Quality Water for Idaho

Water Treatment and Conditioning Systems for Private Water Supplies

E. Porter

Treatment vs. conditioning

Methods used to improve the quality of water are referred to as "treatment" or "conditioning." What is the difference? Water treatment reduces levels of harmful contaminants in the water; therefore, it deals with the health or safety of the water. For example, high levels of coliform bacteria, nitrates, arsenic, lead, and pesticides must be treated before water is safe to drink.

Water "conditioning" generally deals with problems that affect water taste, color, odor, hardness, and corrosivity rather than health and safety. Magnesium, calcium, iron, manganese, and silt are common contaminants that require water conditioning when they reach high levels. It is not uncommon to use both treatment and conditioning methods to improve water quality.

Coliform contamination

Drinking water should be free of coliform bacteria. The Environmental Protection Agency (EPA) drinking water standard is less than one coliform organism in 100 milliliters of water. If your coliform test shows your water is contaminated:

- Disinfect your well.
- Resample the well and have a second coliform test run.
- If possible, locate and correct the source of bacterial contamination.

After you have identified the source of water contamination and corrected the problem, ask your local water treatment professional for guidelines on how long treatment should continue. For example, find out how many negative contamination tests are required.

Water treatment systems

Distillation

Distillation units disinfect water in the home rather than in the well. Distillers are also used to reduce levels of nitrates; remove dissolved salts such as chlorides, sulfates, and carbonates of sodium, potassium, and magnesium; and remove organic matter and other soluble and suspended materials.

Distillation units boil water, making steam that condenses and collects as purified water. Home distillers vary in design; however, the countertop single-batch distillers are most common (fig. 1). These distillers cost $250 to $1,200. All home electric distillers use 100- to 120-volt alternating current.

The water output of a home distiller ranges from 3 to 12 gallons per day. Power consumption ranges from 3 to 5 kilowatt-hours of electricity per gallon of distilled water produced. Thus, the electric cost of distilled water can be high.

There are drawbacks to distillation. The most serious is that organic liquids whose boiling points are less than that of water will condense and collect along with the water. The known or suspected carcinogens chloroform, phenol, and trichloroethylene have been found in finished water.

Because distilled water is mineral free, it tends to taste flat and to corrode metals. It is best to draw water directly from the distiller and not through any metal piping. Distiller tanks, if not properly used and maintained, are notorious breeders of

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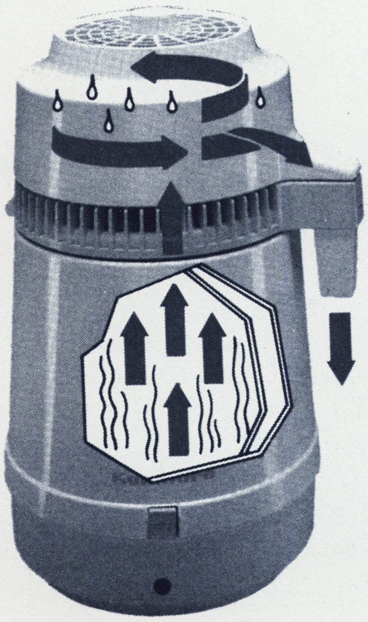

Fig. 1. **Distiller mechanics.** As water boils in the chamber at the bottom, the steam rises into the cooling coils. Contaminants that don't boil or evaporate stay in the chamber. The steam circulates through a metal coil and condenses. The distillate drips out a spout into a collection jug. *From "Fit to Drink" Copyright 1990 by Consumers Union of United States, Inc., Yonkers, NY 10703-1057. Reprinted by permission from* Consumer Reports, *January 1990.*

bacteria because of the presence of warm water. To remove bacteria and concentrated salts, periodic disinfection and cleaning is necessary.

Chlorination

Chlorination is the oldest and most common disinfection method for private water supplies. Chlorine is inexpensive, readily available, reliable, easy to use and monitor, and effective against most harmful bacteria, viruses, and cyst organisms. It also kills less harmful iron, manganese, and sulfur bacteria.

For use in the home, chlorine is readily available as sodium hypochlorite, commonly known as household bleach. This product contains 5 percent available chlorine. Chlorine is also available as calcium hypochlorite, which is sold in the form of dry pellets. The pellets contain about 70 percent available chlorine.

Chlorination may be done in many ways. Dry or liquid chlorine may be continuously dropped or injected into the well water using a chemical feed pump. For chlorine recommendations and installation details, refer to the chemical feed pump's installation manual or contact your local water treatment professional. For periodic or shock water treatment, chlorine can also be poured into the well or fed into the well in solution using a hose.

Shock chlorination. Shock chlorination is recommended whenever a well is new, repaired, or found to be contaminated. It is essential following a flood or the entrance of surface water into the well. Shock chlorination involves pouring a strong solution of chlorine into the well, usually greater than 50 parts per million, and pumping it through the equipment and piping. A good practice is to 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 problem. If bacteriological problems persist following shock chlorination, a continuous chlorination system may be required.

Continuous chlorination. Continuous chlorination requires equipment to add chlorine to all water drawn from the source. The chlorine must be thoroughly mixed with the water and have sufficient time to kill all disease-causing and nuisance organisms.

The time required for disinfection depends on the concentration of chlorine, the temperature and pH of the water, the amount of organic matter in the water, and the discharge rate of the pump. Disinfection for most waterborne, disease-causing organisms occurs after 20 minutes of contact when the pH is between 6 and 8 and the free available chlorine residual is in the range of 0.2 to 0.4 parts per million.

A dry pellet chlorinator is one possibility. The pellets are injected into the well at a calculated rate. This type of system uses the well casing as a retention tank, permitting the chlorine to kill bacteria and oxidize iron and manganese.

Suspected carcinogenic compounds called trihalomethanes can form during chlorine disinfection when organic substances are present. To remedy this, activated carbon filtration or reverse osmosis units should be added to home chlorination systems. An activated carbon filter can remove the chlorine taste. It should be placed after the contact tank and just before the point-of-use faucet. Continuous chlorinators range in price from $500 to $1,300.

Ozonation

An adequate ozone concentration and a sufficient contact time with the water can kill almost all bacteria and inactivate giardia cysts. Viruses are more resistant to ozone than are bacteria. A high relative humidity can reduce ozone production, reducing the unit's efficiency.

Ultraviolet light

Ultraviolet light disinfection is a relatively new method of disinfecting private water systems. Ultraviolet radiation adds nothing to the water and produces no taste or odor. The UV light is produced by a mercury vapor lamp that produces a disinfecting dose rated in microwatt-seconds per square centimeter (MWs/cm^2). Values of 20,000 MWs/cm^2 will kill most types of harmful bacteria; however, viruses are more resistant and variable and may need up to 45,000 MWs/cm^2.

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 located in it. Lamps vary in length from 12 to 48 inches and thus vary in energy output. Water enters one end of the chamber, flows through the chamber and around the lamp, and exits the other end within a few seconds.

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 will be. As a consequence, ultraviolet light treatment should be attempted only on clear water, and prefiltering is recommended.

Without regular inspection and maintenance, a UV system cannot be guaranteed to produce bacteria-free water. The cost will be at least $900 for a 47,000 MWs/cm^2 household UV treatment system with a flow rate of 8 gallons per minute.

Water conditioning systems

Filtration

A broad category of systems uses filtration to remove particles, taste, odor, some organics and minerals, and some bacteria from the water. Filtration systems fall into several categories:

- Mechanical or sedimentation filtration
- Activated carbon filtration
- Activated alumina filtration
- Oxidation filtration
- Neutralizing filtration
- Reverse osmosis or membrane filtration

In many cases, these filtration systems are combined with other water treatment systems. To remain effective, all filtration systems must be regularly inspected and maintained.

Mechanical filtration

Mechanical or sedimentation filters retain debris as water passes through the filter unit. Mechanical filters are most effective for removing particles such as sand, silt, ferric iron, algae, and some bacteria. Their effectiveness depends on the particle size and the exit clearance of the filter.

Activated carbon filtration

Activated carbon filtration is a common water conditioning treatment to remove offensive tastes and odors, color, chlorine, volatile organic chemicals, pesticides, radon, and trihalomethanes (a group of suspected carcinogens) (fig. 2). Activated carbon will not remove bacteria such as coliforms; dissolved metals such as iron, lead, manganese, and copper; or chlorides, nitrates, and fluorides.

Activated carbon filters, usually made up of granulated, powdered, or block carbon, act like a sponge with a large surface area to absorb contaminants in the water. Activated carbon, made from coal and nutshells, has a tremendous surface area—as much as 125 acres per pound of carbon.

The efficiency of an activated carbon filter depends on the amount of carbon in it and the flow rate of water through it. Generally the more carbon and the slower the flow rate, the more effective the filter will be. The typical carbon filter is about 10 inches high and 3 inches in diameter and has enough charcoal to treat about 1,000 gallons of water.

Home-use activated carbon filters are most commonly sold as faucet-mounted, stationary, and line bypass

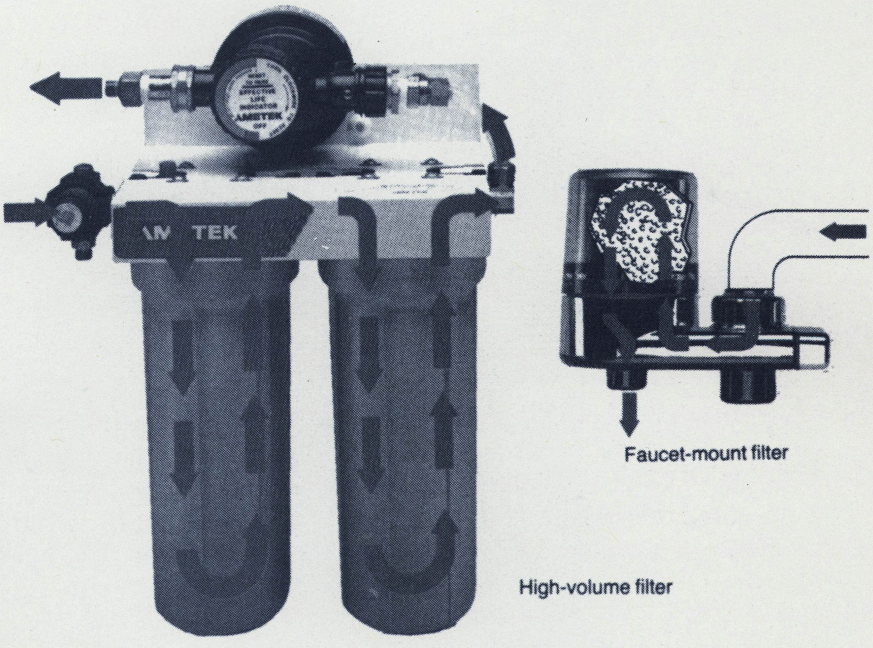

Fig. 2. **Carbon-filter mechanics.** High-volume filters: Water flows through a labyrinth of activated-carbon granules that trap and hold contaminants. The Ametek CCF-201 shown here uses two filter cartridges; most others use one. The Ametek also has a meter that shuts off the water when the cartridges are due to be changed. Faucet-mount filters: As water flows from the tap, it's channeled through a tiny carbon filter. The amount of carbon is too small to be very effective. *From "Fit to Drink" Copyright 1990 by Consumers Union of United States, Inc., Yonkers, NY 10703-1057. Reprinted by permission from* Consumer Reports, *January 1990.*

systems. The stationary system is connected directly to the cold water faucet. The line bypass system has a separate faucet, but is tapped into the cold water pipe for its water supply. These systems are typically installed under the sink and can be purchased for $50 to $375.

Pour-through carbon filters are also on the market, but due to the small amount of carbon they contain and the brief contact time between water and carbon, these systems have limited effectiveness. The faucet-mounted carbon filters costing about $25 also have limited effectiveness.

A carbon unit for radon removal resembles a water softener tank and costs about $1,500, plus installation.

Without periodic replacement, carbon filters may provide a breeding ground for bacteria. To ensure maximum effectiveness, carbon filters should be replaced frequently, following the manufacturer's recommendations.

Activated alumina filtration

Activated alumina filters have one duty: to remove fluoride from water. But there is a tradeoff. Although an activated alumina filter lowers fluoride levels quite well—and arsenic levels, too—it adds a little bit of aluminum to the water. Studies suggest that aluminum may contribute to the onset of Alzheimer's disease or exacerbate it.

Oxidation filtration

Oxidizing filters are used mainly for the removal of iron, manganese, and hydrogen sulfide. A manganese greensand filter provides oxygen to the iron and manganese in solution. As a result, these minerals change from their soluble to their insoluble forms. The "precipitated" minerals become trapped as rust particles within the greensand filter bed. To remain effective, manganese greensand filters must be periodically backwashed to thoroughly remove iron precipitates and regenerated when the oxygen is depleted.

Neutralizing filtration

Neutralizing filters are typically used for pH modification, that is, treating acidic water. A neutralizing filter is normally a pressure filter tank filled with limestone chips. As

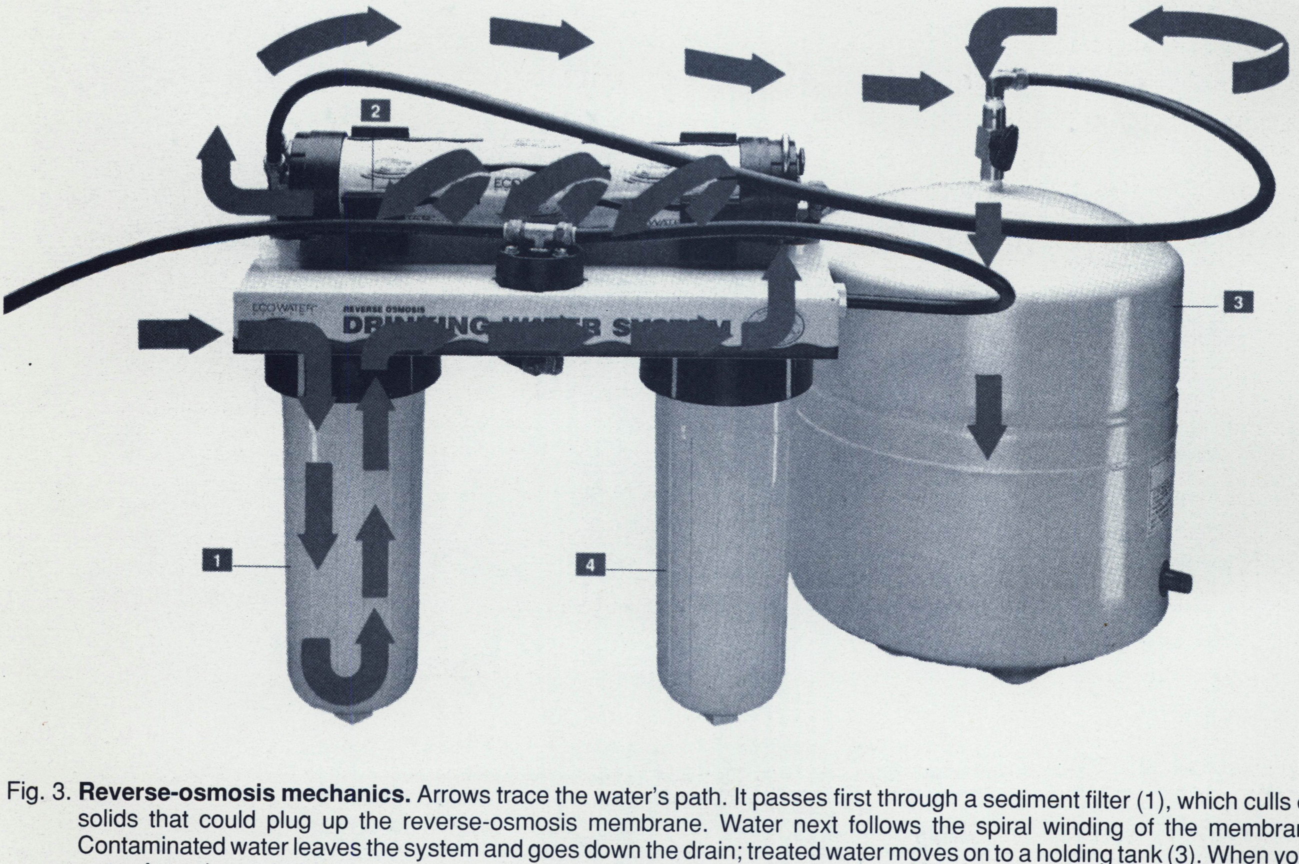

Fig. 3. **Reverse-osmosis mechanics.** Arrows trace the water's path. It passes first through a sediment filter (1), which culls coarse solids that could plug up the reverse-osmosis membrane. Water next follows the spiral winding of the membrane (2). Contaminated water leaves the system and goes down the drain; treated water moves on to a holding tank (3). When you draw water from the tank, it flows through a carbon filter (4) to remove organic chemicals, then out a spigot. *From "Fit to Drink" Copyright 1990 by Consumers Union of United States, Inc., Yonkers, NY 10703-1057. Reprinted by permission from* Consumer Reports, *January 1990.*

the water passes through the filter bed, calcium carbonate dissolves into the water, increasing its pH and reducing its acidity.

Reverse osmosis filtration

Reverse osmosis or R.O. filtration systems for home water conditioning are relatively new, although the process has been used extensively for industrial processes (fig. 3). Reverse osmosis water conditioning decreases the levels of dissolved minerals in the water.

It successfully treats water with a high salt content and with dissolved minerals such as nitrate, sulfate, calcium, magnesium, potassium, manganese, aluminum, fluoride, silica, boron, and bicarbonate. R.O. is also effective with some taste-, color-, and odor-producing chemicals, certain organic contaminants, and some pesticides.

Although the R.O. membrane can reject virtually all microorganisms, it can develop pinholes or tears that allow bacteria or other microorganisms to pass into the treated water. R.O. is thus recommended only for bacteriologically safe water.

Household R.O. systems typically treat 3 to 5 gallons of water per day; however, some can treat as many as 9 gallons. R.O. systems cost between $100 and $850. The wide range reflects differences in capacity and design. The simplest home R.O. system consists of a membrane filter connected to the faucet spout. Most popular is a membrane, a storage container for the treated water, and a flow regulator for the contaminated reject water. The pressure for R.O. is usually supplied by the line pressure of the water system in the home.

A sediment prefilter and activated carbon prefilter or postfilter might be included. The prefilter removes sand, silt, and sediments, while the activated carbon removes organic materials and dissolved gases not treated by the R.O. membrane. Water softeners are placed before the R.O. system when household water is excessively hard.

Water softening or ion exchange

Water softening to condition hard water is perhaps the most familiar water conditioning system known to consumers. Hard water is caused by calcium and magnesium dissolved in the water (table 1). These minerals form scale in hot water pipes and water heaters. They also interfere with the cleaning action of soaps and detergents and form a film on skin, clothing, and fixtures.

Hardness is measured in milligrams per liter (mg/l) or parts per million (ppm); however, it is normally expressed in grains of hardness per gallon of water (gpg).

The most common way to soften water is with a cation-exchange water softener (fig. 4). A synthetic resin with a strong attraction for calcium, magnesium, and other positively charged atoms called "cations" is saturated with sodium from a salt solution. As water passes through the resin, the sodium exchanges with the calcium and magnesium. Softeners also will remove small amounts of dissolved iron and manganese.

Eventually, so much calcium and magnesium collect on the resin that the unit can no longer soften the water and recharging is necessary. Then, the resin is backwashed with a brine solution that replaces the sodium and enables the ion exchange process to continue.

The major disadvantage of water softeners is that they substitute sodium for the calcium and magne-

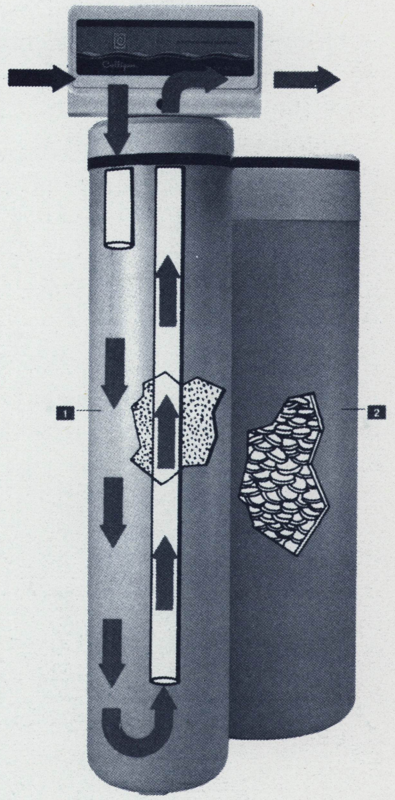

Fig. 4. **Softener mechanics.** Hard water flows through a tank filled with synthetic resin beads (1). Millions of sodium ions are loosely attached to each bead. The water exchanges its "hardness" ions, mostly calcium and magnesium, for the "soft" sodium ions and flows on to the faucets. When the resin is saturated with hardness ions, it must be regenerated in order to work again. Salt water from a brine tank (2) flows through the resin. The resin gives up its mineral ions in exchange for sodium ions. The brine goes down the drain. *From "Fit to Drink" Copyright 1990 by Consumers Union of United States, Inc., Yonkers, NY 10703-1057. Reprinted by permission from* Consumer Reports, *January 1990.*

Table 1. Water hardness of waters with different levels of calcium and magnesium.

Hardness	Calcium and magnesium (mg/l)	Calcium and magnesium (gpg)
	0 to 60	0 to 3½
Moderate	61 to 120	3½ to 7
Hard	121 to 180	7 to 10½
Very hard	more than 180	more than 10½

sium. 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 for drinking, can overcome this problem.

Softened water is more corrosive than unsoftened water, and the waste brine may be a disposal problem. Softening systems range from $650 to $2,100.

Anions resins are also available for exchange of undesirable anions (e.g., nitrate or sulfate) for another anion (e.g., chloride). Such anion resins may work well for nitrate removal but are not in widespread use. This may be due to the possibility of nitrate showing up in the treated water when the system column is exhausted.

Deionization

In another technique for removing inorganics by ion exchange, the mixed-bed ion exchanger removes much of the total dissolved solids in water. Instead of having sodium ions on their resin beads, as in water softeners, these exchangers have hydrogen ions and hydroxyl ions.

When the water is passed over the beads, cations (molecules with a positive charge) exchange with the hydrogen ions and anions (those with a negative charge) exchange with the hydroxyl ions. When the hydrogen and hydroxyl ions are forced into the water, they combine to form molecules of water. In this way, no sodium is added to the water, and both anions and cations are removed, producing very pure water.

Unfortunately, the resins in mixed-bed exchangers cannot be regenerated in the home. They must be regenerated at special service facilities with strong acids and bases. The resin tank can be replaced, but the service is expensive. Moreover, water deionized in this way is of a much higher quality than most people need, and it doesn't taste very good.

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Water problems discovered by testing and their treatment.

Problem	Distillation	Reverse osmosis	Deionization	Ozonation	UV	Cation exchange	Anion exchange	Chlorination	Carbon filters
Bacteria	√	√		√	√			√	
Barium	√	√	√			√			
Calcium	√	√	√			√			
Cadmium	√	√	√			√			
Chloride	√	√	√						√
Chlorine									√
Copper	√	√	√			√			
Hardness	√	√	√			√			
Iron (Fe^{+2})	√	√				√		√	√
Iron (Fe^{+3})									√[1]
Magnesium	√	√	√			√			
Manganese	√	√				√		√	
Nitrates	√	√	√				√		
Radium-226,228	√	√	√			√			
Radon									√
Sodium	√	√	√						
Sulfates	√	√	√				√		
Total dissolved solids	√	√	√						
Volatile organics	√	√							√
Zinc	√	√	√			√			

Note: Recommendations are as reviewed and approved by Water Quality Association.

[1]Precipitated iron may be removed with various filtering media other than activated carbon.

Water problems that you can see, smell, or taste and their treatment.

Problem	Symptom	Cause	Treatment
Hardness	Soap curd and lime scum in bath, white scale in pipes	Excessive magnesium and calcium salts	Water softener (cationic ion exchanger)
Grittiness	Feels abrasive when washing, leaves residue in bath	Silt passing through well screen	Mechanical filtration
Odor	Grassy or musty	Organic matter	Activated carbon filtration
	Chlorine	Excessive chlorination	Activated carbon filtration
	Rotten egg	Hydrogen sulfide	Oxidation filtration, chlorination, aeration
		Sulfate bacteria	Chlorinate pipe system
	Chemical (phenol)	Industrial waste seeping into water supply	Stop seepage, activated carbon filtration
Taste	Salty or brackish	High sodium or magnesium content	Cation/anion exchange, reverse osmosis, distillation
	Metallic	Low pH	Neutralizing filtration
		High iron content	Oxidation and mechanical filtration
Corrosion of stainless steel	Blackening or pitting of sinks and dishwashers	Excessive chloride content	Reverse osmosis
Turbidity	Mud, silt, and clay	Suspended matter in water supply	Mechanical filtration
Acid water	Green stains on plumbing fixtures	Low pH reacting with copper and brass piping and fittings	Neutralizing filtration
Red water	Stains dishes and laundry	Dissolved iron	Oxidation filtration
	Red sediment when water is left standing	Precipitated iron	Filtration
	Red color even after standing for 24 hours	Colloidal iron	Oxidation filtration
Milky water	Cloudiness when drawn	Trapped air from faulty pump	Water will clear quickly upon standing
		Sludge pickup in hot water heater	Clean heater periodically to rid hot water tank of precipitated calcium
		Methane gas	Aeration with proper venting of this volatile gas
Excess fluorides	Yellowish, mottled teeth in children	Excessive fluorides	Activated alumina filtration, reverse osmosis, deionization, distillation

Source: Condensed from Water Quality Association. 1988. Water processing for home, farm, and business. Lisle, Illinois.

Water quality publications from the University of Idaho

CIS 861	Quality Water for Idaho: Pesticide Handling Practices to Protect Groundwater (free)
CIS 865	Quality Water for Idaho: Pesticides and Their Movement in Soil and Water (free)
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