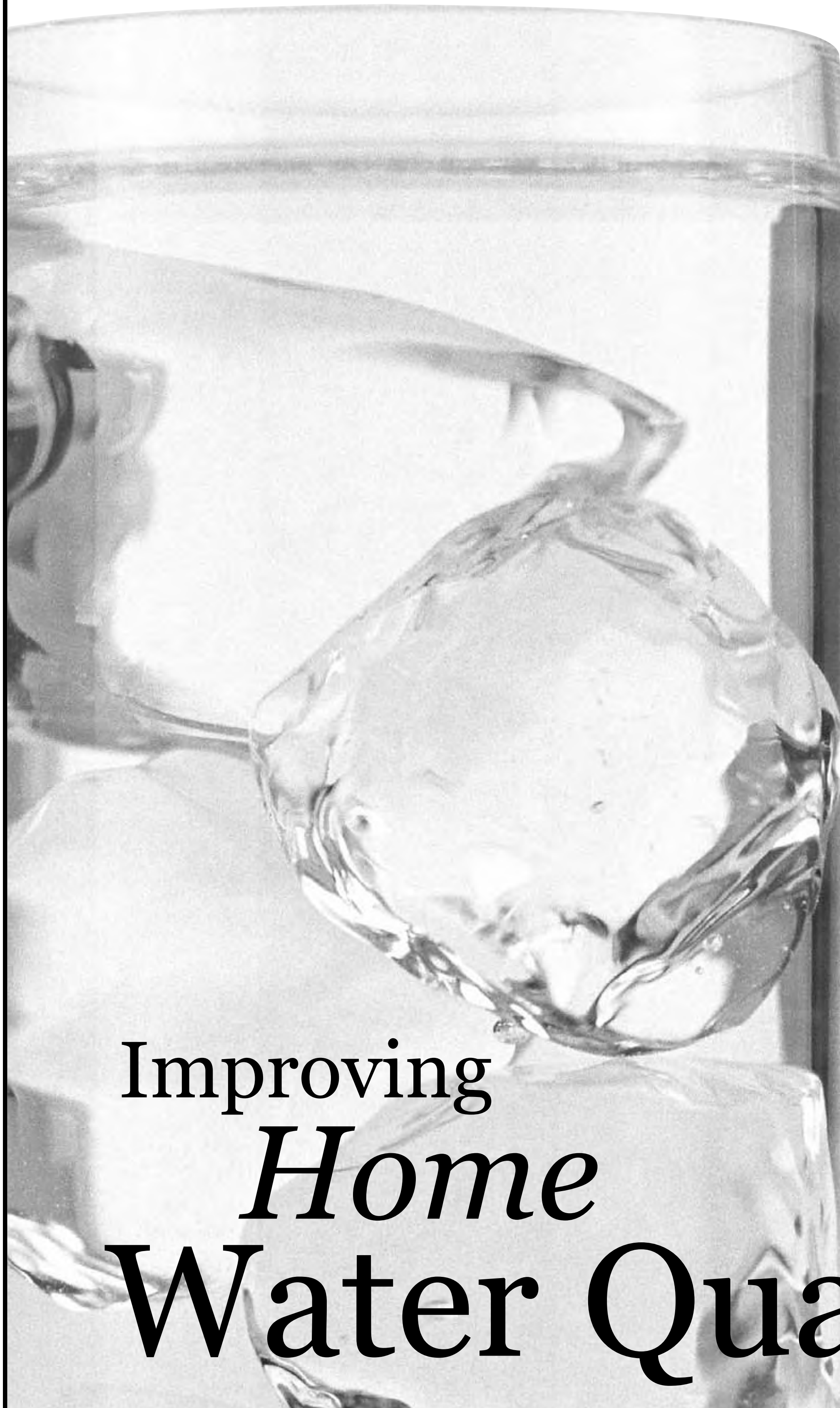
MP292



DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

University of Arkansas, United States Department of Agriculture, and County Governments Cooperating.

Improving *Home* Water Quality

Contents

Tables

Figures

Acknowledgments

The original authors were JOHN LANGSTON and PHIL TACKER, former Extension agricultural engineers. Cover by CHRIS MEUX, Extension design specialist, and inside art by RICHARD DESPAIN, former Extension specialist assistant.

Improving Home Water Quality

DR. MIKE DANIELS, professor - water quality and nutrient management, and **DR. KARL VANDEVENDER**, professor - engineer, University of Arkansas Division of Agriculture, Little Rock

Introduction

Good water is often taken for granted. Most Arkansas families obtain their water supply from a municipality or incorporated water district. All of these public supplies are disinfected, and many are treated to improve quality. These supplies are not always perfect, but the water is free of harmful bacteria, and the quality is generally acceptable to the consumer.

Some Arkansas families do not have access to public water supplies. Most of these families get water from private wells, springs and other surface sources. The quality of private water supplies ranges from excellent to very poor, and the water often has no chlorination or treatment before use. In many cases, the water contains such high mineral concentrations that it must be treated before it is usable. Home treatment equipment is available to correct many undesirable water problems.

Sometimes water which appears desirable for home use may be unsafe to drink from a health standpoint. It must be free of hazardous chemicals and disease-causing microorganisms such as bacteria, viruses and cysts. Some hazardous substances like copper, nitrates and salts are allowed in drinking water if they are below levels that can cause health problems.

Water Testing

Three general types of water testing are applicable to residential water: (1) bacteriological analysis to determine if the water supply is contaminated by human or animal waste; (2) mineral and pH analysis to determine the quality of the water and its desirability for a domestic water supply; and (3) chemical analysis to check for contamination by hazardous chemicals.

Bacteriological Testing

Bacteriological testing is done for a fee by the Arkansas Department of Health (ADH). Contact your local health office for complete instructions for sampling. The test is for a group of bacteria called coliform. Coliform bacteria are found in the digestive system and pass through in the waste of humans and warm-blooded animals. These fecal coliform bacteria are not necessarily harmful, but they indicate that the water supply is being contaminated by human or animal fecal matter which can contain pathogenic organisms. The test report will state whether the water is safe or unsafe to drink. **It is not unusual for private water supplies to have bacteriological contamination. Therefore, it is important that all new wells and private water sources be tested before being used and retested as necessary. Contact your county health office for recommendations for testing.**

Mineral and pH Testing

Mineral and pH tests are done for a fee by the University of Arkansas. Contact your local Cooperative Extension Service office for a sample bottle and sampling instructions. The sample will be sent to Fayetteville for testing by the Water Quality Laboratory at the Arkansas Water Resources Center.

A routine analysis includes fluoride, chloride, sulfate, nitrate-nitrogen, pH, electrical conductivity, total alkalinity, total hardness, sodium, copper, manganese, iron, total dissolved solids and aggressive index. Testing for specific items such as lead is available upon request. Your county Extension office has a list of available tests and the appropriate fees. The test report is returned to the county Extension office and will contain a brief recommendation for water treatment if any is necessary. **It is good practice to have a mineral analysis to determine the quality of a new water supply and to retest after six months of use. After that, repeated testing may be unnecessary unless there is an obvious change in the color, taste, odor or staining affect of the water.**

Chemical Testing

The Water Quality Laboratory does not conduct tests for chemical contamination. Testing for pesticides or other hazardous chemicals is conducted by commercial laboratories. Fees are relatively expensive for this type of analysis, particularly if the lab is asked to screen the water sample for the presence of some unknown chemical. Fees are also high for certain specific chemicals. **Chemical testing is generally considered unnecessary in Arkansas unless a known source is suspected.**

Typical Problems

Hardness

Hardness is typically the most common problem in domestic water samples. The cause is usually calcium or magnesium that dissolves in rainwater as it passes through soil and rock formations. Bicarbonate, sulfate or chloride compounds are formed in the process. Iron and manganese can also contribute to hardness.

Hardness is a nuisance because it combines with soap to form an oily curd. The harder the water, the more soap required to create suds or lather, and the more curd that will be formed. The curd creates the common bathtub ring and forms a dull coating on hair, skin and clothing. This coating is visible on glassware and dishes that have been washed in hard water.

Hardness also forms scale in pipes that can eventually restrict the flow of water. Heat accelerates the scaling process, so it builds up faster in water heaters and hot water pipes.

Treatment is not recommended unless hardness exceeds 3 grains per gallon which is 51 parts per million (ppm) – 1 grain per gallon equals 17 ppm. Small amounts of dissolved minerals cause no problems and improve the taste of water. They also coat piping and fixtures to help insulate them from corrosion. Water that is low in minerals can be very aggressive and cause rapid corrosion of pipes and fixtures even though the pH may be neutral.

There is no well-defined maximum allowable amount of hardness. However, at 30 grains per gallon (about 500 ppm), water is so hard that it has an objectionable taste and may have a laxative effect if the hardness is magnesium sulfate. At that level, soap consumption is very high and pipe and water heater scaling is severe.

Hardness is easily removed by a water softener.

Iron or Manganese

Iron and manganese are discussed together because they cause similar problems, and removal techniques are similar. Very small concentrations of the minerals cause problems – as little as 0.05 ppm manganese or 0.3 ppm iron. Iron is usually present in much higher concentrations than manganese with ten times as much being typical.

Water that is high in these minerals has a metallic or medicinal taste, and it forms the “red water” that causes most of the staining problems so familiar to many areas. These brown-yellow-red stains appear around toilet bowls or on fixtures where water stands or drips. They also appear on laundry, particularly if chlorine bleach is used. Tea or green, leafy vegetables may become very dark when prepared with water that is high in manganese.

Iron and manganese are in the groundwater where rainfall that is high in carbon dioxide has moved through igneous rocks. The minerals dissolve into the water and stay in solution as bicarbonates until they are exposed to air. Air causes oxidation of the minerals, changing them to insoluble hydroxides. The insoluble particles form a reddish-brown precipitate that stains whatever it touches.

This oxidation process is used in all iron-manganese removal systems. The difference in various processes is how the oxygen molecule is supplied to change the minerals from the soluble bicarbonate to the insoluble hydroxide form so it can be filtered from the water. Four methods are typically used: aeration, chlorination, ion exchange or a slow sand filter.

Each of these processes are pH dependent. Iron can normally be removed when the pH is about 7.5 or higher, but manganese is very difficult to remove at pH values below 8.5. The equipment typically used for iron and manganese treatment is as follows:

Equipment	Iron and Manganese
Polyphosphate chemical feeder	**0 to 2 ppm[1]**
Ion exchange filter (softener)	**0 to 10 ppm[2]**
Oxidizing filter (greensand)	**0 to 10 ppm[2]**
Chlorination-filtration	**Any amount**

[1]Polyphosphates do not remove iron or manganese from water. The iron and manganese are held in solution so the troublesome precipitate is not formed. The mineral taste will remain. This process will not work for iron bacteria or iron that has already oxidized to its insoluble form.

[2]Ion exchange and oxidizing filters vary in design and the amount of metallic minerals they will effectively remove. Most work best for small concentrations of iron and manganese, in the range of 2 ppm or less. However, some manufacturers advertise high-capacity units claimed to handle larger amounts. A complete discussion of equipment follows in this publication.

Iron or manganese bacteria should be treated only by shock chlorination or chlorination followed by filtration.

Acid Water (Low pH)

Acid water can be caused by weak concentrations of mineral acids such as sulphuric or nitric, but this is unusual. It is usually caused by dissolved carbon dioxide in groundwater. The $C0_2$ is picked up by rainfall which soaks into the groundwater table before it has a chance to dissipate. Surface water rarely has much CO_2.

Acidity is indicated by the pH of water on a scale of 0 to 14 (Figure 1). Neutral water has a pH of 7.0. Less than 7 is acid and greater than 7 is basic or alkaline. The ideal pH for domestic water is in the range of 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.

Acid water (low pH) is quite common and begins to cause problems when the pH falls below 6.8.

High pH is rarely a problem in natural water supplies. Streams, lakes and groundwater may occasionally occur as high as 8.5, but water generally does not become caustic until the pH is above 9.0 or 10.0. The only problem with water having a pH above 7.5 is that it is usually very hard.

Two problems are caused by acid water. The first is corrosion that destroys pumps, pipes and metallic plumbing fixtures. This is characterized by blue or green stains on plumbing fixtures if the piping is copper. If the pH is low enough, the corrosion process can dissolve enough copper from pipes to exceed the safe level of 1.3 ppm for drinking water. The

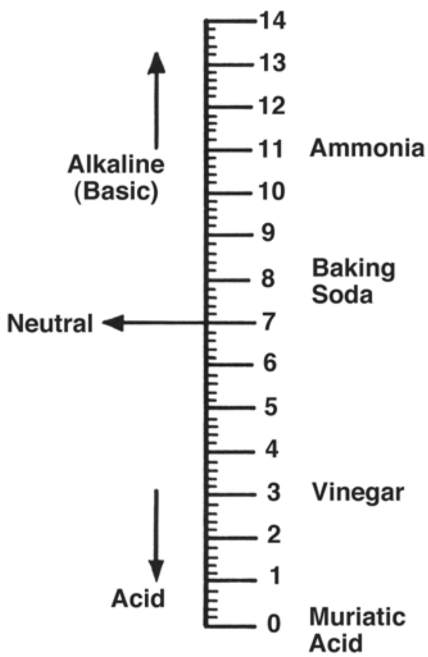


Figure 1. pH scale.

second problem caused by acid water is that it interferes with water treatment, particularly iron and manganese removal.

Two methods are typically used for treatment of acid water – aeration to remove carbon dioxide (CO_2) and the addition of alkalinity. The addition of alkalinity is usually used for home treatment, because aeration requires an open system and two pumps. Alkalinity can be added by a neutralizing tank that is simply a pressure filter tank filled with limestone or marble chips. The water dissolves calcium carbonate from the chips as it passes through the tank, raising the pH and adding to the hardness of the water. This works well if the flow rate through the tank is slow, and the acidity is caused by CO_2. If the acidity is caused by a metallic mineral, pH adjustment will not be accomplished. The major disadvantage is that hardness is increased by this treatment.

Alkalinity can also be added by injecting a soda ash solution with a chemical feed pump. The advantages of this method are that it can be more precisely calibrated for varying flow rates, there is no limit to the pH adjustment that can be made and hardness is not added.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is a general term to describe a group of dissolved salts that includes chlorides, sulphates and carbonates of sodium, potassium and magnesium. Health standards describe water with less than 500 ppm TDS as "Class 1 Water." However, drinking water with TDS concentrations as high as 1,000 ppm is permissible if the chlorides and sulphates are not too high. Some people experience adverse health aspects associated with drinking water containing certain salts. Those that are generally of most concern from a health viewpoint are sodium chloride and sodium carbonate for heart patients and magnesium sulfate because of its laxative effect.

There is no practical way to treat an entire home water supply for high salts. They cannot be "filtered" from the water. Treatment is confined to treating small quantities of water for drinking and cooking purposes, usually in the range of 2 to 3 gallons per day.

Two types of kitchen countertop units are available to remove salts. One is a small distillation unit that works by boiling the water and condensing the vapor, leaving salts and other minerals behind in the process. The other type unit is a reverse osmosis unit that allows the passage of water through a semi-permeable membrane, leaving salts and minerals behind.

Nitrates

Nitrates (NO_3) and nitrate-nitrogen (NO_3-N) both occur naturally in groundwater. They are normally low concentrations that are not a matter of concern. However, if NO_3 is higher than 45 ppm or if NO_3-N is higher than 10 ppm, the water can cause methemoglobinemia in infant babies. Blue baby is the common name for this, and it can be fatal. Babies ingest the NO_3 by drinking water or water mixed with formula. It is also possible for NO_3 to pass through the milk of nursing mothers who drink the water. There is no apparent detrimental health effect to adults.

High NO_3 can indicate contamination of the water supply by sewage, livestock waste or agricultural fertilizers. This type of contamination normally occurs because of surface water infiltration into shallow wells and surface water supplies. High nitrate levels should be taken as a warning to test for bacteriological contamination.

Certain ion exchange processes or reverse osmosis can remove NO_3. However, the equipment must be extremely reliable, particularly in households with infants. Undetected equipment failure can be fatal. Because of this possibility and the potential for pollution in high NO_3 waters, NO_3 removal for home consumption is not recommended. Instead, the cause of the NO_3 contamination should be found and eliminated.

Sulphates and Sulfides

The most common complaint when sulfides are present is, "The water stinks!" The rotten egg odor is actually hydrogen sulfide gas. It occurs naturally around oil and gas fields but is not restricted to those areas, because certain types of bacteria can reduce sulfates, sulfites or sulphur to form the hydrogen sulfide.

Occasionally the foul odor is present only on the hot water side of taps around the home. This can fool the homeowner into thinking he has a sulphur problem. If the rotten egg odor is only noticeable in the hot water, and particularly if the water heater is electric, the problem may be a chemical reaction with the sacrificial element in the water heater. The element is usually a magnesium rod that serves to retard corrosion within the tank. It may be possible to remove and discard the rod if it is contributing to the reaction that is causing the odor. You should refer to the manufacturer's recommendations or contact a plumber before removing the rod. Some water heater manufacturers offer models that have a rod made from materials other than magnesium.

Hydrogen sulfide causes more than a taste and odor problem. It is very corrosive, and it can combine with other minerals to cause black water and black stains. Iron sulfide is quite common when iron and hydrogen sulfide are both present. This forms a black precipitate that causes severe staining and laundry problems. Sulfur-reducing bacteria can also cause problems by developing black slime materials in pipes, fixtures, tanks and toilet flush tanks.

Hydrogen sulfide or other forms of sulfur can be handled in much the same manner as iron and manganese. It must be oxidized and the precipitate filtered out. Aeration followed by filtration, a manganese greensand oxidation type filter or chlorination followed by filtration can be effective for sulfur removal. Suggested equipment is as follows:

Equipment	Sulfur
Oxidizing filter (manganese greensand)	**0 to 5 ppm**
Chlorination and filtration	**Any amount**

Aeration is not encouraged for home water treatment, because it is an open system that requires two pumps.

Home Water Treatment Equipment

Water Softeners

A softener is a tank filled with a zeolite resin that is designed to remove calcium and magnesium hardness by ion exchange. Softeners can also be used to remove iron and manganese that is in the soluble form if the combined concentration of the two minerals does not exceed the capacity of the softener. Manufacturers' specifications generally claim that their softeners will tolerate clear water iron up to about 5 ppm per cubic foot of zeolite bed volume. Oxidized iron or manganese (the insoluble form) should be removed by filtration before it reaches the softener, or it will accumulate on top of the zeolite and foul the softener. The slimy material produced by iron bacteria will also foul a softener.

The ion exchange process typically removes minerals from water by trading sodium ions for the calcium or magnesium ions that are associated with water hardness. **The sodium content is increased in softened water. Persons on low-sodium diets should consult their physician before drinking softened water. If the sodium is a health concern, it is possible to use potassium chloride as a substitute for the sodium chloride.**

Sodium or potassium ions must periodically be replaced by flushing the softener tank with a solution of sodium or potassium chloride salt. Salt consumption is usually about 1/2 pound per 1,000 grains of hardness removed. How often regeneration is required depends on the hardness of the water, size of the softener and the amount of water used. Typically, this is about once per week with automatic two-tank units and as long as once per month with large single-tank units requiring manual service.

Table 1 lists the gallons of water that can be softened with various sized softeners at different levels of water hardness.

Table 1. Water Softener Selector Table

Hardness of Water Supply in Grains Per Gallon	Rated Capacity of Softener in Grains of Hardness Exchange				
	10,000	20,000	50,000	75,000	100,000
	Gallons of Soft Water Between Regenerations				
5	2,000	4,000	10,000	15,000	20,000
10	1,000	2,000	5,000	7,500	10,000
15	666	1,333	3,333	5,000	6,666
20	500	1,000	2,500	3,750	5,000
25	400	800	2,000	3,000	4,000
50	200	400	1,000	1,500	2,000
100	100	200	500	750	1,000

An average family uses about 75 gallons of water per person per day. Multiplying 75 times the number of occupants in the household yields an estimate of the daily water use, Dividing the total water use into the gallons of water between regenerations shown in Table 1 provides an estimate of how often the softener has to be regenerated.

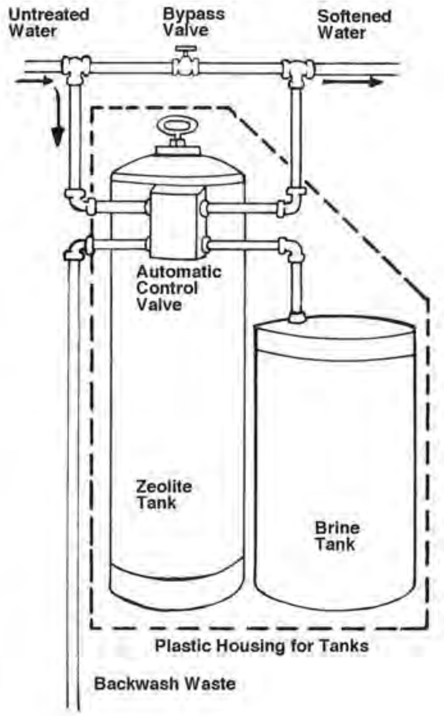


Figure 2. Automatic water softener – two tanks.

A two-tank softener with automatic controls can be programmed to regenerate itself as needed (Figure 2). The regeneration cycle first back-flushes the tank to remove dirt and oxidized iron or manganese that has been filtered out on top of the resin material. Then a brine solution from the salt tank flushes the zeolite tank to recharge the resin material with salt ions and release the calcium and magnesium ions. The zeolite tank is then rinsed with clear water to flush out the brine material. This procedure is usually programmed to occur late at night, because the softener is out of service during the regeneration cycle.

Water softeners can be leased from a commercial water service company for a fee, or a homeowner can purchase his own equipment. The advantage of a water service company is that they install and maintain the equipment.

There is another method for treating water hardness that uses a catalytic process rather than the salt ion exchange process. Anyone interested in treatment alternatives to the salt ion exchange process should contact a water treatment company or explore the internet for more information.

Reverse Osmosis (RO) Units

A very thin membrane separates two chambers in a reverse osmosis (RO) water treatment device. Raw water with all its impurities is pressurized on one side of the membrane. Water seeps through the membrane and collects on the other side, leaving the impurities behind on the membrane. Raw water entering the RO unit rinses accumulated impurities from the membrane and periodically discharges them along with some waste water. This prevents high concentrations of impurities from accumulating on the raw water side of the unit.

The quality of water from a properly working RO unit is similar to that of distilled water. Removal of certain chemicals and those otherwise untreatable problems such as salt and nitrate removal are possible with RO equipment.

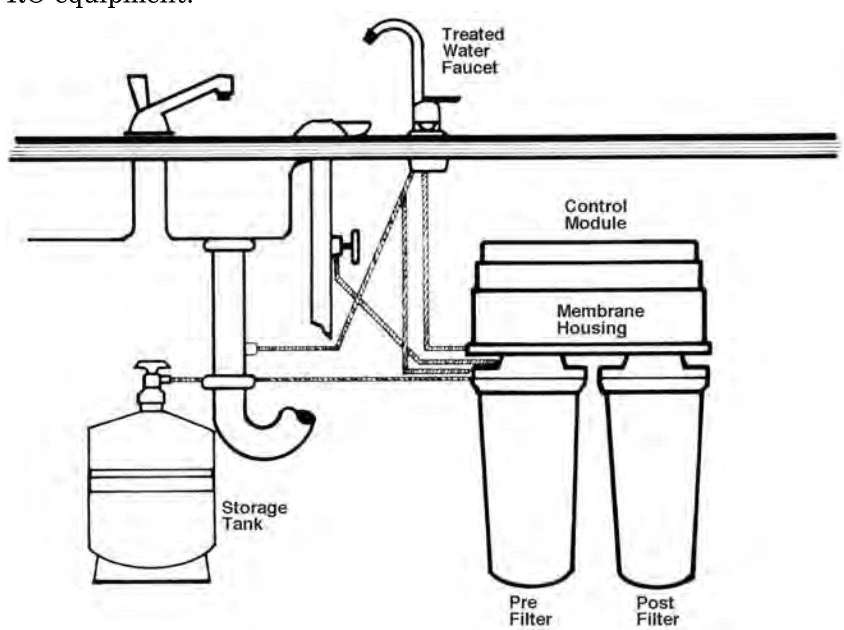


Figure 3. Undercounter reverse osmosis unit.

High-capacity RO equipment is expensive, but small-capacity units that can treat about 5 gallons of water per day are available at reasonable prices from equipment dealers. These units are usually located near the kitchen sink and have a two-gallon reservoir to hold treated water for cooking and drinking (Figure 3).

One disadvantage of an RO unit is that even though it will handle salt, nitrates and certain chemicals, the water must be in excellent condition regarding other quality concerns before it reaches the reverse osmosis unit. Several types of RO membranes are available. Water should be thoroughly tested before one is selected. The membrane in an RO unit is very easily fouled, and it is expensive to replace. Some units include micro-filtration to pretreat the water before it gets to the RO membrane. Depending on the contaminant being removed, a small booster pump may be required to develop enough pressure on the membrane to ensure treatment. Water generally has to have thorough pretreatment (usually with a water softener) before any type membrane will survive for very long. Some membranes will not tolerate iron, manganese, sulfur, turbidity, hardness or even chlorine. The annual costs of replacing filters and membranes are relatively high for most RO units.

Pressure Filters

These devices are used for a variety of water treatment processes such as taste and odor improvement, iron and manganese removal and removal of suspended matter (turbidity) in water that gives it a dirty appearance. Pressure filters are fully enclosed tank type filters that operate at the same pressure as the water delivery system (Figure 4). They have two advantages over open filters – they are not open to contamination, and they can operate with only one pump in the water system. Since pressure filters are part of an enclosed system, the same pump that lifts water from the well can push the water through the filter tank and pressure tank to the house.

The design rate for water flow through pressure filters should be about 3 to 4 gallons per minute (gpm) per square foot (ft^2). This can be more or less depending on the filter material in the tank, quality of water being treated and the desired level of treatment. Higher rates of 10 to 12 gpm per ft^2 can be forced through the tank for short periods of demand if the pressure is high enough. However, consistently high filtration rates give poor treatment and require frequent backwashing.

The correct flow rate through the media during service and the proper backwashing rate during cleaning are the secrets to effective water filtration. Adequate flow is required to clear the filter bed of sediment before it becomes too dirty. Twelve to 15 gpm per ft^2 is the backwash rate required to keep most filters clean. Some filters are backwashed daily, but most are backwashed once or twice per week depending on the condition of the water and the amount used. Backwashing can be done manually by turning valves on and off by hand. However, backwashing is normally accomplished with electric valves that are set to automatically backwash the filter as scheduled by a timer.

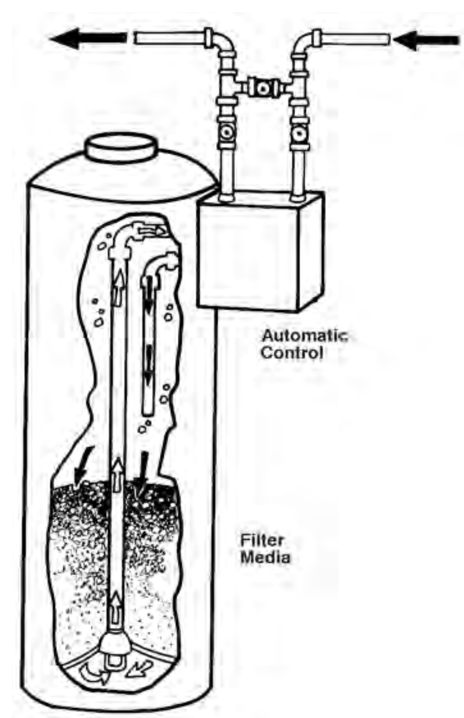


Figure 4. Pressure filter with automatic backwash control.

Table 2. Approximate Flow and Backwash Rates for Pressure Filters

Tank Diameter (inches)	Ideal Service Flow (gpm)	Peak Flow (gpm)	Backwash Flow (gpm)
8	1.5	3.5	4
10	2.0	5.0	6
12	3.0	7.0	9
16	5.0	14.0	16
24	11.0	30.0	35

Table 2 above shows the approximate flow rates and backwash rates for various diameter filters.

Check manufacturers' data for more exact figures. Most home water supply systems cannot supply over 10 to 15 gpm flow. Therefore, the size filter that can be used is limited by the backwash water available. That is why many of the home pressure filters are tall bottle-type units that are only 8 to 10 inches in diameter. This size filter can be backwashed with 8 to 10 gpm flow. However, the low surface area only provides treatment for a limited water flow of about 2 gpm average or about 5 gpm for short peak flows.

It may be necessary to limit the number of fixtures serviced by these small-diameter filters by avoiding putting the whole house on the filtered water system. Greater capacity can be obtained by installing two of the low-capacity filters in a parallel arrangement so the flow is split during service, with half of the water going through each filter. The filters are backwashed one at a time in this arrangement (Figure 5).

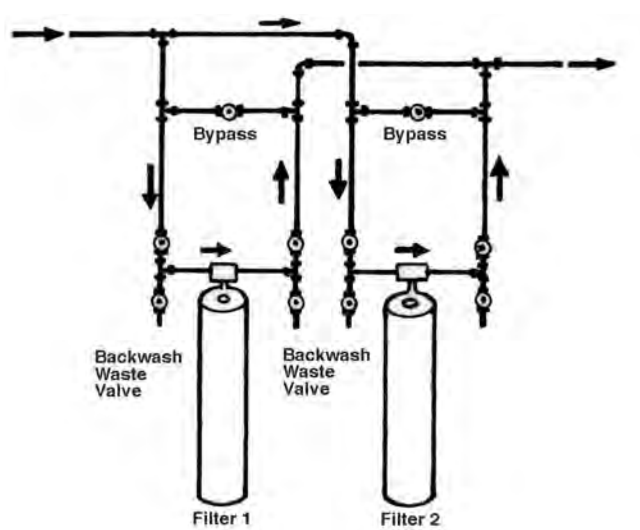


Figure 5. Parallel connection for small-diameter pressure filters.

Larger filters are available (16 to 20 inches in diameter), and they provide much better filtration and treatment for higher flows. However, a flow of 20 gpm or more is needed for backwashing (Figure 6).

The water treatment performed by a pressure filter is determined by the filter media that is inside the tank. Most companies that sell filter equipment use the same tank for all treatments but change the inside filter media depending on the type of treatment needed.

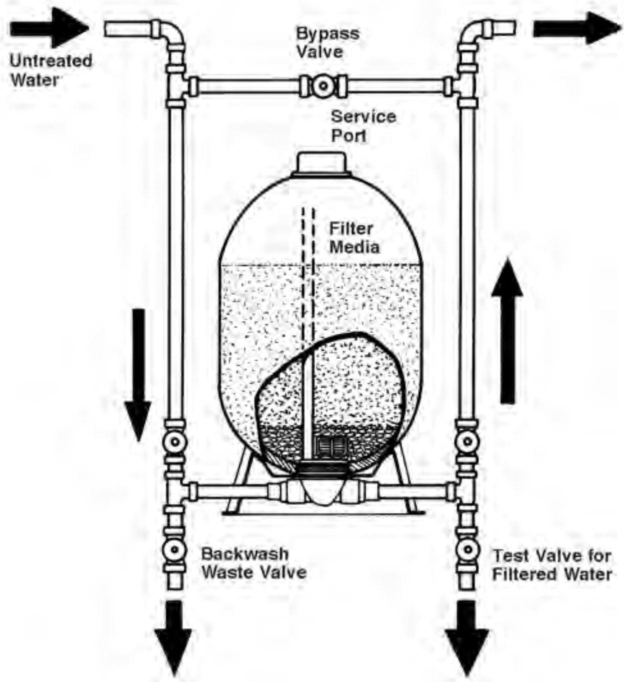


Figure 6. Large-diameter pressure filter.

Pressure filters can be purchased and installed by the homeowner or rented from a water service company.

Manganese Greensand Oxidizing Filter

These filters are often referred to as iron filters or red water filters. The manganese greensand media is a resin designed to remove iron and manganese that is in solution. It will also act as a filter and catch iron and manganese precipitates that have been oxidized before reaching the filter. Some of these units are effective for iron and manganese removal in combined concentrations up to 10 ppm. This type of filter will not tolerate iron bacteria, because the slimy material that is produced coats the greensand and fouls it. Greensand can also be effective in removing sulfur compounds (primarily hydrogen sulfide) in concentrations up to about 5 ppm.

The unit works by providing oxygen to the iron and manganese from the greensand bed. As the metallic minerals flow through the tank, they are oxidized and change from their soluble to insoluble form. These minerals become trapped as rust particles within the greensand filter bed. Because oxidation occurs as water flows through the filter bed, much of the precipitate is filtered out near the discharge side of the greensand bed. If backwashing is not thorough, the precipitated iron and manganese can be expelled from the filter in large masses and cause a disgusting discharge from a faucet or ruin a washer load of clothes.

Manganese greensand filters must be regenerated with a new solution of potassium permanganate when the oxygen is depleted. This process is similar to regenerating a softener and usually must be implemented at intervals from one to four weeks depending on the condition of the water, size of the unit and water consumption.

Taste and Odor Filter

Activated carbon granules are used to absorb a variety of tastes and odors that do not have an easily defined source. Activated carbon is also used to remove chlorine taste and odors from water that has been chlorinated. The carbon granules also provide mechanical filtration much the same as sand. However, activated carbon is more expensive than sand and is normally not used unless taste and odor removal or dechlorination is desired. Carbon must be replaced once it has utilized all of its absorption capacity.

Activated carbon will not control the following specific taste and odor problems: the metallic taste caused by iron and manganese, the rotten egg taste and odor associated with hydrogen sulfide, the salty taste caused by high salt concentrations and the taste and odor associated with some surface water algaes.

Sand Filter to Remove Turbidity (Dirty Appearance)

Finely-graded sands are used as filter media to remove suspended undissolved particles from water. There is no ion exchange or oxidation process taking place within a sand filter, just the process of trapping particles as they move through the void spaces within the sand bed. The particles may be very small and almost invisible as with precipitated iron or manganese. Or they may be large enough to cause the water to have a muddy or dirty appearance. This is usually caused by clay or sand particles, algae or organic matter of some type.

A chemical injector pump is always installed with a sand filter because of the following: If the sand filter is used to remove iron or manganese, an oxidizing agent (chlorine or potassium permanganate) must be injected ahead of the filter to cause the minerals to form solid particles so the filter can remove them. If the sand filter is being used to remove turbidity, chlorine is needed to ensure safety of the drinking water, because turbidity usually indicates there is contamination by surface water.

Neutralizing Filters

This is normally a pressure filter tank filled with limestone chips that serves the purpose of adding alkalinity to the water. As the water passes through the filter bed, calcium carbonate is dissolved into the water and the pH of the water is increased. The calcium carbonate also increases the hardness of the water, so the need for softening is increased.

Filter is not a good description of this equipment, because it is actually a contact tank to expose the water to the limestone chips. It is a very poor filter in terms of removing suspended particles, because the chips are relatively large and provide little resistance to the flow of water. However, enough filtration takes place that it is necessary to occasionally backwash the filter tank. And, if filtration is desirable, it is possible to add layers of fine sand or activated carbon to the tank.

Neutralizing filters do a good job of increasing the pH if the flow rate through the tank is low and the acid water problem is caused by carbon dioxide. However, if the problem is due to mineral acids such as hydrochloric or sulfuric, the limestone chips may be ineffective.

High flow rates at times of peak water consumption offer very little time for water to be in contact with the limestone chips as the water passes through the tank. Less adjustment to pH will occur during those times than periods of low flows.

Point-of-Use Filters

These filters are intended for treatment of limited quantities of water. They are often installed at the kitchen sink to treat water for cooking and drinking (Figure 7). Backwashing is not possible with these filters, so they have replaceable elements that must be changed when the filter becomes loaded with impurities.

The filter life depends on the quantity and quality of water used. Activated carbon filters for dechlorination and improvement of taste and odor are very popular point-of-use filters. Elements for other types of treatment are available. Small distillation units and reverse osmosis units are available if you desire more treatment than is possible with simple filtration.

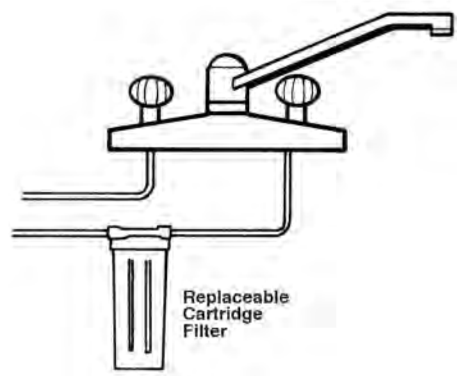


Figure 7. Point-of-use filter.

Soda Ash Feeding

Soda ash is sodium carbonate (Na_2CO_3), and it is used extensively in water treatment to add alkalinity to water to increase pH. It is available as a 58 percent light-grade powder from water treatment and chemical supply companies in 100-pound bags.

Soda ash is added to water by mixing a strong solution of the material and injecting that into the water system with a chemical feed pump. Soda ash is most often used to raise the pH so iron and manganese can be removed, and it is often injected in conjunction with chlorine. Soda ash and chlorine can be mixed in the same solution container and fed together with the same pump. However, calibration to maintain proper chlorine residual and correct pH is more difficult when done this way. Some homeowners prefer to maintain separate solution containers and separate chemical pumps or to use a pump that meters the two chemicals independent of each other.

Regardless of the arrangement, the chemical pump for soda ash is wired with the water pump so they run at the same time to allow precise calibration at any flow rate.

The solubility of soda ash is dependent on temperature. The following chart shows how much will stay in solution without forming a precipitate in the solution tank, injector line and chemical feed pump.

Solubility of Soda Ash (Na_2C0_3)

Pounds Per Gallon			
32ºF	**50ºF**	**68ºF**	**86ºF**
0.58	**1.04**	**1.79**	**3.23**

About 3 pounds of soda ash to 4 or 5 gallons of water is the strongest solution that should be attempted. Soda ash has a tendency to stop up feeder lines and check valves associated with the chemical feed pump. Problems can be minimized by keeping the solution mixture as weak as possible to get the pH adjustment needed.

Several water treatment equipment companies make a plastic solution tank designed to work with their chemical feed pump. A 12- to 15–gallon high-quality hard plastic trash can with a cover makes a good solution container. The cheaper soft plastic containers will not work because they will split when filled with water.

Calibration of Soda Ash

A pH indicator kit is required to determine how much soda ash solution must be added for pH adjustment. Test kits are available from swimming pool chemical supply companies, water treatment supply companies and companies that sell chemical feed pumps. It is usually desirable to purchase a test kit that checks both pH and chlorine residual. **Always calibrate soda ash to achieve proper pH before injecting chlorine into a water system. Chlorine causes the test for pH to give a false reading.**

Install the chemical feed pump according to manufacturer's instructions and inject the soda ash trial solution as near the wellhead as possible. This raises the pH at the earliest opportunity to protect as much piping and equipment as possible. It also provides the maximum time for mixing with water before it reaches a fixture. Installing a feed line into the well to feed soda ash and/or chlorine at the pump intake is an ideal injection approach. However, if the pump is in a high-yielding aquifer, the solution may be diluted below an effective concentration before the pump can pick it up.

Set the feed rate on the chemical feed pump as instructed by the manufacturer and open a hydrant near the wellhead so the well pump and chemical feed pump run. After it has run long enough to begin injecting soda ash, catch a sample and measure the pH. If the pH is low, it can be increased by increasing the feed rate on the pump. If it is high, the rate can be turned down or water can be added to dilute the solution tank. **Let the water run for about 20 minutes between adjustments to completely flush the system.**

Increase the pH to about 7.5 unless the objective is the removal of manganese or reduction of the corrosion potential because of a low aggressive index. For these situations, raising the pH to about 8.5 may be necessary, but the pH should never exceed 9.0.

Chlorination

No other method of home water treatment has as many benefits as chlorination.

Chlorine is an oxidizing agent that changes several problem minerals like iron, manganese and hydrogen sulfide into insoluble precipitates so they can be filtered from the water.

Chlorine effectively improves taste and odor of drinking water by oxidizing noxious substances and by preventing the growth of odor-causing algaes. When surface water is used as the home water supply, chlorine also prevents algaes from developing within pipes and tanks.

Chlorine is a very effective disinfecting agent that kills most pathogenic bacteria, virus and cyst organisms if the chlorine is properly used. It also kills the non-pathogenic iron, manganese and sulfur bacterias.

Chlorine Demand

When chlorine is added to water, it combines with organic and inorganic materials and oxidizes some of the minerals that are present. The amount required to satisfy these needs is called the chlorine demand.

Effective chlorination requires adding enough chlorine to meet the demand of the water plus some additional chlorine to provide disinfection. If too little chlorine is added, complete oxidation of problem minerals will not occur and the free chlorine available to kill pathogens will be inadequate.

The amount of chlorine required to satisfy the demand depends on what is in the water. Water that has little ammonia or mineral content may have a demand of less than 1 part per million (ppm). Demand can easily be as high as 10 ppm if the water is high in ammonia, iron or manganese. Table 3 lists the chlorine dosage required to meet certain water treatment objectives. The dosage for each mineral should be calculated and then added together to determine the total chlorine dosage.

Table 3. Approximate Chlorine Dosage for Oxidation of Selected Minerals (ppm)

Manganese (Mn)	**1.3 x Mn content**
Iron (Fe)	**0.64 x Fe content**
Hydrogen Sulfide (H_2S)	**2.2 x H_2S content**

Example:
Manganese (Mn) level is 0.35 ppm and iron (Fe) is 1.55 ppm.

Chlorine dosage for Mn:	1.3 x 0.35 ppm = 0.5 ppm
Chlorine dosage for Fe:	0.64 x 1.55 = 1.0 ppm
Total chlorine dosage:	0.5 + 1.0 = 1.5 ppm

Contact Time

It takes some time for chlorine to accomplish effective disinfection or oxidation. The time required depends on the concentration of chlorine in the water, temperature and pH of the water and what the desired result is.

Oxidation of iron and hydrogen sulfide is almost instantaneous, but manganese oxidizes very slowly.

Disinfection for most water-borne disease-causing organisms occurs after 10 minutes of contact time if pH is 6 to 8 and the free available chlorine residual is between 0.2 to 0.4 ppm. However, some cysts can tolerate 1 ppm chlorine for more than 1 hour, and some nematodes can live for more than 2 hours in 3 ppm chlorine solutions.

Recommendation: Home water treatment systems should have enough holding capacity within the distribution system to provide at least 20 minutes contact time to ensure mineral oxidation and to achieve an acceptable level of disinfection. However, a great deal of storage capacity is required within the treatment system to assure 20 minutes contact time.

Contact time is determined by the following formula:

$$\textbf{Contact time (min)} = \frac{\textbf{volume of water system (gal)}}{\textbf{pumping rate (gpm)}}$$

For example, at 5 gpm flow, a system capacity of 100 gallons is needed to ensure 20 minutes contact time (20 min = 100 gals/5 gpm).

The pumping rate can be estimated by opening a hydrant near the pump and recording the seconds required to fill a 5-gallon bucket. Pumping rate is then estimated as follows:

Pumping rate (gpm) = 30 seconds ÷ seconds to catch 5 gallons

For example, pumping rate is 5 gpm if it takes 60 seconds to catch 5 gallons (300 ÷ 60 seconds = 5 gpm).

The best way to ensure contact time is to install a contact tank, plumbed with a bottom inlet and top outlet such that it is completely filled with water. This tank is in addition to the pressure tank. The following illustration shows suggested contact tank sizes for various pumping rates (Figure 8).

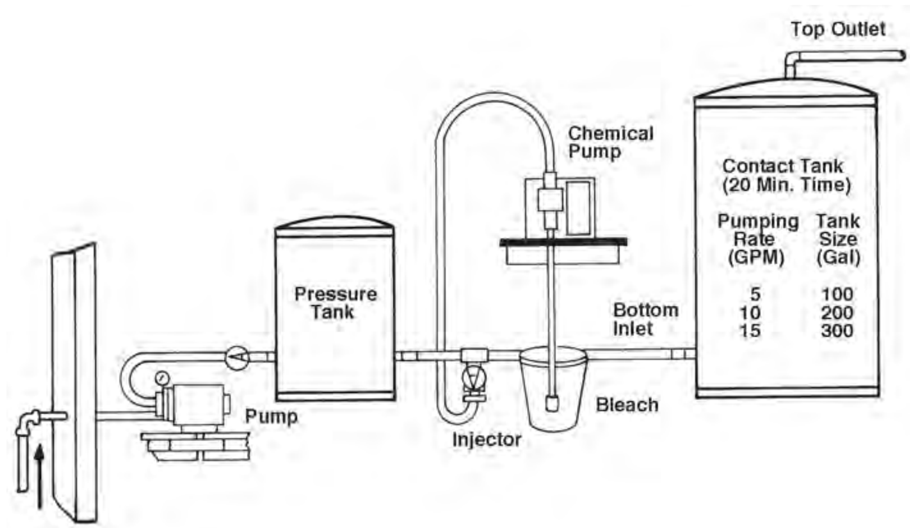


Figure 8. Contact tank size for various pumping rates.

Contact time can be reduced if the chlorine dosage is increased in the water. The following shows the relationship between contact time and concentration of free available chlorine.

Table 4. Recommended Contact Time for Disinfection of Water at 40 to 50 Degrees Fahrenheit

Free Chlorine Residual (ppm)	Contact Time (min)
0.2	40
0.4	20
1.0	8
2.0	4
4.0	2
8.0	1

Too much free chlorine is undesirable. At concentrations above 1 ppm, there will be a distinct chlorine taste and odor. Therefore, adding extra chlorine to shorten contact time requires dechlorination before the water is used. This is generally done with an activated carbon filter that absorbs the free chlorine. The carbon will occasionally be replaced depending on the chlorine concentration and the amount of water used.

Continuous Chlorination

This involves injecting low rates of chlorine into the water system to continuously treat all water flowing through the system. Enough is injected to meet the demand and leave a free residual of 0.2 to 0.4 ppm; more if the contact time is short. Water usually requires the addition of anywhere from 1 to 10 ppm total chlorine.

Household bleach is approximately 5 percent chlorine, so it is generally used as the chlorine source for home water systems. It is injected into the water with a chemical feed pump. The feed pump is wired electrically into the pressure switch controlling the well pump so the well pump and feed pump run at the same time. This treats water as it is pumped and allows a very accurate calibration of the chlorine dosage regardless of how much water is pumped (Figure 9).

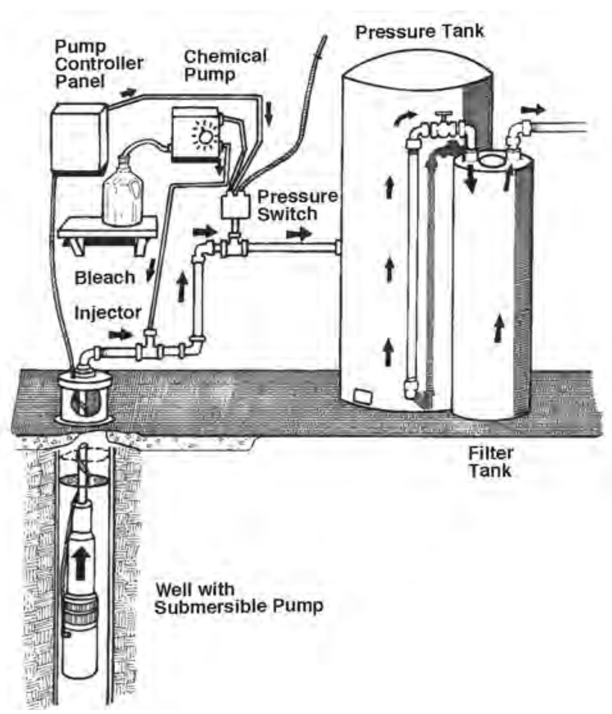


Figure 9. Chlorination by chemical feed pump followed by filtration.

Chlorine Calibration

Chlorine can be fed directly from a bleach jug if the chemical feed pump injection rate can be set low enough to achieve the desired free available chlorine residual. If this is not possible, then a diluted solution can be prepared by adding water. Dilution is always necessary if chlorine and soda ash are fed from the same solution tank.

Install the chemical feed pump as discussed in the paragraphs on feeding soda ash. Open a hydrant so both the well pump and feed pump run until you are satisfied that chlorine is being injected into the system. Catch some of the water in a plastic or glass container and seal the container before letting it set for at least 20 minutes. Then test for free available chlorine. If it is lower than desired, set the injection rate of the feed pump higher. If it is higher than needed, set the injection rate lower or add water to dilute the bleach solution. Always let the water run at least 20 minutes between adjustments so the system is completely flushed before conducting a new test.

The chemical solution tank should have a tight-fitting cover, and no more than a seven-day supply of the solution should be mixed. An open tank or long storage periods cause the solution to lose chlorine.

If you use a charcoal (activated carbon) filter for dechlorination, calibrate the system before running any water through the charcoal filter. High concentrations of chlorine can overload the carbon bed, shortening its life.

Shock Chlorination

Shock chlorination is generally used as a flush or wash-down treatment for disinfection. A chlorine concentration in excess of 50 ppm is usually used for shock chlorination.

New water wells or wells where the pump has been pulled for service should always be shock chlorinated. Wells that have been contaminated by animals or rodents should be disinfected with this process. It should also be used to wash open slow sand filter tanks or closed water treatment equipment that has been opened for servicing. Shock chlorination is an excellent treatment for killing slime-producing bacteria that feed on iron, manganese or sulfur.

Household bleach is usually used for shock chlorination. One quart of bleach is typically the minimum used, although that may be more than necessary. The bleach is generally diluted in a 5-gallon plastic bucket to facilitate handling or mixing the chlorine. This is particularly true if it is to be poured into a well in a manner that will thoroughly wet the inside walls of the well casing.

Never shock chlorinate an activated carbon filter. The chlorine saturates the carbon and renders it ineffective for taste and odor removal.

Table 5. Household Bleach Required Per 50 Feet of Water Depth to Provide at Least 50 ppm Chlorine

Well Diameter (Inches)	Gallons of Water Per 50 Feet of Water Depth	Bleach Required Per 50 Feet of Water Depth
4	32	1 cup
6	73	1 pint
8	128	1 pint
24	1174	5 quarts
30	1833	8 quarts
36	2640	11 quarts

Table 5 lists the minimum quantity of household bleach needed to provide 50 ppm chlorine for shock chlorination of wells and equipment.

Pour the chlorine solution into the well and pump it through the treatment equipment and piping if they are to be disinfected. A good practice is to let this solution stay in the well, equipment and piping overnight. Then pump the well until all noticeable chlorine odor is gone from the water. **Do not use the water for any purpose with this concentration of chlorine present.**

Feeding Soda Ash and Chlorine Together

Soda ash and chlorine can be mixed together in a single solution container and injected with the same chemical feed pump, but calibration is tricky.

First, calibrate the soda ash mixture to the correct pH as described on page 14. This must be done before adding any chlorine, because chlorine will cause the pH test to give incorrect results. After the pH adjustment is correct, you cannot adjust the chemical feed pump again or you will change the pH.

Since the feed pump output cannot be changed, chlorine calibration has to be determined by pouring the correct amount of bleach in the solution container. This will be a trial-and-error method that begins by adding 1 quart of bleach per each 5 gallons of solution. Operate the pump system until chlorine is being injected and then catch a sample of water in a container that you seal. The sample must be taken before the water passes through an activated carbon filter if one is used.

Let the sample sit for 20 minutes and test for free available (residual) chlorine. If the residual chlorine is too low, add another cup of bleach to the solution and repeat the process. If it is too high, you will have to pour the solution out and start over or wait until the solution is depleted and then mix a new batch using less bleach. This process may take several weeks before arriving at an acceptable calibration. The pH and residual chlorine levels should be checked every few months. Recalibration may become necessary if the quality of the well water changes significantly.

Typical Problems and Possible Treatments

Hardness

Symptoms
- Large quantities of soap required.
- Oily ring develops in bathtub and sink after each use.
- Scale forms inside pipes and water heaters.
- Glassware appears cloudy after dishwashing.

Remedy
- Water softener

Comments
- If iron is also a problem, select a softener that can tolerate the iron. At concentrations above 2 ppm, it may be best to remove the iron before softening.
- People on low-sodium diets should consult their physician before drinking water softened by a sodium chloride exchange process.
- If sodium is a concern, consider using potassium chloride or investigate the catalytic process for water softening.

Iron or Manganese (red water)

Symptoms
- Brownish-red to black stains in toilet bowls or areas where water stands or drips.
- Metallic taste in water.
- Rusty stains appear on laundry when chlorine bleach is used.
- Tea and green, leafy vegetables darken when cooked in the water.

Remedies

– Polyphosphate feeder	0 to 2 ppm
– Ion exchange filter (softener)	0 to 10 ppm
– Oxidizing filter (manganese greensand)	0 to 10 ppm
– Chlorination followed by filtration	any amounts

Comments
- Polyphosphate feeders do not remove iron but tend to hold it in solution; the iron taste will still be present.
- Many softeners will tolerate no more than 2 ppm iron; a high-capacity unit is required to handle 10 ppm. Iron or manganese must be in solution for the softener to work properly; softeners will not tolerate suspended iron or manganese.
- Most manganese greensand filters are best suited for 5 ppm of iron or less.
- Softeners or oxidizing filters will be rapidly fouled by the gelatinous material associated with iron or manganese bacteria.

Iron or Manganese Bacteria

Symptoms

- Brownish-red to black slimy, gelatinous material collects inside water storage tanks or toilet flush tanks.
- Brownish-red to black fuzzy flakes appear suspended in water.
- Pipes, fixtures, pump intakes or valves on water system become clogged with gelatin-appearing material.

Remedy

- Clean all accessible areas of the water system; shock chlorinate the well and water supply system; thoroughly pump the system.

Comment

- Shock chlorination requires the addition of at least 50 ppm chlorine.
- Thoroughly pump the system to discharge the high concentration of chlorine before using the water, and don't put the water through charcoal filters.

Acid Water (low pH)

Symptoms

- Water is corrosive to pipes, fixtures and equipment.
- Water dripping from iron pipes has rusty color.
- Water dripping from copper pipes deposits green stain.

Remedies

- Neutralizing filter
- Aeration
- Soda ash injection

Comments

- Neutralizing filters have limited capacity and usually need to be followed by a softener because they increase hardness.
- Aeration is effective only if acidity is due to carbon dioxide; it opens the system to contamination; two pumps are required to operate the system.

Hydrogen Sulfide Gas

Symptoms

- Rotten egg odor in hot and cold water.
- Water is corrosive to piping and fixtures.
- Rapid tarnishing of silverware.
- Black stains on fixtures and black specks in water.

Remedies

– Oxidizing filter (manganese greensand)	0 to 5 ppm
– Chlorination followed by filtration	any amounts

Comment

- Rotten egg odor on the hot side only can mean water is reacting with the sacrificial element in the water heater.
- Check with water heater manufacturer or plumber before removing the element.

Turbid Water (cloudy)

Symptom
– Water has a dirty or cloudy appearance.

Remedies
– Filter
– Possible chlorination

Comment
– Turbidity can be an indication that surface water is contaminating the well. It should be taken as a warning to have the water tested for bacteriological contamination.

Nitrates

Symptoms
– None

Remedy
– Reverse osmosis unit, elimination of cause

Comments
– High nitrates can indicate surface water contamination of a well and should be taken as a warning to test for bacteriological contamination. Nitrates can be ingested in drinking water or passed through the milk of breastfeeding mothers to cause "blue baby" (methemoglobinemia) which can be fatal to infants. Because of the possibility of equipment failure, treatment is not recommended in homes with babies unless there is no other possible source of water.

Total Dissolved Solids (TDS)

Symptom
– Taste may or may not be noticeable.

Remedies
– Reverse osmosis
– Distillation

Comment
– Point-of-use equipment to treat small quantities of water at the kitchen sink for cooking and drinking is all that is practical.

Aggressive Water – Aggressive Index (AI)

AI > 12: Non-aggressive
AI 10 to 12: Moderately aggressive
AI < 10: Highly aggressive

Symptoms
– Corrosion of metal pipes and fixtures.
– Green stains around water outlets serviced by copper pipes.

Remedy

– Increase pH to 8.0 or 8.5 with neutralizing filter or by adding soda ash. A phosphate feeder may also be added in severe cases.

Comment

– Water can be very corrosive even though the pH is neutral. This occurs in water where there is no hardness or dissolved minerals to coat piping and protect it from the natural corrosiveness of water.

Selected References

American Association for Vocational Instructional Materials, *Planning for an Individual Water System*, pp. 57-72, 1973.

The American Water Works Association, Inc., *Water Quality and Treatment*, McGraw Hill.

The American Water Works Association, Inc., *Water Treatment Plant Design*, New York, 1971.

Clark, John W., Warren Viessman, Jr., and Mark J. Hammer, *Water Supply and Pollution Control*, Harper and Row, New York, 1977.

Gattis, James L., *Water Conditioning*, Circular 512, University of Arkansas Cooperative Extension Service, Little Rock, Arkansas.

Kansas State University Cooperative Extension Service, *Household Water Quality Handbook*, 1987.

Lehr, Jay H., Tyler E. Gass, Wayne A. Pettyjohn, and Jack DeMarre, *Domestic Water Treatment*, McGraw Hill, New York, 1980.

Midwest Plan Service, MWPS-14, Private Water Systems Handbook, pp. 51-66, 1979.

Regunathan, P,, and William H. Beauman, "A Comparison of Point-of-Use Disinfection Methods," *Point of Use*, Volume 4, Number 3, 1986.

Steel, Ernest W., *Water Supply and Sewage*, McGraw Hill, New York, 1960.

Tyson, Anthony, and Kerry Harrison, *Water Quality for Private Water Systems*, Bulletin 939, University of Georgia Cooperative Extension Service, Athens, Georgia, 1986.

Internet Web Sites

Arkansas Department of Health

- http://www.healthyarkansas.com/environment/environment_p2.html
  Information on available services related to water.

Arkansas Water Resources Center

- http://www.uark.edu/depts/awrc/index.htm
  Lab sheets on water testing available at the Arkansas Water Resources Center Water Quality Laboratory.

University of Georgia

- http://aesl.ces.uga.edu/publications/watercirc/
  Simple circulars on common domestic water quality concerns.

Alabama Water Quality Program – CSREES

- http://www.aces.edu/waterquality/faq/faq.htm
  This database is a compendium of Frequently Asked Questions (FAQs) on a wide variety of water-related topics. The questions are sub-categorized under General Information or one of the eight current USDA/CSREES Water Quality Themes.
- http://www.aces.edu/waterquality/articles/articles_results.php3?rowid=426
  This article is designed to educate the consumer about the many variations of scams, especially Internet-based scams, dealing with drinking water and water treatment.

Kansas State University

- http://www.oznet.ksu.edu/library/h20ql2/samplers/MF912.pdf
  "Understanding Your Water Test Report"
  Tests for water include microbiological, inorganic chemicals, pesticides, synthetic organic chemicals, volatile organic chemicals, radionuclides, physical, water hardness, taste and odor.

Cornell University

- http://waterquality.cce.cornell.edu
  Information about drinking water quality, home water treatment, wells, septic systems, bottled water, etc.

EPA Web Site

- http://www.epa.gov/safewater/mcl.html, Primary and Secondary Drinking Water Standards
- http://www.epa.gov/ogwdw/, Ground Water and Drinking Water
- http://www.epa.gov/OST/, Water Science

U.S. Food and Drug Administration

- http://www.fda.gov/Food/FoodSafety
  Search the U.S. Food and Drug Administration web site for federal regulations on bottled water and carbonated soft drinks.

CSREES National Water Program

http://www.usawaterquality.org/

Water Quality Association

http://www.wqa.org/
The Water Quality Association is a not-for-profit international trade association representing the household, commercial, industrial and small community water treatment industry.

NSF – Public Health and Safety Company

- The EPA does NOT register or certify any devices for home water treatment, but the NSF International does.
  http://www.nsf.org/

- http://www.nsf.org/consumer/
  NSF International, an independent, not-for-profit organization, has been committed to making the world a safer place for consumers. Explore our consumer web site to learn more about NSF, our programs and services and the many ways we help consumers Live Safer™ every day.

- http://www.nsf.org/consumer/drinking_water/
  Questions and answers about drinking water

- http://www.nsf.org/certified/dwtu/
  Here you can search for any products certified for bacteriostatic effects.

International Bottled Water Association (IBWA)

- http://www.bottledwater.org/
  Most large companies marketing bottled water are members of the IBWA. Their web site provides a lot of information.

Natural Resources Defense Council

http://www.nrdc.org/water/drinking/bw/exesum.asp
NRDC is the nation's most effective environmental action organization. They use law, science and the support of more than 1 million members and online activists to protect the planet's wildlife and wild places to ensure a safe and healthy environment for all living things.

National Ground Water Association

- www.wellowner.org
  This site offers a variety of information relating to groundwater and private water well systems.

National Council Against Health Fraud

- http://www.ncahf.org/pp/homeop.html
  This web site provides facts about homeopathy.

- http://www.chem1.com/CQ/oxyscams.html
  Oxygenated Water – pseudoscientific snake-oil
  This web site explains the "oxygenated water" scam.

- http://www.homeowatch.org/
  This web site is organized by a medical doctor and provides good information about homeopathy.

- http://www.quackwatch.org/
  This web site is "Your Guide to Quackery, Health Fraud and Intelligent Decisions" and is operated by a medical doctor.

- http://www.quackwatch.org/01QuackeryRelatedTopics/waterindex.html
  Links to stories and examples of "water-related frauds and quackery."

Water Treatment Systems

- http://www.purewater2000.com/
  Explore the variety of products and services Pure Water 2000 offers for drinking water purification. Browse through many high-quality products and discover the solutions to common water problems.

- http://www.advancedh2o.com/
  Common systems for water purification.

MP292-PD-9-11RV