

Chlorine Disinfection for Household Water Treatment

Technical Brief
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Technical Brief: Chlorine Disinfection for Household Water Treatment

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This document is part of a collection of resources for learning and training about household water treatment and safe storage (HWTS). To access CAWST’s other HWTS resources, visit cawst.org/resources.

1 Introduction

One of the most common and well-known methods of **household water treatment and safe storage (HWTS)** is chlorine disinfection. Chlorine disinfection has the advantages of being relatively quick, simple, and inexpensive. As well, using an appropriate dose of chlorine can provide **residual disinfectant** in the water to reduce the risk of recontamination.

In this technical brief:

- We describe the different types of chlorine products available for household water disinfection.
- We explain how chlorine inactivates microorganisms in water.
- We describe how to use chlorine for household water treatment, including safety considerations and methods for calculating appropriate doses.

Chlorine disinfection—like all household water treatment methods—should always be combined with safe water storage and handling. As well, cloudy water should be pre-treated through sedimentation or filtration to ensure the best results from chlorination. For more information about HWTS options, refer to *CAWST Technical Brief: Introduction to Household Water Treatment and Safe Storage*.

Key words in this document are marked in a bold font. If you are reading this on a screen, you can go to the definition of key words by clicking on them while holding the Ctrl button. If you are reading a printed copy, please refer to Section 11: Definitions.

2 Effectiveness of Chlorine

In laboratory settings, chlorine disinfection of water has been found to inactivate over 99.9% of bacteria, viruses, and giardia parasites (Thurston-Enriquez et al., 2005; Vaughn, Chen, & Thomas, 1986; Zhao et al., 2001).



Pathogen Resistance

Some **pathogens** are resistant to chlorine. For example:

- *Cryptosporidium parvum* (a widespread parasite that causes severe diarrhea) produces cysts, which can survive heavy doses of chlorine (Peletz et al., 2013).
- *Ascaris lumbricoides* (a parasitic roundworm) produces eggs that are also resistant to chlorine (Krishnaswami, 1968; Oh, Kim, Ahn, & Shin, 2016).

If there is risk of cryptosporidium or ascaris in your region, you should not use chlorination as your only method of household water treatment. Use a sedimentation or filtration method to remove the cysts or eggs before you add chlorine. Cryptosporidium and ascaris are most common in surface water sources.

Chlorine is not always as effective in household settings as in a controlled laboratory environment. Factors such as **turbidity**, contamination levels, and water handling practices can reduce the effectiveness of chlorine disinfection in people’s homes (Levy et al., 2014).

3 Chlorine Products

Many different chlorine products are available around the world. Some products are made and sold specifically for household water treatment, while others are intended for general disinfection and cleaning. The chlorine concentrations of these products can range from 0.5% to 70%. The concentration and expiry date should be listed on a product’s packaging, but this is not always the case. The following table lists common chlorine products, their typical chlorine concentration, and their stability.

Table: Strength and Stability of Common Chlorine Products Used for HWTS

Product	Available Chlorine Concentration (% by weight)	Product Type	Stability*
High Test Hypochlorite (HTH), also known as calcium hypochlorite	65–70%	Usually in granular form	Stable (about 2% active chlorine loss per year).
Chlorinated lime, also known as bleaching powder	25–30%	Usually in powder form	Not stable; chlorine concentration is difficult to estimate unless the product was recently manufactured or has been properly stored.
Sodium hypochlorite, also known as household bleach	2.5–18%	Liquid	Not stable; store away from heat and light, and use by the expiry date on the label (usually within one year).
Sodium dichloroisocyanurate (NaDCC), used in products like Aquatabs	2.5 mg to >5 g active chlorine per tablet (often 60–70%)	Usually in tablets Sometimes available in granular form	Very stable (shelf life of around 5 years). Unstable once dissolved in solution (use within one day).

*Stable means the product does not quickly degrade or lose strength over time. It can last for several years.

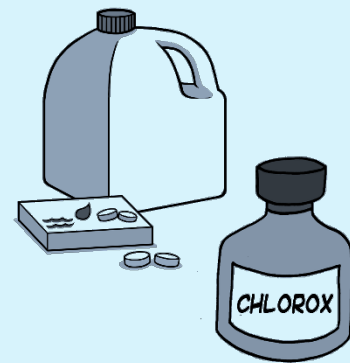
Stability of Chlorine Products

Some chlorine products are stabilized. This means they have added chemicals that help the products last a long time—often two to five years—without breaking down.

Many chlorine products are not stabilized. They degrade more quickly and must be used soon after they are made. These products often have a shelf life of less than 6 months. You should always check the product label to see how to store your chlorine product and how long it will last.

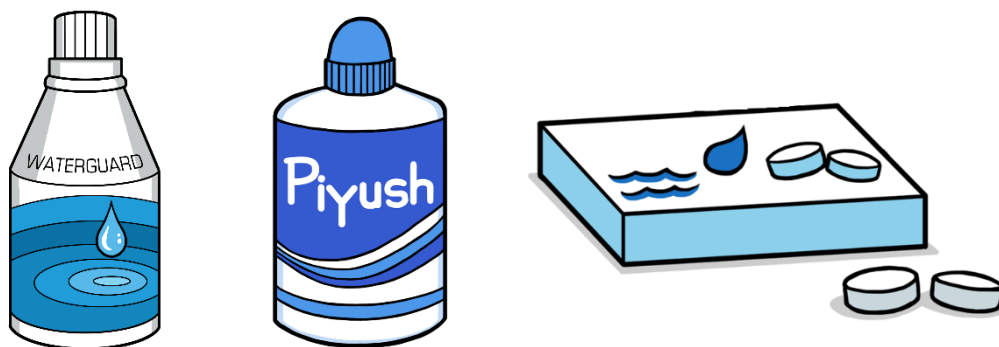
Some people choose to make their own hypochlorite solution using electricity and salts. They do this by using devices like the WATA (produced by Antenna Technologies). The chlorine solution produced through these methods is usually very unstable. It must be used the same day it was produced, or it must be stabilized.

Bleach is not stable. As bleach solution ages, it slowly breaks down. This reduces the amount of available chlorine. As a result, you may need to add more solution to reach the same desired chlorine concentration (World Health Organization, 2017). Bleach will break down faster if it is exposed to heat or light.



Example of chlorine products designed specifically for household water treatment include:

- Safe Water System (SWS): Developed by the Centers for Disease Control and Prevention (CDC) and the Pan American Health Organization (PAHO), SWS uses a combination of disinfection through sodium hypochlorite solution (often marketed as WaterGuard), and safe water storage. SWS can be found in over 35 countries.
- Piyush: Made from diluted bleach (sodium hypochlorite solution), Piyush is manufactured and sold by Environment and Public Health Organization (ENPHO) in Nepal.
- Aquatabs: These NaDCC tablets are manufactured and sold internationally by Medentech.



Examples of chlorine products for household water treatment. From left to right: Waterguard, Piyush, Aquatabs.

Using Household Bleach Products for HWTS

If you choose to use household bleach for water disinfection, first make sure that the product does not contain soap or perfume. You must know the chlorine concentration of your bleach product. The following table shows the variability in advertised chlorine concentrations of some household bleach products.

Table: Advertised Chlorine Content in Various Household Bleach Products

Brand of Bleach (Country of Origin)	Chlorine content (%)
Eau de Javel (France)	2.6%
JIK (Kenya), Robin (Nepal)	3.5%
Clorox (Bangladesh)	5.25%
Lejia (Peru)	6%
Lavandina (Bolivia), Blanqueador cloro (Mexico)	8%

(Adapted from "Infection control in health care settings: Guidelines for MSF projects," 2006)

The quality of household bleach products is variable. Lantagne (2009) analyzed the chlorine concentration of 32 commercially available bleach products from 12 low and middle-income countries. She found an average error of 35% between the advertised and measured concentration. Potential reasons for this high variability include:

- Use of contaminated dilution water when preparing bleach solution.
- Packaging in transparent or low-density plastic bottles, which causes bleach to degrade.
- Insufficient quality control in manufacturing.
- Degradation caused by heat and light exposure during transport and storage.

4 How Chlorine Works

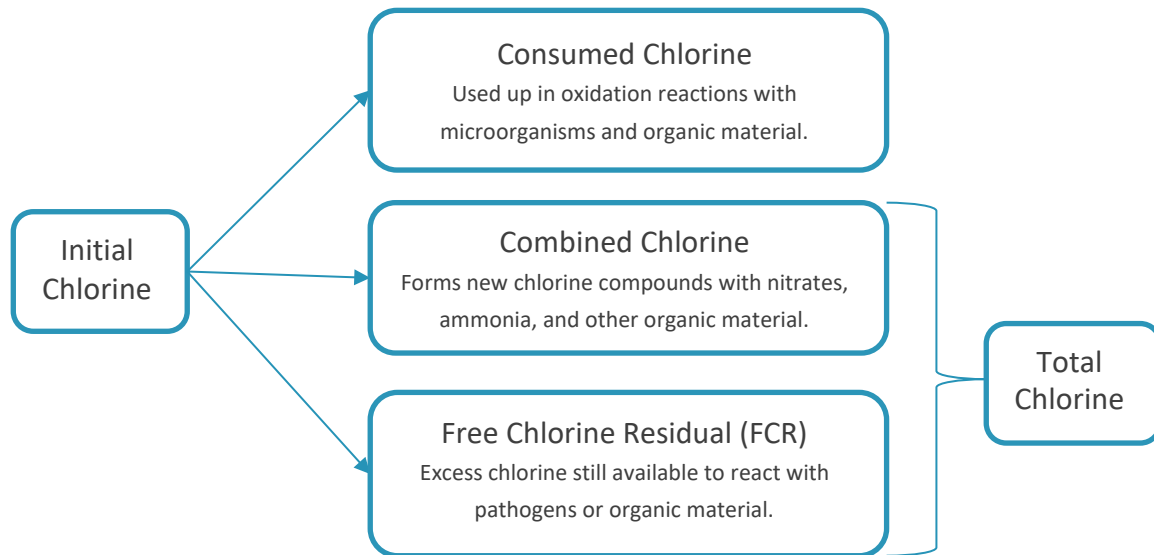
This section describes what happens when you add chlorine to water. Note that chlorine disinfection is affected by turbidity, organic material, temperature, and pH (see Section 8).

The amount of chlorine you add to water is called **initial chlorine**. Initial chlorine is usually given as a concentration (mg/L). This refers to the concentration of chlorine in the water immediately after you add your chlorine product.

The following processes occur when you add chlorine to water:

1. Chlorine and water form hypochlorous acid. This acid reacts with microorganisms, inactivating them. The portion of chlorine that reacts through oxidation with organic material, and microorganisms is called **consumed chlorine**. Once chlorine has been consumed, it is no longer available for other processes.

2. Some of the chlorine reacts with nitrates, ammonia, and other organic material to form new chlorine compounds. This portion is called **combined chlorine**. Some combined chlorine compounds can act as weak disinfectants.
3. Excess chlorine that is not consumed or combined remains in the water. This portion is called the **free chlorine residual (FCR)**. The FCR helps to prevent recontamination of the treated water, as it is available to kill new pathogens that enter the water.



You can use simple swimming pool test kits to measure chlorine in your water. These typically measure either FCR or **total chlorine**. Total chlorine is a measure of the sum of all the combined chlorine and free chlorine residual in a water sample. It does not indicate whether there is any free chlorine residual in the sample; all the chlorine measured as total chlorine *may* be combined.

$$\text{Total Chlorine} = \text{Combined Chlorine} + \text{Free Chlorine Residual (FCR)}$$

When you add chlorine to water, it takes time for it to react and inactivate pathogens. Most manufacturers recommend waiting for a certain period of time to allow the chlorine to oxidize the pathogens in water. This time is called the **contact time**. At normal temperature (around 25°C) and pH (less than 8), contact time is 30 minutes.



5 Recommended Chlorine Concentrations and Doses

To determine your chlorine dose, you must first have a target FCR concentration. Higher FCR concentrations provide more protection against contamination, but may also taste or smell unacceptable to users. Here is a summary of recommended FCR concentrations for drinking water after disinfection with chlorine:

- For general daily use, with low risk of disease outbreak, FCR should be 0.2–0.5 mg/L after the contact time (Branz et al., 2017). WHO Guidelines recommend ≥ 0.5 mg/L after 30 minutes contact time, and at least 0.2 mg/L at the point of delivery (World Health Organization, 2017).
- In emergencies with high risk of disease, FCR should be 0.5–1 mg/L (Branz et al., 2017).
- FCR should never exceed the WHO health-based guideline of 5.0 mg/L (World Health Organization, 2017).

Given the above guidelines, *CAWST usually recommends a target FCR concentration of 0.5 mg/L*. This provides a balance between effective residual for protection and a reasonably acceptable taste.

The initial chlorine dose you must add to achieve your target FCR concentration depends on your drinking water quality. Your initial chlorine dose should:

- Provide enough chlorine to react with microorganisms and compounds in the water.
- Meet the desired FCR concentration (usually 0.5 mg/L) after the contact time. This ensures that some chlorine is available to react with pathogens that enter the water after treatment.
- Not exceed the WHO Guidelines or national standards for chlorine and chlorine disinfection by-products (Branz et al., 2017; World Health Organization, 2017).

Because the amount of chlorine that will be consumed and combined is so variable between different water sources, *CAWST does not have a standard recommended initial chlorine dose*. In order of preference, we recommend doing one of the following:

1. Follow the manufacturer's dosing instructions, if given (see Section 6).
2. If your product does not have dosing instructions, use experimentation and measurement to find the most appropriate dose (see Section 7.2.1). This requires a means of measuring your FCR concentration.
3. If you are unable to measure your FCR concentration, use a dosing table to calculate an appropriate dose for your chlorine product (see Section 7.2.2).

Chlorine Concentration Units

Concentrations are sometimes shown as milligrams of chlorine per litre of water (mg/L) and sometimes as parts per million (ppm). These two units are almost equal for chlorine solutions.

6 How to Use Chlorine Products that Have Instructions

To use chlorine products that were made specifically for household water treatment, follow the manufacturer's instructions. Generally, you add a standard dose to the contaminated water, stir/shake the container, and wait for a specified amount of time. The water is then ready to drink. Remember to sediment or filter cloudy (turbid) water before using chlorine.



Always add the chlorine product into the water. Never pour water into a concentrated chlorine product, as this can cause a dangerous chemical reaction.

7 How to Use Chlorine Products that Lack Instructions

If instructions are not available, you can use the following procedures to determine a chlorine dose.

7.1 Find the Chlorine Concentration of your Product

You must know the chlorine concentration of your product for any of the methods described below. Read the label or contact the manufacturer to determine the % chlorine concentration of your product. Remember to check the shelf life of your product, and use it within the recommended time period.

Household bleach, HTH, bleaching powder, and granular NaDCC contain high concentrations of chlorine. When using these products, you should start by dissolving and/or diluting them to create a 1% solution. A diluted solution will be safer to handle, and makes it easier to measure dosing amounts.

Example: Making a 1% Chlorine Solution

In this example, you have a bleaching powder with 30% chlorine content by weight. You want to create 1 L of a 1% chlorine solution.

1. Calculate how much active chlorine you want per litre of your final solution.
Assuming that 1 L of solution is 1000 g: $1\% \text{ of } 1 \text{ L} = 1000 \text{ g} \times 0.01 = 10 \text{ g}$ active chlorine.
2. Calculate how much of your bleaching powder you need to add to get 10 g of active chlorine. The bleaching powder is 30% active chlorine. Therefore:
 - $? \text{ g of bleaching powder} \times 0.30 = 10 \text{ g active chlorine.}$
 - $10 \text{ g} \div 0.30 = ? \text{ g bleaching powder} = \mathbf{33.3 \text{ g bleaching powder}}$
3. Carefully measure 33.3 g of bleaching powder, and add it to 1 L of distilled water. Mix gently.

7.2 Determine the Chlorine Dose Required

For the following procedures, we use 0.5 mg/L as a suggested target FCR concentration. You may choose to use a different target FCR concentration (see Section 5).

Chlorine dosing is specific to the quality of the source water. The amount you need to add depends on the amount of contamination, turbidity, and organic material in the water.

7.2.1 Determine Chlorine Dose by Experimentation & Measurement (Modified Horrocks Method)

This is the most accurate and source-specific way of figuring out how much chlorine to add to your water, to achieve the target of 0.5 mg/L FCR. For this procedure, you must have a method for testing FCR. FCR can be measured with swimming pool test kits, chlorine test strips, a colour disc comparator, or a colorimeter. Refer to *CAWST's Drinking Water Quality Testing Manual* for more information about measuring chlorine concentrations.

Example: Chlorine Dosing by Experimentation & Measurement

1. Fill five non-metallic containers with a known volume (for example, 20 L) of the water you want to treat.
2. Add a different amount of the chlorine product, bleach, or prepared chlorine stock solution to each container. You can use an eye dropper, pipette, syringe, or other measuring device. Record the amounts you added. For example:
 - Bucket 1: add 0.5 mL of 1% chlorine stock solution
 - Bucket 2: add 0.75 mL of 1% chlorine stock solution
 - Bucket 3: add 1 mL of 1% chlorine stock solution
 - Bucket 4: add 2 mL of 1% chlorine stock solution
 - Bucket 5: add 2.5 mL of 1% chlorine stock solution
3. Wait 30 minutes (the contact time)
4. Measure and record the FCR in each container. Example results might be:
 - Bucket 1: 0 mg/L free chlorine residual
 - Bucket 2: 0.1 mg/L free chlorine residual
 - Bucket 3: 0.4 mg/L free chlorine residual
 - Bucket 4: 0.8 mg/L free chlorine residual
 - Bucket 5: 1.5 mg/L free chlorine residual
5. The correct dose is the container with a FCR concentration closest to 0.5 mg/L. In this case, Bucket 3 has 0.4 mg/L FCR. So the correct dose for this water is about 1 mL of your 1% stock solution per 20 L of water.



6. If you want more precise dosing, repeat the above steps using a smaller range of doses.

Note: If the required dose is very small (less than 1 mL), it is difficult to measure accurately. First dilute the chlorine product with distilled water (e.g., by mixing one part bleach with one part water). This makes the volume you have to add to the source water larger and easier to measure.

Determining Doses for Multiple Households

In a community where all households take their water from a single source, you can sample several households to determine an appropriate chlorine dose and contact time. Advise everyone to use the same dose. Where multiple sources of water are used, it should still be possible to find dose that is appropriate for most users. To avoid confusion, it is usually better to use one recommendation for the entire community.

7.2.2 Determine Chlorine Dose using Standard Dosing Tables

If there is no way for you to measure the FCR concentration, you can use a standard calculated dose.

To use this method you will have to know the chlorine concentration of your product. Your product should be in liquid form. If using a powder or granular product, we suggest that you first create a 1% liquid chlorine solution. See the example given in Section 7.1.



This method is approximate. The actual FCR concentration after the contact time will depend on the amount of contamination, turbidity, and organic material in your water.

The following initial chlorine concentrations are recommended when you cannot measure FCR:

- 2.0 mg/L for water with low turbidity (below 10 NTU, or very clear water)
- 4.0–5.0 mg/L for water that has higher turbidity (10–100 NTU, or slightly cloudy water).

These standard initial concentrations ensure that the FCR never exceeds the WHO Guideline value of 5 mg/L. Using doses in the higher range of these recommendations (4.0–5.0 mg/L) is more protective of health if you are unsure of the water quality. However, higher chlorine doses can also result in stronger chlorine taste and smell, which may be unacceptable to users (Branz et al., 2017).

The following table shows how much product you should add to 20 L of water to achieve initial concentrations of 2.0 or 5.0 mg/L, given the % chlorine concentration of your product.

Table: Standard Chlorine Doses

% Chlorine Concentration of Product	Product dose (mL) per 20 L of water	
	For initial concentration of 2.0 mg/L	For initial concentration of 5.0 mg/L
1%	4.0	10
2%	2.0	5.0
5%	0.80	2.0
10%	0.40	1.0
15%	0.26	0.66

Table values are calculated based on dose recommendations from Branz et al. (2017). Products that are more concentrated should be diluted before dosing.

8 Other Factors Affecting Chlorine Use

The effectiveness and speed of chlorine disinfection are influenced by the turbidity, pH, and temperature of the water. All of these factors can vary from day to day and in different seasons. In this section, we describe how these factors may affect your chlorine dose or contact time.

8.1 Turbidity

Higher levels of turbidity (cloudiness) make chlorination less effective because:

- Chlorine is not able to access and react with pathogens as easily.
- Water with higher turbidity is more likely to contain compounds that chlorine will react with, forming by-products and reducing the amount of chlorine available for disinfection.

Chlorination is not recommended for water with turbidity of over 100 NTU. Turbid water should be filtered or sedimented before you add chlorine. These processes will remove some of the suspended particles and organic material to improve the reaction between chlorine and pathogens (Branz et al., 2017). In emergency contexts, if filters and other methods of pre-treatment are unavailable and your water is turbid, you can use double the usual chlorine dose. Using a double dose is not recommended over the long-term, but can be effective as a short-term solution (Branz et al., 2017; Sphere Project, 2011).

8.2 Microorganisms and Organic Material

Chlorine disinfection is not effective against cryptosporidium and ascaris. Other household water treatment technologies should be used to remove these particular pathogens.

Additional chlorine should be added and the contact time increased to more than 30 minutes if the water has a lot of organic material or microorganisms.

8.3 pH

The optimal pH range for chlorine disinfection is between 5.5 and 7.5. Chlorine disinfection is most effective when pH is below 8, because hypochlorous acid (the chemical that reacts with and causes damage to pathogens) will dissociate and lose effectiveness at high pH. The WHO Guidelines state that for effective disinfection, you should have a FCR concentration of at least 0.5 mg/L after 30 minutes contact time at a pH of less than 8.0 (World Health Organization, 2017). If the pH is above 7.5, a higher FCR concentration of 0.6–1.0 mg/L should be used and the contact time increased to 1 hour.

8.4 Temperature

When water is cold, reactions happen more slowly because the chemicals and particles in the water are not moving around as quickly. This means that chlorine reacts more slowly with pathogens when water is cold, and disinfection takes longer. At 25°C or above, a 30-minute contact time is usually adequate for disinfection. With each 10°C temperature drop, you should double the contact time (World Health Organization, 2017). This means contact time should be 1 hour at 15°C, and 1.5 hours at 5°C.

9 Safety Considerations

9.1 Handling Chlorine Safely

Chlorine bleach is a common cleaning product found in many households. However, chlorine is a **corrosive** chemical. To protect your skin and eyes, you should take certain precautions when handling chlorine products.

Precautions

- Wear gloves and protective eyewear when handling any concentrated chlorine products, including granules, powder, and liquid solutions.
- Do not pour water onto chlorine products; always add chlorine products to water.
- Prepare solutions in a well-ventilated area, preferably in the open air.
- Use plastic equipment and containers to prepare and store solutions. You should not use metal buckets because chlorine will react with the metal.



Storage

Chlorine products lose strength when exposed to air, sunlight, and heat. They should be stored:

- In closed, plastic containers
- In a cool, dark place
- Out of reach of small children

9.2 Chlorine Disinfection By-products

Hypochlorous acid, which is formed when you add chlorine to water, reacts with organic material and bromine naturally present in water to form **disinfection by-products** such as trihalomethanes (THMs).

Some THMs are potentially cancer-causing. However, research suggests that THM levels produced during household chlorination may fall below WHO Guideline values (Lantagne, Cardinali, & Blount, 2010; Lantagne, Quick, Blount, & Cardinali, 2008). Typically, the high short-term risk of ingesting water with pathogens in it far outweighs the low risk of cancer from long-term THM exposure. The WHO Guidelines say: “In all circumstances, disinfection efficiency should not be compromised in trying to meet guidelines for [disinfection by-products], including chlorination by-products, or in trying to reduce concentrations of these substances” (World Health Organization, 2017, p. 188).

10 Summary

Chlorination is an effective method of inactivating most pathogens, except for resistant pathogens such as cryptosporidium and ascaris.

When you add chlorine to water, some chlorine immediately reacts with organic material and microorganisms (consumed chlorine). Some reacts to form new chlorine compounds in the water (combined chlorine). Excess chlorine that is not consumed or combined and remains in drinking water after the contact time is called free chlorine residual (FCR). FCR helps to prevent recontamination of the treated water, as it is available to inactivate new pathogens that enter the water.

For most water sources and at normal pH and temperature, your FCR concentration should be about 0.5 mg/L after 30 minutes of contact time. The dose you need to add to your water to achieve this target FCR depends on the quality of your source water.

When your chlorine product has dosing instructions on the packaging, follow the manufacturer’s instructions. When no dosing instructions are given, you can use one of the two methods outlined in Section 7 to determine how much of your product to use.

Chlorine can degrade over time. Check your product’s shelf life and always store it in a sealed container in a cool, dark place. Wear gloves and protective eyewear when handling any concentrated chlorine products.

11 Definitions

Combined chlorine: Chlorine that has reacted with nitrates, ammonia, and other organic material to form new chlorine compounds.

Consumed chlorine: The portion of chlorine that reacted through oxidation with organic material and microorganisms.

Contact time: The amount of time you wait after adding chlorine to drinking water, before measuring FCR or consuming the water. Contact time is required for chlorine to react with and inactivate pathogens.

Corrosive: Substances that can wear away or eat away at surfaces, clothing, or skin. You should always be careful and use gloves when handling corrosive substances.

Disinfection by-products: Substances produced from chemical reactions between chemical treatment agents (such as chlorine) and organic and inorganic material in water. Some disinfection by-products are potentially cancer-causing.

Free chlorine residual (FCR): Excess chlorine that is not consumed or combined and remains in drinking water after the contact time. FCR helps to prevent recontamination of the treated water, as it is available to kill new pathogens that enter the water.

Household water treatment and safe storage (HWTS): Activities by which household members treat and store water in their homes. Also commonly referred to as managing water at the point-of-use (POU).

Initial chlorine: The concentration of chlorine immediately present when a chlorine product is added to water.

Pathogen: An organism that causes disease.

Residual disinfectant: The amount of a chemical disinfectant (often from chlorination) that remains in water over time. Residual disinfectants help to protect against any pathogens that may contaminate the water after treatment.

Total chlorine: A measure of the concentration of combined chlorine plus free chlorine residual.

Turbidity: The “cloudiness” or “dirtiness” of water. Turbidity is caused by suspended solids, such as sand, silt and clay, floating in water. Light reflects off these particles, which makes the water look cloudy or dirty.

12 Additional Resources

CAWST HWTS Knowledge Base. Available at www.hwts.info.

- A knowledge base for point-of-use water treatment solutions, from technology options to implementation best practices. Includes technical information about different chlorine products commonly used for HWTS.

CAWST Education and Training Materials. Available at <https://resources.cawst.org>.

- Technical briefs, lesson plans, presentations, posters, and other resources about HWTS, drinking water quality testing, and other topics.

World Health Organization. (2017). *Guidelines for drinking-water quality: fourth edition incorporating the first addendum.* Available at:

<http://apps.who.int/iris/handle/10665/43428>

- Detailed information about the WHO’s water quality guidelines, including recommendations for chlorine dosing and free chlorine residual concentrations.

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Calgary, Canada | www.cawst.org | support@cawst.org

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