Residential Water from Nonpublic Sources and its Treatment

Introduction

Once you make the decision to purchase or build a home on rural property, where the water comes from a private well, spring or other nonpublic source, you will need to make some important decisions to protect your families health. The time to start this process is before you commit to the purchase or begin construction. A great piece of rural property with a fabulous view at a good price is no bargain if you can't get good quality water in sufficient quantity to meet your needs. Often the quantity of water is not the issue, but the bacteriological and chemical quality is. The problems can range from the simple, such as very hard water, too serious, such as bacterial contamination, high nitrates, fluoride, total dissolved solids, heavy metals and contamination with pesticides or other organic chemicals. To protect yourself from the expenses and aggravation of water treatment, devote sufficient time to researching the property and the area. Discuss the issues of water quality with several local realtors, local well drillers, other property owners in the area, the State Engineer, the State Geological Survey, local health departments and lenders. When you have finally made the decision to purchase an existing dwelling, we suggest you immediately invest $50 to $150 in having a sample of the water analyzed for total coliform and at least the common chemicals. This sample should be one you collect yourself and the sale should be contingent upon the result of the analysis.

Water Treatment Equipment and Techniques

Much of Wyoming's water is of excellent quality and safe for human consumption without any treatment, however there are areas where the source water needs improvement. If water treatment equipment is expected to do the job of protecting you and your family's health, you must make a serious commitment to:

- Maintaining good records on the water source.
- Keeping good maintenance records and manuals on treatment equipment.
- Adherence to manufacturers recommended maintenance procedures for water treatment equipment.
- Keep files of the analytical results on the source and treated water.
- Have the Total Coliform determined at least twice each year.

Purchasing Water Treatment Equipment

You must have the source water tested before you can even consider the purchase of water treatment equipment. A competent laboratory not engaged in the promotion or sale of any water treatment equipment should perform the analysis of your water. Cooperative Extension Offices should be able to assist you in locating a reliable laboratory. Upon receipt of the analysis report if you have trouble interpreting the test results consult with the laboratory, cooperative extension service or a consulting engineer specializing in water treatment issues.

With a firm grip on your source water's chemical and bacteriological quality and any identified problems, you are now ready to seek out a reputable vendor of the treatment. Some problems, such as sediment, high levels of hardness, dissolved iron and manganese or bacterial contamination, may require treatment at the point where the water enters the house - point-of-entry treatment. This type of treatment protects all appliances, fixtures and uses at any tap. Other problems, such as minor taste or odor, high concentrations of nitrates, fluoride, heavy metals, etc., may best be treated at the primary drinking water location, usually the kitchen sink. These devices provide treatment at a single location and are referred to as point-of-use treatment systems. Residential reverse osmosis (RO) systems and some activated carbon filters fall into this class of equipment. Point-of-use treatment is generally used because the cost of treating the whole house would be too expensive and may not even be desirable for all uses of the water.

Finding the right treatment and dealers is going to take an investment of time and effort. The equipment can be expensive, so you want to make the correct choices up front. We suggest the following:

- Identify all problems with the source water requiring correction.
- Talk with all water treatment equipment dealers in your area who can install and service products.
- Obtain costs of the equipment and installation.
- Find out about the operation costs and required or routine maintenance.
- Inquire as to how long the retailer of the equipment has been in business; how long the manufacturer has been making the equipment and what the warranty covers.
- Evaluate manufacturer literature and specifications and make sure there is nothing in the analysis of your water, which will be detrimental to the equipment.
- Talk to people who are using the equipment.

If you are engaged in new construction, it is best to determine the type of treatment required early and have it installed as the house is being built. Remember that water treatment equipment is expensive and there are a lot of outlandish claims made about what some devices will do or what they will remove from your water. If the treatment technique seems too simplistic and the sales claims too high, there is probably something wrong. Your family's health and the integrity and longevity of the plumbing system and the connected appliances and fixtures depend on the decisions you make now.

In the following sections general information is provided for commonly used water treatment devices:

- Sediment Filters
- Activated Carbon or Charcoal Filters
- Iron Filters
- Reverse Osmosis (RO)
- Water Softeners
- Disinfection Equipment - Chlorination or Ultraviolet Radiation

Sediment Filters

General Use
These filters are used to remove sediment from household water. Sediment can lead to the premature failure of moving pump parts, seals, valves, other water treatment equipment and appliances, such as dishwashers, hot water heaters and clothes washers. While some sediment is generally not harmful to health, it is aesthetically obnoxious.

General Description
Filters used for the removal of sediment (dirt, sand, silt, clay, mud and other suspended particulate material) are mechanical type filters. The type of sediment and quantity in the raw water will determine the type and size of the filter unit for the system. Cartridge type filter units designed for 10 ½ or 20 inch elements can be fitted with a wide variety of filter elements, which will remove particles down to 5 microns. For most household uses a 5 or 10 micron filter element is adequate. If large quantities of sand or other particulate material is present in the raw water, an automatic back washing type filter may be placed ahead of the cartridge filter. This prolongs the service life of the filter element.

Limitations
Sediment filters are designed to remove suspended particles. These devices will not remove bacteria or any other dissolved contaminants.

Maintenance
Cartridge filter elements must be changed on a regular basis, which is dependent on the amount of sediment in the raw water and the rate of use. It is best to have an inlet and outlet pressure gauge installed. This can be used to determine when to change the element. Normally, when the outlet pressure drops to less than 90% of the inlet pressure it is time to change the element. For example, the inlet gauge reads 70 psi and the outlet gauge reads less than 63 psi, while the bathtub is being filled, it is time to replace the filter element.

Activated Carbon or Charcoal Filters

General Use
These filters are generally used to remove chlorine, organic contaminants and small amounts of hydrogen sulfide from the source water. These water contaminants can cause taste and odor problems. Activated carbon filters are reported to be the best method available for removing specific organic chemicals, including some pesticide residues, trihalomethanes and many solvents. Studies have also shown that granular activated carbon (GAC) adsorption is an effective method for radon removal.

General Description
These filter devices are available in small sizes, which fit on kitchen faucets and treat 100 to 300 gallons before a filter change is required. Larger under sink units in-line filters can treat up to 1500 gallons. When purchasing one of these units, be sure to purchase an extra filter and check the availability of additional filters. Verify the credibility of the manufacturer, as well as the local dealer. In addition to the local dealer, it is best if the filters are also available by mail. This caution holds true for replacement parts and consumables of all water treatment equipment. The more carbon contained in the filter, the more water you will be able to treat. Some units have integrated sediment filters but if your source has a high sediment load it is usually less expensive to have a high capacity

sediment filter ahead of all water treatment devices. Designs are highly variable, which will influence efficiency and their ability to remove some contaminates.

Limitations
Activated carbon filters do not remove nitrate, bacteria or metals. Concern about the growth of harmful bacteria contaminating the bed of the activated carbon filters led to the U.S. Environmental Protection Agency study of faucet mounted and under-the-sink activated carbon filters. Partial findings of this study indicated that the five types of bacteria found in the water quality samples are nonpathogenic, meaning they did not cause waterborne disease. The study further indicated that while indigenous bacteria that exist in a water supply may multiply to relatively large numbers, the growth in an activated carbon filter bed created no significant health effects.

Maintenance
A rigorous maintenance schedule must be developed and followed for these filters because there is no easy way to determine when they become ineffective. Larger units may last six months or more, while faucet mounted devices usually last a month or less. Based on family size and use habits the dealer should be able to recommend a schedule. If the filter is left in service too long the water quality may become worse than if the filter was removed from service. You can purchase gallon consumption meters, which will aid in determining filter change schedules.

Iron Filters

General Use
Iron in the ferric form and manganese will stain clothes and plumbing fixtures. Ferrous iron is in the soluble form and cannot be seen in water. When water containing ferrous iron is exposed to air, the iron oxidizes to the insoluble ferric form. Ferric iron usually appears as rust to black colored particles in the water. Water with a high iron or manganese content is not considered a health problem, but it can be very objectionable in taste, odor or appearance, when iron concentrations are greater than 0.3 milligrams per liter or manganese concentrations are greater than 0.05 milligrams per liter. Iron bacteria are nuisance organisms often associated with soluble iron in water. Because they cause a slime buildup they can be quite objectionable with iron concentrations as low as 0.1 milligrams per liter ferrous (soluble) iron. Calcium is an essential nutrient for these bacteria. The presence of iron bacteria is indicated by a gelatinous slime on the inside wall of the toilet flush tank and gelatinous "rusty slugs" being discharged at the tap. High dosages (200 to 500 milligrams per liter) of chlorine (known as shock chlorination or disinfection) are required to control iron bacteria. Shock chlorination must include the well and distribution system.

General Description
Four types of iron-removal equipment are available:

- Oxidation Type Iron Filter - removes 0 to 10 mg/L soluble Iron. Iron filters are only useful for removal of soluble iron and manganese; ferric iron will plug some treatment systems. They appear similar to water softeners but contain a bed of natural or synthetic manganese greensand. Manganese dioxide oxidizes iron and manganese and the oxidized particles are then filtered out in the lower part of the

bed. The filter bed must be regenerated with potassium permanganate to renew oxidation activity and back washed to remove the accumulation of iron oxide particles. Acid water below a pH of 6.8 will pick up manganese from the greensand and cause loss of oxygen exchange capacity. The slime produced by iron bacteria will clog the filter.

- Water Softeners - removes 0 - 5 mg/L soluble Iron. Most water softeners will remove low concentrations of iron and manganese. The rating for iron and manganese removal and whether or not the regeneration will remove the iron from the zeolite must be verified with the manufacturer. Depending on the kind of zeolite used and the regeneration process, up to 5 milligrams per liter of soluble iron can be removed. The slime produced by iron bacteria will clog the zeolite and reduce its effectiveness.
- Polyphosphate feeders - removes 0 to 3 mg/L soluble Iron. These units can handle up to 3 milligrams per liter of soluble iron. These systems inject a polyphosphate compound, which complexes the soluble iron and manganese and prevents its oxidation when the water is exposed to air. The compound is not effective against iron that has already oxidized. Polyphosphate is only effective in cold water. This technique may be ideal for treating the supply water to a swamp cooler. When treated water is heated in a hot water tank the polyphosphate-iron complex will decompose, thereby making the iron available for oxidation. This oxidized iron can now accumulate in the water heater and hot water pipes.
- Chlorination and filter - removes 0 to greater than 10 mg/L soluble Iron. Chlorination followed by filtration through a sand filter can remove any quantity of iron in any form. The chlorine oxidizes and precipitates the iron and the filter strains out the particles. Carbon filtration may be required to remove excess chlorine residue. This method also destroys iron bacteria. When the bacteria cannot be permanently eliminated by shock chlorination, continuous chlorination is required.

Reverse Osmosis (RO)

General Use

Reverse osmosis is primarily used to remove the dissolved minerals from an otherwise less than suitable water supply. Most reverse osmosis systems, when new, are capable of removing 90% of the total dissolved solids but efficiency of the system declines as the reverse osmosis membrane ages. RO is probably the most common treatment technique used to reduce the dissolved solids in poor quality source water in residences connected to private water supplies.

General Description

High dissolved solids source water is introduced into the RO filter at 40 to 200 pounds per square inch against a membrane with microscopic pores. At elevated pressure water molecules pass through the membrane and flow to the purified water storage tank, usually one to three gallons in capacity for most home systems. The minerals removed at the membrane are washed through a backpressure valve to a drain line. Reverse osmosis systems cost from several hundred to several thousand dollars depending on the quality and quantity of purified water required and the quantity of impurities in the source water. A typical home system designed to produce quality drinking water may cost from $500 to $1,000. RO membrane materials and operating pressures vary widely, thus effecting

contaminate chemical removal efficiency from one system to another. Be sure to have the chemical analysis of your water available when discussing RO systems with vendors. You should also know your water systems operating pressure and the volume of drinking water you use each day. The following table lists the nominal rejection for common inorganic ions found in most natural waters.

Species	**% Removal**
Total Dissolved Solids	90-99
Bicarbonate	85-98
Calcium	90-95
Chloride	85-98
Magnesium	85-98
Fluoride	88-98
Sodium	85-93
Nitrate	40-90
Copper	90-99
Sulfate	90-98
Lead	90-98
Zinc	90-95
Iron	90-96

Limitations

Most RO filters will remove bacteria, Giardia and ameobic cysts, however the RO filter should not be relied on for primary removal of these organisms. Any breach in the RO filter membrane will immediately allow disease-producing microorganisms into the drinking water and this may occur without noticing any problems. Home RO systems do not remove 100 percent of most chemicals. Although reverse osmosis removes many organic chemicals, it does not remove all. For instance, it will not remove chloroform. Vendors of RO systems should be able to evaluate the chemical and microbiological contaminants in your source water and recommend a complete system that will provide you with safe quality drinking water. An RO system may, and probably should, include a sediment filter to remove particulate matter and a carbon filter to remove chlorine and organics ahead of the RO filter. Following the RO filter may be another carbon filter to remove any organics or taste and odor contaminates passing through the entire system before the water collects in the storage tank. If nitrate and/or nitrite nitrogen are significantly greater than 10 milligrams per liter removal is generally better at higher inlet pressures (100 psi or higher). Some manufacturers offer special RO filters designed specifically to removing these contaminates. We have actually seen cases where the nitrates in the finished drinking water are over twice the concentration of the source water if the inlet water pressure drops below 30 psi. Remember RO systems waste large amounts of water. Most units will discharge forty, fifty percent, or more, of total water supplied to the system as waste.

Maintenance

The RO membrane's life expectancy will be shortened from sediment, precipitate buildup

and scaling. A softener must be installed ahead of the reverse osmosis system if the source water is hard. The RO system should be able to determine when the RO filter needs to be changed without having to rely on just a fixed time period or the gallons of drinking water produced.

Water Softeners

General Use

Calcium and magnesium cause hard water, and at high levels can precipitate in and/or clog pipes, aeration screens and/or appliances connected to the water supply. Water exceeding about 150 milligrams per liter hardness may interfere with the cleaning action of soaps and detergents, and cause scale buildup in hot water pipes, water heaters and fixtures. The best way to soften household water is to install a self-regenerating water softener connected to the water supply line. If the source water is only moderately hard, it is best to leave the kitchen cold and all outside faucets on unsoftened water. Hard water tastes better than soft water to most people. The softening process exchanges sodium ions for calcium and magnesium ions, therefore making the hard water less suitable for lawn and garden irrigation. For each 1 mg/L of hardness as calcium carbonate softened 0.46 mg of sodium/L will be added to the source water. Most water softening units remove small amounts of soluble iron (refer to the Iron Filter section of this document).

General Description

The most common way to soften household water is to use a cation exchange water softener. A synthetic resin with a strong attraction for calcium, magnesium and other positively charged metal ions (cations) is first saturated with sodium cations from a salt (sodium chloride) solution. As the water passes through the resin, the sodium exchanges with calcium and magnesium. Softeners may also be safely used to remove up to about 5 milligrams per liter of dissolved iron if the water softener is rated for that amount of iron removal. Softeners are automatic, semiautomatic, or manual. Each type is available in several sizes and is rated on the amount of hardness it can remove before regeneration is necessary. Equipment manufacturers usually rate hardness removal in terms of grains of hardness. 1 grain/gallon = 17.1 mg/L (ppm) of hardness expressed as calcium carbonate. Analytical Services classifies hardness in water as follows:

Water Classification	Hardness mg/L	Hardness Grains/Gal	Sodium Added mg/L
Soft	0-49	0 - 2.90	0 - 22.5
Medium	50-149	2.90 - 8.7	22.5 - 68.5
Hard	150-249	8.7 - 14.6	69 - 115
Very Hard	250-299	14.6 - 17.5	115 - 138
Extremely Hard	300 and up	17.5 and up	138 and up

Limitations

Using a softener to remove iron in naturally soft water is not advised; a greensand filter is a better method.

Maintenance
When the resin is filled to capacity, it must be recharged. Fully automatic softeners regenerate on a preset schedule and return to service automatically. Regeneration is usually started by a time clock; water use meters or hardness detectors start regeneration on some units. Remember, during regeneration the softener is bypassed and hard water will flow into the system. For this reason, regeneration is best accomplished between midnight and 5:00 A.M., which accommodates most families.

Disinfection Equipment and Methods

General Use
The EPA drinking water standard for total coliform bacteria is 0 per 100 milliliters. If your total coliform result is unsatisfactory, this section discusses methods and equipment used to resolve the problem. These devices or techniques are used to kill bacteria and viruses in the source water supplying your residence. Most public water supplies are subjected to some type of disinfection process, whereas most private well water supplies are not treated. Generally once a private well is sealed, connected to the residence's plumbing system and shock chlorinated no further treatment is necessary. Regardless of the situation, we strongly suggest the homeowner have their water tested for total coliform at least once in the fall and once in the spring. If bacterial problems persist following shock chlorination, it may be necessary to install a continuous disinfection system. Several techniques are available for disinfecting water, including chlorination, ozonation, ultraviolet radiation and filtration. For home use chlorination and ultraviolet radiation are the most available, reliable and affordable.

General Description - Continuous Chlorination
Chlorination systems inject a solution of household bleach into the raw water based on flow through system. Following the injection, the bleach should remain in contact with the water for approximately 30 minutes prior to consumption of the water. The contact time is dependent on the concentration of free residual chlorine, water temperature, pH and the concentration of any organic material present in the source water. A 30 minutes contact time assumes a free chlorine concentration of 1 to 1.5 parts per million (ppm), a pH of 6 to 8 and no organic material. Chlorine residuals greater than 1 ppm can impart an objectionable odor and taste. It may be advisable to install a 20 - 40 gallon holding tank following the chlorinator to increase the contact time between chlorination and consumption.

Limitations
Sediment should be removed prior to chlorination. Organic material present in the source water can lead to the formation of a class of organic chemicals known as trihalomethanes. These compounds are suspected carcinogens. If the total trihalomethane concentration exceeds 0.05 ppm, an activated carbon filter should follow the holding tank to remove these chemicals. A sediment filter must be placed between the holding tank and the activated carbon filter if the source water contains soluble iron and/or manganese.

Maintenance
Must check and add, as needed household bleach to the chlorinator. Should periodically check the free residual chlorine to ensure proper operation. Should have total coliform determined at least twice a year.

General Description - Ultraviolet Radiation
It has been known for some time, that ultraviolet (UV) radiation will kill microorganisms. This technique has only recently been applied to the treatment of household water connected to a private supply. An ultraviolet radiation disinfection system typically has a stainless steel tube with a mercury vapor lamp inside running the length of the tube. The water inlet and outlet are at the ends of the tube. The water must be in contact with the UV radiation for sufficient time to kill microorganisms. Unlike continuous chlorination, UV radiation adds nothing to the water. UV systems should have the following minimum specifications:

- A flow of at least 6 gallons per minute
- Energy output of at least 30,000 microwatt-sec/cm2
- A lamp envelope made of pure quartz for maximum energy throughput
- An easily changeable source lamp
- A lamp energy detector and audible alarm to warn the user of lamp failure

Limitations
The UV radiation must contact 100% of the water passing through the system for disinfection to take place. For this reason, all sediment, turbidity and organic material must be removed prior to the water entering the UV radiation system. Other treatment devices, except for reverse osmosis units, should be placed in line ahead of an UV radiation disinfection system. If power to the UV system is interrupted, microorganisms will not be killed and contaminated water will pass through the system.

Some units have optional solenoid valves, which stop flow through the system if there is a power loss or lamp failure. If a maintenance bypass is installed around the UV radiation system, we would suggest the bypass contain a 0.22-0.45 micron cartridge filter to remove any microorganisms from the water during maintenance of the UV radiation disinfection system.

Maintenance
Periodic cleaning and replacement of the high intensity UV source lamp is required. Have total coliform determined at least twice a year and possibly more frequently as the end of the source lamps expected life is approached.

Home Water Treatment Configuration

This section is only intended as a guide. The problems associated with each water supply are as varied as the number of supplies, therefore you should consult with a water treatment specialist before installing any equipment.

Legend

SF1 - First Sediment Filter	WS - Water Softener
AC1 - First Activated Carbon Filter	WH - Water Heater
Cl - Chlorination System	RO - Reverse Osmosis System
PT - Household Pressure Tank	FP - Raw Water from Well Pump
SF2 - Second Sediment Filter	DCW - Domestic Cold Water
AC2 - Second Activated Carbon Filter	DrW - Drinking & Cooking Water
OF - Oxidizing Filter (Iron Removal)	DHW - Domestic Hot Water
UV - Ultraviolet Disinfection System	IrgW - Lawn & Garden Irrigation Water

If the raw water has an extremely high particulate or sediment load, a mechanical sediment filter (SF1) with back washing capabilities should be first in line. This filter can be omitted from the treatment if this is not the case. If the raw water has a high level of soluble organic material, is highly colored or you are planning to use a continuous chlorination system to disinfect the water or precipitate high concentrations of iron and manganese, an activated carbon (AC1) filter may be necessary. This filter can be omitted from the treatment system if none of these conditions are present.

If the source water is bacterially contaminated and you plan to disinfect using continuous chlorination (Cl), this device should be placed ahead of the pressure tank (PT). In most cases this configuration will allow sufficient contact time to kill bacteria. If you plan to use ultraviolet disinfection (UV), you can eliminate the continuous chlorinator from the treatment system. All households should have a sediment filter (SF2) located prior to any other treatment equipment in the system. This filter can be the cartridge type with a pore size of 5 microns or less. This filter will trap any small amounts of sediment in the source water and any precipitates produced by a continuous chlorinator. This filter protects down stream devices from sediment buildup and greatly improves the efficiency of ultraviolet disinfection.

Activated carbon filter (AC2) is used in the treatment system if there are small amounts of dissolved organics or taste and odor problems with the source water. This filter will also remove any trihalomethanes formed as a result of using chlorination disinfection. If ultraviolet disinfection is used and there are small amounts of dissolved organics present in the source water, the organics must be removed prior to UV disinfection. This filter can be eliminated from the treatment system if none of these situations exist. The oxidizing filter (OF) can be eliminated from the treatment system if high levels of soluble iron and manganese are not present in the source water or they are removed by continuous chlorination or they are at low enough concentrations to be removed by a water softener (WS), if required to remove hardness ions. Ultraviolet (UV) disinfection may be used instead of continuous chlorination to kill bacteria and viruses. If a water softener is part of the treatment system and all of the household water passes through it,

the UV disinfection equipment should be installed down stream from the water softener. The UV equipment can be eliminated from the treatment system if a chlorinator is used or if the source water is negative for total coliform and the water source is well protected. A water softener (WS) is used to remove calcium and magnesium ions from the source water. A water softener will also remove some soluble iron and manganese. If the total hardness is medium hard to hard, it may not be desirable to soften all of the household water. You may wish to soften only the hot water supply and possibly selected cold water taps, such as the clothes washer and the supply feeding a reverse osmosis system (RO). The efficiency and longevity of the domestic hot water heater (HW) will be greatly improved if it is supplied with soft sediment free water.

A reverse osmosis (RO) system is used to remove high concentrations of dissolved minerals (total dissolved solids) and/or other toxic metals or ions, such as fluoride, nitrates, lead, chromium, etc. RO is typically used to supply water to the kitchen for drinking and cooking. RO systems may also contain sediment and activated carbon filters, in addition to the membrane filter and usually install under the sink.

General Use

All tanks, filters and water treatment devices should be installed with bypass valves. This enables the homeowner or service professionals to perform maintenance of the equipment without stopping water flow to the house. To avoid contamination of household water if UV disinfection is employed, a 0.2 micron cartridge filter should be installed down stream of the bypass valve. The flow through this filter will probably be less than through the UV system but it will keep bacteria and parasitic cysts out of the system. As soon as maintenance or repairs are completed, be sure to close the bypass loop.

Chemically suitable water may be used to supply lawn and garden sprinkler systems even if it is bacterially unsafe for consumption. You may wish to filter out any sediment and use the water for this purpose without further treatment. You may need an auxiliary pressure tank (PT Aux) as part of the sprinkler system. Outside hose faucets should be supplied with disinfected water if the source water is bacterially contaminated, as people can and do drink from these locations. Remember that the household water treatment system can only be properly designed after you have a complete chemical and bacterial analysis of your source water.

References

Manual of Individual and Non-Public Water Supply Systems, United States Environmental Protection Agency, EPA 570/9-91-004, May 1991

Manual of Small Public Water Supply Systems, United States Environmental Protection Agency, EPA 570/9-91-003, May 1991