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What Well Owners Should Know about Shock Chlorination

Why it works for some well problems and not for others

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Pouring Bleach Down Your Well? Read this Publication First

Introduction

The intended purpose of shock chlorination is to reduce the levels of microorganisms that can cause illnesses (pathogens) present in water using a concentrated liquid chlorine solution. There are two places where this disinfection treatment method is typically applied: down the water well itself and/or inside water storage tanks. The practical benefits of shock chlorination are different for each application, as are the risks.

The purpose of this publication is to make well owners aware of the benefits and potential problems associated with water well shock chlorination, including when and who should do it.

A reason often cited for shock chlorinating a well is that it has tested positive for total coliform bacteria (commonly found throughout the environment), which is not a health threat in itself, and/or positive for fecal coliform bacteria, i.e. *E. coli* bacteria, which can indicate a health threat since they are more frequently associated with fecal contamination (USEPA, 2013). These tests indicate the presence or absence of harmless coliform bacteria and only imply the likely presence of potentially harmful organisms (pathogens) in the water.

Natural waters contain materials such as salts, metals, and nutrients that provide an ideal medium for many types of organisms including algae and bacteria to grow. Many organisms found in water sources are not necessary harmful when ingested and form part of a complex network of naturally occurring organisms. Unfortunately, human or animal wastes can quickly degrade natural waters including groundwater, adding pathogens such as intestinal bacteria, viruses, and even parasites. The U.S. Environmental Protection Agency (USEPA, 2013) considers that there is no safe level of any pathogen in drinking water.

Shock chlorination typically uses a strong bleach solution, which can kill most microorganisms it comes into contact. Bleach can also react with well components and naturally occurring chemicals found in groundwater aquifers with unpredictable results. For this reason, private well owners should use caution when attempting to disinfect their water well using common household bleach for shock chlorination.

Water Well Components

The four basic components of a well are a well casing (protects the bore hole) with a screen (where the water enters the well) and a drop pipe with a submersible pump (to extract water from the aquifer). A working well has the surfaces of these components fully or partially in contact with water (submerged) most of the time. These surfaces, which are either plastic (PVC) or steel (low carbon, galvanized, or stainless steel), will interact with chemicals and microorganisms found in the soil and in the groundwater (see next section).

Typical Composition of Groundwater

Wells are designed to extract water from aquifers that contain water with varying amounts of dissolved inorganic (salts, metals, nutrients, etc.) and organic (carbon-based) chemicals, and living microorganisms such as bacteria. Many chemicals and microorganisms are naturally occurring in soils and aquifers. Common chemicals found in all natural waters include: sodium, calcium, chloride, sulfate, nitrate, phosphate, and organics made up of plant and animal residues (this group of chemicals is also known as dissolved organic matter or dissolved organic carbon). Common bacteria found in all waters include coliforms. See Extension publication AZ1578 (Artiola et al., 2012) for a detailed discussion of the types of chemicals and common contaminants present in water.

Deep groundwater aquifers are not easily impacted by human activities such as the introduction of industrial wastes, wastewaters, or direct surface recharge. Deep aquifers typically contain low concentrations of the nutrients necessary for bacteria and other organisms to grow. Therefore, normally, there are fewer living microorganisms present in deep compared to shallow aquifers since microorganisms grow slowly and compete for nutrients in this nutrient starved environment (BSIa, 2013).

Installing a well into an aquifer and then pumping water changes the delicate balance (dynamics) between naturally occurring organisms and nutrients in the groundwater. As pumping starts, the pump suction creates a funneling effect that draws water through the screen openings into the well much faster than water that moves through the rest of the aquifer. This means that any organisms attached to the well components are able to harvest more nutrients since fresh, nutrient-rich water passes by them more frequently. In addition, the opening into the aquifer (the well casing) brings oxygen directly to the well water, which also promotes the growth of oxygen-loving organisms. Thus, in this artificially created environment naturally occurring bacteria and other organisms are able to thrive (BSIa, 2013).

As microorganisms grow in numbers, they form groups and associations (consortia) that look and feel like slime on the surfaces of well components and on the insides of both pressure and storage tanks.

Slime (Biofilm) Formation

There is evidence that layers of slime begin to form quickly (hours to weeks) on surfaces exposed to moisture or submerged in water (Mittelman, 1985), see Figure 2.

The process of slime formation starts with the exposure of well components to dissolved organic chemicals that attach to their surfaces, see Figure 3.

Figure 2. Louvered well screen covered with slime within days of being installed in new water well. Photo by G. Hix, 2012.

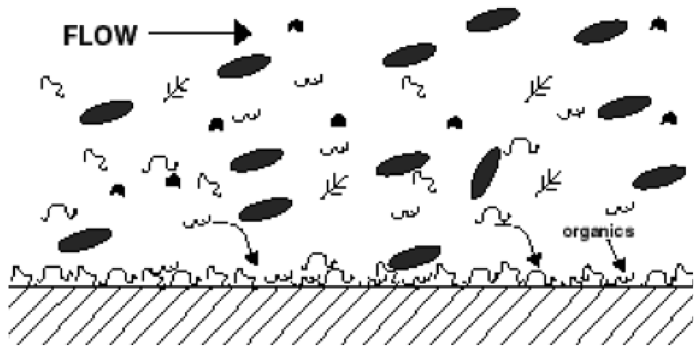

Figure 3. Water-soluble organic chemicals (strings) and bacteria (oval shapes) present in aquifer waters attach to well components. Source: Characklis & Marshall, 1990.

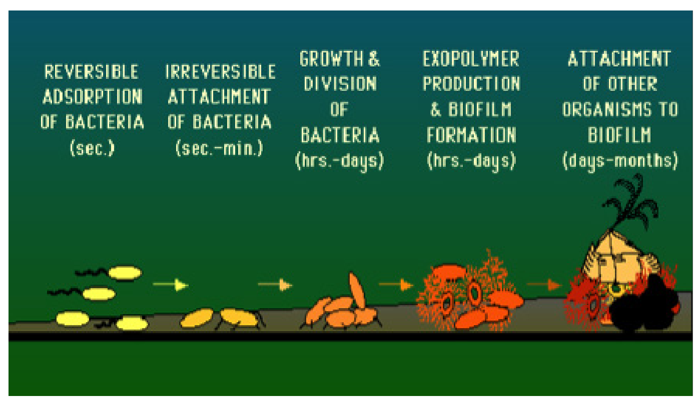

Figure 4. Steps to slime formation on wet or submerged surfaces. Source: K. Todar, U. Wisconsin.

Soon after, bacteria looking for food land on these surfaces and eventually attach themselves there permanently.

Slime is produced by anchored bacteria that excrete long strands of chained sugar molecules (polysaccharides), which form a sticky mat that covers to the surfaces of well components (BSIa, 2013). The slime is formed of layers and strands that are porous. This multistep process is shown in Figure 4.

Slime can also filter and concentrate nutrients (such as nitrate and phosphate) from the water that are used by organisms living in the slime layer to grow and multiply and coat well and water system components. Therefore, once formed, slime provides an ideal environment for many organisms, good and bad (pathogens) to exist inside wells, tanks, and even pipes used to produce, store, and transport water.

Is Slime Beneficial?

We have shown why and how slime is produced on well components and we have described how the well environment changes the natural chemical composition of aquifer water in ways that favor the rapid growth of microorganisms that attach to well surfaces. Once attached, microorganisms form consortia. As these grow, they begin to disperse bacteria that act as scouting and pioneering groups that grow in places outside the well casing and screens that are virtually impossible to reach, making them difficult to remove with shock chlorination.

Research indicates that slime (biofilm) is made up of a highly complex and collaborative group of many species of organisms (mostly bacteria) that interact in many different ways. For example, waste produced by one species may be used by another species as food. Several species of bacteria may collaborate to breakdown a food source using different methods (enzymes) for the benefit of all.

The slime itself and organisms that live inside may also filter and degrade (use as food) contaminants such as nutrients (previously discussed), organic residues, and some salts and metals, **making the water safer to drink.** However, excessive slime growth can be detrimental to well performance and components and facilitate the growth of pathogens and other unwanted organisms as shown in the next sections.

Iron, Oxygen, Corrosion, and Slime

Many Arizona aquifers often contain some dissolved oxygen and very low levels of dissolved iron. But some shallow aquifers, regularly impacted by surface recharge, have high concentrations of dissolved organic matter. These conditions can increase microbial activity, depleting oxygen quickly and increasing the levels of soluble iron in the water. When iron-rich and oxygen-poor water from the aquifer is drawn into the well, oxygen is mixed into the water, which together with the presence of iron oxidizing bacteria (see Figure 5) produces a reddish slime (hydrated iron oxides) and favors the growth of iron-loving bacteria that produce well damaging red slime, see Figure 6.

These red residues and red slime can form and deposit in storage tanks, toilets, and sinks, giving water a yellow to red color, often with a musty, swampy smell. Excessive growth (also known as biofouling) of these iron bacteria can clog pipes and shut down wells (BSIb, 2013).

When well water stagnates for several days, the oxygen dissolved in the water is depleted (microbes use it up to grow) and organic matter (in the form of microbes) accumulates. Under these conditions, if iron-reducing bacteria are present, they become active and start to use oxygen from the iron (rust), which re-dissolves iron in the water. When this happens, the typical red colors in the water and walls begin to disappear. If these conditions are prolonged, sulfur-reducing bacteria may begin to thrive. These bacteria also steal oxygen but from sulfates (commonly found in water) producing a highly toxic, corrosive, rotten-egg smelling gas called hydrogen sulfide. This gas dissolves in water and reacts with soluble iron producing a black residue that coats surfaces.

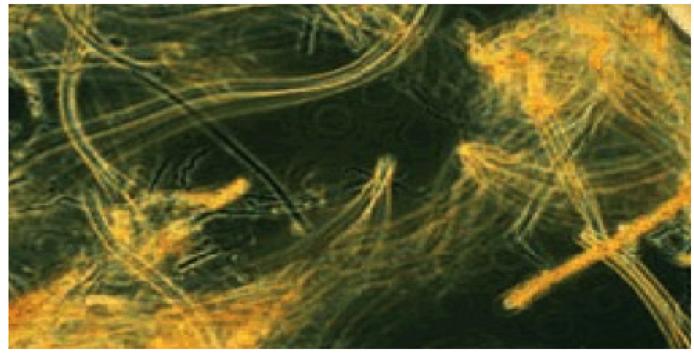

Figure 5. Example of a filament-producing bacterium (Leptohrix) that produces red slime. Source: BSIb, 2013.

Figure 6. A well pump intake screen covered with red slime and iron rust formed by bacteria living inside a pumping well. Photo by G. Hix.

Research also indicates that sulfur-reducing bacteria prefer to grow deep inside the slime layers where oxygen gas levels tend to be very low (Edstrom, 2004). Thus, when these bacteria produce hydrogen sulfide, the gas can move back into an oxygen-rich zone, re-oxidize, and form sulfuric acid that can corrode iron surfaces such as metal casings and screens.

Sediments, Pathogens, Slime, and Chlorine

Although slime is mostly composed of living organisms and organic residues, it may also filter out and trap inorganic materials such as rust particles (produced during the oxidation of iron components) and aquifer materials such as sand, silt, and clay particles. Slime can trap aquifer materials as they enter the well and facilitate the formation of mineral deposits (encrustations) on the small screen slits that can progressively lower the well yield.

Figure 7. Wire wrapped well screen plugged with slime and mineral deposits. Photo by G. Hix.

Figure 8. A water well pump encrusted with iron rust tubercles. Photo by G. Hix.

Excessive accumulation of slime and mineral deposits on a well screen can reduce water flow and lower well yields as shown in Figure 7. These mineral deposits are often calcareous (calcium carbonate) in composition and are not affected or removed by shock chlorination.

When bleach (liquid chlorine--5.25% sodium hypochlorite solution) is poured down a water well, is not effective against the biomass and iron-reducing bacteria living in wells. The disinfecting power of the chlorine does not fully penetrate the outer layers of the biomass to reach the majority of the bacteria living beneath. Shock chlorination is most effective against the floating (planktonic) microbes found in well water, but these microbes represent only a very small fraction (one millionth) of the total population of bacteria living in a well.

In order to truly disinfect a water well with a chlorine solution, the biomass, iron stained coatings, and iron rust scale (tubercles) (see Figure 8) and encrustations must be physically scraped away to expose the bacteria living beneath their protective shells. Then, when the chlorine solution is applied at the proper concentration and given enough contact time, disinfection of many (not all) of the microorganisms can take place.

Sodium hypochlorite, the chlorine chemical found in bleach, when used as disinfectant, is more than 99% effective within a pH range of 5 to 7 at killing bacteria. But its effectiveness drops dramatically for water pH values greater than 7 or less than 5 (Hanson, 2001). In Arizona, groundwater pH values range from high 7 to high 8. For this reason, shock chlorination without pH adjustment is much less effective, particularly if calcium hypochlorite (solid form of chlorine) is used.

This chlorine chemical is particularly ineffective (and potentially damaging to well components) when used to disinfect wells with water that is alkaline and hard, a common characteristic of Arizona aquifers.

Any attempt to use shock chlorination inside a water well to do anything other than to obtain a negative result from a test for the presence or absence of a single colony of harmless bacteria is fruitless. Well owner shock chlorination treatment will do little or nothing to control or prevent the growth of biomass, and iron- and sulfur-reducing bacteria.

Truly effective water well treatment methods for the temporary control of coliform and iron-, and sulfur-reducing bacteria should and can only be performed when the pump is out of the well. The well can then be brushed, bailed, and disinfected using National Sanitation Foundation (NSF) approved commercial well treatment chemicals and methods applied by qualified and licensed water well contractors.

Slime Formers in Water Storage Tanks

Under certain conditions slime may also allow waterborne pathogens such as viruses and parasites to survive and even thrive in water. Excessive slime growth and warm temperatures in storage tanks, filters, and distribution pipes are ideal for the survival of dangerous amoeba parasites See Extension Publication AZ#1586 (Artiola et al., 2012). Well owners who have water storage tanks can safely disinfect them using shock chlorination, see also above publication for details on storage tank disinfection.

Shock Chlorination to Remove Slime?

All evidence suggests that shock chlorination alone will not remove all the slime from well components since slime is attached to the surfaces and must be scrubbed off. Iron- and sulfur-reducing bacteria, in particular, are very difficult to kill with shock chlorination alone since they reside deep inside the slime layers. Strong chlorine solutions, used for shock chlorination, may damage (partially oxidize) biofilms but will not kill all the organisms in them since the chlorine may not fully penetrate inside or destroy all the slime filament-like structures. Once chlorine is flushed out of the well, organisms will re-grow, often more rapidly than before (Characklis & Marshall, 1990) for several reasons, including:

a) Surviving organisms are already used (adapted) to the well environment, can start growing quicker, and produce even more slime than before.
b) Microbes attach easier to unclean surfaces (rough) than on clean surfaces.

In conclusion, shock chlorination alone may kill the planktonic bacteria and other organisms such as algae in the well water, and only damage or partially destroy parts of slime layers and organisms that reside close to the surface layers. Slime re-growth often occurs faster after shock chlorination.

Shock Chlorination and Well Water Quality

Well shock chlorination usually requires adding sufficient bleach (liquid sodium hypochlorite or powdered calcium hypochlorite) to raise the chlorine equivalent concentration inside the well to between 200 and 300 parts per million (ppm). And the chlorine chemical must be maintained in the well for 6-12 hours with the pH maintained between 5 and 7. During this time, this strong oxidant can react not only with microorganisms and other organic matter but also with rubber and plastic found in well and storage tank components, sometimes with unpredictable results.

Most of the living organisms are killed (inactivated) when they come into contact with chlorine chemicals. Their dead tissue, other animal or plant residues, and some inorganic chemicals like bromide and chloride can react with any excess chlorine present to form new chemicals called disinfection byproducts (DBPs). Some of the chemicals and groups of chemicals that can be formed include: chlorite, bromate, trihalomethanes such as chloroform, and haloacetic acids. If these disinfection byproducts are ingested regularly, they can affect the nervous system and increase the risk of cancer (USEPA, 2013).

Most public drinking water sources are chlorinated, and the USEPA regulates the levels of these chemicals in public water supplies. The formation of DBPs in chlorinated waters is difficult to predict because it depends on many things including levels of chlorine, type of organic matter present, contact time, temperature, and other water quality parameters.

When a well is purged following shock chlorination, residual chlorine and DBPs are quickly removed from the well if they are in the free water, but they are not so easily removed if they are inside any remaining slime residues. Chemicals move slowly in an out of slime because it is made up of thick, sticky strands of fiber-like chemicals, as previously discussed.

Studies have shown that DBPs can be detected in well water after it has been purged four (4) well volumes, and these chemicals can be found in well water even after no free chlorine is detected (Seiler, 2006; Walker and Newman, 2011).

Studies have also shown that shock chlorination may temporarily increase the concentrations of some metals in well water. Elevated levels of metals such as lead, copper, zinc, iron, and arsenic have been measured in well water just after chlorination. In some cases, wells had to be purged more than four (4) well volumes before metal levels returned to normal, (Seiler, 2006; WDNR, 2008; and Walker and Newman, 2011).

Figure 9. Contractor chlorinating a well. Note safety equipment and water circulation hose through the opened well seal, something most well owners cannot do themselves. Photo by G. Hix.

In conclusion, following shock chlorination, it is very important to flush residual chlorine and any toxic chemicals that may have been formed or released from the well components or aquifer materials. Shock chlorinated wells should be purged at least four (4) well volumes or until no residual chlorine is detected in the well water using a chlorine test kit, see Extension Publication #AZ1586 (Artiola et al., 2012).

Was Your Well Disinfected?

The construction and design standards for private (also called exempt) wells in Arizona require that a new well be "disinfected" before use by humans. According to Arizona Department of Water Resources (ADWR) Rule 12-15-814 any well from which the water is to be withdrawn is intended to be utilized for human consumption or culinary (cooking) purposes without prior treatment shall be disinfected by the well drilling contractor **before** removing the drill rig from the well site." However, in Arizona, a well driller may or may not install a pump in a new well, leaving this last step to a pump contractor. But, since no method of disinfection is specified in the regulations and without a pump in the well, the driller has no means to effectively disinfect a new well.

Additional confusion arises because the ADWR does not license or regulate water well pump installers. Therefore, there is no requirement for them to disinfect the pump or any other well components at any time. In short, your well may never have been disinfected.

Who Should Disinfect a Well?

Well disinfection should be done by a qualified well driller or pump contractor **at the time the well is equipped with a pump for human use.**

Owners of existing wells should remember that it is a good practice to disinfect any well that has had major maintenance (such as pump replacement, well rehabilitation procedures, or new equipment installed in the water system) with a strong chlorine solutions to kill pathogens that might be left on the surfaces of any drinking water system components during construction and/or maintenance.

There are several reasons for leaving well disinfection (using shock chlorination or other methods) to professional drillers or pump installers. These professionals:

a) Are trained to safely handle strong chlorine solutions and dispose of them offsite;
b) Adjust the well water pH as needed using strong acids and water testing equipment;
c) Use appropriate amounts of chlorine chemicals to prevent damage to well components [1]; and
d) Purge sufficient well water volumes and test residual chlorine levels in the well water.

Note that well disinfection is no guarantee that the well water will pass the fecal or total coliform tests a few days after shock chlorination, because:

a) Bacteria in the remaining slime that are not affected by the chlorine may re-grow and contaminate the well water;
b) Improperly capped/sealed wells can allow bacteria to enter the well;
c) A non-existent or compromised surface seal surrounding the upper twenty feet of well casing may allow surface water and contaminates to enter the aquifer; and
d) Contamination may be in the aquifer water, not the well itself.

What If Your Well Water Fails the Total Coliform, Fecal Coliform, or *E. coli* Tests?

One of the main reasons for collecting and performing a water quality test for the presence or absence of coliform bacteria is to satisfy homebuyer or mortgage lender requirements during the sale and transfer of real estate. While Arizona has no specific requirements for water quality of private water wells, including during the sale and transfer of real estate, a "potability" test is often a part of the terms of the sale when a private or shared water well is the source of domestic water for the home.

Laboratory results from these tests indicate that a "Positive" test result will be found in approximately 10% of the samples submitted for coliform bacteria testing, personal communication (Turner, 2013). Less than half of the samples that tested positive for coliform also test "Positive" for fecal coliform or *E.coli*. Obtaining a totally bacteria free water sample in the field is not as simple as it may seem and the accidental introduction of coliform is quite possible. See Arizona Extension Publications AZ1486f (Farrell-Poe et al., 2011) & AZ1486g (Farrell-Poe, 2010).

When a "potability" test is required for the transfer or financing of real property and the coliform test results come back "Positive," shock chlorination of the well or water storage tanks and distribution system may be what is needed to pass the test.

Well owners, buyers, estate brokers, and mortgage lenders must understand that even if the test results are "Negative" for total coliforms, this does not mean that the well water is totally safe to drink. However, if the tests are "Positive" for total and fecal coliforms, then the well water is most likely contaminated with feces and not safe to drink (USEPA, 2006)

Ultimately, **a private well owner has the sole responsibility for the quality of water produced by their well.** It is up to the well owner to insure that the well water remains free of harmful bacteria and/or other potentially harmful contaminants. Well owners that are concerned about the re-occurring presence of pathogens and/or other contaminants such as DBPs in their well water should consider home water treatment devices either as point of entry (whole house) or point of use (prior to faucet or use). These treatment options are discussed in detail in the Arizona Publication AZ1578 (Artiola et al., 2012).

Summary

Shock chlorination alone may not remove slime that quickly forms in wet and submerged surfaces of well components. Slime is made up of a complex mixture of organisms that live together benefiting from each other and improving water quality. However, excessive slime growth can clog well screens and pump intakes and can also harbor pathogens that can make well water unsafe to drink.

Arizona regulations on private wells are not clear on how wells should be disinfected and by whom.

It is a good practice to disinfect all new wells and old wells after maintenance. Proper well shock chlorination requires well equipment removal, surface scrubbing, proper chlorine dose, and water pH adjustment, followed by thorough well purging to remove disinfection byproducts and testing for residual chlorine – this should be done by qualified water well personnel (www.AzWWA.Org, www.NGWA.Org). Well owners should also clean and disinfect their water storage tanks regularly.

Well owners should also consider home water treatment devices either for the entire home (point of entry) or at the point of use to treat all or some of their well water to insure potability.

[1] Chlorine chemicals are strong oxidants: strong bleach solutions may damage plastic pipes, electric cables, and rubber diaphragms in pressure tanks.

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