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(Revision of ANSI/AWWA C654-03)

American Water Works Association

AWWA Standard

# Disinfection of Wells



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American Water Works Association STANDARD Since 1881

Approved American National Standard ANSI

## AWWA Standard

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# Contents

*All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.*

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# Foreword

*This foreword is for information only and is not a part of ANSI*/AWWA C654.*

## I. Introduction.

I.A. *Background.* During construction of a well, the bore hole may become contaminated by surface-water inflow and undesirable fluids through which the bore hole may penetrate. In addition, contamination may be introduced in a well by the drilling fluid, on equipment, or through the bore hole itself. A part of this contamination may be carried into the water-producing formations. During repairs or maintenance of an existing well, contamination may be introduced by the work practices performed or replacement components.

Well disinfection in accordance with this standard includes chlorination of the well casing, the pump and associated piping, and the gravel pack and immediate area of the aquifer around the casing, as well as verification of satisfactory bacteriological quality of the water. This standard is not intended to provide procedures for disinfection of the aquifer beyond the immediate location of a well; aquifer disinfection can best be handled by an engineering evaluation of all the conditions present at a specific location. The procedures for disinfection described in this standard are expanded beyond, and are intended to complement, information contained in AWWA A100, Standard for Water Wells, Section 11, Well Disinfection.

I.B. *History.* This is the fourth edition of AWWA C654, Standard for Disinfection of Wells. The first edition was approved by the AWWA Board of Directors on Jan. 25, 1987. The second edition was approved on June 15, 1997. The third edition was approved Jan. 19, 2003. This fourth edition was approved January 20, 2013.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF) to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the American Water Works Association Research Foundation (AwwaRF, now Water Research Foundation) and the Conference of State Health and Environmental Managers (COSHEM). The American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

* American National Standards Institute, 25 West 43rd street, Fourth Floor, New York, NY 10036.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. An advisory program formerly administered by USEPA, Office of Drinking Water, discontinued on Apr. 7, 1990.
2. Specific policies of the state or local agency.
3. Two standards developed under the direction of NSF,† NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.
4. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,‡ and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdiction. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, "Toxicology Review and Evaluation Procedures," to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of "unregulated contaminants" are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C654 does not address additives requirements. Users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by all parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

* Persons outside the United States should contact the appropriate authority having jurisdiction.

† NSF International, 789 N. Dixboro Road, Ann Arbor, MI 48105.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

**II. Special Issues.** Disinfection of wells requires high levels of disinfectant to be applied to ensure bacteria and other potential pathogens are inactivated. It should be noted that pH and temperature are two important factors affecting the disinfection process. Above pH 9, chlorine is in the form of hypochlorite, which is not as effective a disinfectant as hypochlorous acid, which is more prevalent at pH lower than 9. Temperature also affects the disinfection process; low temperatures are not as effective as high temperatures.

Disinfectants other than chlorine may be appropriate to use. While this standard describes only the use of liquid chlorine, sodium hypochlorite solutions, and calcium hypochlorite, the applicability of other disinfectants should be evaluated. Ozone and chemical cleaners have been used, and these warrant further investigation. Whichever disinfectant or method is selected, approval from the local regulatory agency may be required.

**III. Use of This Standard.** It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* The following information should be provided by the purchaser:

1. Standard used—that is, ANSI/AWWA C654, Standard for Disinfection of Wells, of latest revision.
2. Whether compliance with NSF/ANSI 60, Drinking Water Chemicals—Health Effects, is required.
3. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.
4. Method of disinfection to be used.
5. Any required disposal and precautions to be taken in disposing of chlorinated water.
6. Method of dechlorination to be used—ANSI/AWWA C655, Field Dechlorination, of latest revision.
7. Bacteriological testing and method to be used.
8. Redisinfection procedure to be used if required.
9. Details of other federal, state or provincial, and local requirements (Sec. 4).

III.B. *Modification to Standard.* Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

**IV. Major Revisions.** Major changes made to the standard in this revision include the following:

1. The Special Issues section of the foreword has been updated to include a note to the user on the effect of pH and temperature on the disinfection process, as well as a note on consideration of alternative disinfectants (foreword, Section II).

2. Definitions for *available chlorine*, *free chlorine*, *chlorine residual*, *contractor*, *gravel-packed well*, *manufacturer*, *purchaser*, and *supplier* have been added (Section 3).

3. A requirement for compliance with the Safe Drinking Water Act has been added (Section 4).

4. A cautionary note on potential corrosion of pumps and appurtenances from highly chlorinated water has been added (Sec. 4.1).

5. An advisory note on using appropriate personal protective equipment when handling chlorine products has been added (Sec. 4.2).

6. An informational note on using calcium hypochlorite in water with high calcium hardness has been added (Sec. 4.2.3).

7. Chlorination of gravel installed in new wells has been clarified to include requirements for chlorination of drilling fluid and volume of chlorinated water to add to well (Sec. 4.3.1.2).

8. Circulating the chlorinated water (Sec. 4.5.2) has been made an optional procedure.

9. Reference to ANSI/AWWA C655 for field dechlorination practices has been added (Sec. 4.6).

10. The sampling requirement (timing and number of samples) has been clarified (Sec. 5.1).

11. A section on optional sampling and testing has been added (Sec. 5.4).

12. Appendix B on Disposal of Heavily Chlorinated Water has been removed. This information is now covered in more detail in ANSI/AWWA C655, Field Dechlorination.

**V. Comments.** If you have any comments or questions about this standard, please call AWWA Engineering & Technical Services at 303.794.7711, FAX at 303.795.7603, write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098, or email at standards@awwa.org.

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# Disinfection of Wells

## SECTION 1: GENERAL

### Sec. 1.1 Scope

This standard describes the procedures for disinfection and bacteriological testing of wells for potable water service following construction, servicing, maintenance, or any other activity or event that might lead to contamination of the water. The chlorination procedures provided in this standard are for the gravel pack, well casing, pump, and appurtenant piping and are presented in the sequence in which they generally would be implemented.

### Sec. 1.2 Purpose

The purpose of this standard is to establish the minimum requirements for the disinfection of wells for potable water service, including procedures for disinfection and bacteriological testing.

### Sec. 1.3 Application

This standard can be referenced in specifications for the disinfection of wells and can be used as a guide for procedures for chlorination and bacteriological testing. The stipulations of this standard apply when this document has been referenced and then only to the disinfection of wells.

## SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, they form a part of this standard to the extent specified within the standard. In any case of conflict, the requirements of this standard shall prevail.

ANSI*/AWWA A100—Water Wells.

ANSI/AWWA B300—Hypochlorites.

ANSI/AWWA B301—Liquid Chlorine.

ANSI/AWWA C655—Field Dechlorination.

*Standard Methods for the Examination of Water and Wastewater.* APHA,† AWWA, and WEF.‡

NSF/ANSI 60—Drinking Water Treatment Chemicals—Health Effects.

NSF/ANSI 61—Drinking Water System Components—Health Effects.

## SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Available chlorine:* A measure of the amount of chlorine in chlorinated lime, hypochlorite compounds, chloramines, and other materials that are used for disinfection compared with the amount in elemental (liquid or gaseous) chlorine.

2. *Chlorine, free:* Also called *free available chlorine*, the amount of chlorine available as dissolved gas ($Cl_2$), hypochlorous acid (HOCl), and hypochlorite ($OCl^-$) that is not combined with ammonia ($NH_3$) or other compounds in water that is available for disinfection.

3. *Chlorine residual:* Concentration of chlorine species present in water after the oxidant demand has been satisfied.

4. *Contractor:* The party that provides the work and materials for placement or installation.

5. *Gravel-packed well:* A well in which gravel is placed in the annular space of the well adjacent to the screen section.

6. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.
† American Public Health Association, 800 I Street NW, Washington, DC 20001.
‡ Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314.

7. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

8. *Supplier:* The party that supplies material or services. A supplier may or may not be the manufacturer.

## SECTION 4: REQUIREMENTS

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable water, wastewater, and reclaimed water systems as applicable.

### Sec. 4.1 Preventive Actions

Sanitary conditions are necessary for effective well disinfection. During construction and maintenance operations, precautions shall be taken to minimize contamination. Surface runoff shall be diverted away from the well, drilling fluid pond, and other construction areas. Drilling equipment, gravel, pump column, and any other items and materials that will be inserted in the well shall be used and stored in a manner that minimizes contamination. Special care should be taken with grease and other lubricants to protect them from contamination. Some drilling fluid additives have been demonstrated to promote bacterial growth; consult with supplier to avoid this situation. Cover the well securely between work periods. Care should be employed when using highly chlorinated water with pumps and appurtenances to avoid potential corrosion.

### Sec. 4.2 Forms of Chlorine for Disinfection

The forms of chlorine that may be used in the disinfecting operations are liquid chlorine, sodium hypochlorite solution, and calcium hypochlorite granules or tablets. All disinfectants shall be approved for use in potable water. Appropriate personal protective equipment should be worn when using these products.

4.2.1 *Liquid chlorine.* Liquid chlorine conforming to ANSI/AWWA B301 contains 100 percent available chlorine and is packaged in steel containers usually of 100-lb, 150-lb, or 1-ton net chlorine weight. Liquid chlorine shall be used only (1) in combination with appropriate gas-flow chlorinators and injectors to provide a controlled high-concentration solution feed to the water to be chlorinated; (2) under the direct supervision of a person who is familiar with the physiological, chemical, and physical properties of liquid chlorine, and who is trained

and equipped to handle any emergency that may arise; and (3) when appropriate safety practices are observed to protect working personnel and the public.

4.2.2 *Sodium hypochlorite.* Sodium hypochlorite conforming to ANSI/AWWA B300 is available in liquid form in glass, rubber-lined, or plastic containers typically ranging in size from 1 qt to 5 gal; containers of 30 gal or larger size may be available in some areas. Sodium hypochlorite contains approximately 5 percent to 15 percent available chlorine, but care must be used in control of conditions and length of storage to minimize its deterioration.

4.2.3 *Calcium hypochlorite.* Calcium hypochlorite conforming to ANSI/AWWA B300 is available in granular form or in small tablets, and contains approximately 65 percent available chlorine by weight. The material should be stored in a cool, dry, and dark environment to minimize its deterioration. The precautions listed on the container label should be carefully noted.

NOTE: Calcium hypochlorite may be difficult to dissolve in water with high calcium hardness (hardness in excess of 100 mg/L). In this case, using sodium hypochlorite, or dissolving calcium hypochlorite in solution before introduction to the well, is suggested.

## Sec. 4.3 Gravel and Gravel-Pack Chlorination

4.3.1 *Chlorination of gravel installed in new wells.* Gravel being installed in new wells shall be chlorinated by one of the following two procedures. In either case, before gravel is installed, the drilling fluid shall be thinned as described in ANSI/AWWA A100 and shall extend to the top of the casing.

4.3.1.1 Tablet or granular procedure in gravel. Calcium hypochlorite shall be uniformly mixed with the gravel at the rate of ¼ lb to ½ lb of calcium hypochlorite per ton of gravel. The mixture shall then be fed into the gravel chute and shall completely fill the annular void outside the casing to the level desired.

WARNING: Gravel used in any water well should be free of organic material. Otherwise, there is potential for an explosion when gravel containing organic material is mixed with hypochlorite tablets.

4.3.1.2 Chlorine residual in drilling fluid. After the drilling fluid has been thinned, gravel can then be added to fill the annular void outside the well casing. The drilling fluid shall be chlorinated before the gravel is added to the annular space. After any drilling mud has been displaced, chlorinated water is put into the well to produce a chlorine residual of not less than 50 mg/L in the entire volume of fluid within the well. The chlorinated water shall be fed down the gravel chute until the chute will no longer take water or until the volume down the chute

is equal to at least twice the calculated volume of the annular space outside the well casing. The chlorine residual shall be measured periodically during this operation and the chlorine feed adjusted if necessary.

4.3.2 *Chlorination of gravel being installed in existing wells.* When gravel has settled in an existing well, any replacement gravel used to fill the void shall be soaked, immediately prior to its use, for at least 30 min in a chlorine solution maintained at a concentration of not less than 50 mg/L.

4.3.3 *Chlorination of existing gravel pack in wells.* When an existing gravel pack appears to be the source of contamination in a well, it shall be chlorinated by feeding water containing not less than 100-mg/L chlorine residual down the gravel chute, if one is present. The chlorinated water shall be fed down the gravel chute until the chute will no longer take water or until the volume down the chute is equal to at least twice the calculated volume of the annular space outside the well casing. The chlorinated water should be fed into the gravel chute through an air-gap system to avoid a pressure buildup that would lift the pump base. The maximum rate at which the gravel will accept water may vary greatly from one well to another, but rates of 20 gpm to 50 gpm (70 L/min to 190 L/min) are not unusual. (See Figure A.1 for suggested feed system.) If a gravel chute is not present, additional chlorination and well surging, as determined by a qualified groundwater professional or engineer may be used.

## Sec. 4.4 Chlorination of Permanent Equipment and Material Used in Wells

All permanent equipment and material to be installed in the well shall be chlorinated just before installation. This shall be done by spraying exposed areas with a solution having a chlorine residual of not less than 200 mg/L.

## Sec. 4.5 Chlorination of Well After Permanent Equipment Is Installed

After permanent equipment is installed, the well shall be chlorinated by (1) treating the water in the well casing to provide a chlorine residual of no less than 50 mg/L; (2) circulating the chlorinated water within the well casing and pump column; and (3) pumping the well to waste to remove chlorinated water. NOTE: Circulation must be done with care, especially in older existing wells, as it may flush or loosen casings or screens.

4.5.1 *Treating the water in the well casing.* The water in the casing shall be treated with chlorine so that chlorine residual of no less than 50 mg/L is in the entire volume of water in the casing. This may be done by using granular calcium

hypochlorite, calcium hypochlorite tablets, or sodium hypochlorite solution in the amounts shown in Table A.1.

If calcium hypochlorite tablets are used, they shall be dribbled down the casing vent and at least 30 min shall pass to allow the tablets to fall through the water and dissolve.

If sodium hypochlorite, or calcium hypochlorite dissolved on-site, is used, the solution must reach all parts of the well. To accomplish this, a tube shall be suspended through the well-casing vent, when possible, so that it reaches the bottom of the well. After it reaches the well bottom, it shall be withdrawn as the sodium hypochlorite solution is pumped through the tube. If not possible, the use of calcium hypochlorite tablets as described above may be appropriate.

After the chlorine has been applied, the well shall be surged at least three times to improve the mixing and induce contact of the chlorinated water with the adjacent aquifer. The chlorine residual of this water shall be verified. The chlorinated water shall be allowed to rest in the casing for at least 12 hr.

After the well has been chlorinated and allowed to rest for at least 12 hr, it shall be pumped to waste. The discharge water shall be tested periodically for chlorine residual. When no detectable chlorine residual is measured, the well shall continue to be pumped to waste for at least 15 min before proceeding with bacteriological sampling (Sec 5.1).

4.5.2 *Circulating the chlorinated water: optional procedure.* Following completion of the procedure described in Sec. 4.5.1, a pressure-tight connection shall be made at least 2 in. in diameter (but not larger than the discharge piping) from the pump discharge piping to the casing vent. The pump shall be operated against a throttled discharge valve to return a flow of several hundred gallons per minute down the well casing while the rest of the pumped water is discharged to waste. In low-producing wells, the rate of return need not exceed one-half the maximum rate of production of the well (see Figure A.2).

CAUTION: The discharge valve shall not be throttled to the extent that the pressure developed will damage equipment or pipe-restraining ties. This procedure will remove oil or other material that has accumulated on the water surface; care must be used to ensure that such material is recovered for proper waste disposal.

The discharge water shall be tested periodically for chlorine residual. When no detectable chlorine residual is measured, the well shall continue to be pumped to waste for at least 15 min. The well shall then be sampled for bacteriological testing.

### Sec. 4.6 Disposal of Contaminants

Any oil or other contaminant pumped from the well must be collected for proper disposal. In addition, if the discharge of chlorinated water would be harmful to vegetation or wildlife, measures must be taken either to impound the highly chlorinated water or to neutralize the chlorine. Federal, state or provincial, or local environmental regulations may require special provisions or permits before the disposal of highly chlorinated water. Refer to ANSI/AWWA C655, Field Dechlorination, for appropriate dechlorination requirements.

## SECTION 5: VERIFICATION

### Sec. 5.1 Bacteriological Testing

After the well has been chlorinated, allowed to rest for at least 12 hr, and pumped to waste for a minimum of 15 min with no detectable chlorine residual, a minimum of two water samples shall be taken while the well is being continuously pumped not less than 30 min apart, and the samples shall be tested for the presence of coliform in accordance with *Standard Methods for the Examination of Water and Wastewater*. If none of these samples shows the presence of coliform, the well may be placed in service.

If any of these samples shows the presence of coliform, one of the following procedures shall be followed:

1. Pump the well to waste for a minimum of an additional 15 min, then take a minimum of two water samples while the well is being continuously pumped not less than 30 min apart and test for the presence of coliform in accordance with the latest edition of *Standard Methods for the Examination of Water and Wastewater*. If none of these samples shows the presence of coliform, the well may be placed in service. (If any of these samples shows the presence of coliform, follow procedure 2 or 3 below.)
2. Chlorinate and test the well as described in Sec. 4.5 and 5.1.
3. Perform corrective action as determined by a qualified groundwater professional or engineer experienced in water well disinfection.

### Sec. 5.2 Disinfection of Flowing Wells

Flowing wells discharging at the surface generally do not require chlorination. Nevertheless, bacteriological sampling and testing for coliform shall be done as described in Sec. 5.1. If it is determined that coliforms are present, chlo-

rine should be applied at or below the lowest aquifer formation producing the artesian condition in an amount that will produce a chlorine concentration of at least 25 mg/L in the flowing water. The chlorine may be introduced through a weighted tube discharging a solution with a high concentration of chlorine (such as 15,000 mg/L) or using calcium hypochlorite tablets confined in a perforated container. If bacteriological testing shows the presence of coliform after this disinfection, procedure 3 of Sec. 5.1 shall be followed.

### Sec. 5.3 Record of Compliance

The report of bacteriological test results certifying that the well is producing water free of contamination by coliform bacteria shall be the record of compliance.

### Sec. 5.4 Optional Sampling and Testing

Following disinfection and prior to activating the well for use, water from the well should be evaluated to determine that it meets expected parameters. Test results should confirm that the water quality is appropriate for distribution or that levels are as expected for subsequent treatment. This assessment is unique for each system.

## SECTION 6: DELIVERY

This standard has no applicable information for this section.

# APPENDIX A

## Chemical Requirements for 50-mg/L Chlorine Solution

*This appendix is for information only and is not a part of AWWA C654.*

**Table A.1 Chlorine compound required to dose 100 ft of water-filled well at 50 mg/L**

| Well-Hole or Well-Casing Diameter *in.* | Volume per 100 ft of Water Depth *gal* | Amount of Chemical Compound | | |
|---|---|---|---|---|
| | | Calcium Hypochlorite* (65 percent available $Cl_2$) | Sodium Hypochlorite† (12 trade percent§) | Liquid Chlorine‡ (100 percent available $Cl_2$) *lb* |
| 4 | 65.28 | 0.7 oz | 3.5 fl oz | 0.03 |
| 6 | 146.9 | 1.5 oz | 7.8 fl oz | 0.06 |
| 8 | 261.1 | 2.7 oz | 13.9 fl oz | 0.11 |
| 10 | 408.0 | 4.2 oz | 1.4 pt | 0.17 |
| 12 | 587.5 | 6.0 oz | 2.0 pt | 0.25 |
| 16 | 1,044.0 | 10.7 oz | 3.5 pt | 0.44 |
| 20 | 1,632.0 | 1 lb 1 oz | 0.7 gal | 0.68 |
| 24 | 2,350.0 | 1 lb 8 oz | 1.0 gal | 0.98 |
| 30 | 3,672.0 | 2 lb 6 oz | 1.5 gal | 1.53 |
| 36 | 5,287.0 | 3 lb 6 oz | 2.2 gal | 2.21 |
| 48 | 9,400.0 | 6 lb 1 oz | 3.9 gal | 3.92 |
| 60 | 14,690.0 | 9 lb 7 oz | 6.1 gal | 6.13 |

NOTE: See Table A.2 for metric conversions.

* Quantities of $Ca(OCl)_2$ based on 65 percent available chlorine by dry weight (16 oz = 1 lb).

† Quantities of NaOCl based on 12 trade-percent available chlorine by US liquid measure (1 gal = 4 qt = 8 pt = 128 fl oz).

‡ Quantities of $Cl_2$ based on 100 percent available chlorine by weight.

§ *Trade percent* is a term used by chlorine manufacturers: trade percent × 10 = grams of available chlorine in 1 L of solution.

**Table A.2 Metric conversion factors**

| US Customary Unit | Conversion Factor | Metric Equivalent |
|---|---|---|
| inch (in.) | × 25.4 | millimeter (mm) |
| feet (ft) | × 0.3048 | meter (m) |
| US gallon (gal) | × 3.7854 | liter (L) |
| US quart (qt) | × 0.9463 | liter (L) |
| fluid ounce (fl oz) | × 0.02957 | liter (L) |
| avoirdupois ounce (avdp oz) | × 0.02835 | kilogram (kg) |
| avoirdupois pound (avdp lb) | × 0.45359 | kilogram (kg) |

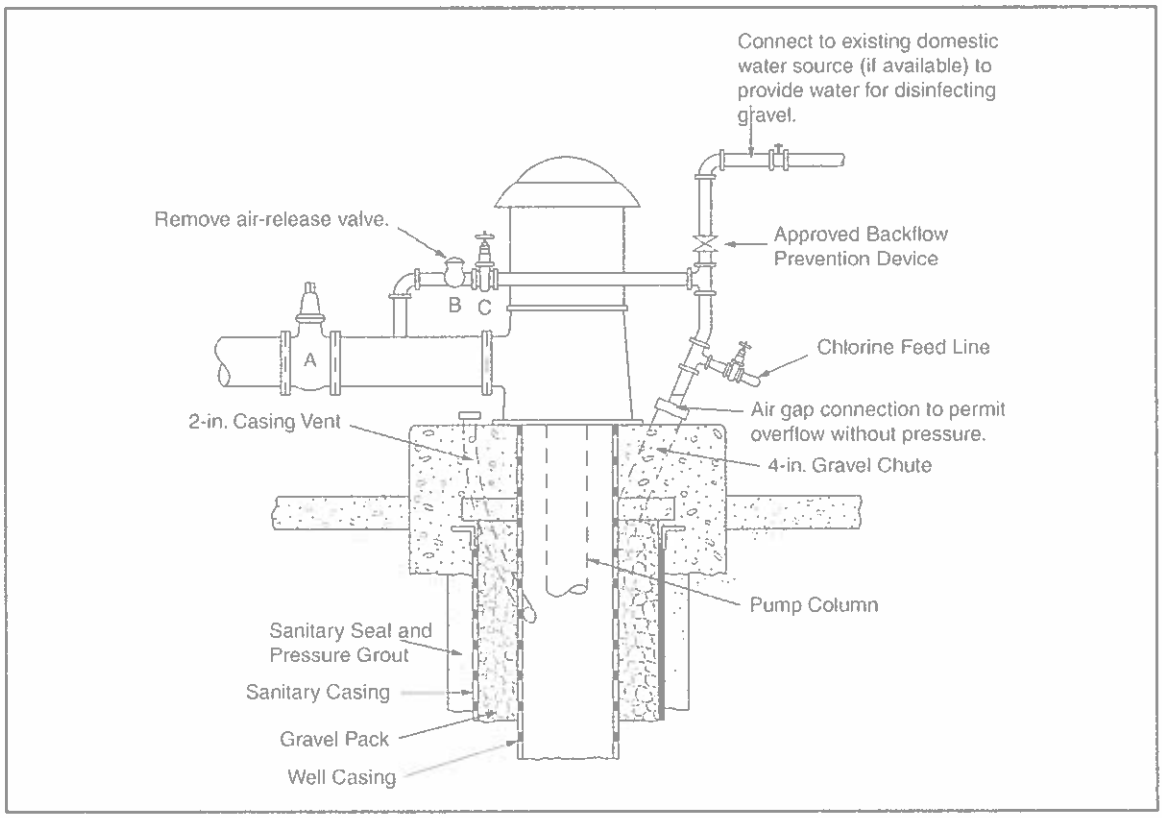


Figure 1 Gravel-pack chlorination

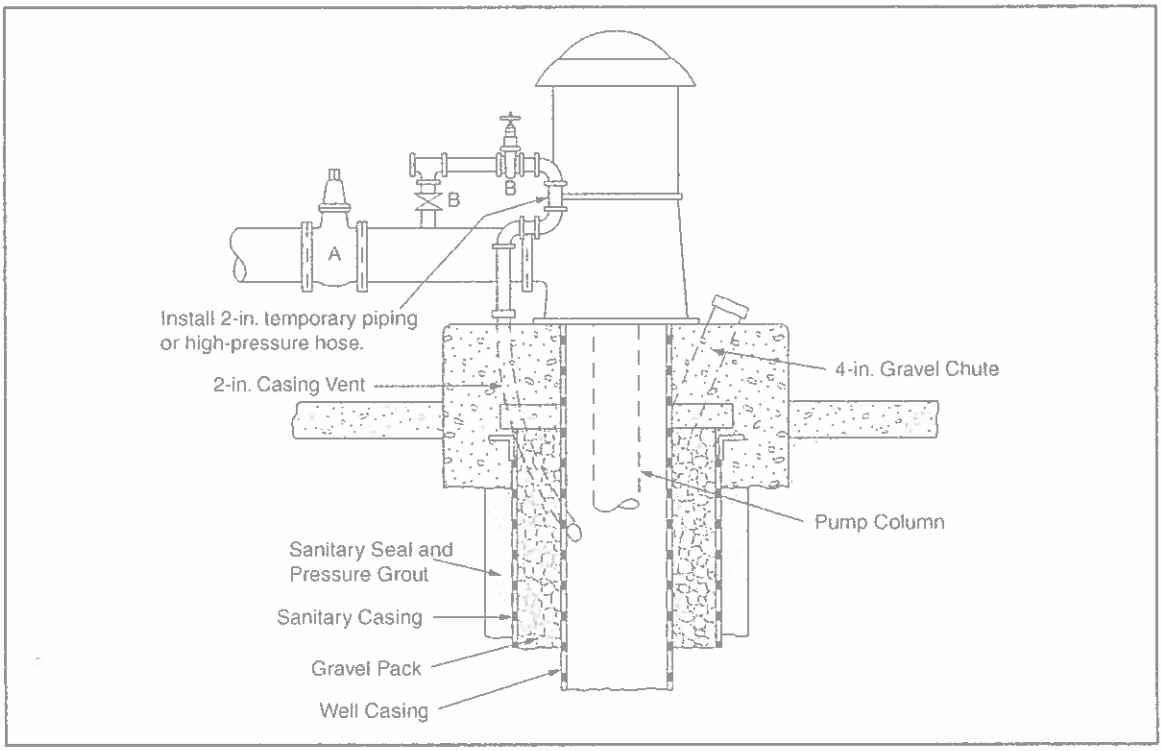


Figure 2 Circulating chlorinated water inside well casing

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