Residential Water Well Disinfection Following a Flood Event: Procedures for Water Well System Professionals

NGWA BEST SUGGESTED PRACTICES

Introduction

As a service to members of the National Ground Water Association, this document provides the water well system professional (WWSP) with basic knowledge and suggested practices on this subject. Because of varying geologic conditions and other factors, it is not practical to develop a totally prescriptive guideline and this document is not a substitute for independent professional judgment by a WWSP.

There are references throughout this document to public health standards in the United States; other nations may have different standards. Recommended procedures are always subject to review and revision by local or state regulation and advisories by local or state authorities.

This document provides best suggested practices (BSPs) for emergency water well disinfection following inundation from a flooding event for residential wells. While disinfection procedures should be tailored to each well's dimensions, design, and conditions, the following recommendations are general requirements of emergency disinfection in response to inundation from floodwaters. Such decisions are site-specific and, thus, should be based on careful analysis by the WWSP. Subsequent positive coliform test results may require thorough cleaning of the well by the WWSP with removal of the pump including brushing and airlifting of debris from the very bottom of the well.

After the residential water well has experienced a flood event, the residents shall boil their water or use an alternate clean water supply until a WWSP has completed inspection and/or disinfection of their well system. All disinfection procedures shall be performed by a WWSP.

- Section 1 provides general recommendations for emergency well disinfection of a drilled water well.
- Section 2 provides specific steps for disinfection, dependent on well configuration.
- Section 3 discusses proper disinfection follow-up procedures.

Definitions

bacteria:

1. Typically, unicellular microorganisms which multiply by simple division. Some bacteria cause disease, but others are necessary for everyday organic interactions, including fermentation, nitrogen fixation, composting, cheese production, etc. Some bacteria produce corrosion and slimy debris, unaffected by chlorination, which can plug or damage pipelines and wells.

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2. Single-cell microorganisms (kingdom Prokaryota) that do not possess a defined nucleus or chlorophyll and reproduce by binary fission. They can take in food and produce energy, and are microscopic. They have a distinct cell wall that contains peptidoglycan. Archaeans are another form of ecologically important single-celled microorganisms that are distinguished from bacteria by cell and cell membrane structure.

bored well:
A shallow (10 to 100 ft, or 3 to 30 m), large-diameter (8- to 36-in, or 20- to 90-cm) water well constructed by hand-operated or power-driven augers.

contaminant:
Any physical, chemical, biological, or radiological substance or matter in water that has an adverse impact.

deep well jet pump:
Type of pump used when the suction lift is more than 25 feet. Deep well jet pumps can also have variations, i.e., multistage and various pressure and capacity capabilities. Deep well jet pumps are also centrifugal pumps plus a "jet." However, with this pump the jet is installed down the well instead of into the pump case.

disinfection:
The act of removal, inactivation, or killing of microorganisms that reduces microbial loads to a target level, such as a negative bacteriological test. Disinfection does not imply sterilization, which is the absolute removal of microorganisms.

domestic water well:
A water well that furnishes water for human consumption, including the watering of livestock, farm, and domestic animals.

drilled well:
A well constructed by either cable-tool or rotary methods usually to depths exceeding 50 feet with capacities to provide for industry, irrigation, or municipalities.

fungus/fungi:
Fungi are a group of organisms, ranging from a single-celled yeast to multi-celled organisms such as mushrooms. Some species may be present in water wells. Some are known to be allergenic or toxic.

microorganism:
Microorganisms include bacteria, protozoa, and fungi.

pathogen:
Any agent that has the potential to cause disease.

potable water:
Water suitable for drinking or cooking purposes from both health and aesthetic considerations.

protozoan:
A single-celled organism (kingdom Eukaryota) that has a nucleus, cellular organelles, and the ability to ingest food. Protozoans may be a health concern, so identification is important.

residential water well system:
The well system used by a private household, including the well, pumping equipment, and treatment equipment, if needed.

viruses:
Large group of infectious agents ranging in size from 20 to 14,000 nanometers in diameter (0.002 to 1.4 microns). They are not cells, but particles composed of a protein sheath surrounding a nucleic acid core. Viruses are characterized by their total dependency on living cells for reproduction. They do not usually reproduce in water except for those that are capable of infecting bacteria or protozoa.

water well:

An excavation that is drilled, cored, bored, washed, driven, dug, jetted, or otherwise constructed for the purposes of extracting groundwater, monitoring groundwater, using the geothermal properties of the earth, or injecting water into an aquifer or subsurface reservoir.

General Recommendation for Emergency Well Disinfection of a Drilled Water Well[1]

The household should arrange for an alternative clean water supply for about a week, as cleaning and disinfection requires several days to complete.[2]

For the purpose of well disinfection following a flooding event, two categories of wells exist: category one, wells that are not generally at risk based on their construction and maintenance, and category two, wells that are at risk due to construction deficiencies and/or lack of maintenance, compromising the integrity of the well.

Category one wells have only one avenue for outside water to penetrate the well: the vent. Well vents are normally a ½″ diameter opening that is protected with a small mesh screen. As water enters through the vent, the air being discharged from the water well has to exit through the same path. This burping process is dependent upon the parameters of the water well. Over an extended period of time, the water well will fill with contaminated water and this water can be "pushed" into the aquifer.

Category two wells may have a risk in the annular space or a defective water cap or casing, in which debris and mud (dirt) can enter the well. This mud and debris has to be physically removed from the water well to properly disinfect the water well. The effort to clean the water well combined with the physical integrity of the water well could dictate the construction of a new water well. This becomes a judgment for the WWSP to make.

Organic matter may be present in floodwaters. An inspection of the pump and well should include looking for a presence of organic matter such as grass, leaves, plants, etc. If present, the well needs to be airlifted, bailed, or flushed prior to pumping. Organic matter present upon disinfection with certain chemicals, such as chlorine, can react to create a disinfection by-product known as trihalomethane, a cancer-causing agent. If organic matter is suspected but cannot be determined to have entered the well, water can be tested for disinfection by-products before being used for consumption.

Discharge groundwater from the first discharge point or at the wellhead to avoid pumping the flushed water through treatment equipment or the distribution system. It is critical that the pump operate continuously during the flushing process. Normally, this will require that the existing pump be used to pump the water directly from the water well. The time period for pumping the well will be dependent upon the time the water well is flooded. The purpose for pumping is to remove as much contaminated water from the well as possible.

Caution: Always mix chemicals on the surface to avoid introducing insoluble solids into the well. Individuals who create the disinfection mixture need safety training in the specific safety issues of these chemicals and mixtures. They must have equipment available to avoid injury and to respond to spills. Sulfamic, hydrochloric, or other concentrated acids, when combined with chlorine, create a toxic gas and are extremely dangerous. Use of these chemicals in combination is highly discouraged.

Warning: It is critical to read the entirety of the instructions below before performing disinfection, to ensure these procedures are effective and to protect public health and personal safety.

In a clean mixing tank or container, mix a solution with 200 mg/L (ppm) chlorine, maximized for hypochlorous acid by following these steps:

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[1] This section generally applies to a drilled well that is larger than 2 inches in diameter and contains a working well pump.

[2] If the well is substandard at inspection, then repair or replace the well.

1. Compute one well volume from the well diameter, depth, and depth to static water level.[3]
2. Mix two well volumes of clean water and acidify to approximately pH 5.0 with white distilled, food-grade vinegar. The pH of the solution volume of acid varies according to water pH and buffering capacity. One gallon (3.785 liters) of 5% vinegar will adjust 100 gallons of water where average alkalinity is 100 mg/L and the chlorine is 500 mg/L. The following formula may assist in estimating the required vinegar to reach the pH of 5.0.[4]

$$\text{Gallons or liters of vinegar} = \frac{\text{Alkalinity}}{100\ \text{mg/L}} \times \frac{\text{Desired Chlorine Levels}}{500\ \text{mg/L}} \times \frac{\text{Volume}}{100\ \text{gal. (378.5 L)}}$$

3. Slowly mix in the sodium hypochlorite solution (NaOCl, generally 5-12 percent by volume) to make a 200 ppm solution.
4. If available, commercial pH buffering compounds that adjust pH are alternatives to the acid. Adjustment of pH once the hypochlorite has been added is discouraged, as adjustments below 5.0 will release chlorine gas, and the addition of acid to the hypochlorite solution will result in pH below 5.0 in the immediate area of the introduction. This can be dangerous and usually results in too much or too little acid addition. For practical purposes, if the pH is below 7.5, some hypochlorous acid will be present and introduction of the disinfectant should proceed.
5. Alternatively, one addition of disinfectant can be effective if done as follows: Introduce the entire solution to the bottom of the well (if liquid use tremie, if tablet use free fall). Either break the seal of the pitless unit and run the pump while still suspended in the well, or backwash with a hose from the nearest spigot until a disinfectant is detected at the hose; this backwashes the entire well volume with disinfectant. Disinfectant shall then be pumped through the distribution system until the disinfectant can be detected in all taps of the home. The well is then turned off for a minimum of 6 hours before flushing plumbing for 24 hours or until minimal disinfectant is detected. Water is sampled for total coliforms. If zero coliform count is registered, water is presumed safe for consumption. A second sample 24 hours later is recommended to confirm that the system is totally disinfected. Proceed to step 12.
6. Start agitation or pumping to pull solution upward throughout the water column.
7. Allow contact time, up to 24 hours. The treated well water should be re-agitated for at least a short period of time immediately prior to removal from the well.
8. Pump off waste, avoiding environmental harm by dechlorinating as needed with thiosulfate compounds, until measured total chlorine is less than 0.2 mg/L.
9. Conduct disinfection of water distribution system, according to state rules and recommendations.
10. After one week, test for coliform bacteria and nitrates. In the interim, residents should boil water for drinking and cooking.[5]
11. Use the coliform bacteria test results to compare after multiple chlorination to monitor progress.
12. Repeat as needed. If the well does not respond to treatment, then follow-up action should include replacement or repair of the well and appropriate assistance.

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[3] Calculating well borehole volume:
- Determine depth of water in well [(depth of wellbore) – (depth of static water level)]
- Determine diameter of well
- The value of pi = 3.1416
- The well volume (ft^3) = (depth of water in well (in feet)) × π × (diameter of well (in feet)$^2 \div 4$) = (depth of water in well) times pi times (the diameter of well squared divided by four)

[4] If hydrogen sulfide is present in the well, increase chlorine by 2 ppm for 1 ppm of hydrogen sulfide (2:1).

[5] **Exception:** When a history of high nitrates exists, avoid boiling and substitute with filtration or solar disinfection using specific procedures (e.g., SOLIS).

Specific Steps Which Depend on Well Configuration

Specific steps for a 2-inch well with a deep well jet

1. Pull in-well pipe and jet assembly. Inspect, clean, and replace components as needed so pump is operable.
2. Either re-install the pump and proceed to the next step, or use gentle airlift pumping to clear the well column.
3. Pump inundated wells for 8-10 hours to clear dirt, debris, and floodwater contaminants.
4. As per step 2 in General Recommendation for Emergency Well Disinfection of a Drilled Water Well, in large plastic tubs, mix vinegar for acidifying and sufficient NaOCl (sodium hypochlorite) to treat two well volumes.
5. Pour or pump chlorine solution into well—tremie the chlorine to the bottom of the screen.
6. Agitate the chlorine solution.
7. Allow contact time overnight or up to 24 hours. The treated well water should be reagitated for at least 15 minutes immediately prior to removal from the well.
8. Disinfect pump components with a 200 mg/L chlorine solution. Re-install pump and hook up jet pump.
9. Pump off waste, avoiding environmental harm by dechlorinating as needed with thiosulfate compounds, until measured total chlorine is less than 0.2 mg/L.
10. Conduct disinfection of water distribution system, according to state rules and recommendations.
11. After one week, test for coliform bacteria and nitrates. In the interim, residents should boil water for drinking and cooking.[6]
12. Use the coliform bacteria test results to compare after multiple chlorination to monitor progress.
13. Repeat as needed. If the well does not respond to treatment, then follow-up action should include replacement or repair of the well and appropriate assistance.

Specific steps for a bored well producing over ½ gpm

1. Pump inundated wells for 3-5 well volumes to clear dirt, debris, and floodwater contaminants. In the case of slow recovery, the WWSP should use professional judgment to determine when the well is cleared. The pumped water should be tested for contaminants and solids.
2. As per step 2 in General Recommendation for Emergency Well Disinfection of a Drilled Water Well, in large plastic tubs, mix vinegar for acidifying and sufficient NaOCl (sodium hypochlorite) to treat one bore volume to 200 mg/L solution.
3. Dose with chlorine solution by pumping or pouring the solution down the casing. If the well has a gravel pack in the annular space, the only procedure for chlorinating the gravel pack is to create an artificial head to push the chlorinated water into the annular space. This is accomplished by filling the bored water well to the surface and keeping the water level at the surface by continuously filling with chlorinated water.
4. Pump off well. For a water well with a submersible pumping system, lifting the pump from the pitless adapter and pumping "open-discharge" at the wellhead is the desired procedure. For a submersible system operating on a 40-60 psig cycle, the submersible pump will pump approximately 30% more water at open discharge than the average pumping rate during the cycle. Pumping the water well at the wellhead where the flow can be controlled with a discharge valve is ideal for flushing, cleaning, and disinfecting the water well. Brush well walls with a brush, or wash with a low pressure jetting tool to remove biological and mineral deposits from the borehole wall. A bored water well with a buried slab cannot be brushed and is difficult to jet effectively. Filling the well with chlorinated water and keeping filled is the most effective method for decontaminating a well of this construction.

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[6] **Exception:** When a history of high nitrates exists, avoid boiling and substitute with filtration or solar disinfection using specific procedures (e.g., SOLIS).

5. Allow borehole refill, if slow to respond after emptying.
6. Pump chlorine solution and discolored water (result from brushing) until clear, and recirculate with pump.
7. Allow contact time, up to 24 hours. The treated borehole should be re-agitated for at least a short period of time immediately prior to removal from the well.
8. Conduct disinfection of water distribution system, according to state rules and recommendations.
9. After one week, test for coliform bacteria and nitrates. In the interim, residents should boil water for drinking and cooking.[7]
10. Use the coliform bacteria test results to compare after multiple chlorination to monitor progress.
11. Repeat as needed.

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Primary

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[7] **Exception:** When a history of high nitrates exists, avoid boiling and substitute with filtration or solar disinfection using specific procedures (e.g., SOLIS).

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