Chlorine Disinfection

Chlorine is widely used for disinfection of drinking water and also for general disinfection and decontamination. It is cheap, widely available and effective.

Chlorine Products

The following table lists common chlorine generating products and their typical chlorine content or percentage strength.

Product	Strength	Remarks
High Test Hypochlorite (HTH) (calcium hypochlorite)	65% - 70%	Usually in granular form. Stable (≈2% active chlorine loss per year).
Chlorinated Lime, aka Bleaching Powder	30%	Usually in powder form. Not stable.
Household Bleach (sodium hypochlorite)	2.5% – 10%	Liquid form. Not stable; only use if manufactured recently (< 3 months), and stored away from heat and light.
Sodium Dichloro-Isocyanurate (NaDCC), used in products such as “Aquatabs”.	50% - 60% as granules. 5mg to > 5 g active chlorine per tablet.	Usually in tablet form, also available in granular form. Tablets pre-dosed for water treatment. Very stable (shelf life ≈ 5 years).

The chlorine content should be listed on the product’s labelling or packaging. In some markets around the world, chlorine solutions specifically produced for household water treatment are readily available. For example, in Nepal, the brand Piyush is available as a 0.5% chlorine solution in a 60 mL bottle.

Household Bleach

Bleach products (sodium hypochlorite) are commonly used to disinfect drinking water at the household level. However, it is important to ensure that the products do not contain soap/detergent or perfume.

The strength of the product must be determined in order to calculate the volume of bleach required to disinfect a given volume of water. The following table illustrates the variation in chlorine content of some household bleach products.

Brands of bleach and country of origin	Chlorine content %
Eau de Javel (France)	2.6%
JIK (Kenya), Robin bleach (Nepal)	3.5%
Lejia (Peru)	6%
Lanvandina (Bolivia), Blanqueador cloro (Mexico)	8%

As can be seen, the strength of bleach products varies widely between countries, and also within the same country (contact the manufacturer for this information if it is not given on the bottle). This is why disinfection recommendations given as “drops per litre”, “spoons per drum” or similar, are product specific.

Disinfecting filtered water is a necessary final step in the water treatment process. Chemical disinfection using chlorine has the benefits of being relatively quick, simple, and cheap and allows a residual amount of chlorine to remain in the water to provide some protection against subsequent contamination. Determining the correct dose to add to a particular volume of water is quite straightforward.

Three things can happen when chlorine is added to water:

1. Some chlorine reacts through oxidization with organic matter and the pathogens in the water and kills them. This portion of the added chlorine is said to be consumed.
2. Some chlorine reacts with other organic matter and forms new chlorine compounds. This portion is called combined chlorine.
3. Excess chlorine that is not consumed or combined and remains in the water is known as free residual chlorine (FRC).

Using an empirical process of trial and error is the best way to determine how much chlorine is required to disinfect water. It is relatively simple to measure the FRC in water, therefore the procedure is essentially adding increasing amounts of chlorine to the water until all reactions have occurred and an acceptable level of FRC can be measured.

Recommendations for FRC concentrations are usually in the range 0.2 mg/L up to about 0.6 mg/L. This range provides a balance between a reasonably effective residual and acceptable taste.

Procedure to Determine Chlorine Disinfection Dose

1. Fill 4 buckets of known volume (10 - 20 L) with the water to be treated.

2. Using a syringe or similar add a different amount to each bucket of the chlorine product to be used. For example:
    - Bucket 1 – 0.2 ml
    - Bucket 2 – 0.5 ml
    - Bucket 3 – 0.75 ml
    - Bucket 4 – 1 ml

3. Wait 30 minutes and measure FRC in each bucket using a pool tester or similar. Example results
    - Bucket 1 – 0 mg/L
    - Bucket 2 – 0.1mg/L
    - Bucket 3 – 0.4mg/L
    - Bucket 4 – 1mg/L

4. Select the dosage which delivers the best level of FRC. In this case, Bucket 3 with 0.75 mL of the chlorine product in 20 L gives a FRC of 0.4 mg/L.

Diluting the chlorine product to approximately 1% active chlorine or less makes the dose volumes larger and easier to measure.

A simple and cheap method of measuring chlorine and pH is by using a pool tester kit (as used for swimming pool water).

A typical “rule of thumb” dose of chlorine is 5 mg of active chlorine per L of water to be treated. After the chlorine reacts with the organic matter and pathogens in the water, the aim is to have a FRC content of approximately 0.5 mg/L.

Once the percentage chlorine content is known for a product, it is straightforward to calculate how much of the product to add to a particular volume of water to achieve the 5 mg/L dose.

For example: 1 L of a bleach solution containing 2% chlorine equates to 20 000mg/L of chlorine. To treat 20 L of water requires 100 mg of chlorine. Therefore the volume of bleach product to add in mL = 100/20 000 x 1 000 = 5 mL

The quantity of chlorine required (the chlorine demand) depends mainly on the amount of organic matter, and the number of pathogens. The efficiency and speed of the disinfection process is affected by the chemistry of the water, pH, and temperature. All of these factors can vary from day to day and in different seasons. Therefore, giving a reliable rule of thumb quantity of chlorine to use and a contact time is not always straightforward.

pH

The optimum range for chlorine disinfection is between 5.5 and 7.5 (effectiveness of chlorine disinfection can reduce by a factor of between 3 and 6 when pH rises from 6 up to 9). Chlorine disinfection is not reliable when the pH is above 9.

If ph is above the 5.5 - 7.5 range then the:

- pH can be adjusted which is not very practical at the household level.
- Quantity of chlorine can be increased. Aim for a higher FRC at the end of the contact time (0.5 mg/L from pH 7-8, and 0.6 mg/L from pH 8-9).
- Contact time should be lengthened.

Temperature

At 18 - 20˚C and above, a contact time of 30 minutes is adequate. For every 10˚C drop in temperature the efficiency of disinfection reduces by 50-60% (at close to 0˚C disinfection efficiency is very poor).

- Double the contact time if temperature falls to 10˚C
- At least quadruple contact time if temp is approaching zero.

In a community where all the householders take their water from a single source it is fairly straightforward to sample a number of filters and determine an appropriate chlorine dose and contact time. Where multiple sources of water are used, it should still be possible to arrive at a dose which will be appropriate for the majority of users. To avoid confusion, it is probably better to use a single dose recommendation for a community rather than multiple doses depending on source water.

The combined chlorine compounds are responsible for the strong chlorine taste and smell that is sometimes apparent in treated water. Water with little or no combined chlorine and a FRC level in the 0.3 - 0.6 mg/L range usually does not have a strong smell or taste of chlorine.

Precautions when Handling Chlorine Products

Household bleach is a common cleaning product found in many households, however chlorine is an aggressive and corrosive chemical, and certain precautions must be taken.

Household bleach degrades and loses strength quite quickly after manufacture. The loss of strength is faster if it is not kept in sealed containers and stored in a cool, dark place. To ensure that the chlorine content is close to the design strength, verify that the product is not older than three months and that it has been transported and stored properly.

!	**Precautions** Protect the eyes and skin when handling chlorine granules and solutions: • Prepare chlorine solutions in a well-ventilated area, preferably in the open air. • Use plastic equipment and containers to prepare and store chlorine solutions. **Storage** Chlorine products and solutions lose strength rapidly with exposure to air, sunlight, and heat: • Store products and solutions in plastic or plastic lined containers, and keep closed. • Store products and solutions in a cool, shaded (ideally dark) area.