CHANGE IS GOOD

Making changes in design or operation can lead to longer well life.

By John Schnieders, Ph.D.

Water wells have been constructed and operated much the same way for many years. As the need for water becomes greater, and regulations dictate better quality, poor designs are more often than not the reason for well replacement or abandonment.

Laboratory studies of simulated well environments and follow-up observations on actual wells have shown many conditions exist in operating wells that previously were of little concern. Most of these changes are brought about by natural chemical and biological activity within the well. These changes often affect well structure, and of consequence can directly impact water production and water quality.

The chemical or chemical/biological activities that affect well structure are usually the result of corrosive activity against the well components and can result in either structural or pump failure, plugging (reducing water production), or the loss of water quality. While corrosion is an electrochemical activity, bacterial growth and specifically the chemical byproducts of their activity promulgate the chemical conditions that can force the corrosive action.

To mitigate the changes brought about by chemical reactions against the well structure or water quality, there are specific design changes and choices of well components that can lead to longer well life or decreases in the biological activity that impact water quality and often well production.

The first change recommended is perhaps the easiest to incorporate. This change can be responsible for reducing many water quality complaints of red water, coliform contamination, as well as taste and odor issues.

Consider not drilling below the intake zone for the well. Do not produce a "sump" or "dead leg" to collect debris.

Sumps are collecting zones designed to accumulate sediment, improving water quality particularly during the first few weeks of a well's life. Over time, as the well continues to operate, these "sumps" become collection zones for organic debris as bacterial growth that takes place in the upper part of the well yields dead bacteria that gravitate to the bottom. Even within the first few months of the well's existence (not necessarily operation), the zone becomes anoxic and the rapid collection of organic material leads to establishment of anaerobic bacterial growth. These types of bacteria are known for the gases and acids that are byproducts of their metabolism. The byproducts mix into solution with the water, producing taste and odor changes that degrade water quality.

A major player in this environment are sulfate-reducing bacteria (SRBs), which produce hydrogen sulfide gas, an acidic gas which, when dissolved in water or even in the condensate above the water line, produces a strong acid. This then is corrosive to the casing and even destructive to the structure above the water line. The destruction above the water line is especially noticeable in agricultural wells or wells that sit idle for extended periods. SRBs and the resulting hydrogen sulfide gas produced in wells is usually recognized by its "rotten egg" smell.

Many of the anaerobic organisms (those which do not require oxygen) that live in the well bottom or non-aerated zone are actually what microbiologists call facultative bacteria. These can live

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in aerobic water and in anaerobic conditions, areas that include stagnant zones or areas of reduced flow.

Why is this important to know? Because coliform bacteria are facultative and while they may swim in the aerobic flow from the aquifer, they reside and proliferate in the anaerobic zone. Only when populations become large do they begin to leave the safety of the anaerobic zone and enter the active portion of the well. Of course, if you had a contaminating source, such as a sewer leak or septic tank, the offending organisms would enter the well in large numbers and generally impact the whole well. These bacteria would be reported continuously during coliform testing.

Other water quality changes can take place in wells with sumps. For instance, in wells with blank casing extending to the bottom, the well structure can be exposed to a severe drop in pH. The pH change caused by the anaerobic bacteria can approach an acidic level of pH 4. In this area of no or significantly reduced flow, rapid corrosion of steel—even stainless—can occur.

Iron oxides build to excessive concentrations in the water that is gradually drawn into the water flow, resulting in "red water" being delivered to the distribution system. The corrosion is not always limited to the area below intake levels. As the severity of the pH drop leads to lowering of the pH in the water flow, corrosion is encouraged much higher in the casing. This results in elevated iron in the discharge water. Considering this phenomena, even open borehole wells with limited casing installed are subject to this form of red water production.

Consider using either stainless steel or PVC for casing material, particularly when you are constructing potable water wells.

Column pipe corrosion is often a reason that discharged water tests positive for iron.

The nail test showing exposure for one year. The test is from two separate aquifers both with a positive saturation index.

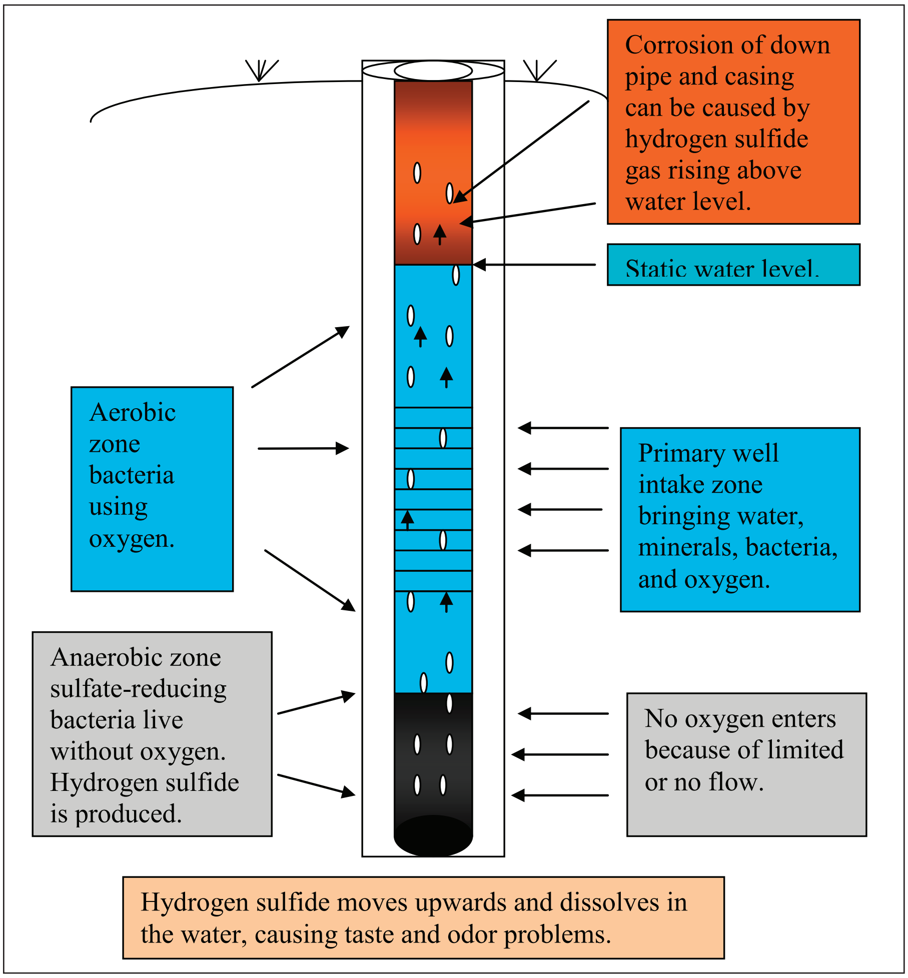
While I believe this specification should be used all the time to ensure long-lasting, pristine water supply, there is a test that can make the decision more of a science and in some cases give true indication of the need.

The reason iron often appears in discharge water is not always the presence of iron in the aquifer. In fact, most of the red water complaints that come to our laboratory are from wells in aquifers not contaminated with iron. The answer of course as to where the iron comes from is corrosion of the well structure, and in particular, the casing.

Iron is corrosive in any water at a pH below 9.3. The degree of corrosivity just below 9.3 is minimal and wouldn't be noticed, much less traceable. But as the difference widens, noticeable corrosion appears—and with that, iron in the water.

Of course, the presence and activity of microbial induced corrosion such as iron-oxidizing bacteria will further aggravate the effects of corrosive water chemistry. My rule of thumb for not using carbon steel casing is to drop a

Well flow showing dead zone.



six-penny iron nail in a cup of the local aquifer water and if iron appears in the water overnight, the same will happen in the well. Even the various saturation indices do not work as well as this test.

The use of PVC or stainless steel casing and column pipe reduces the amount of reactive materials downhole, thus reducing a variety of types of corrosive activity occurring in wells.

Consider placing the pump to ensure good draw from the aquifer into the well with sufficient water flow to ensure continuous movement and aeration near the lowest portion of the well.

Pump placement in high production wells is dictated by the need for maximum water production. This is not always the case for many private wells that often have more than needed supply. This can result in pumps placed high in the column or just above the screened zone. This placement may allow dead zones or anoxic zones to develop below the active flow zone. Without continual aeration of the lower zone, the aerobic bacteria present will use up all available oxygen and an anoxic zone supportive of anaerobic bacteria usually develops.

In the simplest sense, wells are a pipe standing in an aquifer. As long as pumping is taking place, the water and well environment is fresh and aerated. But when the well is idle, the water is more stagnant and becomes stratified. This stratification can be physical in the case of water temperature, with colder water most of the time being lower in the well and warmer water subject to more bacterial growth higher in the well.

Stratification can also be dictated by biological activity. In the previous section I discussed the anaerobic zone. Here, growth and chemical activity is so dense the water is visibly more concentrated or congested. The point is that this stratification often makes it difficult to disinfect a well. The addition of hypochlorite or any disinfectant to the top of the well is almost never dispersed throughout the well sufficiently to provide the necessary levels for effective disinfection. Which brings me to the next design suggestion.

Consider placing a tube for the addition of cleaner or disinfectant to the bottom of the well. This should be a permanent installation available whenever the well is to be disinfected.

While we are on the subject of disinfectants, let's talk about when to use chemicals and why certain choices are wrong and can hurt the well. These involve changes in operation and well maintenance, more than design, but should be considered as they extend the life of the well and the objective of high quality water production.

When we think of cleaning a well, we know that we most likely will need to remove mineral deposits as well as corrosion byproducts, and in most cases, biological accumulations. Most often the primary cleaner of choice is hydrochloric acid, also known as muriatic acid. This choice is good from the standpoint of dissolving carbonates and iron oxides, but it's dangerous from a safety position and in regard to its impact on the well structure.

Hydrochloric acid fumes will even attack the casing above the water line as well as any electrical wiring or equipment located there. In addition, hydrochloric acid is one of the most corrosive agents that attack stainless steel. Therefore, if a stainless steel screen is present, you are doing it a great deal of harm.

Generally, the practice is to acid clean the screen and casing, evacuate the chemical, and then disinfect the system before the well is returned to active use. When this procedure is followed and hydrochloric acid is used, the casing is generally stripped of any protective iron oxides. The resulting use of very strong oxidants (like chlorine) for disinfection thoroughly conditions the iron surfaces towards additional rapid oxidation (rusting), which can ensure iron in the production water.

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Consider using less corrosive acids, such as sulfamic or phosphoric acids.

While both of these acids will still require the use of dispersants, neither will cause the same severe corrosive activity or result in over-sensitized metal surfaces in the well like hydrochloric acid. You will also notice less red water or "dirty water" complaints from your customers following cleaning efforts.

The strong oxidant used in well disinfection of course usually refers to either calcium hypochlorite (HTH or powdered chlorine) or sodium hypochlorite (industrial hypochlorite or the commercially available liquid products such as Clorox). These products are effective disinfectants because they kill bacteria and viruses by oxidative action towards the organism. They unfortunately also oxidize metal surfaces, resulting in corrosive destruction and the release of iron (from steel surfaces) into the water. While it takes only a 0.5 to 1.0 mg/L (ppm) chlorine to kill free-swimming bacteria, it can take more if they are protected in a biofilm. Doses in excess of 500 mg/L, however, can seal the slime and limit penetration that might kill the organisms (*Water Well Journal*, October 2001).

When we disinfect a well, we often find ourselves increasing the dosage to be sure we are effective, and then again if we are going to let the well sit for an extended period. We have to consider that when we subject the well to an excessive dosage of chorine, we could be doing considerable damage to the well. The proper use of chlorine is to use only what is necessary, adapting of course to local regulatory requirements. Wells which are to sit idle for extended periods should be treated at a lower dose on an intermittent basis.

Consider holding routine well chlorination to a level of 200 mg/L (ppm) or lower and never use a dose in excess of 500 mg/L. Well dosage should be calculated for 1.5 times the standing well volume.

Many of these recommendations are all tied together. For instance, if you build the well without a collection zone in the well, bottom management of well operation becomes much easier.

Let's review some of them, both to drive home the idea and to better explain why some operational changes can make a difference in water quality.

Consider limiting periods of inactivity, particularly those longer than four days and especially if this is a regular or continuous occurrence.

Well environments, by nature, have a strong population of environmental organisms present in the water flow. These mostly aerobic organisms are non-pathogenic, and for the most part not even harmful to the well structure. They enter the well with the water flow and they remain there when the pumping stops. When pumping stops, no more oxygen is brought into the well. The bacteria living in the water column continue to multiply until the population often is as much as five to 10 times the number initially found in the aquifer. Oxygen is depleted the longer this condition exists and gradually the bacteria begin to die. As the bacteria die, the organic debris falls to the bottom of the well. This then becomes a rich source of food for the anaerobic bacteria residing there.

This cycle can happen to a lesser extent in private home wells that are cycled several times daily but have eight to 10 hours of stagnation between uses. When the bacteria multiply and die, most of the well's biological fouling takes place and the ensuing changes in water quality follow. If the well has been built with a sump, then perhaps you might lower the pump to an area that would provide a draw from the well bottom, effectively keeping this area cleaned of debris.

Consider installing a flush valve in the water storage tank bottom.

Here again we are dealing with settling of organic debris and the development of an anaerobic growing zone. If a coliform were to make it to this area, it could multiply and prosper. Monthly (or more often) flushing would limit any accumulation. This valve would also make it easy to track down the source of contamination within the system, as the coliform population (if present) would be much higher in flow from this area rather than in the water flow from elsewhere in the distribution.

Challenge

I have only scratched the surface of the many chemical and biological changes that can take place in a water well. However, many of them can be prevented or limited by changes in the design or operation.

I challenge all members of the groundwater community to seek ideas to modify the draw into a well, to prevent the development of zones, or to facilitate easier addition of chemistry to the well bottom. Pump manufacturers should develop extensions that can be added to a pump to easily divert draw lower in the well. Screen manufacturers might offer a special screen designed for the bottom of the well that would allow flow, and perhaps a casing with tubing attached to facilitate the addition of disinfectants and cleaners to the well bottom. *WWJ*

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