



## Bacteria in Drinking Water

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From *Bacteria in Drinking Water* by  
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### Can bacteria in water make me sick?

The transmission of disease through drinking water is one of the primary concerns for a safe water supply. Human illness such as typhoid, dysentery, cholera, hepatitis, and giardiasis have been linked to drinking water contaminated by human waste.

### Can bacteria in water affect livestock?

Bacteria levels for livestock vary with intended water use (Table 1). Adult animals are more tolerant of bacteria than young animals. Water for cleaning and sanitizing must be of very high quality to prevent infections and contamination of food products.

**Table 1. Bacteria guidelines for livestock water supplies**

Adult animals .....	1000 fecal coliforms/100 ml
Young animals.....	1 fecal coliform/100 ml
Dairy wash water .....	1 coliform/100 ml

### How to tell if water is contaminated with bacteria

Testing a water supply for specific disease-causing organisms is expensive. Handling and culturing disease organisms requires special training and

equipment. Also, if the water supply is being contaminated by human wastes, but the disease organism is not present the day a sample is taken, the risk of future exposure to the illness is still present.

Instead, water supplies are tested for an indicator of human or animal waste—coliform bacteria. Coliforms do not cause disease. They are, however, always present in the digestive systems of humans and animals and can be found in their wastes. Coliforms are also present in the soil and plant material.

If a water supply is found to contain coliform bacteria, it may be contaminated by sewage or manure, and there is a risk of exposure to water-borne disease. The test for coliform bacteria is relatively inexpensive (usually \$6 to \$15 per sample) and easy to perform.

To determine whether the bacteria present is from human or animal waste, additional tests must be performed. Coliform bacteria also could come from natural sources such as soil or decaying vegetation. Some coliform bacteria are only present in fecal material; these are called fecal coliforms. These bacteria indicate the presence of human or animal waste.

A test for a third bacteria, fecal streptococci, must be performed to determine if it is of human or animal origin. The ratio of fecal coliforms to fecal streptococci vary for different animals (Table 2). If the ratio is near four, the waste is from humans. The ratio is less than one for animal wastes.

Another type of bacteria, referred to as iron bacteria, is a major nuisance in many well water supplies. (Iron bacteria should not be confused with iron dissolved in water that causes red water and stains on

clothing and plumbing fixtures.) This naturally-occurring bacteria does not cause disease, but does form a reddish-brown slime that coats the inside of pipes, fouls pumps and clogs waterers.

**Table 2. Typical fecal coliform/fecal streptococci ratios for humans and various animals**

Human .....	4.4
Duck.....	0.6
Sheep .....	0.4
Chicken.....	0.4
Pig.....	0.4
Cow.....	0.2
Turkey .....	0.1

## How to collect and handle a water sample

Proper collection and handling of a water sample is critical for a meaningful water test. Sample containers should always be obtained from the testing laboratory because containers may be specially prepared for a specific contaminant. Sampling and handling procedures will depend on the specific water quality concern and should be followed carefully. If the water is being treated, it may be necessary to sample both before and after the water goes through the treatment equipment.

## Bacteria sampling

Water samples for bacteria tests must always be collected in a sterile container. Take the sample from an inside faucet with the aerator removed. Sterilize by flaming the end of the tap with a disposable butane lighter. Run the water for two minutes to clear the water lines and bring in fresh water. Do not touch or contaminate the inside of the bottle or cap. Carefully open the sample container and hold the outside of the cap. Fill the container to the line to allow mixing and replace the top.

Refrigerate the sample and transport it to the testing laboratory within 36 hours (preferably in an ice chest). Many labs, including the state Health Department, will not accept bacteria samples on Friday or before a holiday, so check the lab's schedule.

Iron bacteria forms a very obvious slime on the inside of pipes and fixtures. A water test is not needed for identification. Check for a reddish-brown slime inside a toilet tank or where water stands for several days.

## What should I do if my water is contaminated with bacteria?

First, don't panic! Bacterial contamination is very common. Studies have found that over 40% of private water supplies are contaminated with coliform bacteria. Spring water supplies are the most frequently contaminated, with over 70% containing coliform bacteria.

Improving protection of a well or spring from the inflow of surface water is an important option to consider if the supply is contaminated with bacteria. It is important to remember that the groundwater is not necessarily contaminated in these cases, rather the well is acting to funnel contaminants down into the groundwater.

Although well pits were the common method of construction several years ago, they are no longer considered sanitary construction and are not approved. Pitless well adapters are approved, but the casing must extend at least one foot above ground and be provided with an approved cap.

A properly protected well is evidenced by the well casing extending above the surface of the ground and the ground sloping away from the well to prevent water from collecting around the casing.

A properly protected spring is developed underground and the water channeled to a sealed spring box. At no time should the water be exposed to the ground surface.

Keeping the plumbing system clean is an important part of maintaining a sanitary water supply. Anytime work is performed on the plumbing or pump, the entire water system should be disinfected with chlorine. Simply pulling the pump out of the well, setting it on the grass to work on it, and returning it to the well is enough to contaminate the well with bacteria.

The procedure for cleaning and sanitizing a well or spring with chlorine is called shock chlorination. Concentrations of chlorine ranging from 50 to 200 mg/l are used in the shock chlorination process. This is 100 to 400 times the amount of chlorine found in city water. The highly chlorinated water is held in the pipes for 12 to 24 hours before it is flushed out and the system is ready to be used again.

Periodic shock chlorination also may be effective in reducing an iron bacteria problem. The amount of chlorine needed to shock chlorinate a water system is determined by the amount of water standing in the well.

Table 3 lists the amount of chlorine laundry bleach or powdered high-test hypochlorite (HTH) that is needed for wells. If in doubt, it is better to use more chlorine than less.

# Shock chlorination process

1. Pour the proper amount of chlorine bleach or powdered chlorine dissolved in a small amount of water directly into the well.
2. Connect a garden hose to a nearby faucet and wash down the inside of the well.
3. Open each faucet one by one and let the water run until a strong odor of chlorine is detected. If strong odor is not detected, add more chlorine to the well.
4. Flush the toilets.
5. Let the water stand in the water system for at least 12 to 24 hours.
6. Flush the system of remaining chlorine. Start by turning on outside faucets and letting them run until the chlorine smell dissipates. Finally, run the indoor faucets until the system is completely flushed. There should be no detectable smell and the water should be clear. This procedure will reduce the load on your septic system.

Most water treatment equipment, such as water softeners, iron filters and sand filters, should also be shock chlorinated. Check manufacturers' literature

before chlorinating treatment equipment and pressure tank to prevent damage from strong chlorine solutions. Do not chlorinate carbon or charcoal filters or reverse osmosis units because it will use up their capacity.

Be careful when handling concentrated chlorine solutions. Wear rubber gloves, goggles, and a protective apron when handling chlorine solutions. If it accidentally gets on your skin, flush immediately with clean water.

Never mix chlorine solutions with other cleaning agents or ammonia because toxic gases are formed.

Do not use fresh scent bleach or other special laundry products to disinfect wells. The plain and usually least expensive laundry bleach should be used for disinfecting water.

## How can water be disinfected?

If a bacteria problem cannot be eliminated through improved water supply protection and shock chlorination, an alternative water supply or additional water treatment may be needed.

**Table 3. Amount of chlorine needed for shock chlorination**

*Liquid Laundry Bleach (about 5.25% Hypochlorite)*

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

*High-Test Hypochlorite (HTH 65-75% Hypochlorite)*

Depth of water in well	Casing Diameter				
	4 inch	6 inch	8 inch	10 inch	12 inch
10 feet	—	—	—	—	—
25	—	—	—	1/4 lb	1/2 lb
50	—	—	1/3 lb	1/2 lb	3/4 lb
100	—	1/3 lb	3/4 lb	1 lb	1-1/2 lb
150	1/4 lb	1/2 lb	1 lb	1-1/2 lb	4 lb

Three methods are available to disinfect water. There is no ideal disinfection method; each has its advantages and limitations. Choosing a disinfection technique involves accepting the advantages and living with the limitations. Water can be disinfected by boiling it, by adding oxidizing agents like chlorine or iodine, or by exposing it to ultraviolet light.

### Boiling water

Boiling water is extremely effective as a disinfectant. *Vigorous* boiling for three minutes kills bacteria, including disease-causing organisms and giardia cysts.

Any heat source, such as electric or gas ranges, camp stoves or wood fires can be used to boil water. Even microwave ovens can heat water to boiling. This makes it the most widely available form of disinfection.

Mineral deposits may build up in vessels used for boiling water. Soaking these vessels in a weak acid solution such as vinegar or lemon juice can help dissolve the mineral scale.

Boiled water can taste stale and it is not usually drawn from the tap. It is an off-line treatment system

which requires separate water storage.

### Chlorine

Chlorine kills bacteria, including disease-causing organisms and the nuisance organism, iron bacteria. However, low levels of chlorine, normally used to disinfect water, are not an effective treatment for giardia cysts. A chlorine level of over 10 mg/l must be maintained for at least 30 minutes to kill giardia cysts.

Chlorine has been used since 1908 to disinfect water supplies in the United States to protect public health. The effectiveness of chlorination depends on the chlorine demand of the water, the concentration of the chlorine solution added, the time that chlorine is in contact with the organism, and water quality. These effects can be summarized in the following manner:

- As the concentration of the chlorine increases, the required contact time to disinfect decreases.
- Chlorination is more effective as water temperature increases.
- Chlorination is less effective as the water's pH increases (becomes more alkaline).
- Chlorination is less effective in cloudy (turbid)

## Giardiasis

Giardiasis is a gastrointestinal illness affecting people and animals of all ages. The symptoms of Giardiasis include diarrhea, abdominal cramps and gas. It is caused not by a bacteria or virus, but by the protozoan parasite, *Giardia lamblia*. One of the most common intestinal parasites of man, *Giardia lamblia* is carried by a number of animal hosts. *Giardia* organisms form a resistant cyst that is shed by the host in its waste. Infections are acquired by ingesting these cysts in food and water or by personal contact with an infected person.

Individuals exposed to Giardiasis respond differently. After parasite ingestion, the symptoms may take one to four weeks to appear. The number of cysts consumed is not related to the persistence or severity of the infection. As few as 10 cysts have been known to cause infections. Infected individuals can be treated with prescription medication that eliminates the parasite from the intestine. A large number of infections disappear spontaneously without any treatment. In persistent cases of Giardiasis, individuals can go through periods in which stool samples alternate between positive and negative. There is also evidence that some individuals can develop resistance to *Giardia* infections.

Drinking water is a prime carrier of *Giardia*

cysts for several reasons. Individuals infected with the parasite shed cysts in their waste. Therefore, surface water supplies (like streams, lakes, and ponds) can be contaminated with *Giardia* cysts through the introduction of sewage or animal wastes. Groundwater supplies are usually protected by the filtering action of the soil which removes the cysts. Humans, dogs, cats, cattle, deer, and other mammals can carry *Giardia*. Beavers are often found to be the source of contamination because they can become infected and introduce their waste directly into the water near a water supply intake. Once in the water, *Giardia* cysts can persist for over 60 days.

*Giardia* cysts are difficult to identify in a water supply. There is no routine test a water company can use to check for *Giardia* contamination. Water testing for *Giardia* is currently used to confirm suspected contamination. It involves filtering several hundred gallons of water and identifying the cysts through microscopic examination by a trained analyst. Negative results are not a guarantee of a safe water supply because of the unknown sensitivity of the test. *Giardia* cysts are more easily identified in stool samples taken from an exposed person or animal. One gram of feces may contain as many as 2 million cysts.

water.

- When chlorine is added to the water supply, part of it combines with other chemicals in water (like iron, manganese, hydrogen sulfide, and ammonia) and is not available for disinfection. The amount of chlorine that reacts with the other chemicals plus the amount required to achieve disinfection is the chlorine demand of the water.

**Table 4. Necessary chlorine residual to disinfect water for various contact times, water temperatures and pH**

*Water Temp. 50 degrees F*

Contact time (minutes)	Necessary chlorine residual (mg/l)		
	pH 7	pH 7.5	pH 8
40	0.2	0.3	0.4
30	0.3	0.4	0.5
20	0.4	0.6	0.8
10	0.8	1.2	1.6
5	1.6	2.4	3.2
2	4.0	6.0	8.0
1	8.0	12.0	16.0

*Water Temp. 32 - 40 degrees F*

Contact time (minutes)	Necessary chlorine residual (mg/l)		
	pH 7	pH 7.5	pH 8
40	0.3	0.5	0.6
30	0.4	0.6	0.8
20	0.6	0.9	1.2
10	1.2	1.8	2.4
5	2.4	3.6	4.8
2	6.0	9.0	12.0
1	12.0	18.0	24.0

**Example**

What is the necessary chlorine residual for well water with pH 7.5?

The well water is 38 degrees when it enters the house. The pump delivers 7 gallons per minute and after the chlorine is added it is held in a 100 gallon holding tank.

- Contact time (from Table 5) - gallons per minute for 50-gallon tank = 5 minutes
- Multiply by 2 for 100-gallon tank = 10 minutes
- Necessary chlorine residual (from Table 4) - for water at 38 degrees and pH 7.5 = 1.8 mg/l

The safest way to be sure that the amount of chlorine added is sufficient is to add a little more than is required. This will result in a free chlorine residual

that can be measured easily. This chlorine residual must be maintained for several minutes depending on chlorine level and water quality. Table 4 lists the free chlorine residual level needed for different contact times, water temperatures and pH levels.

Kits are available for measuring the chlorine residual by looking for a color change after the test chemical is added. The test is simple and easy for a homeowner to perform. If chlorination is required for the water supply, the chlorine residual should be tested regularly to make sure the system is working properly.

The kit should specify that it measures the *free chlorine residual* and not the total chlorine. Once chlorine has combined with other chemicals it is not effective as a disinfectant. If a test kit does not distinguish between free chlorine and chlorine combined with other chemicals, the test may result in an overestimation of the chlorine residual.

Chlorine will kill bacteria in water, but it takes some time (Table 4). The time needed depends on the concentration of chlorine. Two methods of chlorination are used to disinfect water: simple chlorination and superchlorination.

Simple chlorination involves maintaining a low level of free residual chlorine at a concentration of 0.3 - 0.5 mg/l for at least 30 minutes. The residual is measured at the faucet most distant from where chlorine is added to the water supply.

To ensure the proper contact time of at least 30 minutes, a holding tank can be installed (Table 5). Pressure tanks, while often thought to be sufficient,

**Table 5. Available contact time from a 50-gallon holding tank**

Water flow rate (gallons per minute)	Holding time (minutes)
5	7.0
7	5.0
10	3.5

are usually too small to always provide 30 minutes of contact time.

Another way to maintain necessary contact time

**Table 6. Available contact time from 1000 feet of 1-1/4 inch pipe**

Water flow rate (gallons per minute)	Holding time (minutes)
5	9.2
7	6.6
10	4.6

is to run the chlorinated water through a coil of pipe (Table 6).

When the water cannot be held for at least 30 minutes before it is used, superchlorination is an alternative. For superchlorination, a chlorine solution is added to the water to produce a chlorine residual of between 3.0 and 5.0 mg/l, which is about ten times stronger than for simple chlorination. The necessary contact time for this concentration is reduced to less than five minutes (Table 4). The water will have a very strong chlorine smell. If this is not desirable, the chlorine can be removed just before it is used with a carbon filter.

## Types of chlorinators

Chlorine can be purchased in two formulations: calcium hypochlorite, which is a dry powder or tablet, and sodium hypochlorite, which is a liquid (commonly called chlorine bleach). Calcium hypochlorite dissolved in water or sodium hypochlorite are added to the water system through an injection pump. These pumps can be adjusted to add the prescribed amount of chlorine and are activated by the well pump. Other liquid chemicals (such as soda ash solutions) in addition to chlorine can be injected using the same pump.

The most commonly used chemical injection pump for individual water treatment is the positive displacement diaphragm pump. These pumps are equipped with: an electric motor, a piston, a diaphragm, a suction and injection valve, a chemical holding tank, and a foot valve. The motor first withdraws the piston to pull back the diaphragm. This creates a vacuum in the chamber that opens the suction valve, drawing in the chemical. The motor then drives the piston to push on the diaphragm. This forces the chemical out of the chamber, through the injection valve, and into the water line.

Maintenance of the injection pump is crucial to its reliable operation. The motor and piston must be lubricated. Because of the corrosive nature of the concentrated chlorine solutions, the valves wear out and have to be replaced. Chlorine storage containers must also be corrosion resistant and kept out of the light. The chemical tank also needs to be checked and kept full, and occasionally cleaned if chlorine solutions are prepared with powdered hypochlorite (sediment tends to accumulate in storage containers). Advantages of this type of injection pump are its ability to deliver chemicals over a wide range of injection rates and ease of adjustment.

Other types of chlorinators add chlorine tablets to the water supply, often at the well. They are called erosion and pellet chlorinators.

Erosion chlorinators consist of a canister to hold a supply of chlorine tablets and a chamber to allow

water to flow over and dissolve the tablets. These units have the advantage of using chlorine tablets that are easy to handle and store. However, the chlorine they deliver tends to fluctuate greatly and is difficult to control. Tablet bridging can occur when the tablets get damp in the storage canister and stick together. Tapping the storage canister occasionally can help break down the bridging that occurs.

Pellet chlorinators also stand on top of the well and drop chlorine tablets directly into the well. A preset number of tablets are dropped in response to water being pumped. The well must be clear of obstructions to ensure that the tablets do not become lodged before reaching water level.

## Careful use of chlorine

The size of chlorination systems is unlimited. A few drops of chlorine can be added to a gallon of water in an emergency or on a camping trip. Yet millions of gallons of water are chlorinated daily at large water treatment plants.

Some water supplies (mostly ponds and streams) contain some natural organic chemicals from the breakdown of plants and leaves. These organic chemicals (called precursors) can combine with chlorine to form chemicals called THMs or trihalomethanes. Trihalomethanes are suspected cancer-causing agents. Activated carbon filters can be used to remove THMs.

As with chlorine bleach, both solid and liquid formulations of chlorine are irritating to the skin and are poisonous in their concentrated form. They must be carefully handled and stored. Chlorine tablets must be stored in a dry location and both liquids and solids should be stored in their original labeled container away from children and animals. All chlorine solutions should be stored in a dark place because light can cause a photochemical reaction which reduces their potency.

## Ultraviolet

Ultraviolet (UV) light has disinfection properties that kill bacteria, viruses, and some cysts. However, it will not kill giardia cysts.

While not allowed under the current rules of the Missouri Department of Health for private water supplies, the concept of using light to treat water supplies has been around for over 75 years.

## Iodine

Iodine kills bacteria and disease-causing organisms, but is slow acting. Iodine is, however, ineffective as an algicide.

Iodine has been used to disinfect water since the early 1900s. In its natural state, iodine is a solid black

crystal. Iodine crystals will dissolve in water, dependent on the water temperature. The higher the temperature, the more will dissolve. The simplest method of disinfecting water with iodine is by dissolving iodine in water to form a saturated solution and then injecting the iodine solution into a water system.

Iodine does not kill bacteria on contact; a holding time of at least 20 minutes is needed depending on the iodine concentration. An iodine residual of 0.5 to 1.0 mg/l should be maintained and iodine at this level gives the water little or no iodine taste or odor. Iodine can be removed from water with a carbon filter just before drinking.

Iodine dosage is very temperature dependent because iodine crystals are more soluble at higher temperatures. Iodine remains effective over a wide range of pH and does not lose effectiveness until the pH of water reaches 10. Iodine residuals in water can easily be measured using a test kit that indicates a color change.

Iodine tablets were developed during World War II to disinfect small amounts of water for emergency or temporary use. A few drops of tincture of iodine or iodine tablets are popular with campers and the military for disinfecting water.

## Types of iodinator

Iodine solutions are injected into a water system using bypass saturator systems or injection pumps. A holding tank or coil of pipe is used after the iodine injection to provide the necessary holding time.

The most common type of iodinator is called a bypass saturator and consists of a solution tank containing iodine crystals. Bypass saturators do not require any electrical connections. The solution tank is connected to the water system and diverts a small amount of water through it and back into the water line. Valves are placed on either side of the iodinator to control the iodine dose. Fluctuation in water temperature affects the solubility of iodine. Adjustments in the bypass rate are needed if water temperature changes.

Chemical injection pumps can also be used to inject iodine solutions for individual water treatment. These are the same injection systems that are used for chlorine.

Iodinators are in-line systems that are sized to treat all the water used in a household.

## Careful use of iodine

The question of possible health effects of iodine is still unanswered. No adverse health effects have been shown, yet continuous consumption of iodine-treated water is not recommended. Carbon filters can be used to remove iodine just before drinking. (NOTE: Iodine

treatment is not currently approved under the Missouri Department of Health for private water supplies.) Iodine is also appropriate for occasional use in vacation homes, campgrounds, and restaurants.

Iodine treatment of drinking water supplies for dairy cattle is also a concern. Because dairy cattle can drink from 15 to 30 gallons of water a day, normal levels of iodine used for disinfection may cause iodine carryover into milk.

## “We’ve been using this water for years and we’re OK”

Bacterial contamination of private water supplies is common, so why aren’t more people sick?

1. The coliform bacteria identified in a water test do not cause disease. These bacteria are used to identify an unsanitary water supply and indicate the risk of exposure to water-borne disease.
2. Water-borne diseases may be mistaken for the flu or food poisoning.

Remember that coliform bacteria in your water supply is a warning of contamination. Only through routine water testing, proper water supply construction and protection, and any necessary water treatment can you ensure a safe water supply for your family and livestock.

## Disinfection methods

### Boiling water

#### Advantages:

- Readily available.
- Well-suited for emergency and temporary disinfection.
- Will drive volatile organic chemicals out of water.
- Extremely effective disinfectant that will kill even giardia cysts.

#### Disadvantages:

- Requires a great deal of heat.
- Time to bring water to boil and cool before use can give water stale taste.
- Typically limited capacity.
- Not an in-line treatment system.
- Requires separate storage of treated water.

### Chlorination

#### Advantages:

- Provides residual disinfectant.
- Residual easy to measure.
- Chlorine readily available at reasonable cost.

- Can be used for multiple water problems (bacteria, iron, manganese, hydrogen sulfide).
- Can treat large volumes of water.
- Low electrical requirement.

Disadvantages:

- Requires contact time of 30 minutes for simple chlorination.
- Gives water a chlorine taste.
- Turbidity (cloudy water) can reduce the effectiveness of chlorine.
- May combine with precursors to form THMs.
- Does not kill giardia cysts at low levels.
- Careful storage and handling of chlorine is required.

**Ultraviolet light**

Not currently approved by the Missouri Department of Health for residential/private drinking water supplies.

Advantages:

- Does not change taste or odor of water.
- Compact and easy to use.
- Kills bacteria almost immediately.

Disadvantages:

- No disinfection residual.
- High electrical demand
- Requires pretreatment of cloudy or colored water.
- Requires cleaning and new lamp annually.

**Iodine**

Not currently approved by the Missouri Department of Health for residential/private drinking water supplies.

Advantages:

- Does not require electricity.
- Requires little maintenance.
- Provides residual treatment.
- Residual easy to measure.

Disadvantages:

- Health effects of iodine undetermined.
- Gives water a slight straw color at high levels.
- Concentration affected by water temperature.
- Gives water an iodine taste.
- Not effective as an algicide.

**Emergency disinfection**

Boiling water is extremely effective as a disinfectant. Vigorous boiling for three minutes kills bacteria including disease-causing organisms and giardia cysts.

A few drops of chlorine bleach can be added to a gallon of water in an emergency or on a camping trip.

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<u>Available Chlorine in Bleach</u>	<u>Number of Drops to Disinfect One Gallon of Water</u>	
	<u>Clean Water</u>	<u>Cloudy Water</u>
5.25% .....	8 .....	16

Mix water thoroughly and let stand for 20-30 minutes. Chlorine and iodine tablets are also available in drug stores and camping goods stores. Follow the directions on the container.

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Tincture of Iodine from a home medicine chest may be used to disinfect water.

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<u>Volume of Water</u>	<u>Number of Drops Iodine</u>	
	<u>Clean Water</u>	<u>Cloudy Water</u>
One quart.....	5 .....	10
One gallon .....	20 .....	40

Mix water thoroughly and let stand for 20-30 minutes.

**For more information**

These MU publications provide more information about private water supplies:

- WQ 100, *Water Testing: What to Test For;*
- WQ 101, *Understanding Your Water Test Report;*
- WQ 103, *Nitrate in Drinking Water;*
- WQ 104, *Understanding Home Water Treatment Systems.*

To order these publications, contact Extension Publications, University of Missouri–Columbia, 2800



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