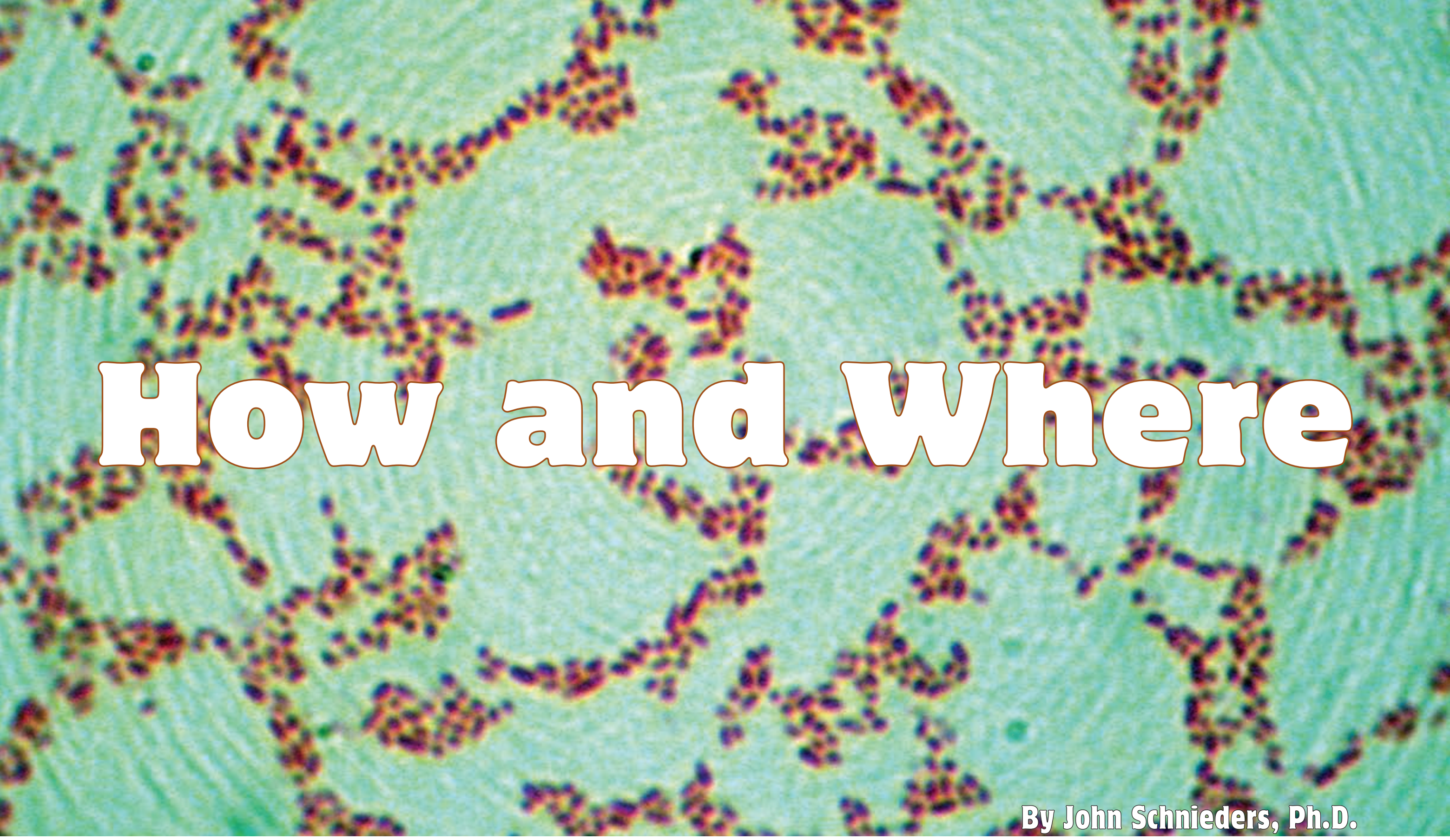

How and Where

By John Schnieders, Ph.D.

Find out why coliforms sometimes live in water wells and exactly where they do so.

How wells become contaminated or how they harbor coliforms and other potential pathogens depends a lot on the general structure of a well and how it is operated. Water wells have many designs, and each day a new idea for the building of a well is put forward. But in general, a well is designed and built with some basic features.

Some coliforms are adapted to living in the gut of animals and humans, but as we have discovered, they are also found in many other environments. Their presence in sewage has made them useful as an indicator of potential pathogens, and some of their adaptations have made them particularly elusive in water wells.

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Drilled wells vary in diameter from the 1-inch wells drilled in the granitic formations of Alaska and the Northeast, to some as large as 24 inches in the municipal wells of the Southwest. Of course, there are even larger diameter wells, but this range covers the greatest number. Drilled wells are constructed either as an open borehole or as a screened and gravel-packed well.

Open-borehole wells are drilled into the aquifer with a casing provided at a minimum in the upper 20-foot range in order to stabilize the formation and provide for the placement of a sanitary seal. In larger wells, the casing may extend to the top of the aquifer or at least 25% of the well depth. Smaller private wells often only receive the minimum casing placed at a depth sufficient to support the required sanitary seal. On the other hand, screened wells are usually cased to the bottom of the well with the casing replaced with screen in the aquifer or water-bearing zones.

It was a common practice in years past to drill the borehole deeper than the aquifer, which in effect provided a sump for the collection of sediment and drilling debris that was not removed during development after the well was drilled. It was reasoned that the presence of the sump actually provided cleaner water as it gave a collection area for the heavy particulates often present in a new well. Since this area was below the pump intake or production zone in the open borehole well and the screened zone in a cased and gravel-pack well, flow into the well was unable to disturb or resuspend the sediment and carry it out with the produced water.

Wells are also classified by their operating schedule, which to some extent is determined by their size, location, and ownership. Wells owned by a municipality or type of industry are responsible for water production for many people or regularly scheduled needs. These are usually larger wells of diameters greater than 6 inches. Municipal and industrial

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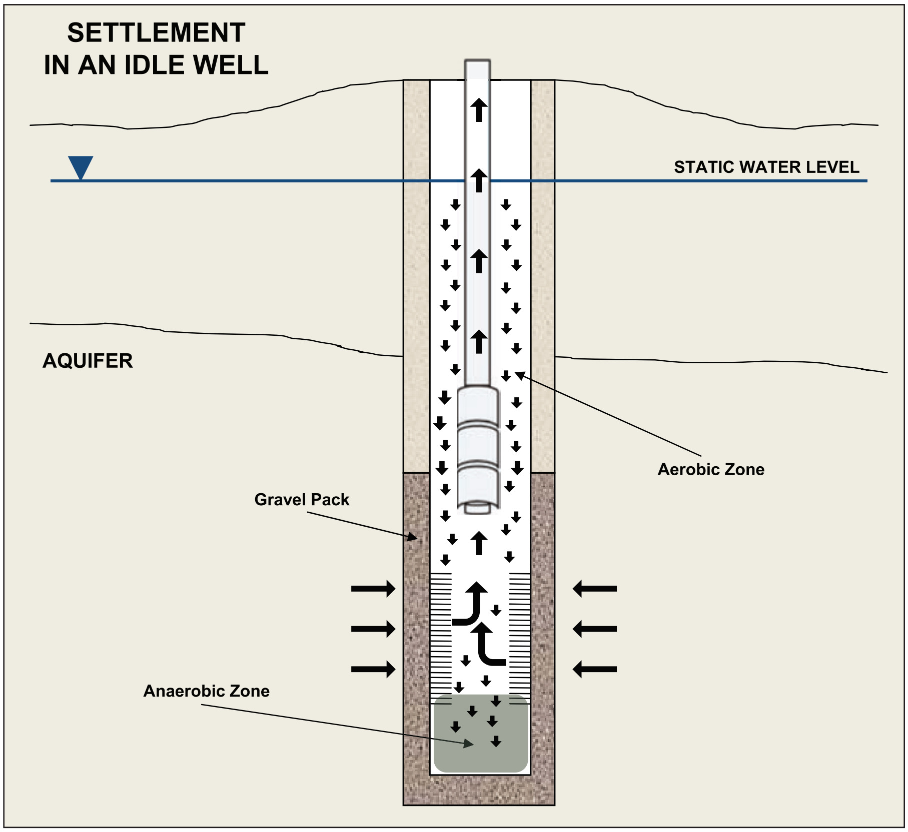
wells often have to supply water for a sustained period of time—8 to 16 hours of pumping daily. Another category of larger wells are agricultural wells that also have a sustained pumping schedule, but only for a given season.

The largest group of wells in North America are private home wells. Private wells are usually smaller than 6 inches in diameter. Since these wells most often furnish water for a single family or a limited group of people, they are pumped for a limited schedule. It is this limited schedule of pumping that is the biggest characteristic difference of all drilled wells. In the understanding of well fouling and contamination, it is the most important with the exception of direct pollution.

Since most home wells pump to a limited capacity tank, they come on whenever more than 15 to 20 gallons of water are required. Therefore, they pump water whenever the washing machine or dishwasher is used, whenever a bath or shower is taken, or a large meal is prepared. In scheduling, this means the well pump draws from the aquifer around 6 a.m. when the family is getting up and leaving for school or work, and again when everyone comes home around 5 p.m. and again later in the evening for washing clothes or getting ready for bed. On this schedule, the well sits idle for 8 to 10 hours in the daytime and about the same during the night.

In contrast, the larger well is used to fulfill water requirements throughout the day and to fill large storage in the late afternoon or evening. Large well pumps are operated not only continuously to deliver water but are scheduled for continuous long runs to conserve energy as intermittent operation requires additional electrical power. While these wells also experience some idle periods when excess bacterial growth can populate a well environment, they also are pumped for longer periods at greater capacities during which much of the accumulation of biological or mineral material is flushed from the well. With the exception of areas in the well that experience limited flow, this periodic pumping over extended periods does much to limit bacterial and mineral accumulation on the interior surfaces and structure of the well.

Coliform bacteria can live in the oxygen-laden aerobic zone or the oxygen-free anaerobic zone.



As a well is pumped, water from the aquifer is drawn into the open borehole or screen and up through the pump, column pipe, and out to the distribution piping. The water coming from the aquifer is generally clean but does contain dissolved solids like calcium and magnesium, the hardness minerals, or iron and manganese whose oxidized form becomes a suspended particle. These suspended particles will deposit as fouling, or settle as sediment to the well bottom or within the distribution piping (or even sinks, toilets, or on washed clothing).

Of course, bacteria are also present, as natural residents of the aquifer, or mobilized as the water moved through the soil into the aquifer. There are many different types of bacteria, which for the most part are not harmful to humans. In some cases, they actually are cleaning the water of organic debris that has made its way into the aquifer. These many different species of bacteria can inhabit a variety of locations within the well, in either a free-swimming or planktonic form, or as part of a biofilm structure.

Bacteria are classified as aerobic or anaerobic, which means they require oxygen to live (aerobic) or they do not require oxygen (anaerobic). Most aquifers, particularly shallow aquifers that receive recharge more directly from the vadose zone, have water that is aerated and has oxygen present. Therefore, as the water moves into the well it is always carrying minerals, bacteria, oxygen, and some food (as organic molecules) into the well structure. At this point, how the well is operated and the structure of the well impacts the natural chemistry and the biology and determines just how clean the well will be maintained. It is this degree of cleanliness that will determine the mineral and biological fouling and the potential for contaminant accumulation. Contaminant accumulation from a regulatory viewpoint often becomes "coliforms" in the well.

What are coliform bacteria and how do they often inhabit water wells?

Coliforms are bacteria that are used as indicators of contamination in drinking water supplies. They are part of the regulations because they are relatively easy to test for and because they were once believed to be found only in the gut of warm-blooded animals, including humans.

Coliforms are not a particular species of bacteria. They are, however, a group of bacteria made up of many different genera and species that conform to certain growth requirements. These requirements are present in the separate species to different degrees, and some are quite capable of existing in natural environments. In the many years since coliforms have been used to monitor our well systems, we have come to recognize there are many natural habitats for their growth and indeed many are not indicators of a fecal source. On the other hand, their presence has given us a target to hit. Thus, the cleaning and disinfecting of wells to remove coliforms has given us much cleaner and "safer" water wells.

Why then do coliforms get into our wells?

Forget that coliforms have any particular connotation of contamination and think of them as just some of the many bacterial species that are part of our environment. Bacteria that are in our soils are often transported into the near surface aquifers and eventually even get to the deep aquifers. Other bacteria from surface water sources often reach the aquifer as the surface water flows into river alluviums. And of course there are the improperly designed or poorly maintained septic and sewer systems that can feed bacteria into the ground water environment.

All these bacteria enter the well environment with the aquifer water as the well is pumped. If the well continues to be pumped, the organism might pass right on through the well system and out for distribution. When the well sits idle, the bacteria tend to colonize and may remain in a given area until the dynamics of the microenvironment changes. For example, of all the bacteria that reach the column going up to the pump, the aerobic bacteria (those which require oxygen to live) thrive. Any anaerobic bacteria (those which are killed by any oxygen present) generally die or attempt to find crevices or deposits where there is no oxygen. As the aerobes grow and use up the oxygen, they begin to die and their debris falls to the bottom of the well. This debris is heavy in organic content.

The second important zone in the well is the bottom or near bottom area that often is below the water intake. It can be a deliberately constructed sump with no water intake or just an area of reduced flow. In this area of no fresh water, anaerobic bacteria that have drifted into the well begin to thrive and their population expands with the organic food source drifting down from the settling of solids and death of the aerobes as the oxygen in the idle well is used up.

Coliform bacteria are often facultative, meaning they can live with or without oxygen. They can live free, swimming in the oxygen-laden aerobic zone or in the anaerobic zone where strictly anaerobes live and develop heavy biofilms. Among the many anaerobic bacteria, this zone usually harbors the sulfur-reducing bacteria. These bacteria are known for their hydrogen sulfide production (rotten egg odor) and black slimy deposits containing iron sulfide. Here in this murky, heavily protected zone the coliforms reside and build their population.

The anaerobic zone easily provides protection. Food in the form of organics is readily available. The slimy material limits the penetration of chlorine and the presence of heavy bacterial growth, and slime production provides considerable chlorine demand, further reducing effective disinfection.

Okay! But what causes a clean test result and several days later another positive?

Once the coliform has left the idled aerobic zone due to lack of oxygen or perhaps the addition of chlorine, the bacteria enter the anaerobic zone and find food and relative safety. This population grows much greater than the occasional bacteria or small coliform group entering the well in the aerobic zone. The heavy population growth forces a systematic release of coliforms into the upper water flow and out to the discharge water. These bacteria are the ones that are caught in the periodic tests following chlorination. It usually takes a few days for the expanded coliform population to begin feeding organisms in the water flow.

Chlorination without systematic and thorough cleaning of the bottom of the well results in lethal chlorine levels only in upper flowing areas of the well. The heavy slime present in the lower sections continues to consume the chlorine and reduce its penetration of the anaerobic breeding ground. Therefore, it is essential that this area be cleaned of all debris before the addition of hypochlorite. Numerous tests have shown that the mixing of disinfectant into the well bottom without removal of debris does not penetrate all levels of biofilm and many pockets of viable bacteria, including coliforms, still exist. *WWJ*

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