Back to Basics - Well disinfection with Household Bleach

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Household chlorine bleach is the most common product used to disinfect wells in Wisconsin. The most common misconception is that if a little bleach is good, then more is better. This is simply not true when it comes to disinfecting wells. To understand this concept, one must first understand the basic chemistry of chlorine.

Basic Chlorine Chemistry:

Household chlorine bleach is a sodium hypochlorite solution that can contain from 3.0 to 6.0% available chlorine, depending on the brand, density and age. The available chlorine concentration decreases over time so it is important to understand that the percentage stated on the label is only an approximation. In water, bleach very quickly changes (dissociates) into two different chemical forms: hypochlorous acid (HOCl) and hypochlorite ion (OCl^-). For you chemistry geeks, the following two reactions occur:

(1) $NaOCl$ (bleach) + $H_2O \rightarrow Na^+ + HOCl + OH^-$

(2) $HOCl \leftrightarrow H^+ + OCl^-$

Equation 2 is really a delicate balance controlled by pH (see Figure 1). At pH 7.5, both forms of chlorine are present in equal concentrations (50:50), but this balance shifts rapidly with even a very minor change in pH.

Both of these forms are considered “free” or “available” chlorine. The form of chlorine varies depending on the pH of the solution. Figure 1 illustrates the relationship between pH and the chlorine form (species). So, who cares what form the chlorine takes on in water? Both forms kill bacteria given the proper concentration and contact time. However, hypochlorous acid is about 20 times more powerful a germicide than hypochlorite. This means chlorine bleach has the best germicidal properties when the pH is between 6 and7. Consequently, less bleach is needed to disinfect a well if pH is considered. This translates into savings for the well drillers, pump installers, plumbers and homeowners.

Another critical reason for not overloading the system with chlorine relates to chlorine chemistry and its effect on pH. Chlorine bleach is very alkaline.. As you increase the amount of bleach, the pH will slowly increase. As the pH increases, the hypochlorous acid concentration decreases and the hypochlorite concentration increases. The germicidal properties subsequently decrease. The old adage, “less is more” couldn’t be more appropriate here. When a homeowner opts for a more intensive chlorination strategy than the well requires, the end result is <u>less</u> germicidal action.

Table 1 illustrates the effect of additions of bleach on the pH of water taken from the City of Madison drinking water system. The trick here is to minimize any minor increases in pH that result in reduced germicidal effectiveness by limiting the addition of bleach. In the example illustrated in Table 1, the 100-ppm mixture provides that largest fraction of hypochlorous acid and more than adequate disinfecting capabilities. This strategy will give you the "best bang for the buck".

Practical Application of Chlorine Concepts:

The Wisconsin Department of Natural Resources recommends two different disinfecting practices using household bleach based on geographic area. The practice recommended for most geographic areas of Wisconsin (DNR Publication PUB-DG-003-200) requires a solution containing about 500-ppm of free available chlorine and a 24-hour contact period. The second practice (DNR Publication PUB-DR-069-2002) is recommended for use in Northeast Wisconsin in a geographic area designated as the Arsenic Advisory Area. This practice requires a solution containing about 100-ppm of free available chlorine, a 30-minute contact time. The two approaches are summarized in Table 2.

So why is there a concern about using too much chlorine in Northeastern Wisconsin? High levels of arsenic have been found in hundreds of wells, primarily in Winnebago, Outagamie and Brown Counties. Scientists believe the arsenic is released into drinking water when arsenic bearing minerals are exposed to oxygen as a result of rotary-air drilling methods and the regional lowering of water levels due to increased consumption. There is some evidence to suggest that excessive chlorination may also contribute to the release of arsenic. Consequently, the Department of Natural Resources worked closely with public health officials to determine that100-ppm of free available chlorine and 30-minute contact time would effectively kill most microorganisms and viruses while minimizing exposure of arsenic bearing minerals to chlorine.

What are the practical applications of pH and disinfecting a well? A well can be disinfected with a minimum of chlorine solution if the pH is in the 6-to7.5 range. However, the pH of natural ground water can vary from 5 to 8.5 depending on the geographic location, bedrock and aquifer. Consequently, it may be necessary to adjust the pH to about 6.5. This process will provide optimum germicidal action from a minimum of chlorine bleach. Chlorination with pH adjustment may be more effective in treating persistent or recurring well problems (such as iron bacteria and other biofilms) when conventional chlorination has failed. However, pH adjustment in the presence of bleach can be dangerous unless it is properly administered. This approach should only be undertaken by licensed, trained Well Drillers and Pump Installers. Contact the Department of Natural Resources Bureau of Drinking Water and Groundwater for information regarding this approach and for a list of professionals who can do this type of chlorination.

Summary and Recommendations:

The bottom line is that you **DO NOT** need excessive amounts of chlorine to effectively disinfect a well, particularly if the pH is in the 6 to 7.5 range. Here is what we recommend:

1. Follow the Department of Natural Resources recommendations for disinfecting wells.
2. Disinfect with a minimum of 100-ppm free chlorine and a maximum of 250-ppm. **DO NOT** exceed 100-ppm and 30-minute contact time in the arsenic advisory area.
3. **DO NOT** add calcium hypochlorite tablets as part of the disinfecting process. This is an unnecessary and costly practice.
4. Because the available chlorine levels vary from manufacturer to manufacture, and decrease with age, it is a good idea to confirm the concentration of the chlorine in the well using a test kit. This process will assure that you are adding enough, but not too much bleach solution.
5. You may wish to confirm the pH with test paper for reassurance.
6. If you wish to optimize the pH to obtain peak germicidal action from the chlorine, contact one of the Department of Natural Resources Drinking Water and Groundwater staff or a Licensed Well Driller or Pump Installer for guidance.
7. Test the well water for coliform bacteria about a week after chlorinating and yearly thereafter. **DO NOT** chlorinate as part of regular well maintenance unless there are recurring or other persistent problems.
8. Contact your area Department of Natural Resource Bureau of Drinking Water and Ground Water staff for assistance if you have any questions or concerns.

Remember, less bleach is *more* – more germicidal power and more cost savings for you and your clients.

Table 1. The Effect of Various Household Bleach Mixtures on the pH of a Typical Southwest Wisconsin Well Water [1]

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Household Bleach[2] Madison Tap Water Mixture ratio	Approximate Free Available Chlorine Concentration (ppm)	pH	Approximate % Hypchlorous Acid	Approximate % Hypochlorite Ion
Madison Tap Water only	0.12	7.68	40%	60%
0.7 quarts per 100 gallons tap water[3]	100	7.83	30%	70%
1.4 quarts per 100 gallons tap water	200	8.33	10%	90%
1 gallon per 100 gallons tap water	500	8.73	5%	95%
2 gallons per 100 gallons tap water	1000	9.24	3%	97%
4 gallons per 100 gallons tap water	2000	9.57	2%	98%

1City of Madison drinking water

[2]Household bleach, 5.25% available chlorine

[3]The 100-ppm mixture, shaded in gray, provides optimum germicidal action.

Table 2. Comparison of Well Chlorination Practices Recommended by the Wisconsin Department of Natural Resources.
(NOTE: Practices for Arsenic Advisory Areas ONLY are shaded in gray.)

Steps	Chlorination Practice	
	Arsenic Advisory Area[1]	**Other Parts of Wisconsin[2]**
Calculate well volume based on casing diameter and depth. Prepare enough solution to meet or exceed volume of well. (e.g., 6 " casing and 80 foot depth)	1.5 gallons/foot-6 " casing *1.5 x 80 = 120 gallons*	
Calculate volume of chlorine solution needed based on casing diameter and well depth (e.g., 120 gallon well volume)	0.7 quarts of 5.25% bleach per 100 gallons of well water. *0.7 quarts x 1.2 = 0.84 quarts of bleach needed*	1 volume of 5.25% bleach per 100 unit volumes of well water. *1 gallon x 1.2 = 1.2 gallons of bleach needed.*
Prepare solution	Prepare chlorine solution by mixing the bleach in "new" 25-gallon garbage cans (or a large tank). Note: Pour part of the bleach in each of the 5 garbage cans required to prepare 120 gallons of solution.	
Transfer to well	Turn off power to the well; remove the well cap and pour contents of the garbage cans down the well.	
Mixing and contact time for chlorine solution	Turn on the power to the well, connect a garden hose to nearby faucet, open and re-circulate the chlorinated water for 30 minute, rinsing down the sides of the well.	Turn on the power to the well, connect a garden hose to nearby faucet, open and re-circulate the chlorinated water for 5-10 minutes, rinsing down the sides of the well. Let solution sit in well for 24 hours.
To disinfect household plumbing	Turn on each tap, run water until the bleach smell can be detected and turn them off. Note: Bypass water softeners during this process as chlorine can damage the media.	
Flush time	Flush the entire system until no chlorine odor can be detected. Run chlorinated solution outdoors to a suitable area.	

1. Well Chlorination in Arsenic Sensitive Areas (under revision). Wisconsin Department of Natural Resources Publication # PUB-DG-069-2002.
2. Bacterial Contamination of Drinking Water. Wisconsin Department of Natural Resources Publication # PUB-DG-003-2000.

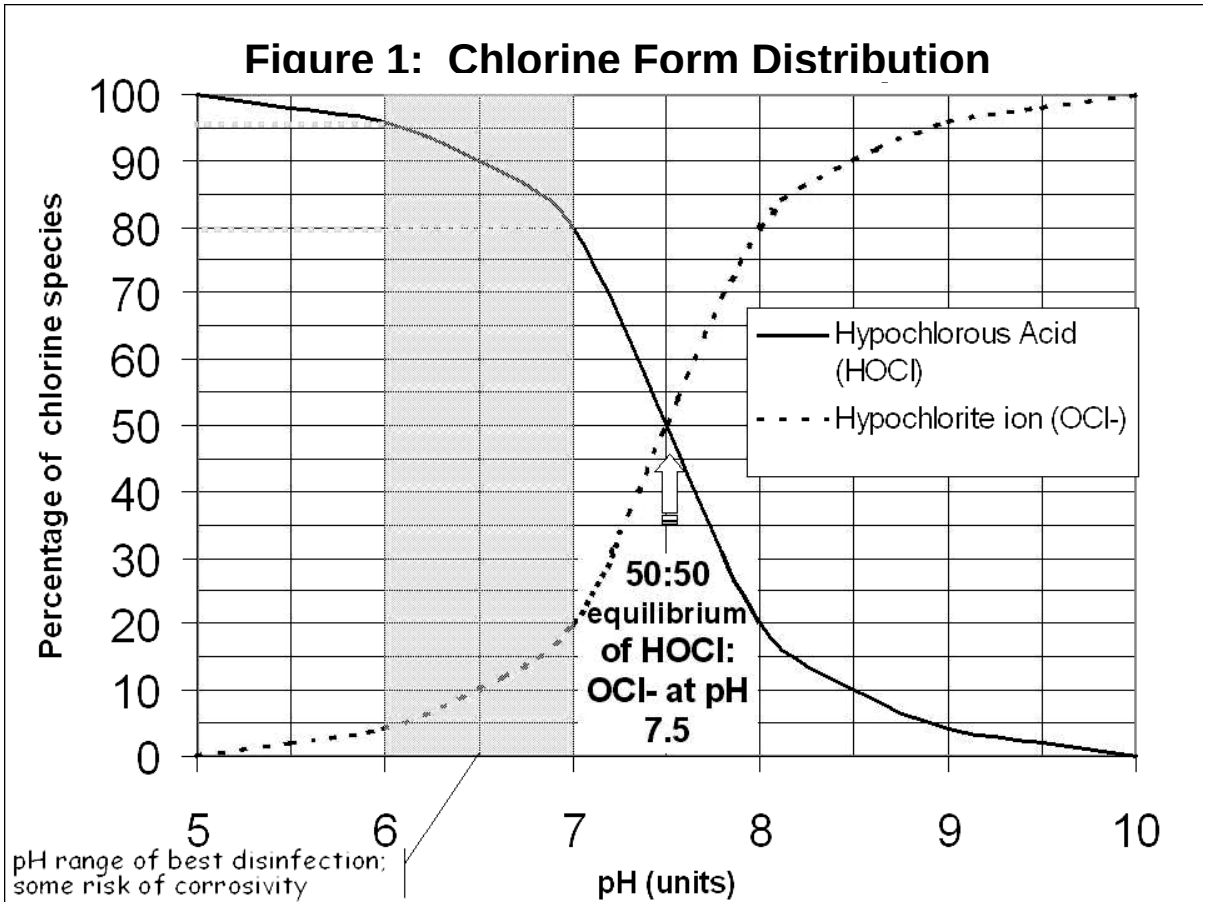
Figure 1: Chlorine Form Distribution
Percentage of chlorine species
100
90
80
70
60
50
40
30
20
10
0
5
6
7
8
9
10
pH (units)
Hypochlorous Acid (HOCl)
Hypochlorite ion (OCl-)
50:50 equilibrium of HOCl: OCl- at pH 7.5
pH range of best disinfection; some risk of corrosivity