Earn 1 CEP

Quizzes available through NGWA's online bookstore.

Just click the link in the right-hand column.

Sulfate-Reducing Bacteria

You should know how to treat problems associated with hydrogen sulfide.

By John H. Schnieders, Ph.D.

While we receive a lot of inquiries at our lab, the most asked question recently seems to center on hydrogen sulfide gas (H_2S) or that obnoxious rotten egg odor. People ask "Where does it come from?" and "How do we get rid of it?"

Hydrogen sulfide gas is produced in water environments primarily by sulfate-reducing bacteria (SRBs). These bacteria are anaerobic, that is, they live without oxygen. In fact, SRBs die when they come in contact with oxygen. This means we don't usually find them in areas that are being fed by aerated water, such as near the normal ground water flow zones or intake areas in a well (see Figure 1). The sulfate reducers are normally found in the well bottom, particularly if the well was constructed with a sump to collect debris. The sump usually has little or no flow and often is a collection zone for sediments, sands, and anything allowed by gravity to settle to the bottom of the well.

Part of the debris that falls to the bottom in a normal operating well is organic debris or residue from the aerobic bacterial growth in the upper zones of the well. These bacteria come in from the aquifer and proliferate in the aerated section of the well particularly during downtimes when the well is quiet and water, along with the normal bacterial flora, is not being removed. During this period, bacteria, which can reproduce as often as every 20 minutes, die off and their body debris drifts downward where it becomes an excellent food source for the different types of anaerobic bacteria residing there.

The anaerobes in the protected well bottom flourish with fermentative bacteria, another type of anaerobic bacteria living off the organic debris, producing food and a hydrogen source for the sulfate-reducing bacteria. The SRBs are then able to grow and reduce sulfate to sulfide, which in turn reacts with hydrogen to produce hydrogen sulfide (rotten egg odor). It can also react with iron, which produces iron sulfides, the black color or precipitate often seen in the well bottom.

The hydrogen sulfide gas produced is not only foul smelling but also corrosive and results in a very corrosive environment, usually destroying the casing in that area. As the gas moves upward, it becomes mixed with the water being drawn into the well during pumping and causes both odor and taste problems. In seldom-pumped wells such as irrigation wells (in the off-season) we often see severe corrosion resulting from the hydrogen sulfide gas collecting in the upper portion of the well even above the water line.

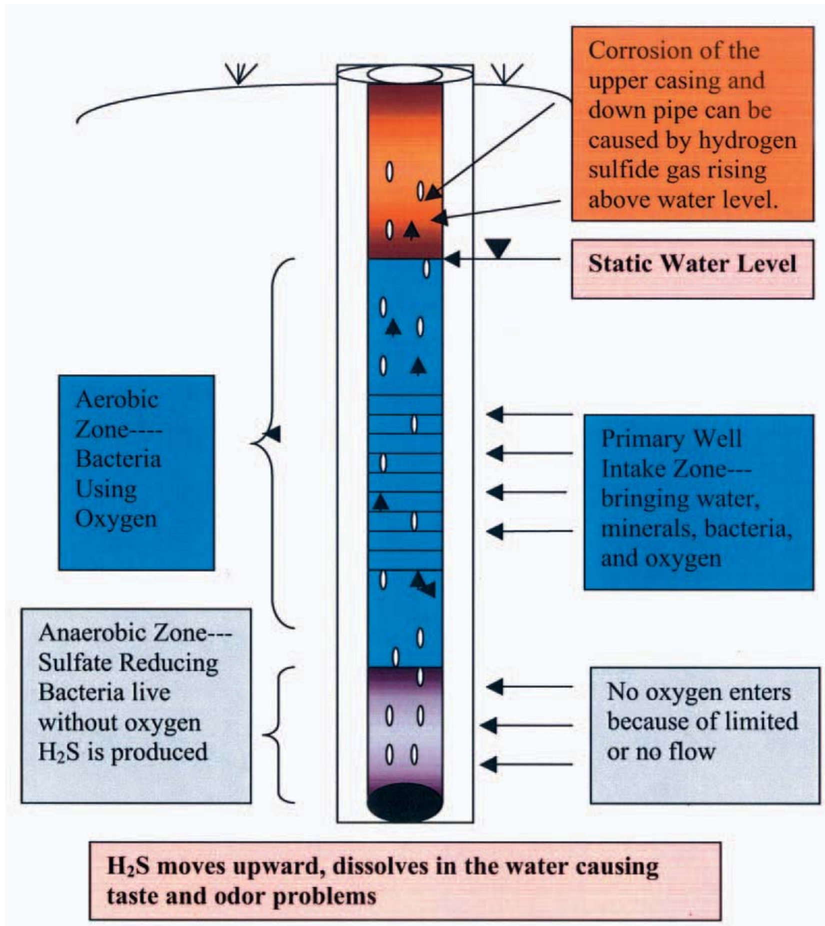

Figure 1. Water well geography.

Even in new wells?

We see this problem not only in old wells, which you would expect to collect a lot of debris over time, but often in new wells. In the new wells that exhibit the foul odor of rotten eggs a slight variation occasionally occurs. Often the new well was allowed to sit idle for some time. This could have been due to construction schedules or the well completion at the end of a production season. For whatever reason, the well was not used for an extended period.

During well construction, considerable air is introduced into the immediate aquifer and bacteria present in the aquifer water find the quiet well an ideal habitat in which to grow and multiply. The water under normal operation would be removed from the well continuously and the population would be maintained at a reasonable or acceptable level. Even if the well is flushed, the increased oxygen from the aeration during construction encourages a high growth rate for a period of time. If the well is not pumped regularly, no new aerated water is brought into the well and eventually the high bacterial population literally uses up all the oxygen and begins to die off. The heavy growth then settles to the well bottom, encouraging anaerobic bacteria to grow. The phenomenon doesn't take a long time to develop, either. I have seen these conditions develop in as little as six weeks, although it usually takes closer to six months. The condition can be aggravated by the presence of iron bacteria that often reproduce rapidly and produce an abundance of organic debris, while depleting the oxygen level at the same time.

How do we fix the problem? I have already chlorinated three times!

This is another question we often hear, so let's look at the dynamics of chlorine in the well and just why chlorine appears not to do the job (see Figure 2).

Consider the scenario of just adding a hypochlorite solution to the well at water level. The chlorine solution moves downward more slowly than we

well science/continues on page 70

John H. Schnieders, Ph.D., C.P.C., is a Certified Professional Chemist and the Principal Chemist of Water Systems Engineering Inc., an investigative and research laboratory. He has more than 40 years experience in the study of microbial and chemical processes in water systems. Since 1984, he has specialized in the diagnosis of well problems and the proper use of chemistry for well cleaning and disinfection. He presents seminars for NGWA and was the association's McEllhiney Lecturer in 2001-2002. He can be reached at john@h2osystems.com.

might anticipate. Studies in our laboratory show that a minimum of three hours is required to reach bottom in shallow wells. And even in this time, no chlorine penetrated the gravel pack or formation around the well. An average of six hours was required to show good dispersal of chlorine throughout the well. This means that if you plan a five-hour contact time, you must start the clock no sooner than six hours after addition to the well. That is exactly why those of us who leave the chlorine in the well overnight, scheduling pump-out the next day, have a much higher success rate for coliform removal.

What else besides not waiting long enough for the chlorine to act might go wrong and result in a failed disinfection? First, we could have a dirty well and the bacteria are protected by corrosion and biofilm deposits in the well. We are not capable of breaking those deposits loose and exposing the bacteria to the chlorine without some swabbing or brushing.

A second problem deals with the fate of the hypochlorite solution as it slowly dilutes on its way to the well bottom. The normally alkaline pH of the hypochlorite is reduced as it moves downward and it can encounter a very acidic zone when it reaches the area near the well bottom. This is especially true if there are sulfate-reducers present. Remember that in about 90% of the cases where coliforms are detected in a well, anaerobic bacteria and SRBs are present.

As the now diluted hypochlorite solution reaches the low pH, chlorine gas is released. The gas immediately moves upward away from the lower zone. This results in a reduced presence of hypochlorite or even hypochlorous acid in the area to be disinfected. With- out swabbing or surging you are unable to bring higher levels of hypochlorite, present in the water above, back down to the bottom zones where it is needed the most.

At this point you may decide to use some palletized calcium hypochlorite or perhaps the even larger tablets which will easily settle to the well bottom and provide the chlorine level needed. While this theory may be good, the high chlorine levels don't always penetrate and the solubility of the product is very limited without agitation or circulation of some type. This results in a high chlorine presence for an extended period of time. Current research shows disinfection byproducts can lead to long-term health problems. Leaving these pellets in a well system, especially in the presence of a high concentration of organic material, would not be doing any favor for the well owner.

This condition first became evident when we began to find sulfamic acid pellets in well sumps many months and even years after their use. Subsequent investigation showed that many of the larger solids were chlorine products, usually calcium hypochlorite. We first theorized that the water hardness or calcium concentration limited the dissolving of the pellet. We later discovered that the almost stagnant condition of the well sump allowed limited dissolving unless agitation was provided or some flow existed to help dilute the concentration in the confined area. This condition is almost always magnified by the improper sizing of the dosage in proportion to the area or volume being treated.

So what method do I use?

First let's look at an ideal way. I have limited it to an outline because I have covered well disinfection in several other articles.

1. Remove the pump and wire brush the casing and screen if present.
2. Evacuate the debris completely to the bottom of the well.
3. Tremie the hypochlorite mixture into the well, particularly in the area of well intake, and be sure to reach to the well bottom. Also flush the upper well with the chlorine solution, cleaning the pump and down pipe before reinstalling.
4. Swab or surge the well to help the chlorine solution penetrate all areas of the well and the immediate formation.
5. Use at least 200 mg/L of chlorine and leave it in the well for at least five hours.
6. Use of pH control during chlorination improves biocidal activity.
7. Evacuate the well all the way to the bottom until no chlorine residual remains.

To try to disinfect a well without removing the pump and cleaning first is like asking your son to keep his white jeans clean. If you have to attempt to do so, here is a suggested method that has been successful. I am sure you can improve on it, taking into consideration your equipment, the well, and the well condition.

1. Pump the well for at least 30 minutes to remove any solids in the piping and to remove stagnant water.
2. Blend the chlorine solution in a tank in a volume equal to four times the standing water volume. Use of pH control improves the success rate.
3. Using a tremie line, add 20% of the solution to the top part of the well, using this volume to wash the upper well.
4. Depending on the well depth and length of the screen or open area, try to tremie 60% of the solution over the area between the static and the bottom zone. More than half of this volume should be in the screen zone or the primary intake areas for the well.
5. Lastly, apply the remaining 20% to the well bottom and actually tremie it to the bottom.

The treated well at this point needs some agitation. In shallow small-diameter wells, you may be able to pump out of the well and return the treated water to the well bottom, or you might be able to bump the pump. Some contractors have used air pressure to agitate the mixture, but occasionally this backfires and appears to cause an excessive bacterial growth spurt. One contractor I know uses nitrogen gas (an inert gas) to agitate and mix the lower well zones. He applies the pressurized gas, providing strong agitation, and then lets the well sit idle for five to 10 hours. Following this quiet period, he again agitates before pumping the well for an extended period, removing much of the stirred-up debris from the well bottom. This procedure has generated quite a bit of success against taste and odor problems from sulfate-reducing bacteria as well as coliform positive wells.

Of course you will run into pumps that will not allow access to the lower well for even a tremie line, but I think you have the idea that we need to get the chlorine to the area of concern, the well sump or bottom. You must also apply some energy to the area to disrupt the heavy biofilm and expose the sulfate reducers, coliforms, or other offending organisms to the disinfecting chlorine chemistry. *WWJ*

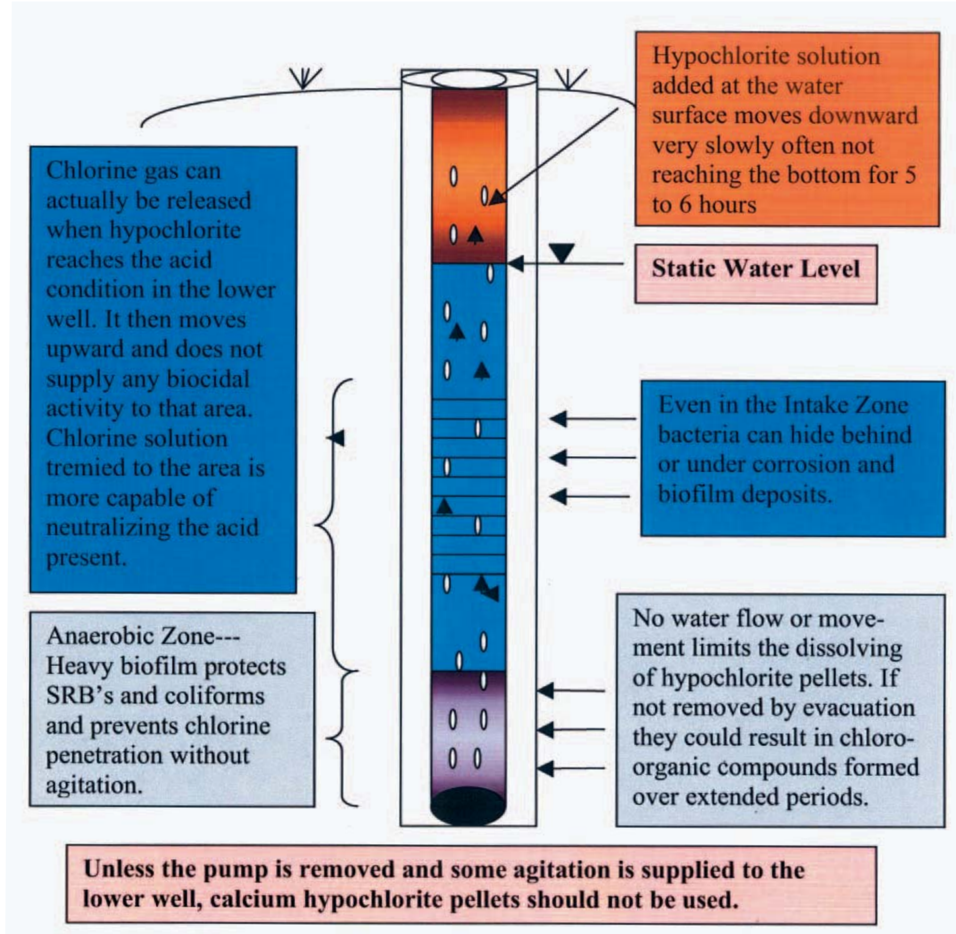

Figure 2. Dynamics of chlorine in wells.