Preparing and Measuring High Chlorine Concentration Solutions for Disinfection

Technical Information Paper No. 13-034-1114

1. Purpose. This information paper provides guidance for preparing high concentrations of a chlorine solution for use as a disinfectant and identifies simple chlorine test products designed to measure these high concentrations.

2. Applicability. The high disinfecting concentrations presented in this paper are intended for hospital infection control and may be applied to any operation, to include Ebola virus disease (EVD) response, in which control over the spread of communicable diseases is a concern.

3. Background. Disinfection is a process of inactivating or destroying harmful microorganisms (germs) from nonliving or inert surfaces. It is not the same as sterilization, which is the removal or destruction of all forms of life to include bacterial spores. There are many chemical products available commercially that are specially formulated for disinfecting various surface types and textiles. The effectiveness of the product to destroy different types of harmful microorganisms is dependent on the disinfecting agent, the chemical concentration, and contact time; therefore, selecting an appropriate product for the intended application is important. Chlorine bleach is the disinfecting agent discussed in this paper.

a. Bleach is an effective, inexpensive and universally available product. The term “bleach” refers to a chemical with the inherent properties of removing color, whitening, and disinfecting. Oxidation is the active chemical process that enables most bleach agents to work. There are two basic types of bleach products: those with chlorine and those without. Non-chlorine bleaches, or oxygen bleaches, use peroxides and sodium percarbonate as the non-chlorine bleaching agent.

(1) The active ingredient of chlorine bleach is sodium hypochlorite, an effective oxidizing agent and broad spectrum disinfectant. The mixture of sodium hypochlorite and water (pH 7.2 - 7.4) produces a chemical reaction that causes proteins to lose their structure. Microbes are killed through the inactivation of proteins.

(2) Sodium hypochlorite decomposes over time and the rate of decomposition increases with exposure to elevated temperatures (above 70°F/21°C). A high concentration also affects the decomposition rate. For example, a 16% solution degrades in a few minutes while a 3% solution can last for months. Decomposition occurs regardless of whether the product's container is open or remains sealed. Some manufacturers compensate for the increased rate of dissipation during the summer production period by increasing the base strength of the sodium hypochlorite compared to winter production. Because of these variables, users must not rely solely on the base concentration specified on the manufacturer's label and must not assume the desired disinfecting concentration will be achieved when using the prescribed formula for preparing a disinfecting solution. See discussion in paragraph 4.e.(4), below.

b. The Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) prescribe two levels of bleach dilution for disinfection tasks associated with hospital infection control and EVD support operations. The dilutions, 0.05% and 0.5%, are equivalent to 500 parts per million (ppm) and 5,000 ppm free available chlorine (FAC), respectively and assume that the product used to prepare the disinfecting solution has a starting base strength of at least 5 percent available chlorine.[1, 2] The recommended application of each of these dilutions is summarized in Table 1.

Table 1. Bleach Dilutions and Disinfection Applications[1, 2, 3]

<table>
<tr><th colspan="2">Disinfection Application</th><th>Contact Time to Achieve Disinfection</th></tr>
<tr><td rowspan="5">0.5%
(5,000 ppm)</td><td>Excreta</td><td rowspan="4">10 minute wet contact
Gross contamination must be removed first; pre-disinfection treatment may be required. Final disinfection applied after cleaning the surface.</td></tr>
<tr><td>Bodies</td></tr>
<tr><td>Spills of blood & body fluids</td></tr>
<tr><td>Vehicles & tires</td></tr>
<tr><td colspan="2">Also used to prepare a 0.05% [500 ppm] bleach solution by diluting 1 part of the 0.5% [5,000 ppm] solution with 9 equal parts of water.</td></tr>
<tr><td rowspan="6">0.05%
(500 ppm)</td><td>Surfaces (not contaminated with blood or body fluids)</td><td>1 minute wet contact</td></tr>
<tr><td>Medical equipment (not contaminated with blood or body fluids)</td><td>1 minute wet contact</td></tr>
<tr><td rowspan="2">Bedding</td><td>10 minutes – infection control pretreatment if heavily soiled with excreta or body fluids</td></tr>
<tr><td>30 minutes – disinfecting rinse if pretreatment was not performed</td></tr>
<tr><td>Reusable protective clothing (before and after laundering or washing)</td><td>1 minute wet contact</td></tr>
<tr><td>Disinfecting contaminated waste before disposal</td><td>Saturate items to ensure 10-minute minimum wet contact time</td></tr>
</table>

(1) The CDC and WHO often refer to the percent of bleach in solution as a ratio of bleach to water. A ratio depicted as 1:10 represents a 0.5% solution and intended to represent a 5,000 ppm FAC solution; 1:100 represents a 0.05% solution or 500 ppm. In the ratio the value "1" is the volume of bleach and the value "10" or "100" is the total volume of the prepared solution. For example, for a 0.5% solution, 1 part bleach is added to 9 equal parts of water to yield a 1:10 ratio. The ratios 1:10 and 1:100 will not represent a 5,000 or 500 ppm dilution if the base strength of the concentrated chlorine bleach product is less than 5 percent.

(2) A wide variety of chlorine bleaches are produced worldwide and are available in different base strengths. Standard bleach designated for general purpose or household use may vary between 3 and 15 percent base strength; industrial strength bleaches are often formulated at high concentrations above 20 percent. Table 2 provides a list of common household-type bleach products that are manufactured or used around the world, the associated product base strength, and the corresponding volume of water that must be added to 1-part bleach to achieve a 5,000 ppm disinfecting concentration.

Table 2. Liquid Base Strength Bleach by Brand or Country of Origin[2]

Bleach Brand; Country Manufactured or Used	**% Active Chlorine *(base strength)***	**Volume of Water Added to 1 Part Bleach to Prepare a 5,000 ppm Concentration**[a]
8 °chlorum[b]	2.4%	4
JIK (Kenya, Liberia)	3.5%	6
Ajax (Jamaica)		
12 °chlorum[b]	3.6%	6
Bref Javel (Senegal)	4%	7
Eau de Javel (France)	5%	9
Household bleach (USA[c], Indonesia, Canada)	5.25%	9
ACE (Turkey,)		
Blanquedor, Cloro (Mexico)	6%	11
Household bleach (USA) *(Clorox® and other brands)*	8.25%	15
Blanquedor (Mexico)	8%	15
Lavindina (Bolivia)		
Chloros (UK)	10%	19
La Croix Eau (Guinea)	14%	27
Chloros (UK)	15%	29
Extrait de Javel (France)		
48 °chlorum[b]		

[a] Reads as one part (e.g., cup or liter) concentrated bleach to *x* parts water (e.g., for JIK mix 1 cup bleach with 6 cups water for a total of 7 cups).
[b] In some countries the concentration of sodium hypochlorite is expressed in chlorometric degrees (°chlorum); one °chlorum is approximately equivalent to 0.3% available chlorine.
[c] Chlorine bleach manufacturers in the United States are moving away from a 5.25% base strength and are now producing products with an 8.25% base. The product strength is indicated on the label.

(3) Household bleach manufactured in the United States (U.S.) was previously formulated between 5.25% and 6%. Many of the leading manufacturers, such as Clorox®, are now producing household bleach at 8.25%; therefore, the 1:10 and 1:100 mixing ratios specified in paragraph b(1), above, no longer apply.

4. Preparing Chlorine Bleach Solutions.

a. Industrial strength chlorine bleaches are highly caustic and should not be used for preparation of disinfecting solutions.

b. Wear personal protective equipment such as impermeable gloves and apron and chemical splash goggles or face shield when preparing and applying the disinfecting solution. Ensure the area where solution preparation occurs is well ventilated.

c. Use only liquid, unscented bleach to prepare a disinfecting solution. Although gel-type or "thick" bleaches may be used to disinfect facilities, such as toilets, they must not be used to prepare chlorine bleach dilutions identified in this paper.

d. When liquid bleach is not available, a bleach powder may be used (Table 3).

Table 3. Preparing Dilute Chlorine Bleach Solutions using Bleach Powder [2, 4]

Type of Bleach	% Active Chlorine	Amount of bleach required per liter[a] of water for a 5,000 mg/L[b] solution
Calcium hypochlorite	70%	7 grams
Calcium hypochlorite	35%	14 grams
Sodium dichloroisocyanurate (NaDCC)	60%	8.3 grams
Chloramine tablets[c]	1 gram of available chlorine per tablet[c]	20 grams (20 tablets)[c]
NaDCC-based tablets[c]	1.5 grams of available chlorine per tablet[c]	4 tablets[c]

[a] 1 liter is approximately equal to 34 ounces or 4.25 cups
[b] 1 mg/L is equivalent to 1 ppm
[c] Chloramine releases chlorine at a slower rate than does hypochlorite. Before using the solution, be sure the tablet is completely dissolved.

e. Steps for preparing a bleach solution:

(1) Preparing a fresh disinfecting solution each day is highly recommended as the active disinfecting ingredient, sodium hypochlorite, will dissipate over time and exposure to elevated temperatures. Availability of the desired FAC concentration is key

to ensuring proper disinfection. When operating in high temperature environments, spot check the chlorine residual (FAC) of prepared solutions multiple times during the day to ensure the desired disinfecting concentration remains available. Never "top off" degraded solutions; clean the container and prepare a fresh batch.

(2) Identify the base strength of the bleach as indicated on the product label (see Table 2).

(3) Determine the desired concentration for disinfection (0.5% or 0.05%) based on the target microorganism or application (see Table 1).

(4) Determine the total parts of water to mix with 1 part bleach by using the values presented in Table 2 for various products, or calculate the *total parts* water using the formula provided in Figure 1. When dry bleach is used, follow the mixing guidance presented in Table 3. NOTE: The amount of powder/dry bleach indicated in Table 4 is added to 1 liter of water, which is approximately equivalent to 34 ounces or 4.25 cups.

- Check the concentration (% concentrate) of the chlorine product you are using.
- Determine the total parts water needed using Table 2 or the formula below; any concentration can be used to make a dilute chlorine solution

$$\textit{Total Parts (TP) water} = \left[\frac{\text{\% Bleach Concentrate}}{\text{Desired \% Dilution}}\right] - 1$$

- Mix 1 part concentrated bleach with the total parts water required.

Example 1: To make a **0.5%** chlorine solution (**5,000 ppm**) from 8.25% Clorox bleach—

STEP 1: Calculate TP water: $\left[\frac{8.25\%}{0.5\%}\right] - 1 = 16.5 - 1 = 15.5$

NOTE: *Do not convert the percentage values to a true decimal before dividing.*

STEP 2: Take 1 part concentrated solution [Chlorox 8.25%] and add 15 equal parts water to make a 5,000 ppm disinfecting solution.

- The calculated value for TP may be rounded up or down.
- Apply this formula using any volume (e.g., 1 cup bleach to 15 cups water; 1 tablespoon bleach to 15 tablespoons water)

- For a 0.05% (500 ppm) dilution, prepare a 0.5% solution first and then dilute at a 1:10 ratio by mixing 1 part of the 0.5% solution with 9 parts water; or apply the formula.

Example 2: To make a **0.05%** chlorine solution (**500 ppm**) from 3.5% JIK bleach—

STEP 1: TP water: $\left[\frac{3.5\%}{0.05\%}\right] - 1 = 70 - 1 = 69$

STEP 2: Take 1 part concentrated solution [JIK 3.5%] and add 69 equal parts water to make a 500 ppm disinfecting solution.

Figure 1. Formula for making a dilute bleach solution from a concentrated product[2]

f. Testing is the only reliable way to assure the desired disinfecting strength of a prepared chlorine solution is achieved and maintained.

(1) Verify the concentration every time a new solution is prepared, even when solutions are prepared multiple times during the day using the same container of the base product.

(2) Use chlorine test paper that is capable of detecting the target range of FAC. The detection range of the test paper should be broad enough such that the target FAC concentration is close to the midpoint on the test paper scale. For example, if the desired concentration is 500 ppm chlorine, the test range of the chlorine paper should be capable of detecting 0 to 800 ppm or 0 to 1000 ppm. Table 4 provides a short reference list of chlorine test strip suppliers and associated products for detecting high concentrations of FAC in water. This list is not all inclusive.

Table 4. Manufacturers of High Chlorine Test Strips

Detection Range (ppm)	Product Name	Manufacturer or Source
100 - 750	Free Chlorine Testing Strips ▪ Increments 100, 200, 350, 500, 750 ppm http://www.testkitcentral.com/Chlorine-Test-Strips-High-Range-Prodview.html	Serim Research Corp. P.O. Box 4002, Elkhart, IN 46514 Phone: 800- 542-4670; 574 264-3440 Fax: (574) 266-6222 Web: www.serim.com Email: lmontgomery@serim.com
0 - 800	Insta-Test High Range Chlorine Test Strips ▪ Increments 50, 100, 250, 500, 800 ppm http://www.lamotte.com/en/water-wastewater/test-strips/3031.html	LaMotte Company 802 Washington Avenue, PO Box 329 Chestertown, MD 21620 Phone: 410-778-3100 ; 800-344-3100 FAX:410-778-6394 http://www.lamotte.com/en/
0 – 750 0 – 2,000	WaterWorks™ Free Chlorine Ultra High test strips; Free Chlorine Ultra High II test strips ▪ Increments 0, 25, 50, 100, 200, 300, 400, 500, 750 ppm ▪ Increments 0, 25, 50, 200, 500, 800, 1100, 1500, 2000 ppm http://www.sensafe.com/?s=free+chlorine+ultra+high+test+strips	Industrial Test Systems Phone: 800-861-9712 http://www.sensafe.com/chlorine-tests-2/
0 - 10,000	Activate™ High-level Sanitizer Test Strips ▪ Increments 0, 1000, 2500, 5000, 7500, 10,000 ppm http://www.testkitcentral.com/High-level-Chlorine-Test-Strips-Prodview.html	Deardorff Fitzsimmons Corporation, Customer Service PO Box 539 Merlin, OR 97532 Phone: 888-582-2700; 541-476-6065 Fax: 541-476-2336 http://dfcorp.us/where_to_buy.php E-mail: info@dfcorp.us

5. Point of contact. The point of contact for this document is the Army Institute of Public Health, Drinking Water and Sanitation Program, at 410-436-3919, DSN 584-3919, or email usarmy.apg.medcom-phc.mbx.environmentalhealthsanitation@mail.mil.

References.

[1] CDC, Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008, http://www.cdc.gov/hicpac/pdf/guidelines/disinfection_nov_2008.pdf

[2] WHO, Manual, Infection and Prevention Control Policies and Guidelines, Section VII: Disinfection and Sterilization, May 2003.

[3] WHO, Collecting, preserving and shipping specimens for the diagnosis of avian influenza A(H5N1) virus infection, Annex 7-Disinfection, http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_ARO_2006_1/en/

[4] WHO, Infection Control for Viral Haemorrhagic Fevers in the African Health Care Setting (1998), http://www.who.int/csr/resources/publications/ebola/whoemcesr982sec1-4.pdf