1,350 wells from every state. In 1989, the EPA published health advisory summaries for 56 of more than 100 pesticides and breakdown products that were tested during the two-year study. The health advisory summaries describe possible health effects of these pesticides and suggest actions that may be taken by a well owner to ensure safe drinking water. Table 16 lists the results of the treatments recommended in the U.S. EPA health advisory summaries.

REMOVAL OF PESTICIDES



**Table 15. Comparison of devices for pesticide and synthetic organic chemical/volatile organic chemical removal.**

<b>Feature</b>	<b>Granular Activated Carbon</b>	<b>Reverse Osmosis</b>	<b>Distillation</b>
<b>Water availability</b>	On demand	Need storage tank; limited production	Need storage tank; limited production
<b>Mechanism of removal</b>	Carbon absorption	Membrane permeation	Distillation
<b>Total capacity</b>	Fixed capacity; need to replace periodically	Large; needs occasional membrane replacement	Large; depends on maintenance
<b>Rated life</b>	Typically three months or 1,000 gallons	Membrane life up to three years	Very long equipment life
<b>Applicability for SOCs/pesticide</b>	Can provide complete removal	Partial to complete removal	Partial removal, dependent on compounds and design
<b>Applicability for VOCs</b>	Reduce all VOCs to below SDWA limits	Partial removal for VOCs	Partial to poor removal
<b>Best application</b>	Best for organics	Good job both organics & inorganics; not complete for either	Best for inorganics

*Adapted from: Water Technology, June, 1990*

## PROTECTION AND TREATMENT



Table 16. Pesticide treatment recommendations**			
Pesticide	Treatment	Pesticide	Treatment
acifluorfe	* activated carbon adsorption * reverse osmosis	chlorothalonil	* activated carbon adsorption * reverse osmosis
alachlor	alternative drinking supply new or deeper well	cyanazine	granular activated carbon
aldicarb (sulfone and sulfoxide)	activated carbon adsorption	dalapon	* activated carbon adsorption * ion exchange
ametryn	granular activated carbon	2,4-Dichlorophenoxyacetic Acid	* activated carbon adsorption * reverse osmosis
atrazine	activated carbon adsorption	1,2-Dibromo-3-Chloropropane(DBCP)	aeration carbon absorption
baygon	* granular activated carbon	diazinon	reverse osmosis granular activated carbon ozonation
bentazon	alternative drinking supply new or deeper well	dicamba	* granular activated carbon
bromacil	alternative drinking supply new or deeper well	1,2-Dichloropropane	granular activated carbon packed tower aeration
butylate	alternative drinking supply new or deeper well	1,3-Dichloropropene	* granular activated carbon
carbaryl	activated carbon adsorption ozonation, coagulation, settling and filtration	dieldrin	reverse osmosis granular activated carbon ozonation conventional treatment
carbofuran	activated carbon adsorption lime softening	dinoseb	activated carbon adsorption ion exchange
carboxin	activated carbon adsorption reverse osmosis	diphenamid	granular activated carbon
chloramben	* activated carbon adsorption * ion exchange	disulfoton	alternative drinking supply new or deeper well
chlordan	activated carbon adsorption * aeration	diuron	activated carbon adsorption chlorination
* indicates POSSIBLE treatments			
** summarizes the results of the treatments recommended in the U.S. EPA Health Advisory Summaries, 1989.			

## TREATMENTS FOR

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Table 16, continued. Pesticide treatment recommendations**			
Pesticide	Treatment	Pesticide	Treatment
endrin	activated carbon adsorption reverse osmosis coagulation/filtration	prometon	granular activated carbon resin adsorption reverse osmosis
ethylene dibromide	* activated carbon adsorption * boiling	pronamide	reverse osmosis * activated carbon adsorption
ethylene thiourea	alternative drinking supply new or deeper well	propachlor	* activated carbon adsorption * ozonation * reverse osmosis
fenamiphos	alternative drinking supply new or deeper well	propazine	alternative drinking supply new or deeper well
fluometuron	granular activated carbon	propham	granular activated carbon
heptachlor and heptachlor epoxide	* granular activated carbon * packed tower aeration	simazine	activated carbon adsorption * ion exchange * oxidation
hexachlorobenzene	* activated carbon adsorption	2,4,5-Trichlorophenoxyacetic Acid	activated carbon adsorption
hexazinone	alternative drinking supply new or deeper well	2,4,5-TP (Silvex)	activated carbon adsorption
methomyl	granular activated carbon	tebuthiuron	alternative drinking supply new or deeper well
methoxychlor	granular activated carbon reverse osmosis	terbacil	alternative drinking supply new or deeper well
metolachlor	* granular activated carbon	terbufos	* ion exchange * activated carbon adsorption
metribuzin	granular activated carbon	trifluralin	reverse osmosis activated carbon adsorption conventional treatment * air stripping
nitrate/nitrite	ion exchange, distillation reverse osmosis		
oxamyl	activated carbon adsorption		
pentachlorophenol (PCP)	activated carbon adsorption		
picloram	granular activated carbon		





### Focus on Giardiasis

Giardiasis is a gastrointestinal illness also known as "backpackers disease." It is sometimes contracted by unwary campers drinking pond, lake or stream water. Severe diarrhea, stomach cramps and sulfurous belching are common symptoms of giardiasis. However it may take one to four weeks for symptoms to appear. Giardiasis is caused by the protozoan parasite, *Giardia lamblia* or more commonly, *Giardia*.

Infectious *Giardia* cysts are often associated with aquatic animals, such as beavers and muskrats. These animals have been proven carriers of *Giardia* and are often found to be the culprits that contaminate public water supplies. However, studies by the Wild Animal Disease Center at Colorado State University have identified more than 30 species of animals as carriers of *Giardia*. Dogs, cattle, coyotes, deer, cats, marmots, and ground squirrels contribute to the *Giardia* infection in humans. Humans are also common hosts and transmitters of the disease. Day-care centers have high rates of incidence when babies are mobile and not toilet-trained. Day-care employees may spread the infection by diapering several babies in a row if they do not carefully wash their hands in between. As few as 10 cysts hidden under the fingernails can spread the disease if ingested.

In Montana, *Giardia* often gains attention when it invades public drinking water supplies. All public systems that use unfiltered or undertreated surface water from lakes, streams and rivers run the risk of contamination. To prevent people from contracting the disease, proper steps must be taken to assure that viable *Giardia* cysts are not ingested. Two acceptable methods that insure public water supplies are safe to drink are 1) filtration with chemical pre-chlorination or 2) a switch from surface water to groundwater wells. Groundwater sources are less susceptible to normal means of contamination.

Boiling, super-chlorination, and certain filtrations are effective for home treatment of water contaminated with *Giardia* cysts. Ultraviolet light disinfection has no effect on *Giardia* cysts. Only treated water should be used for drinking, cooking, making ice, and washing fruits and vegetables. Dishes washed with untreated water must be thoroughly air dried; the cysts will not live on dry surfaces.

**Super-Chlorination.** *Giardia* cysts are resistant to the levels of chlorine normally used to disinfect water. Only very high concentrations of chlorine will

destroy these cysts. Depending on the temperature and pH of the water, a level of at least 3 to 8 ppm of free chlorine with a contact time of 30 minutes is needed to kill *Giardia* cysts. At these chlorine levels, the water may not be palatable unless dechlorinated with a carbon filter.

**Filtration.** Point-of-use water filters can be used to eliminate *Giardia*. Cartridge filters rated at 1-2 microns have been tested and found to be effective for *Giardia* removal; however, a filter rated at less than 0.5 microns is usually recommended. Any household unit used to filter water for *Giardia* cysts should be tested and approved for that purpose by the National Sanitation Foundation. For a list of treatment devices shown to be effective in removing *Giardia* cysts, contact the Montana Department of Health and Environmental Science—Water Quality Bureau in Helena.

To be effective, *Giardia* filters must be changed or backwashed regularly and operated at the recommended flow rate. If too much water is forced through the units, particles may be washed through the filter medium. If the filter collects too much material, the particles may break through the filter medium.

**Boiling.** Until a properly designed and operated treatment device is installed on a suspect water supply, all water for human consumption should be boiled for at least five minutes prior to use. Exposure to heat supplied by a home water heater is not sufficient to kill *Giardia*.

**Alternatives for Treatment in Remote Locations.** For campers and backpackers, boiling water remains the most reliable treatment for *Giardia*. When boiling is not practical, chemical disinfection—iodine or chlorine—are common alternatives. However, some researchers studying *Giardia* insist that there are too many critical factors to make chemical treatment reliable. Iodine and chlorine both have an uncertain effect of *Giardia*, depending on the temperature, pH of the water, and the chemical contact time.

Portable water filters specifically designed for hiking and backpacking are also available for removing *Giardia* from drinking water. Be aware that some manufacturers have made claims that far exceed the capabilities of their filters. Some of these filters fail to trap objects as tiny as *Giardia* cysts. For a list of travel treatment devices shown to be effective in removing *Giardia* cysts, contact the Montana Department of Health and Environmental Science-Water Quality Bureau in Helena.



## PROTECTION AND TREATMENT



### Focus on Arsenic

Arsenic is found naturally in rocks and soil. The presence of arsenic in water supplies may also be related to the past use of arsenic in various pesticide formulations. Arsenic is also a contaminant found in copper metal, and a residue of smelting and coal mining.

Minor symptoms of chronic arsenic poisoning are similar to those of many common ailments, making it difficult to diagnose. This type of poisoning can make people tired, lethargic, and depressed. Other symptoms are white lines across the toenails and fingernails, weight loss, nausea and diarrhea alternating with constipation, and loss of hair. Arsenic is also a carcinogen.

Much has been heard recently about arsenic in Montana's water supplies. Bringing this issue to the forefront is the proposed curtailment of consumptive uses of water or other activities that elevate arsenic concentration in streams. The instream standard (20 nanograms/L) is already exceeded in the Missouri, Yellowstone, and Clark Fork Rivers.

For example, upper Missouri River water between Three Forks and Fort Peck Reservoir now contains arsenic concentrations 500 to 2,500 times greater than the 20-nanogram standard; the Madison River's concentrations are 2,500 to 10,000 greater. A recently published Montana Bureau of Mines and Geology/ Dept. of Health and Environmental Sciences study shows extensive, shallow groundwater contamination in the Madison Valley—domestic wells reveal levels up to 170 micrograms/L (the standard is 50 micrograms/L). The study identifies the problem source as long-term irrigation with Madison River water and recommends effective, relatively inexpensive domestic well treatment methods.

**Arsenic Treatment.** For reduction of arsenic in drinking water the Montana Department of Health and Environmental Sciences recommends distillation and reverse osmosis. However, RO is marginally effective against high levels of arsenic (see Table 12) so its use should be limited to water supplies with relatively low arsenic concentrations. The use of activated alumina is also an acceptable method of arsenic treatment. Activated alumina is a granulated form of aluminum oxide. In this process, water containing arsenic is passed through a cartridge or canister of activated alumina. The alumina absorbs the arsenic and fresh water continues to the service faucet. The cartridge of activated alumina has to be replaced periodically. Water treatment specialists should be consulted for details relating to these treatments. For high levels of arsenic, alternative water sources should also be considered.

**Focus on Sodium**

Sodium salts are present to a greater or lesser degree in all natural waters. Their concentrations vary from a few parts per million in some surface supplies to several hundred parts per million in well supplies. Sodium varies geographically in relation to soils, major geologic formation, annual climatic patterns and the extent to which the soils have been naturally leached.

Sodium concentration increases as total salt concentration increases as you move from the mountainous areas of western Montana to eastern Montana. Sodium is not a toxic contaminant and standards for drinking water are ambiguous. Sodium levels below 20 ppm are considered excellent while concentrations as high as 250 ppm are considered acceptable.

Some patients with heart disease have difficulty in excreting sodium and are put on a low sodium diets. Depending on age, general health, and sex, sodium may present a problem in drinking water. If the sodium in water exceeds 20 ppm, it is advisable to contact the family physician for an opinion. It is important to note that only about 10 percent of dietary sodium come from drinking water.

**Sodium Treatment.** Reverse osmosis, distillation or deionization are effective methods for removing sodium from drinking and cooking water. The use of sodium-free bottled water is also a viable alternative.

**What About Water Softeners and Sodium?** Water softening is commonly used to condition water that is very hard. The softening process exchanges calcium and magnesium ions for ions of sodium. The amount of sodium in softened water depends on the hardness of the water being softened. For each grain per gallon of hardness, 7.5 milligrams of sodium per quart of water is added. Table 17 give some examples.

Actually, the amount of sodium present in softened water is small when compared to the sodium present in foods (Table 18).

It is sometimes recommended that persons with high blood pressure who are on a medically-supervised restricted sodium diet not drink softened water. This can be accomplished if a hard water faucet is installed to bypass the water softener or by installing the softener so it bypasses the main drinking faucet. Another way is to install a drinking water system, such as reverse osmosis or a distiller, to remove sodium from the drinking water.

**Table 17. Sodium added to water by softening**

Initial Water Hardness	Sodium Added by Softening
1.0 grain per gallon	7.5 milligrams/quart
5.0 grains per gallon	37.5 milligrams/quart
10.0 grains per gallon	75.0 milligrams/quart
20.0 grains per gallon	150.0 milligrams/quart
40.0 grains per gallon	300.0 milligrams/quart

*Source: Water Quality Association, 1989*

**Table 18. Sodium present in selected foods**

Food	Food measurement	Milligrams of sodium
Milk	1 cup	122
Eggs	1	59
Meat	4 ounces	76
Bread	1 slice	114
Cereal	1 cup	256
Potatoes	1 medium	5
Vegetable (peas)	3 ounces	402
Vegetable (cauliflower)	3 servings	18
Fruit (apple)	1	2
Fruit (grapefruit)	1/2	1



## PROTECTION AND TREATMENT

## Focus on Nitrate

Many groundwaters contain small amounts of nitrate nitrogen. Concentrations range from 0.1 ppm to 3-4 ppm in many areas. The maximum U.S. EPA allowable level for nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ) in drinking water is 10 ppm. During the 1989 well test program in Montana, nitrate nitrogen levels greater than the 10 ppm standard were detected in about six percent of the private well waters tested. Almost half of the nitrate-contaminated samples came from the three counties of Daniels, Judith Basin and Roosevelt.

Nitrate contamination usually occurs in shallow wells in agricultural areas. Run-off from fertilized fields, animal containment facilities and septic tank percolation may readily affect such wells. However, some subsoils accumulate enough nitrates to leach into the shallow aquifers causing increasing nitrate levels in ground water supplies. (Figure 21)

Nitrate contamination of drinking water is of concern because it affects human and livestock health (Figure 22). In the intestines of children less than six months old, nitrate is reduced to nitrites. This readily combines with hemoglobin and impairs the body's oxygen carrying capability. The resulting disorder, infant methemoglobinemia, or "blue baby syndrome," can be fatal. Epidemiological studies also show a correlation between high nitrate levels and gastric and stomach cancers in humans. Poultry and livestock can like wise be affected by high levels of nitrate in water.

**Nitrate Treatment.** Three methods can be used to reduce nitrate: 1) demineralization by distillation or reverse osmosis; 2) anion exchange; and, 3) blending. Of these systems, distillation and reverse osmosis are the most common and offer perhaps the most complete treatment for nitrates.

Using bottled water or drilling a deeper well are also options to consider for nitrate-free water supplies. NOTE: Boiling nitrate bearing water will concentrate the nitrate and thus is not recommended.

Because ion-exchange systems can treat large volumes of water, they are more appropriate for treatment of livestock water supplies. In the ion-exchange

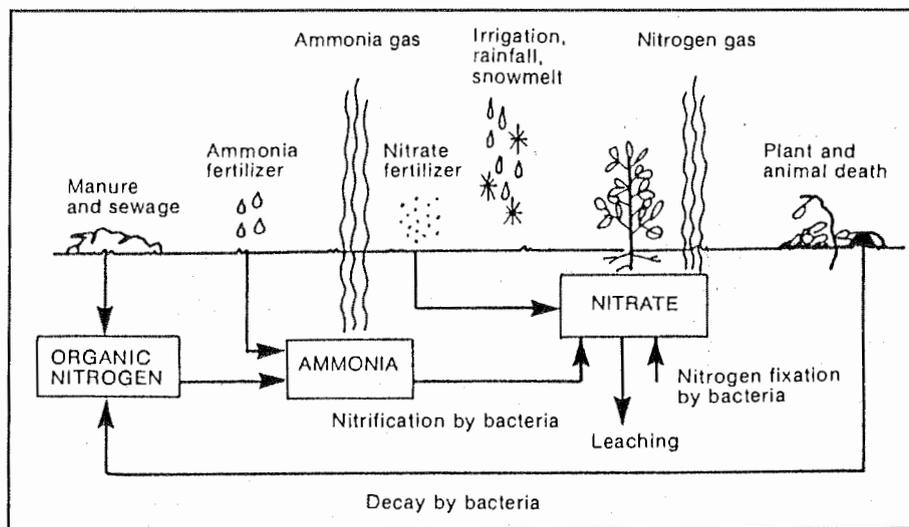


Figure 21. The nitrogen cycle of nature. Source: Pennsylvania State University Extension Service, 308, 1985.

process, the anion resin in use takes up nitrate in exchange for chloride. In time, all the chloride will be exchanged for nitrate. The anion resin must then be recharged by backwashing with a brine solution (potassium or sodium chloride) (Figure 23). Since the backwash brine is high in nitrate it should be disposed of properly so as not to recontaminate the groundwater supply.

Blending is the process of diluting the nitrate-contaminated water with water from another source that has very low nitrate concentrations. Blending the two waters produces water that is low in nitrate concentration. Blended water is not safe for infants but is frequently used for livestock.

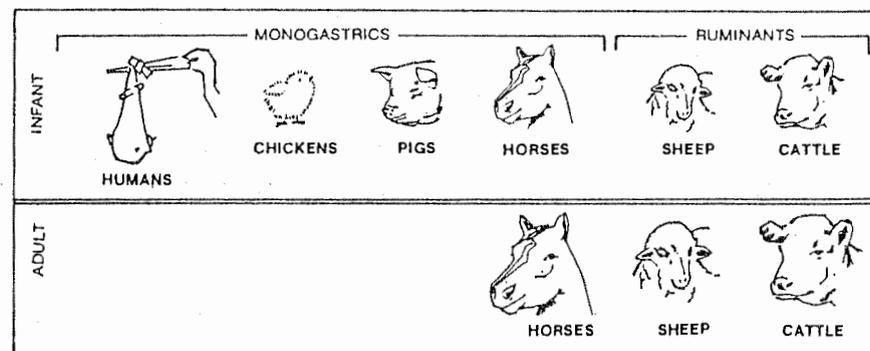
### Focus on Lead

Lead in drinking water is not natural and too much lead in the human body can cause serious damage to the brain, kidneys, nervous system, and red blood cells. Because infants and children more rapidly absorb any lead they ingest, they are most susceptible to lead toxicity. A child's mental and physical development can be irreversibly stunted by over-exposure to lead. Pregnant and lactating women should be aware that fetuses and breastfed infants can have symptoms of lead toxicity even when they themselves suffer no effects.

U.S. Environmental Protection Agency standards limit the amount of lead in water to 0.05 ppm. Even when source water entering a water main is lead free, it might contain metals picked up in the plumbing system when it reaches the tap. Lead contamination is most often a problem in homes, that are either very old or homes that used lead solders for connecting copper piping. In older homes, it was common practice to use lead piping and for the service connection. Since lead levels decrease as a building ages, the highest concentration of lead occur in new plumbing installations—after five years, lead levels are minimal. The most common cause is corrosion, caused by soft or acidic water leaching lead from pipes. Lead levels in drinking water are likely to be highest if your home or water system has lead pipes. However, leaching of lead from some brass fixtures and lead base solders (tin/lead - 50/50 percent) is also common.

One factor that increases corrosion in pipes and therefore potential lead contamination is the practice of grounding electrical equipment (such as tele-

Figure 22. Excess of Nitrate Can Be Harmful to:



Source: Pennsylvania State University Extension Service, #308, 1985

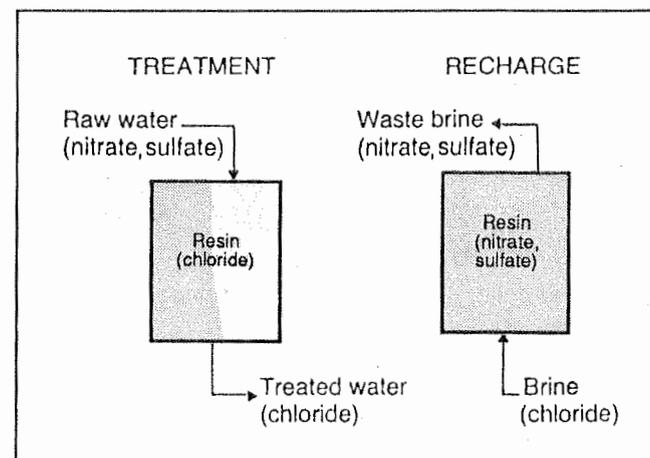


Figure 23. Ion exchange for nitrate removal.  
Source: Pennsylvania State University Extension Service, #308, 1985.



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phones) to water pipes. Electric current traveling through the ground wire may accelerate corrosion. A qualified electrician should evaluate the system and make alternative grounding arrangements if necessary.

**Reduction of Lead.** The first step to reduce exposure to lead is to refrain from drinking or cooking water that has been standing in the home's plumbing for more than six hours. Before using water for drinking and cooking, "flush" the cold water faucet by letting the water run until you can feel that the water has become colder.

Buildings built prior to 1930 may have lead service connectors. In this case, letting the water run for an extra 15 seconds after it cools should also flush this service connector.

Because hot water dissolves lead more quickly than cold water, it is important to cook with or drink water from only the cold-water tap. This is especially critical for water used to prepare baby formula.

For new homes and those to be remodeled, solder and flux containing not more than 0.2 percent lead should be used. Alternatives to tin/lead solder are tin/antimony (95/5 percent) or tin/silver (96/4 percent).

Lead can also be reduced with point-of-use treatment devices such as reverse osmosis or distillation. A water softener can also reduce lead in the water entering the home. Even though these treatments will effectively reduce lead, they can also contribute to the corrosiveness of the water and, thus, to the potential of lead contamination by leaching lead from older lead pipes, or brass fittings that contain lead. In homes where lead is a problem, these treatment systems should not be connected to pipes leading to drinking-water pipes.

## WATER TREATMENT EQUIPMENT TESTING

**W**ater treatment devices are not regulated by the U.S. EPA or any other federal agency. To provide consumers with the assurance of quality water treatment systems, many manufacturers of water treatment products use independent laboratories to test their systems. One such lab is operated by the National Sanitation Foundation. The foundation is an independent, not-for-profit organization which provides third party evaluations, testing, and inspection of various drinking water treatment units and related products, components and materials.

The foundation publishes a listing book for their Drinking Water Treatment Unit Program. The listing information for each unit indicates the water treatment claims that have been verified by National Sanitation Foundation. The listing is based on five standards for drinking water treatment units:

- Standard Number 42: Drinking Water Treatment Units, Aesthetic Effects;
- Standard Number 44: Cation Exchange Water Softeners;
- Standard Number 53: Drinking Water Treatment Units, Health Effects;
- Standard Number 58: Reverse Osmosis Drinking Water Treatment Systems.
- Standard 62: Distillation Systems

The foundation is also in the process of developing Standard 55 for ultraviolet disinfection systems.

National Sanitation Foundation standards are developed with the participation of public health and other regulatory officials, users, and industry personnel. Information regarding these standards and the units listed for meeting "claims" under these standards can be obtained by calling the foundation (313-769-8010) or by writing to them at P.O. Box 1468, Ann Arbor, Michigan 48106.

The Water Quality Association (WQA), a not-for-profit international trade association of firms that sell and manufacture point-of-use/point-of-entry devices, has developed voluntary standards and testing programs for water softening, reverse osmosis, distillation, and water filtration units (see Table 19). The

**Table 19. Voluntary test standards of the Water Quality Association**

Test Standard	Standard Coverage
WQA S-100-85	Household, commercial and portable exchange tank water softener equipment.
WQA S-101-90	Efficiency rated water softeners
WQA S-200-91	Household and commercial filter equipment
WQA S-300-84	Low pressure reverse osmosis drinking water systems
WQA S-301-91*	Efficiency rated, point-of-use reverse osmosis drinking water systems
WQA S-400-86	Point-of-use distillation drinking water systems
* Standard Pending	



## PROTECTION AND TREATMENT

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WQA publishes a semi-annual Validated Water Treatment Equipment Directory which lists the specific models which are authorized by the association. Validation means that a manufacturer-selected sample of a production line water conditioning product was tested at the WQA laboratory and was found to have met the requirements of the appropriate voluntary industry standard. Information regarding WQA services may be obtained by calling WQA, (708) 505-0160 or by writing to the association at 4151 Naperville Road, Lisle, Illinois 60532.

### BOTTLED WATER

If your water becomes contaminated you may choose to use bottled water until your water supply situation changes. The U.S. Food and Drug Administration regulates bottlers if their product is shipped from one state to another. The FDA sets the minimum standards for the quality of bottled water which match the standards for municipal water supplies set by the U.S. EPA. The FDA requires regular sampling and inspects facilities for cleanliness and quality control. Additionally, some states have an inspection program for bottled water. In Montana, the Department of Health and Environmental Sciences regulates all bottled water that originates in Montana, whether or not it leaves the state. The International Bottled Water Association, an industry trade group, also inspects facilities of its members to assure quality control.

The National Sanitation Foundation also operates a certification program. Manufacturers who belong to IBWA or have NSF certification usually indicate this quality assurance on their product labels. Consumers who have questions about bottled water should contact the bottler, the Bottled Water Association or the sanitation foundation for information. To help assure bottled water quality, purchase from a quality retailer who handles enough volume to rotate stock.

There are four basic types of bottled water that offer varying degrees of treatment:

**Distilled water or demineralized water** has been treated to remove nearly all of the minerals that occur naturally in water. Through distillation, reverse osmosis, or deionization, or a combination of those processes, the water contains less than 10 parts per million of total dissolved solids. Virtually all sodium is removed. The resulting water has the highest degree of purity and is excellent for use in steam irons or for watering plants, but may be considered flat and tasteless for drinking because of the lack of minerals.

**Drinking water** may come from municipal water systems, wells or springs. It often is treated by reverse osmosis to remove minerals and organic chemicals and some pesticides. The resulting water is treated but still contains some dissolved solids. Distillation, deionization or a combination of processes also may be used to remove contaminants. Distillation produces a purer water than reverse osmosis because it removes more of the dissolved solids. Deionization removes minerals but not necessarily organic chemicals, pesticides, and other contaminants unless other processes also are used. Water bottlers often add back certain minerals (but usually not sodium) to improve the taste of drinking water.

**Natural water** comes from a protected well or spring and is bottled without extensive treatment. This water typically is free of the trace chemical additives found in some public water supplies. However, it contains most of the mineral contaminants commonly picked up by water as it moves through the air, soil and rock materials. Because this is almost exclusively groundwater, it usually contains a wide range of minerals and is therefore quite flavorful. Spring water is really no different from groundwater except that it is forced to the surface from deeper layers or reaches the surface as it flows through the aquifer. Natural waters often have a high degree of hardness resulting from the wide range of minerals that occur naturally in groundwater. Natural waters may also contain other undesirable contaminants such as pesticides or organic chemicals if these substances occur in the area recharging the aquifer. Since natural water may not receive treatment other than disinfection, it may contain some undesirable contaminants.

**Mineral water** is obtained from a natural spring or underground source. The mineral content is not modified by the manufacturer and may contain 500 or greater ppm total dissolved solids. It may be still or sparkling (club soda and seltzer), a version that is currently in demand as a cocktail substitute. The carbon dioxide that causes carbonation may be natural or added during bottling. Both domestic and imported mineral waters are subject to federal standards for safety and purity under the guidelines for soda water. Both domestic and imported mineral waters are subject to federal standards for safety and purity under the guidelines for soda water.



## PROTECTION AND TREATMENT

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### SUMMING UP: GUIDELINES FOR BUYING A WATER TREATMENT SYSTEM

**B**uying a water treatment product can be confusing and expensive. Before choosing a treatment system be sure to:

1. Have your water tested by a certified laboratory.
2. If possible, locate and control the source(s) of contamination.
3. Review your treatment options with a reputable water treatment specialist.
4. Get a second opinion

If treatment is necessary:

✓ Beware of advertising and salespeople that claim that all public water is unsafe. Municipal water systems are monitored by the U.S. EPA and are required to report contaminants that are in violation of the federal drinking water standards.

✓ Avoid doing business with someone who tries to scare you into buying a system with some of his or her testing methods.

✓ Beware of misrepresented claims. If the product sounds too good to be true, it probably is.

✓ Make sure the salesperson addresses these issues:

- what the treatment capabilities are
- limitations of the system
- how much water will be treated
- how the system works — step-by-step
- effect the system has on home water pressure
- servicing needs of the system

## GUIDELINES FOR BUYING

- maintenance needs required by the consumer
- warranty coverage and limitations
- system cost, installation cost, maintenance cost and operating costs

While some of these tips may seem quite simple, it is wise to get as much information as possible. After all, the final decision is yours.

The Extension Service offers consumers fact sheets dealing with water quality and treatment issues. Contact your county Extension agent for these educational materials.

### Claims to Watch Out For\*

Be suspicious of water treatment salespersons and advertising that claim that public drinking water is unsafe or contains particular harmful substances, that use ambiguous terms to describe the effectiveness of water treatment systems, that offer water tests without disclosing sales purposes, and that overstate the degree to which a water treatment system has been "federally recognized." Some phrases and images that should alert you to be wary:

- "Your tap water is killing you!"
- "Chlorine in municipal drinking water supplies causes cancer and heart disease."
- Use of skull and crossbones or some other creature flowing from a faucet.
- "Warning! Toxic chemicals could be in your water."
- "Don't jeopardize your children's health by allowing them to drink contaminated tap water."
- "Tap water should not be relied on because it contains toxic chemicals."
- "Fluoride is poisonous."
- "The results of contaminants in your tap water include cancer, leukemia, birth defects, sterility and death."

\* Adapted from *Water Technology*, October, 1989, "WQA's First Product Promotion Advisory."



## PROTECTION AND TREATMENT

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- “Chlorine is the biggest poison found in drinking water, causing millions to die each year from heart attacks.”

- “Public water treatment plants are inadequate.”

- “All municipal water lines are made of toxic asbestos piping.”

Here are some misrepresentations used in selling water treatment systems:

- “Removes” when what is really meant is “reduces.”

- “Pure” without clearly defining the use of “pure,” “purification,” or other derivatives of “pure.” The U.S. EPA defines “pure” to mean that a product must remove/disinfect all types of disease-causing microorganisms in raw water, including bacteria, viruses and protozoan cysts, so as to render the processed water safe for drinking.

- “Remove 99 percent of contaminants in your tap water” without qualifying what the percent means.

- “Provide maximum safety and protection by removing 100 percent of cancer causing chemicals.”

- “Magnetic or catalytic devices improve water solvency that results in better cleaning, like soft water.”

- Representing that calcium or magnesium content causes a health risk.

- Using a water sampling program, the title of which erroneously implies official sanction, or offering any program which does not disclose that the analysis will be used for purposes of selling a water treatment system.

- Claiming a water treatment system is U.S. EPA “approved” when in fact it is EPA “registered.”

## GLOSSARY OF WATER TREATMENT TERMS

*The following compilation includes commonly-used water treatment/industry terms and their definitions.*

- Absolute** — Used in reference to micron rating of cartridge filters. Refers to an exact size of particles that will not pass through, and all particles larger than that size are trapped within the filter.
- Absorption** — The process in which one substance is taken into the body of another substance, termed the absorbent. An example is the absorption of water into soil.
- Acid** — A substance which releases hydrogen ions when dissolved in water. Most acids will dissolve the common metals, and will react with a base to form a neutral salt and water.
- Activated carbon** — Granulated active carbon used to remove tastes, odor, chlorine, chloramines and some organics from water.
- Activated silica** — A material usually formed from the reaction of a dilute silicate solution with a dilute acid, and used as a coagulant aid.
- Adsorption** — The process in which a vapor, dissolved material or very small particle adheres to the surface of a solid.
- Aeration** — The process in which air is brought into intimate contact with water, often by spraying water through air, or by bubbling air through water. Aeration may be used to add oxygen to the water for the oxidation of matter such as iron, or to cause the release of dissolved gases such as carbon dioxide or hydrogen sulfide from the water.
- Alkali** — A group of water soluble mineral compounds, usually considered to have moderate strengths as bases, as opposed to the caustic or strongly basic hydroxides, although this differentiation is not always made. In general the term is applied to the carbonates, and the borates, phosphates, and silicates when these are present in the water or solution. (See **base**.)
- Anion** — A negatively charged ion in solution, such as bicarbonate, chloride or sulfate.
- Anion Exchange** — An ion exchange process in which anions in solution are exchanged for other anions from an ion exchanger. In demineralization, for example, bicarbonate, chloride and sulfate anions are removed from solution in exchange for a chemically equivalent number of hydroxide anions from the anion exchange resin. (See **demineralization**, **ion exchange**.)
- Angstrom unit** — A unit of wavelength of light equal to one tenth of a millimicron or one ten-millionth of a millimeter.
- Aquifer** — A layer or zone below the surface of the earth which is capable of yielding a significant volume of water.
- Backwash** — The process in which beds or filter or ion exchange media are subjected to flow opposite to the service flow direction to loosen the bed and to flush suspended matter, collected during the service run, to waste.
- Bacteria** — Unicellular micro-organisms which typically reproduce by cell division. Although usually classed as plants, bacteria contain no chlorophyll. (See **Coliform bacteria**.)



## PROTECTION AND TREATMENT

- Base** — A substance which releases hydroxyl ions when dissolved in water. Bases react with acids to form a neutral salt and water. (See alkali.)
- Bed** — The ion exchanger or filter media in a column or other tank or operational vessel.
- Breakpoint chlorination** — A chlorination procedure in which the chlorine is added until the chlorine demand is satisfied and a dip (breakpoint) in the chlorine residual occurs. Further additions of chlorine produce a chlorine residual proportional to the amount added.
- Breakthrough** — The appearance in the effluent from a water conditioner of the material to be removed by the conditioner, such as hardness in the effluent of a softener, or turbidity in the effluent of a mechanical filter; an indication that regeneration, backwashing, or other treatment is necessary for further service.
- Brine** — A strong solution of salt(s), such as the sodium chloride brine used in the regeneration of ion exchange water softeners, but also applied to the mixed sodium, calcium and magnesium chloride waste solution from regeneration.
- Cation** — An ion with a positive electrical charge, such as calcium, magnesium and sodium.
- Cation Exchange** — Ion exchange process in which cations in solution are exchanged for other cations from an ion exchanger.
- Caustic** — Any substance capable of burning or destroying animal flesh or tissue. The term is usually applied to strong bases.
- Caustic Soda** — The common name for sodium hydroxide.
- Chemical Solution Feeder** — A pump used to meter chemicals such as chlorine or polyphosphate into a water supply.

**Chlorine** — A very toxic biocide. A halogen element isolated as a heavy irritating greenish-yellow gas of pungent odor used especially as a bleach, oxidizing agent and a disinfectant in water purification.

**Chlorine Demand** — A measure of the amount of chlorine which will be consumed by organic matter and other oxidizable substances in water before a chlorine residual will be found; the difference between the total chlorine fed and the chlorine residual. Chlorine demand does not provide disinfection but is “reduced” or “destroyed.”

**Chlorine Dose** — Total amount of chlorine put into the water.

**Coagulant** — A material, such as alum, which will form a gelatinous precipitate in water, and cause the agglomeration of finely divided particles into larger particles which can then be removed by settling and/or filtration.

**Coliform Bacteria** — A group or organisms primarily found in human and animal intestines and wastes, and thus widely used as indicator organisms to show the presence of such wastes in water, and the possible presence of pathogenic (disease producing) bacteria.

**Colloid** — Very finely divided solid particles which will not settle out of a solution; intermediate between a true dissolved particle and a suspended solid which will settle out of solution. The removal of colloidal particles usually requires coagulation to form larger particles which may be removed by sedimentation and/or filtration.

**Combined Available Chlorine (also Combined Chlorine Residual)** — The “unreduced chlorine” present as chloramines and chloro-organic compounds produced by chlorine reacting to ammonia and organics in the water. The combined chlorine residual provides some disinfection.

**Conductivity** — The quality or power to carry electrical current; in water, the conductivity is related to the concentration of ions capable of carrying electrical current.

## GLOSSARY

**Contact Time.** Time that the chlorine has to work on the water.

**Contamination** — The addition of foreign matter to a substance which reduces the value of the substance, or interferes with its intended use.

**Corrosion** — The destructive disintegration of a metal by electrochemical means.

**Cross Connection** — A direct link between a potable water system and a non-potable water system, which would permit undesirable substances to be drawn into the potable water.

**Deionization** — Use of ion exchange resin to remove salts from water. Deionization does not remove organics, virus or bacteria, except through accidental trapping in the resin.

**Demineralization** — The process of removing minerals from water e.g. deionization, reverse osmosis and distillation.

**Disinfection** — A process in which pathogenic (disease producing) bacteria are killed; may involve disinfecting agents such as chlorine or physical processes such as heating.

**Dissolved Solids** — Includes colloidal and small suspended particles.

**Distillation** — Steam from boiling water is condensed on a cool surface, collected and stored. Most contaminants do not vaporize and therefore do not pass to the condensate. Removes nearly 100 percent of salts and those organics that do not have a vaporizing temperature near or below that of water.

**E. Coli** — *Escherichia coli*, a member of the coliform group of bacteria indicating fecal contamination.

**Effluent** — The stream emerging from a unit, systems or process, such as the softened water from an ion exchange softener.

**Feed** — The input solution to a system.

**Filtrate** — The portion of the feed stream that has passed through the membrane.

**Flocculent** — Chemical which, when added to water, causes particles to coagulate into larger, settleable groupings (flocs).

**Flow Rate** — The quantity of water or regenerant which passes a given point in a specified unit of time, often expressed in gallons per minute.

**Fouling** — The process in which undesirable foreign matter accumulates in a bed of filter media or ion exchanger, clogging pores and coating surfaces and thus inhibiting or retarding the proper operation of the bed.

**Free Available Chlorine** — The concentration of residual chlorine present as dissolved gas, hypochlorous acid or hypochlorite, not combined with ammonia or in other less readily available form.

**Gallionella Ferruginea** — A genus of stalked, ribbon-like bacteria which utilize iron in their metabolism, and cause staining, plugging and odor problems in water systems. (See iron bacteria.)

**GPD** — Abbreviation for "gallons per day."

**GPG** — Abbreviation for "grains per gallon."

**Grain (gr.)** — A unit of weight equal to 1/7000th of a pound, or 0.0648 gram.

**Grains Per Gallon (gpg)** — A common basis for reporting water analyses in the United States and Canada; one grain per U.S. gallon equals 17.12 milligrams per liter (mg/L) or parts per million (ppm). One grain per British (Imperial) gallon equals 14.3 milligrams per liter or parts per million.

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## PROTECTION AND TREATMENT

**Greensand** — A natural mineral, primarily composed of complex silicates, which possess ion exchange properties. ( See manganese greensand, zeolite.)

**Ground Water** — Water confined in semipermeable rock layers.

**Hardness** — A characteristic of natural water due to the presence of dissolved calcium and magnesium; water hardness is responsible for most scale formation in pipes and water heaters, and forms insoluble “ curd” when it reacts with soaps. Hardness is usually expressed in grains per gallon, parts per million, or milligrams per liter, all as calcium carbonate equivalent.

**Heavy Metals** — Metals having a high density or specific gravity. A generic term used to classify contaminants such as cadmium, lead and mercury.

**Hydrogen Ion Concentration** — The concentration of hydrogen ions in moles per liter of solution; often expressed as pH. (See pH.)

**Hydrogen Sulfide** — A toxic gas ( $H_2S$ ) that is detectable because of its strong “rotten egg” odor.

**Hydrologic Cycle** — The term used to describe how water travels through the environment by evaporation, condensation and precipitation.

**Influent** — The stream entering a unit, stream or process, such as the hard water entering an ion exchange water softener.

**Inorganic matter** — Matter which is not derived from living organisms and contains no organically produced carbon; includes rocks, minerals and metals.

**Iodine Number** — The amount of iodine, in milligrams, absorbed by one gram of carbon under certain conditions. The larger the iodine number, the more adsorptive the carbon. An iodine number of 500 or greater is considered good.

**Ion** — An atom, or group of atoms which function as a unit, and has a positive or negative electrical charge, due to the gain or loss of one or more electrons.

**Ion Exchange** — A reversible process in which ions are released from an insoluble permanent material in exchange for other ions in a surrounding solution; the direction of the exchange depends upon the affinities of the ion exchanger for the ions present, and the concentrations of the ions in the solution.

**Iron** — An element often found dissolved in ground water (in the form of ferrous iron), usually in concentrations ranging from zero to 10 ppm (mg/L). It is objectionable in water supplies due to staining caused after oxidation and precipitation (as ferric hydroxide), because of tastes, and because of unsightly colors produced when iron reacts with tannins in beverages such as coffee and tea.

**Iron Bacteria** — Organisms which are capable of utilizing ferrous iron, either from the water or from steel pipe, in their metabolism, and precipitating ferric hydroxide in their sheaths and gelatinous deposits. These organisms tend to collect in pipe lines and tanks during periods of low flow, and to break loose in slugs of turbid water to create staining, taste and odor problems. (see *Gallionella ferruginea*.)

**Laminar** — Nonturbulent flow membrane.

**Magnesium** — One of the elements making up the earth's crust, the compounds of which when dissolved in water make the water hard. The presence of magnesium in water is a factor contributing to the formation of scale in pipes and insoluble soap curds.

**Manganese Greensand** — Greensand which has been processed to incorporate in its pores and on its surface the higher oxides of manganese. The product has a mild oxidizing power and is often used in the oxidation and precipitation of iron, manganese and/or hydrogen sulfide, and in their removal from water.

**MCL** — Abbreviation for "Maximum Contaminant Level;" the maximum allowable concentration of a contaminant in water as established in the U.S. EPA Drinking Water Regulations.

**Mechanical Filter** — A filter primarily designed for the removal of suspended solid particles, as opposed to filters with additional capabilities.

**Media** — The selected materials in a filter that form the barrier to the passage of certain suspended solids or dissolved molecules.

**Mg/L** — Milligrams per liter. Equivalent to parts per million (ppm).

**Micron** — A linear measure equal to one millionth of a meter, or .00003937 inch. The symbol for the micron is the Greek letter " $\mu$ ."

**Micron Rating** — The term applied to a filter or filter medium to indicate the particle size above which all suspended solids will be removed, throughout the rated capacity. As used in industry standards, this in an "absolute" — not "nominal" — rating.

**Mole** — The molecular weight of a chemical compound expressed in grams.

**Nephelometric Turbidity Unit** — The standard unit of measurement for turbidity in water analysis.

**Nominal** — When used in reference to micron rating of cartridge filters, refers to an approximate size particle that will not pass through a filter. A small number of particles exceeding this size may pass through the filter.

**Operating Pressure** — The range of pressure, usually expressed in pounds per square inch, over which a water conditioning device or water system is designed to function.

**Organic Matter** — Substances of or derived from plant or animal matter, as opposed to inorganic matter derived from rocks and minerals. Organic matter is characterized by its carbon-hydrogen structure.

**Osmosis** — A process of diffusion of a solvent such as water through a semipermeable membrane which will transmit the solvent but impede most dissolved substances. The normal flow of solvent is from the dilute solution to the concentrated solution. (See **reverse osmosis**.)

**Oxidation** — A chemical process in which electrons are removed from an atom, ion or compound. The addition of oxygen is a specific form of oxidation. Combustion is an extremely rapid form of oxidation, while the rusting of iron is a slow form.

**Oxidizing Filters** — Filters that use a catalytic media, such as manganous oxides, to oxidize iron, manganese and other impurities from water.

**Ozone** — An unstable form of oxygen ( $O_3$ ), which can be generated by an electrical discharge through air or regular oxygen. It is a strong oxidizing agent and has been used in water conditioning as a disinfectant.

**Parts Per Million (ppm)** — A common basis for reporting the results of water and wastewater analyses, indicating the number of parts by weight of a dissolved or suspended constituent, per million parts by weight of water or other solvent. In dilute water solutions, one part per million is practically equal to one milligram per liter, which is the preferred unit, while 17.12 ppm equals one grain per U.S. gallon.

**Permeable** — Allowing some material to pass through.

**Permeate** — The portion of the feed stream that passes through the membrane.

**pH** — The reciprocal of the logarithm of the hydrogen ion concentration. The pH scale is from zero to 14, and 7.0 is the neutral point, indicating the presence of equal concentrations of free hydrogen and hydroxide ions. pH values below 7.0 indicate increasing acidity, and pH values above 7.0 indicate increasing base concentrations.





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**Phenol Value** — amount of carbon, measured in ppm, required to reduce a standard concentration of phenol from 100 ppb to 10 ppb. Most commercial carbons have a phenol value between 15 and 30 ppm. The lower the phenol number, the better the carbon is at removing organics.

**Potable Water** — Water which is suitable for human consumption.

**PPB** — Abbreviation for “parts per billion.”

**PSI** — Abbreviation for “pounds per square inch” (pressure).

**Rated In-Service Life** — The length of time or total gallons delivered between servicing of the media in a filter, as determined under standard test conditions.

**Raw Water** — Untreated water, or any water before it reaches a specific water treatment device or process.

**Red Water** — Water which has a reddish or brownish appearance due to the presence of precipitated iron and/or iron bacteria.

**Regeneration** — In general, includes the backwash, brine, and fresh water rinse steps necessary to prepare a water softener exchange bed for service after exhaustion. Specifically, the term may be applied to the “brine” step in which the sodium chloride solution is passed through the exchanger bed. The term may also be used for similar operations relating to demineralizers and certain filters.

**Residual Chlorine** — Chlorine remaining in treated water after a specified period of contact time, to provide protection throughout a distribution system; the difference between the total chlorine added, and that consumed by oxidizable matter. (See **free available chlorine**.)

**Resin** — Synthetic organic ion exchange material, such as the high capacity cation exchange resin widely used in water softeners.

**Reverse Osmosis (RO)** — A process that reverses, by the application of pressure, the flow of water in a natural process osmosis so that the water passes from the more concentrated to the more dilute solution through a semi-permeable membrane.

**Semipermeable** — Able to allow certain size material to pass through while rejecting other size material.

**Sequestering Agent** — A chemical compound sometimes fed into water to tie up undesirable ions, keep them in solution, and eliminate or reduce the normal effect of the ions. For example, polyphosphates can sequester hardness and prevent reactions with soap.

**Soda Ash** — The common name for sodium carbonate, a chemical compound used as an alkaline builder in some soap and detergent formulations, to neutralize acid water, and in the lime-soda ash water treatment process.

**Sodium** — An ion found in natural water supplies, and introduced to water in the ion exchange water softening process. Sodium compounds are highly soluble, and do not react with soaps or detergents.

**Sodium Chloride** — The chemical name for common salt, widely used in the regeneration of ion exchange water softeners.

**Soft Water** — Any water which contains less than 1.0 gpg (17.1 mg/L) of calcium or magnesium, expressed as calcium carbonate.

**Solvent** — The liquid, such as water, in which other materials (solutes) are dissolved.

**Superchlorination** — The addition of excess amounts of chlorine to a water supply to speed chemical reactions or insure disinfection with short contact time. The chlorine residual following superchlorination is high enough to be unpalatable, and thus dechlorination is commonly employed before the water is used.

**Suspended Solids** — Solid particles in water which are not in solution.



**TDS** — The abbreviation for “total dissolved solids.”

**Titration** — An analytical process in which a standard solution in a calibrated vessel is added to a measured volume of sample until an endpoint, such as a color change, is reached. From the volume of the sample and the volume of standard solution used, the concentration of a specific material may be calculated.

**Total Acidity** — The total of all forms of acidity, including mineral acidity, carbon dioxide, and acid salts. Total acidity is usually determined by titration with a standard base solution to the phenolphthalein endpoint (pH 8.3).

**Total Alkalinity** — The alkalinity of a water as determined by titration with standard acid solution to the methyl orange endpoint (pH approximately 4.5); sometimes abbreviated as “M alkalinity.” Total alkalinity includes many alkalinity components, such as hydroxides, carbonates and bicarbonates.

**Total Chlorine** — The total concentration of chlorine in a water, including combined and free chlorine.

**Total Dissolved Solids** — The weight of solids per unit volume of water which are in true solution, usually determined by the evaporation of a measured volume of filtered water, and determination of the residue weight.

**Turbidity** — A measure of the amount of finely divided suspended matter in water which causes the scattering and adsorption of light rays. Turbidity is usually reported in arbitrary units determined by measurements of light scattering.

**Ultraviolet Disinfection** — The use of ultraviolet waves to kill bacteria. The ultraviolet spectrum includes wavelengths from 2000 to 3900 Angstrom units (A). One unit is one ten billionth of a meter. Short-wave ultraviolet is 2000 to 2950 A. This segment possesses by far the greatest germicidal effectiveness of all ultraviolet wavelengths. It is employed extensively to destroy bacteria, virus, mold, spores, etc., both air- and water-borne. Short-wave ultraviolet does not occur naturally at the earth's surface; it is necessary to produce this form of radiant energy through the conversion of electrical energy. The conversion of electrical energy to short-wave radiant ultraviolet is accomplished in a mercury vapor lamp.

**Water Conditioning** — Virtually any form of water treatment designed to improve the aesthetic quality of water by the neutralization, inhibition or removal of undesirable substances. (Not health related.)

**Zeolite** — A group of hydrated sodium alumino silicates, either natural or synthetic, with ion exchange properties.

## PROTECTION AND TREATMENT



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## APPENDIX A

## APPENDIX A

### Calculating Chlorination Contact Time

To determine the proper chlorination contact time use the following procedure:

Step 1. Estimate the coldest temperature of the water to be disinfected. \_\_\_\_\_ °F

Step 2. Determine the amount of chlorine residual desired. \_\_\_\_\_ ppm

Step 3. Test the pH of the water. \_\_\_\_\_ pH

Step 4. Using Table B-1 determine the "K" value. \_\_\_\_\_ K

Step 5. Solve the following equation:

$$\text{Contact Time (minutes)} = \frac{\text{K (from Table B-1)}}{\text{Chlorine residual (ppm)}}$$

$$K = \frac{\text{ppm}}{\text{contact time}} = \text{minutes}$$

#### Example

Determine the contact time for well water that is 40°F or colder and has a pH of 8.5.

#### Solution

The "K" value from Table B-1 is 30. A chlorine residual of 4 ppm is selected (within the recommended range of 3-5 ppm). Solving the equation:

$$\text{Contact time in minutes} = 30 (K) / 4 \text{ ppm} = 7.5 \text{ minutes}$$

Required contact time is seven and one half minutes.

NOTES: Any time equal to or greater than that computed above should be satisfactory but a lower limit of 2 or 3 minutes should always be observed. A fixed concentration of chlorine and contact time may yield variable results depending on what happens to the water temperature or pH during the year. An adequate procedure may become inadequate depending upon what changes occur. Increasing the pH or decreasing the water temperature lowers the effectiveness of chlorine disinfection. To be safe, the highest pH and lowest water temperature that can be expected should be used when choosing a design value for K. In order to properly disinfect water with chlorine, the chemical must have adequate contact time with the water.

**Table A-1. "K" values for chlorine disinfection\***

Highest Expected pH	Coldest Expected Water Temperature 50°F or warmer	45°F	Temperature 40°F or colder
6.5	4	5	6
7.0	8	10	12
7.5	12	15	18
8.0	16	20	24
8.5	20	25	30
9.0	24	30	36

\* Surface water K values must be much higher to insure disinfection of pathogens like Giardia.

Source: Private Water Systems Handbook, Midwest Plan Service, 1989



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Table B-1. Chlorine contact time — pipe storage: Length of 1½ Inch plastic pipe required (feet)*						
Contact Time (min.)	Maximum Flow Rate, gpm					
	2	5	10	15	20	30
1	25	63	126	189	252	378
2	50	126	252	378	504	756
3	76	189	378	567	756	1135
4	101	252	504	756	1009	1513
5	126	315	630	946	1261	1891
6	151	378	756	1135	1513	2269
7	177	441	883	1324	1765	2648
8	202	504	1009	1513	2017	3026
9	227	567	1135	1702	2269	3404
10	252	630	1261	1891	2521	3782

*\*The lengths shown assume a 0.75 efficiency. Larger or smaller pipe may be used by making the following corrections: 1¼-inch pipe, multiply length by 1.361. Or 2-inch pipe, multiply by 0.607.*

Table B-2. Chlorine contact time — tank storage: Volume of tank required (gpm)*						
Contact Time (min.)	Maximum Flow Rate, gpm					
	3	5	10	15	20	30
1	7	18	36	54	71	107
2	14	36	71	107	143	214
3	21	54	107	161	214	321
4	29	71	143	214	286	429
5	36	89	179	268	357	536
6	43	107	214	321	429	643
7	50	125	250	375	500	750
8	57	143	286	429	571	857
9	64	161	321	482	643	964
10	71	179	357	536	714	1071

*\*The volumes shown assume a 0.28 efficiency for aggregate-filled tanks.*

APPENDIX B

Calculating Pipe and Tank Storage for Chlorination

Contact time can be provided by holding the chlorinated water in a storage tank or an extended length of supply-pipe between the water pump and the first water outlet.

The volume needed is a function of the contact time, the maximum flow rate and the efficiency of the storage device. The contact time is determined as indicated above. Flow rate is the pumping rate in gallons per minute (gpm).

The pipe or tank volume needed to produce the required contact time is computed by multiplying the contact time by the flow rate and dividing by the efficiency of the storage device as shown below. Assume a contact time of 7½ minutes and pumping rate of 10 gpm in the following examples.

Example 1: Pipe Storage

$$\text{Pipe volume} = \frac{7\frac{1}{2} \text{ min.} \times 10 \text{ gpm}}{0.75 \text{ (pipe volume efficiency)}} = 100 \text{ gallons}$$

The volume of a 1½-inch diameter plastic pipe 100 feet is 10.58 gallons. A length of 945 feet would be required to equal 100 gallons. Table C-1 has been provided to quickly calculate pipe storage.

Example 2 - Tank Storage

$$\text{Tank volume} = \frac{7\frac{1}{2} \text{ min.} \times 10 \text{ gpm}}{0.28 \text{ (aggregate filled tank volume efficiency)}} = 268 \text{ gallons}$$

A tank of 268 gallons is not standard so the next size larger must be used. Table C-2 has been provided to quickly calculate tank storage.

## APPENDIX C

## Chlorine Needed for Shock Chlorination

Tables C-1 and C-2 indicate how much household laundry bleach (5.25 percent sodium hypochlorite [NaOCl] or high-test hypochlorite powder [65-75 percent calcium hypochlorite [Ca(OCl)<sub>2</sub>] commonly referred to as HTH) is needed to yield a chlorine concentration of 200 parts per million (ppm) in wells of various depth and diameter. Water containing substantial amounts of iron, hydrogen sulfide, or organic material will require more chemical because chlorine is depleted by these substances. Table C-3 can be used to determine the storage capacity of a well casing or pipe.



**Table C-1. Pints of bleach\* needed to shock chlorinate wells of various depths and diameters.**

Well Water Depth (feet)	Well Diameter (inches)								
	4	6	8	12	18	24	30	36	48
25	0.5	1.2	2.1	4.7	10.6	18.8	29.3	42.2	75.1
50	1.0	2.3	4.3	9.4	21.1	37.5	58.7		
75	1.6	3.5	6.3	14.1	31.7	56.3			
100	2.1	4.7	8.3	18.8	42.2	75.1			
125	2.6	5.9	10.4	23.5	52.8				
150	3.1	7.0	12.5	28.2	63.4				
175	3.7	8.2	14.6	32.9	73.9				
200	4.2	9.4	15.7	37.5					
250	5.2	11.7	20.9	46.9					
300	6.3	14.1	25.0	56.3					
350	7.3	16.4	29.2	65.7					
400	8.3	18.8	33.4	75.1					
450	9.4	21.1	37.5						
500	10.4	23.5	41.7						

\*For bleach containing 5.25 percent NaOCl.

Source: Iowa State University, 1989

**Table C-2. Pounds of HTH\* needed to shock chlorinate wells of various depths and diameters**

Well Water Depth (feet)	Well Diameter (inches)								
	4	6	8	12	18	24	30	36	
25	0.04	0.09	0.16	0.35	0.8	1.4	2.2	3.2	
50	0.08	0.18	0.31	0.7	1.6	2.8	4.4	6.4	
75	0.12	0.26	0.47	1.1	2.4	4.2	6.6	9.5	
100	0.16	0.35	0.6	1.4	3.2	5.6	8.8	12.7	
125	0.20	0.44	0.8	1.8	4.0	7.1	11.0	15.9	
150	0.24	0.5	0.9	2.1	4.8	8.5	13.2	19.1	
175	0.27	0.6	1.1	2.5	5.6	9.9	15.4	22.2	
200	0.31	0.7	1.3	2.8	6.4	11.3	17.6	25.4	
250	0.39	0.9	1.6	3.5	7.9	14.1	22.1	31.8	
300	0.47	1.1	1.9	4.2	9.5	16.9	26.5	38.1	
350	0.5	1.2	2.2	4.9	11.1	19.8	30.9	44.5	
400	0.6	1.4	2.5	5.6	12.7	22.6	35.3	50.8	
450	0.7	1.6	2.8	6.4	14.3	25.4	39.7	57.2	
500	0.8	1.8	3.1	7.1	15.9	28.2	44.1	63.5	

\*For products containing 65 to 75 percent Ca(OCl)<sub>2</sub>

Source: Iowa State University, 1989

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**Table C-3. Storage capacities of well casing or pipe.**

Diameter of Well (inches)	Storage in Gallons for Each Foot of Depth
2"	0.163
3"	0.368
4"	0.654
5"	1.02
6"	1.47
7"	2.00
8"	2.62
9"	3.31
10"	4.09
11"	4.95
(feet)	
1'	5.89
2'	23.66
3'	53.02
4'	94.27
5'	147.22
6'	212.02
7'	288.60
8'	377.02
9'	477.15
10'	589.05

**Shock Chlorination Example 1:** How much household bleach, containing 5.25 percent NaOCl, would be needed to shock a 6-inch diameter, 100 foot deep well?

From Table C-1 read down the column for a 6-inch well until the row for 100 feet of water depth is reached. In this case 4.7 pints of bleach is recommended.

**Shock Chlorination Example 2:** Approximately how much HTH would be used to shock chlorinate a 6-inch diameter, 100 foot deep well?

From Table C2 enter the column for a 6-inch well and read down to the row for 100 foot depth. Approximately 0.35 pounds of HTH is needed.

It is not necessary that chlorine levels in the well be exactly 200 ppm; 100 to 200 is adequate. A strong chlorine odor, however, should be present in water pumped from the well to other parts of the plumbing system. If a strong odor is not noticeable, more chlorine should be added.