

# HYDROGEN SULFIDE IN DRINKING WATER

## Causes and Treatment Alternatives

Mark L. McFarland and T. L. Provin\*

**D**rinking water with a nuisance “rotten egg” odor contains hydrogen sulfide ( $H_2S$ ), a gas that dissolves readily in water. This sulfide-rich water commonly is referred to as sulfur water.

Although typical concentrations in household water are not a health risk, high concentrations do affect the taste of water. A concentration as low as 0.1 milligram hydrogen sulfide per liter of water (mg/l) is detectable by smell by most people. As a point of reference, 1 teaspoon of salt dissolved in 1,000 gallons of water produces a concentration equal to about 1 mg/l. A characteristic hydrogen sulfide taste can be detected in water with a concentration as low as 0.05 mg/l. Some people become accustomed to the odor and taste and tolerate hydrogen sulfide levels as high as 5 to 6 mg/l. Most people, unaccustomed to sulfur water, find it highly unpleasant.

Hydrogen sulfide also can corrode plumbing metals (iron, steel, copper, brass) and exposed metal parts in washing machines and other water-using appliances. Corrosion of iron and steel by hydrogen sulfide forms a black precipitate (ferrous sulfide) that can stain laundry and bathroom fixtures, darken silverware and discolor copper and brass utensils.

### Sources of hydrogen sulfide

Hydrogen sulfide is formed by sulfur- and sulfate-reducing bacteria that can occur naturally in water. These anaerobic bacteria use sulfates and sulfur compounds found in decaying plant material, rocks or soil to convert organic compounds into energy. Under these anaerobic

(without oxygen) conditions, hydrogen sulfide forms as a by-product. Hydrogen sulfide can occur in deep or shallow wells and also can enter surface water through springs.

Shallow, poorly constructed wells or those located close to sewer lines or septic systems and surface water can become contaminated with sewage and develop problems with hydrogen sulfide. Wells drilled in shale or sandstone or near coal or oil fields often will have hydrogen sulfide present in the water.

### Odors from hot water only

In the home, the foul odor caused by hydrogen sulfide sometimes is detected only on the hot water side of taps. If the water heater is electric, the problem might be caused by a chemical reaction with the sacrificial metal rod (anode). Electric water heaters often contain a magnesium rod that functions to retard corrosion of the tank. As the rod releases small amounts of magnesium, some hydrogen also is released. The hydrogen can then combine with sulfur in the water to form hydrogen sulfide. To correct the problem, the magnesium rod can be removed or replaced by an aluminum or zinc rod. However, such action could void the manufacturer’s warranty on the water heater. Chemical feeder systems using polyphosphate also can retard corrosion, but generally are more costly.

\* Former Associate Professor and Extension Water Quality Coordinator and Assistant Professor and Extension Soil Chemist, The Texas A&M University System

Sometimes hot water will have a “sour” smell, similar to that of an old damp rag. This smell often develops when the thermostat has been lowered to save energy or reduce the potential for scalding. Odor-causing bacteria live and thrive in warm water and can infest the water heater. The problem frequently can be corrected by returning the thermostat to its recommended operating temperature (approximately 160 degrees F) for 8 hours. This will kill the bacteria. (Caution: Be sure the water heater has an operable pressure relief valve before increasing the temperature, and warn occupants of the scalding hazard.) If a lower temperature is preferred for routine operation, periodic high temperature flushing can be used whenever the odor returns.

### Testing for hydrogen sulfide

The cause of the hydrogen sulfide problem must be determined before proper testing and appropriate treatment can be applied. If the problem is caused by hydrogen sulfide in the groundwater, then the concentration of the gas in the water must be measured in order to select and properly size a treatment system. Hydrogen sulfide gas dissolves readily in water and can readily escape from it (volatilize). Thus, water samples must be tested on-site, or immediately stabilized for laboratory analysis. Sample bottles with stabilizing chemicals should be obtained from the laboratory that does the analysis. Careful sampling according to laboratory recommendations is critical to ensure accurate and reliable results. In general, the requirements will involve delivery of a refrigerated sample within 48 hours of collection. Sulfide concentrations are reported by laboratories in units of milligrams per liter (mg/l) or parts per million (ppm). These two terms are used interchangeably.

If the gas is being produced by an active colony of sulfur-reducing bacteria, this must be determined. Active colonies could be located anywhere within the plumbing system, well casing or in the aquifer. Selected commercial water testing laboratories can determine the presence of sulfur-reducing bacteria. If

the bacteria are detected, treatment to control the bacteria should eliminate the problem.

Other contaminants (sulfate, organic compounds and metals) can cause taste and odor problems in drinking water. Water tests should always be conducted on new wells or when problems are suspected in an existing water supply. This can be particularly important if more than one contaminant is involved because it will affect proper diagnosis of the problem and selection of the most effective and economical water treatment system.

### Treatment options for hydrogen sulfide

The recommended treatment to remove hydrogen sulfide from a water supply depends largely on the gas concentration.

#### Trace amounts of hydrogen sulfide (0.05 - 0.3 mg/l)

Activated carbon adsorbs soluble organic compounds and certain gases, such as chlorine and hydrogen sulfide, that contribute tastes and odors to a water supply. Very small amounts of hydrogen sulfide can be removed from water with activated carbon filters (Fig.1). Activated carbon is used as a granular form in tank-type filters and as finely divided powder in a cartridge.

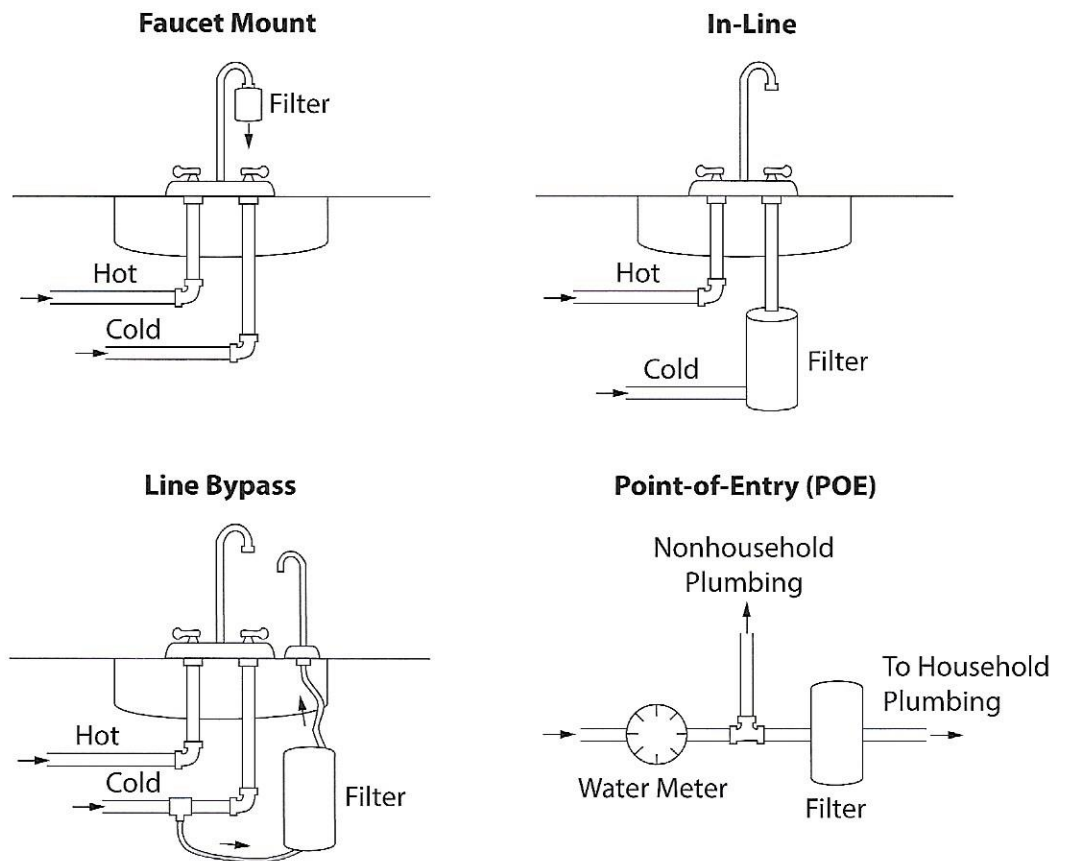


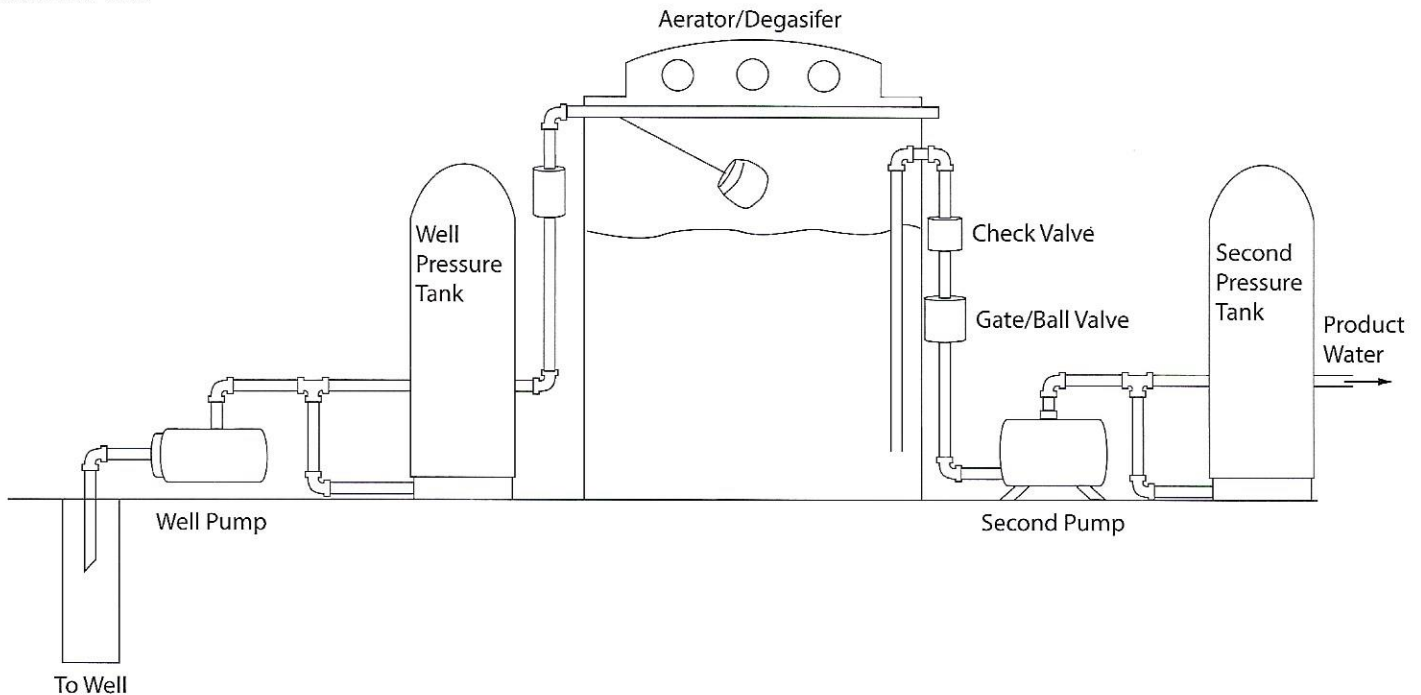
Figure 1. Point-of-use and point-of-entry placements of activated carbon filters.

sulfide is adsorbed onto the surface of the carbon particles. Some filters will improve taste, but will not eliminate unpleasant odors. A granular filter must be backwashed periodically; a cartridge filter must be cleaned or replaced periodically. Cleaning frequency depends on the amount of hydrogen sulfide in the water and the volume of water treated. Moderate to high levels of hydrogen sulfide will require frequent filter replacement. These filters also can remove tannins and other dissolved organic compounds.

**Less than 2 mg/l hydrogen sulfide**

Aeration (adding air to the water) is a treatment option for this concentration range, and is commonly used by city water treatment systems. Oxygen in the air reacts with hydrogen sulfide to form an odorless, dissolved form of sulfur called sulfate. Several types of aeration systems are available. In one type, compressed air is injected into the water system. The air then must be removed from the water to prevent knocking or air-blocks in the system and to reduce the corrosion potential caused by dissolved oxygen. In another type, water is sprayed into a nonpressurized storage tank (Fig. 2). A second pump is needed to re-pressurize the water. The storage tank provides 6 to 8 hours holding time for oxidation of hydrogen sulfide, iron and manganese. The storage tank and aerator must remain secure to prevent contamination of the water supply, or the system must be chlorinated. This process usually produces a strong hydrogen sulfide odor near the aerator, and may not always reduce the hydrogen sulfide to nondetectable levels. In such cases, a carbon filter can be used to remove some of the remaining trace amounts of hydrogen sulfide.

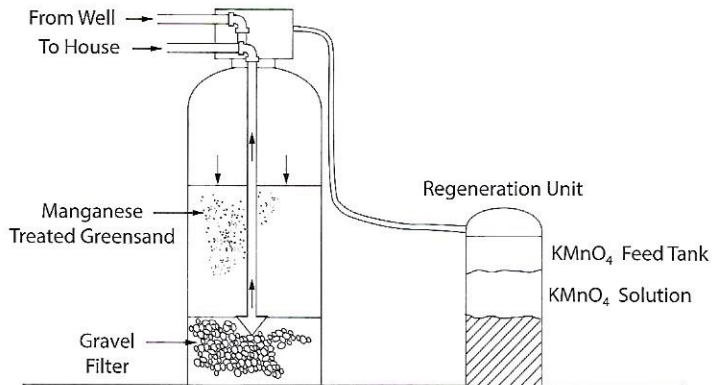
These complex systems are not recommended for household use.



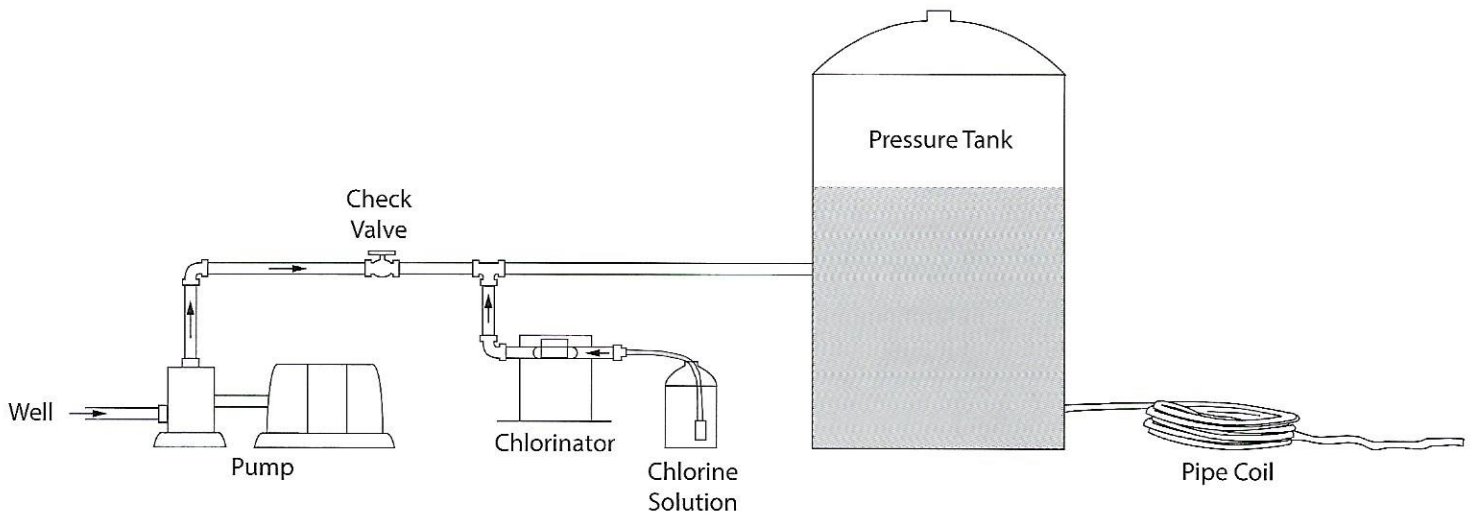
**Figure 2. Nonpressurized aeration system for hydrogen sulfide removal.**

**Up to 10 mg/l hydrogen sulfide**

An iron removal filter containing manganese greensand can remove low to moderate levels of hydrogen sulfide in addition to iron and manganese. The process oxidizes hydrogen sulfide into sulfate; iron and manganese form precipitates that are filtered out (Fig. 3). Manganese greensand filters must be recharged with a solution of potassium permanganate when the oxygen is depleted. This process is very similar to the regeneration process used in water softeners, and must be performed at regular intervals of 1 to 4 weeks depending on the chemical composition of the water, size of the unit and amount of water processed. Water with a pH below 6.7 could require acid neutralization, increasing the pH to 7.5 to 8.3, before iron removal will be effective. These filter systems are very specialized and the installation and operation instructions of the manufacturer should be followed precisely.



**Figure 3. Manganese greensand and pressure filtration system for removal of hydrogen sulfide, iron and manganese.**



**Figure 4. Chlorine injection system for removal of hydrogen sulfide.**

### Up to 75 mg/l hydrogen sulfide

Continuous chlorination using an automatic chemical feed pump can effectively remove medium to high levels of hydrogen sulfide (Fig. 4). Chlorine quickly oxidizes hydrogen sulfide into a tasteless, odorless form. Continuous chlorination also effectively removes iron and manganese that can occur in association with hydrogen sulfide.

Chlorine demand (concentration) and contact time are very important to successful chlorination. The amount of chlorine needed to react with organic and inorganic materials in the water can range from 1 mg/l to more than 10 mg/l if the water is high in sulfide, ammonia, iron or manganese. Table 1 presents typical dosages required to treat specific problems.

Contact time (exposure) depends on the concentration of chlorine in the water, water temperature and pH. Oxidation of iron and hydrogen sulfide is instantaneous, while manganese oxidizes more slowly. Chlorine should be introduced into the system before it reaches the storage tank. The tank must have sufficient volume to provide a 20-minute contact time between the water and the chemical. In addition, a fine-retention sediment filter can be used to remove any oxidized iron and manganese.

Excess free chlorine is undesirable and can produce an objectionable taste in the water. An activated carbon filter can be used to obtain chlorine-free water for cooking and drinking.

### Controlling hydrogen sulfide bacteria in wells

Shock chlorination can effectively eliminate hydrogen sulfide when the problem is caused by the presence of sulfate- and sulfur-reducing bacteria in the plumbing sys-

**Table 1. Approximate chlorine dosage for oxidation of selected minerals based on concentration (mg/l).**

Manganese	1.3 Times mn concentration (mg/l)
Iron	0.64 Times fe concentration (mg/l)
Hydrogen sulfide	2.2 Times h <sub>2</sub> s concentration (mg/l)

tem. Shock chlorination uses a single high dose of chlorine placed in direct contact with water and the plumbing system. Chlorine, if used in sufficient concentration and with adequate contact time, is an excellent disinfectant that kills most disease-causing bacteria, viruses and cysts of protozoans. It also kills nonpathogenic iron, manganese and sulfur bacteria.

In some cases, iron and sulfur bacteria are more resistant to chlorine because they occur in thick layers and are protected by a slimy secretion. If problems with hydrogen sulfide persist after two attempts at shock chlorination, continuous chlorination could be required.

Concentrations of chlorine used in shock chlorination are 100 to 400 times the amount found in treated “city water.” The amount of chlorine needed is determined by the amount of water standing in the well. Table 2 lists the amount of ordinary household bleach (5.25 percent hypochlorite) needed for shock chlorination based on casing diameter and water depth in the well. If the depth of the water in the well is unknown, use a volume of bleach equal to two times the 150-foot depth for the appropriate casing diameter. For example, an 8-inch casing diameter with unknown water depth would require 3 gallons of household bleach. Do not use bleach in excess of the recommended amount because it is not necessary and will require additional flushing before household use.

**Table 2. Amount of chlorine needed for shock chlorination.**

Depth of water in well	Casing diameter				
	4-inch	6-inch	8-inch	10-inch	12-inch
10 feet	1/2 cup	1 cup	1.5 cups	1 pint	2 pints
25 feet	1 cup	1 pint	2 pints	3 pints	4.5 pints
50 feet	1 pint	1 quart	2 quarts	3 quarts	1 gallon
100 feet	1 quart	2 quarts	1 gallon	1.5 gallons	2 gallons
150 feet	3 pints	3 quarts	1.5 gallons	2 gallons	3 gallons

The procedure for treatment is as follows:

1. Dilute the bleach with water in a 5-gallon bucket. This increases the volume. Pour the solution around the sides of the well casing.
2. Connect a garden hose to a nearby faucet and wash down the inside of the well.
3. Do not operate the water system for 2 hours.
4. Next, open each faucet one by one and allow water to run until a strong odor of chlorine is detected. If the odor is not detected, check the rate from Table 2 and add more chlorine to the well, repeating steps one through three.
5. Do not operate the water system for at least 12 to 24 hours.
6. Next, flush the system of remaining chlorine. Begin by turning on outside faucets and letting the water run until the chlorine smell dissipates. Let the water run on the ground to reduce the load on your septic system. High loads of chlorine in the septic tank can kill beneficial bacteria and require re-inoculation of the septic system. Also, do not apply water with high

chlorine levels to lawns, gardens or other sensitive plants because injury can occur.

7. Finally, turn on the indoor faucets until the system is completely flushed.

### Summary

Hydrogen sulfide in drinking water is a common nuisance contaminant. Although it is generally not a health hazard, the offensive odor and corrosivity of water containing hydrogen sulfide usually make treatment necessary. Various treatment alternatives exist; however, chlorination is the most common and effective method. Iron and manganese frequently occur in association with hydrogen sulfide, and chlorination is an effective treatment for removing all three of these nuisance contaminants. Table 3 presents a summary of treatment options with estimated cost ranges and associated benefits. Always compare installation and maintenance costs and efficiencies of appropriate treatment alternatives and use qualified professionals for installation and service.

**Table 3. Treatment options for removal of hydrogen sulfide.\***

Treatment Type	Cost	Treatment Range	Comments
Disposable carbon cartridge	\$25-100	<1 ppm	Requires regular replacement.
Air purge systems	+\$600	<20 ppm	Requires sizeable equipment placed away from residence. Chlorination of water could be required in some cases. Not recommended for hard water.
Oxidizing carbon filter	\$800-1,200	<2-4 ppm	Can be used in conjunction systems with chlorination systems to remove all hydrogen sulfide greater than 2 ppm in water.
Greensand/Potassium Permanganate	\$1,200-1,400	<10 ppm	System requires regeneration of oxidizing media. Chemicals can be messy and unpleasant.
Chlorination systems	\$900-1,800	<75 ppm	Upper cost range assumes removal of chlorine using a carbon filter system.

\*(Based on informal survey of water treatment/equipment suppliers in November 1998)