Coliform Bacteria

This article describes what coliform bacteria are, where they come from and how to remove them from drinking water.

What Are Coliform Bacteria?

Coliform bacteria include a large group of many types of bacteria that occur throughout the environment. They are common in soil and surface water and may even occur on your skin. Large numbers of certain kinds of coliform bacteria can also be found in waste from humans and animals. Most types of coliform bacteria are harmless to humans, but some can cause mild illnesses and a few can lead to serious waterborne diseases.

Coliform bacteria are often referred to as "indicator organisms" because they indicate the potential presence of disease-causing bacteria in water. The presence of coliform bacteria in water does not guarantee that drinking the water will cause an illness. Rather, their presence indicates that a contamination pathway exists between a source of bacteria (surface water, septic system, animal waste, etc.) and the water supply. Disease-causing bacteria may use this pathway to enter the water supply.

Specific types of coliform bacteria may be tested for, especially after a total coliform bacteria test is positive. These subgroups of coliform bacteria include fecal coliform and *Escherichia coli* or *E. coli*. Fecal coliform bacteria are specific to the intestinal tracts of warm-blooded animals, including humans, and thus require a more specific test for sewage or animal waste contamination. *E. coli* is a type of fecal coliform bacteria commonly found in the intestines of animals and humans. A positive *E. coli* result is much more serious than coliform bacteria alone because it indicates that human or animal waste is entering the water supply. There are hundreds of strains of *E. coli*. Although most strains are harmless and live in the intestines of healthy humans and animals, a few strains can produce a powerful toxin and can cause severe illness and death.

Health Effects of Coliform Bacteria

As mentioned earlier, drinking water that is contaminated with coliform bacteria does not always cause illness. Most of these bacteria are harmless to humans. If disease-causing bacteria are present, the most common symptoms are gastrointestinal upset and general flu-like symptoms such as fever, abdominal cramps, and diarrhea. Symptoms are most likely in children or elderly household members. In some cases, household residents acquire immunity to waterborne bacteria that are common in their drinking water. In this case, visitors to the home that have not acquired immunity may become ill after drinking the water. Since the symptoms of drinking water with coliform bacteria are common to many human illnesses, knowing that water is the source of the problem is difficult without having the water tested.

Drinking Water Standards

Most bacteria in the coliform group do not cause disease, but the greater their number the greater the likelihood that disease-causing bacteria may be present. Since coliform bacteria usually persist in water longer than most disease-causing organisms, the absence of coliform bacteria leads to the assumption that the water supply is microbiologically safe to drink. Therefore, the drinking water standard requires that no coliform bacteria be present in drinking water. Fecal coliform and *E. coli* bacteria should also be totally absent from drinking water.

PennState Extension

Testing Water for Coliform Bacteria

The most common water test for bacteria is for total coliform bacteria. This test is readily available to the public and is inexpensive (generally $10 to $30). Water tests for total coliform bacteria can be arranged through a local office of the Pennsylvania Department of Environmental Protection (DEP) or by a state certified commercial water-testing laboratory. A list of certified commercial labs, organized by county, can be found online from the DEP. You can also call your local DEP or Penn State Extension office to find a local certified laboratory.

Penn State Extension recommends that all private water supplies (wells, springs, and cisterns serving an individual house) be tested for total coliform bacteria every year. If your initial water test indicates that total coliform bacteria are present, additional tests for fecal coliform and *E. coli* bacteria may be warranted.

Time of year and weather conditions can affect the occurrence and amount of coliform bacteria in wells. A recent Penn State study looked at 38 wells that tested positive for coliform bacteria during a year when precipitation was near normal. These 38 wells were retested during a cold, dry weather spell a year later. Fewer than half still contained coliform bacteria, and most of these had lower numbers of bacteria than previously found. Since coliform bacteria like to live near the surface of the earth and prefer warm temperatures, it is reasonable that bacteria would be more likely to occur in groundwater wells during warmer, wetter weather conditions when surface water is recharging groundwater aquifers. Thus, the highest number of bacteria will be found by testing your well shortly after several weeks of rainy weather, while the fewest bacteria will be found when testing during dry, cold conditions in the winter. These variations in bacteria with season and weather conditions need to be considered when testing your water supply for bacteria.

Proper water testing for bacteria will require that you obtain a sterilized sample bottle from the laboratory and collect the sample strictly according to their instructions. Failure to collect the sample in a sterile container may cause bacteria to be introduced during the sampling process.

Once at the laboratory, your water may be analyzed for coliform bacteria using a variety of methods. A common method is to pass 100 milliliters (mL) of water through a membrane filter to capture the bacteria. The filter is then placed in a petri dish with agar to grow the bacteria overnight. If bacteria are present, they appear as colonies on the filter paper that can be counted (Figure 1). The bacteria results are then reported as the number of colonies per 100 mL of water.
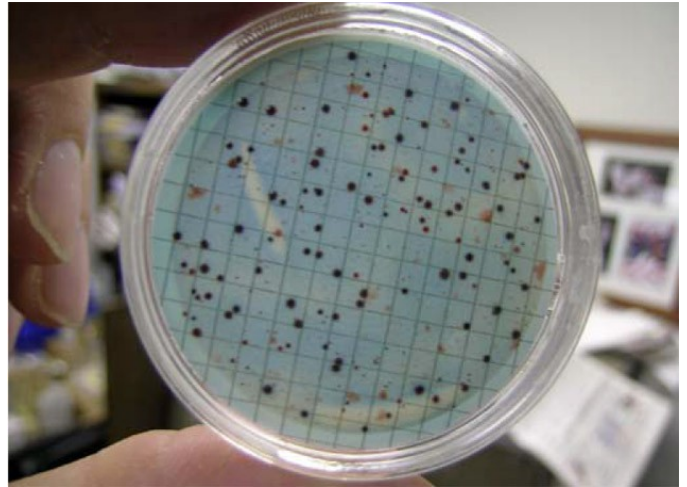

Figure 1. A petri dish showing coliform bacteria that have grown after 24 hours of incubation from filtration of 100 mL of well water.

Other bacteria-testing methods look for color changes in test tubes that have been incubated with a water sample. These methods may simply express coliform bacteria results as "present" (P) or "absent" (A). In this case, "present" only indicates that at least one bacterium was present in 100 mL of water. These presence/ absence methods have become popular because they are simple, less expensive, and quicker than enumeration methods. But, they also provide less information about the severity of the bacteria problem that can be helpful when trying to determine the causes and solutions.

There are other coliform-bacteria testing methods that rely on color changes but also provide an estimate of the number of bacteria present. These are often referred to as "most probable number" (MPN) methods, which use a statistical relationship to estimate the number of bacteria in your sample based on color changes in multiple test tubes.

Sometimes, coliform bacteria results are reported as "TNTC" (too numerous to count) or "confluent." TNTC means that the bacteria concentration was so high that it could not be counted (generally higher than 200 colonies per 100 mL). Confluent means that numerous other noncoliform bacteria grew on the plate, making identification of coliform bacteria impossible. In either case, another sample should be submitted to the laboratory for a more accurate determination.

How Common Are Coliform Bacteria?

Coliform bacteria are one of the most common water contamination problems in private water systems in Pennsylvania and throughout the United States. A 2006 survey of 450 private wells found coliform bacteria in approximately 35 percent and *E. coli* bacteria in about 15 percent of private wells.

Coliform bacteria are much more common in springs and shallow wells compared to deeper wells because bacteria are naturally filtered out by soil and rock as surface water

infiltrates into the ground. Deeper wells (greater than 100 feet) can still be contaminated by coliform bacteria if they are improperly constructed by allowing surface water to flow along the well casing directly into the deep groundwater or if nearby land uses are causing contamination of deep groundwater.

Removing Bacteria from Drinking Water

Problems with wells or springs that test positive for coliform bacteria can sometimes be solved with relatively simple actions. If your water supply tests positive, consider the following steps to solve the problem.

- *Confirm Test Results*: Before making any costly decisions about your water supply, make sure the coliform bacteria result you have received is accurate. Make sure you used a certified water-testing laboratory and that you carefully followed the sample collection procedure using a sterile sample bottle. You may want to submit a second sample just to confirm the initial result. Also, if you only had a presence/absence test done, you may want to consider asking the lab to count (enumerate) the bacteria in your water. It is also important to follow up positive total coliform bacteria tests with a test for *E. coli* bacteria to help determine the severity of the bacteria problem.

- *System Maintenance*: Sometimes some simple maintenance of the water supply may eliminate the source of bacterial contamination. For example, you may want to extend a buried well casing above the ground and slope the ground away from the casing to prevent surface water from entering the well. Also, make sure the top of the casing has a tight, sanitary well cap that prevents insects and surface water from entering. If you have a spring, make sure the spring box is sealed to prevent insects and animals from entering. If *E. coli* bacteria are present, check your septic system for proper functioning and remove or divert obvious sources of animal waste from around the well or spring. If you have a loose-fitting basic well cap, consider switching to a sanitary well cap; see the article Protecting Wells with Sanitary Well Caps and Grouting.

- Shock Chlorination: In some cases, coliform bacteria can be introduced to a well or spring from a one-time or temporary contamination event such as a heavy rainstorm or installation of a new submersible pump. Shock chlorination can be used to disinfect a well or spring by introducing a high concentration of chlorine to the water for a short time. More information on this procedure is in the article Shock Chlorination of Wells and Springs. Retest the water for coliform bacteria within 10 to 14 days and again several months later. If the follow-up coliform bacteria tests are negative, it is likely that a onetime contamination event occurred that has been successfully treated. If the bacteria have returned, you will need to consider a continuous disinfection treatment system such as those described below. A Penn State study found that

approximately 15 percent of wells with coliform bacteria could be treated by shock chlorinating the well and installing a sanitary well cap. This was especially true for wells that had small numbers of coliform bacteria (fewer than 10 colonies per 100 mL).

- Continuous Disinfection: If shock chlorination is unsuccessful at eliminating coliform bacteria from your water supply, you'll need to consider buying a disinfection treatment system that continuously treats all of the water entering the home. Many types of disinfection treatment systems using the processes described below are commercially available.

Continuous Disinfection Methods

Chlorination

Municipal water treatment plants throughout the United States continuously add chlorine to ensure that their water is free of bacteria. Chlorination treatment systems are basically composed of a feed system that injects a chlorine solution (sodium hypochlorite) or dry powder (calcium hypochlorite) into the water ahead of a storage tank. Most chlorinators use positive displacement feed pumps to meter the chlorine into the water. Other units may use suction-type chlorinators or pellet droppers to deliver the chlorine.

The raw water entering the chlorinator should be perfectly clear or free of any suspended sediment or cloudiness in order for the chlorine to effectively kill the bacteria. A sediment filter is routinely installed ahead of the chlorinator to remove small amounts of suspended material.

The chlorine that is injected into the water is consumed as it kills bacteria. The chlorine is also consumed by impurities in water such as iron, hydrogen sulfide, and organic materials. The amount of chlorine needed to kill bacteria and oxidize all the impurities in the water is known as the *chlorine demand*. Thus, the total amount of chlorine that must be injected into the water will depend on the chlorine demand of the raw water. Other water characteristics such as pH and temperature will also affect the amount of chlorine that must be injected into the water. The goal of continuous chlorination is to provide enough chlorine to satisfy the chlorine demand and still allow for approximately 0.3 to 0.5 milligrams per liter of residual chlorine in the water. This residual chlorine is then available to kill bacteria that may enter the water after the chlorinator.

The time required for the chlorine to kill bacteria is known as the *contact time*. The required contact time will vary depending on water characteristics, but a general rule of is to provide approximately 30 minutes of contact time. Standard pressure tanks are usually not large enough to provide sufficient contact time, so a larger intermediate holding tank may need to be installed. Sufficient contact time can also be achieved by running the water through a series of coiled pipes. Contact time requirements can be shortened by increasing the chlorine dose (superchlorination), but this may require the

addition of a carbon filter to remove the objectionable chlorine taste and odor.

Continuous chlorination treatment systems require significant maintenance. Chlorinators must be routinely checked to ensure proper operation and chlorine supplies must be continually replenished. Both liquid and solid forms of chlorine are poisonous and irritants that must be handled according to specific safety measures.

Ultraviolet Light

Ultraviolet (UV) light has become a popular option for disinfection treatment because it does not add any chemical to the water. However, UV light units are not recommended for water supplies where total coliform bacteria exceed 1,000 colonies per 100 mL or fecal coliform bacteria exceed 100 colonies per 100 mL.

The unit consists of a UV light bulb encased by a quartz glass sleeve (Figure 2). Water is irradiated with UV light as it flows over the glass sleeve. The untreated water entering the unit must be completely clear and free from any suspended sediment or turbidity to allow all of the bacteria to be irradiated by the light. A sediment filter is often installed ahead of the UV unit to remove any sediment or organic matter before it enters the unit. The quartz glass sleeve must also be kept free of any film. Overnight cleaning solutions can be used to keep the glass sleeve clean, or optional wipers can be purchased with the unit to manually clean the glass. Water with a high hardness (calcium and magnesium) may also coat the sleeve with scale (a whitish deposit of hardness), which may require routine cleaning or addition of a water softener. The unit also requires electricity and will cause a small but noticeable increase in your electric bill (perhaps $2 to $4 per month).

Figure 2. A typical UV light installation with a small canister sediment filter (bottom) ahead of the UV light unit.

The disadvantage of this system is that it only kills bacteria inside the unit and does not provide any residual disinfectant for bacteria that may survive or be introduced into the plumbing after the UV light unit. Maintenance requirements are minimal for UV units but the light bulb will slowly lose intensity over time and will require replacement about once a year. Some units come equipped with a UV light intensity sensor that can detect when the bulb is not emitting sufficient UV light. These sensors add to the initial cost of the unit but may pay for themselves in increased bulb life.

Other Options

Numerous other treatment processes can be used to disinfect water. They are not recommended for continuous disinfection for a variety of reasons.

Boiling

Boiling water for about one minute effectively kills bacteria. This method is frequently used to disinfect water during emergencies or while camping. Boiling is time and energy intensive, however, and only supplies small amounts of water. It is not a long-term or continuous option for water supply disinfection.

Ozonation

In recent years, ozonation has received more attention as a method for treating water quality problems including bacterial contamination. Like chlorine, ozone is a strong oxidant that kills bacteria, but it is a much more unstable gas that must be generated on site using electricity. Once the ozone is produced, it is injected into the water where it kills the bacteria. Ozonation units are generally not recommended for disinfection because they are much more costly than chlorination or UV light systems. They may be useful where multiple water quality problems must be treated, such as disinfection in combination with removal of iron and manganese.

Iodination

Iodine has been used in the past, similar to chlorine, to continuously disinfect water. Iodination is no longer considered a permanent disinfection option due to health concerns related to long-term exposure to low levels of iodine residual in water. The U.S. Environmental Protection Agency now recommends iodination only for short-term or emergency disinfection. Iodine tablets are a popular choice among campers and hikers for water disinfection.

More Information

For more discussion on the advantages and disadvantages of treatment equipment and for guidance on equipment selection, consult Tips for Buying Water Treament Equipment.

Prepared by Bryan R. Swistock, extension associate, Stephanie Clemens, research assistant, and William Sharpe, professor of forest hydrology.

Authors

Bryan Swistock
Senior Extension Associate; Water Resources Coordinator
brs@psu.edu
814-863-0194

William Sharpe, Ph.D.
Professor Emeritus of Forest Hydrology

extension.psu.edu