

Chlorine Residual Testing

The presence of chlorine residual in drinking water indicates that: 1) a sufficient amount of chlorine was added initially to the water to inactivate the bacteria and some viruses that cause diarrheal disease; and, 2) the water is protected from recontamination during storage. The presence of free residual chlorine in drinking water is correlated with the absence of disease-causing organisms, and thus is a measure of the potability of water.

This Fact Sheet describes:

1. The processes that occur when chlorine is added to water, and the definitions involved with these processes;
2. How and why the Safe Water System project recommends testing of free chlorine;
3. Methods to test free chlorine in the field in developing countries.

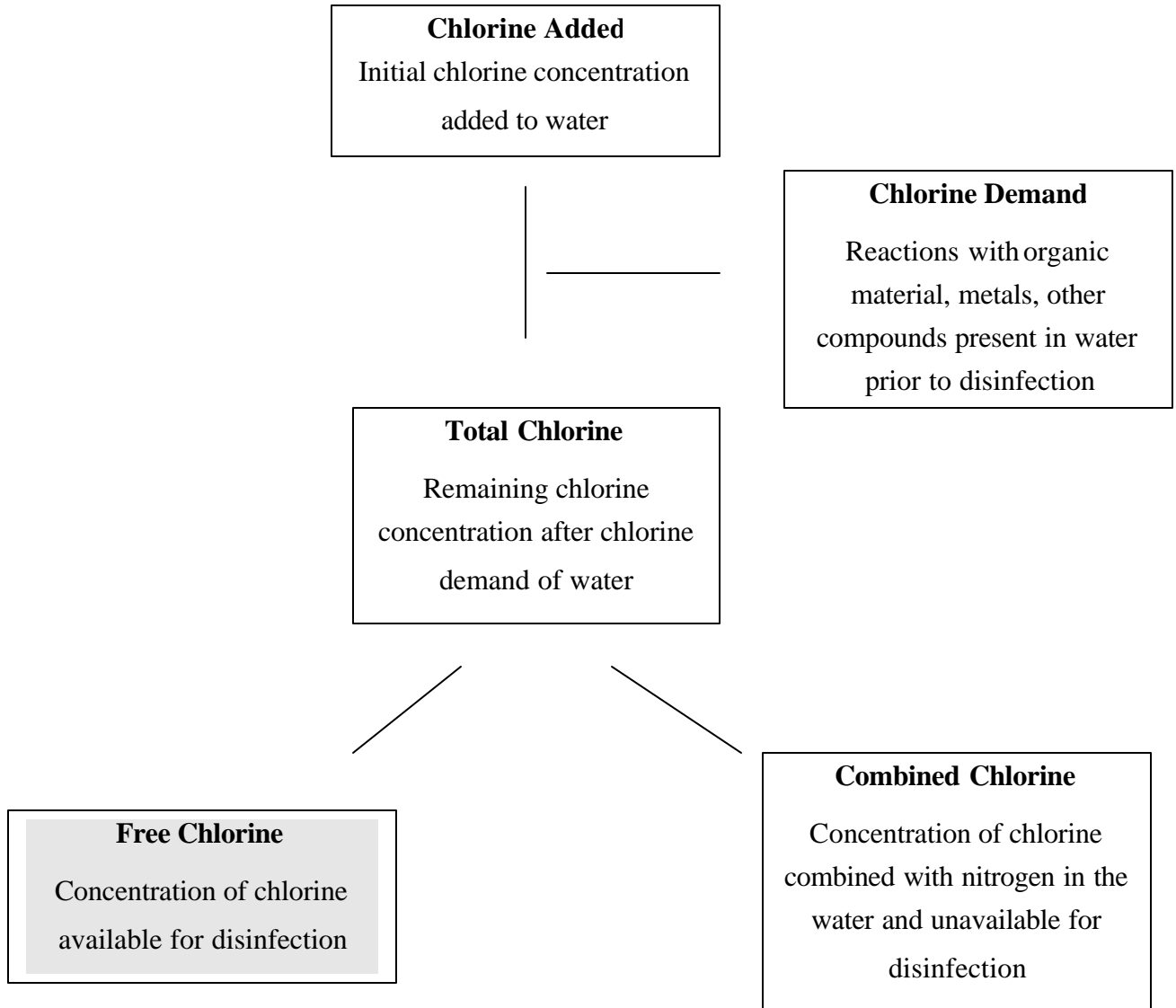
Definitions

When chlorine is added to drinking water, it proceeds through a series of reactions described below and depicted graphically on the next page.

When chlorine is added to water, some of the chlorine reacts first with organic materials and metals in the water and is not available for disinfection (this is called the *chlorine demand* of the water). The remaining chlorine concentration after the chlorine demand is accounted for is called *total chlorine*. Total chlorine is further divided into: 1) the amount of chlorine that has reacted with nitrates and is unavailable for disinfection which is called *combined chlorine* and, 2) the *free chlorine*, which is the chlorine available to inactivate disease-causing organisms, and thus a measure to determine the potability of water.

For example, if using completely clean water the chlorine demand will be zero, and there will be no nitrates present, so no combined chlorine will be present. Thus, the free chlorine concentration will be equal to the concentration of chlorine initially added. In natural waters, especially surface water supplies such as rivers, organic material will exert a chlorine demand, and nitrates will form combined chlorine. Thus, the free chlorine concentration will be less than the concentration of chlorine initially added.

Chlorine Addition Flow Chart



Why Do We Test Free Chlorine in Drinking Water?

The SWS project recommends testing free chlorine in two circumstances:

- To conduct dosage testing in project areas prior to the start of a program.
- To monitor and evaluate projects by testing stored water in households.

The goal of dosage testing is to determine how much sodium hypochlorite solution to add to water that will be used for drinking to maintain free chlorine residual in the water for the average time of storage of water in the household (typically 4-24 hours). This goal differs from the goal of infrastructure-based (piped) water treatment systems, whose aim is effective disinfection at the endpoints (i.e., water taps) of the system: defined by the WHO (1993) as: “a residual concentration of free chlorine of greater than or equal to 0.5 mg/litre after at least 30 minutes contact time at pH less than 8.0.” This definition is only appropriate when users drink water directly from the flowing tap. A free chlorine level of 0.5 mg/Liter of free chlorine will be enough residual to maintain the quality of water through the distribution network, but is most likely not adequate to maintain the quality of the water when this water is stored in the home in a bucket or jerry can for 24 hours.

Thus, the SWS program recommends in our dosage testing that:

1. At 30 minutes after the addition of sodium hypochlorite there should be no more than 2.0 mg/L of free chlorine residual present (this ensures the water does not have an unpleasant taste or odor).
2. At 24 hours after the addition of sodium hypochlorite to containers that are used by families to store water there should be a minimum of 0.2 mg/L of free chlorine residual present (this ensures microbiologically clean water).

The SWS project methodology leads to chlorine residual levels that are significantly lower than the WHO guideline value for free chlorine residual in drinking water, which is 5 mg/L value.

The SWS project recommends testing free chlorine in homes of SWS users for evaluation of whether or not users are using the system and if they are using it correctly. Households can be visited and ‘spot checked’ to determine if, and how much, free chlorine residual is present in their drinking water. This approach is very useful for program monitoring because the presence of free chlorine residuals in stored water obtained from an unchlorinated source is an objective measure that people are using the hypochlorite solution.

Methods to Test Free Chlorine in the Field in Developing Countries

There are three main methods to test free chlorine residual in drinking water in the field in developing countries: 1) Pool test kits, 2) Color-wheel test kits, and 3) Digital colorimeters. All three methods depend on a color change to identify the presence of chlorine, and a measurement of the intensity of that color to determine how much chlorine is present.

1. Pool Test Kits

The first option for testing uses a liquid chemical OTO (othotolidine) that causes a color change to yellow in the presence of total chlorine. You simply fill a tube with water, add 1-5 drops of the solution, and look for the color change. These kits are sold in many stores as a way to test the concentration of total chlorine in swimming pool water. This method does not measure free chlorine.

Benefits of the pool test kits are:

- Low cost
- Very easy to use

Drawbacks of the pool test kits are:

- Degradation of the OTO solution that causes inaccurate readings over time
- Generally not reliable quantitative results
- Lack of calibration and standardization



How to order and cost information:

Many large home supply stores, and pool stores
Approximately \$5-20 USD each

2. Color-wheel Test Kit

Color wheel test kits use a powder or tablet chemical DPD (N,N diethyl-p-phenylene diamine) that causes a color change to pink in the presence of chlorine. The color wheels are simpler and less expensive than digital meters because to measure the intensity of the color change, the field worker uses a color wheel to visually match the color to a numerical free or total chlorine reading. The test kit can be used to measure free chlorine and/or total chlorine, with a range of 0 – 3.5 mg/L, equivalent to 0 – 3.5 ppm (parts per million).

Benefits of the color-wheel test kits are:

- Accurate readings if used properly
- Low cost

Drawbacks of the color-wheel test kits are:

- Potential for user error
- Lack of calibration and standardization



How to order and cost information:

Hach Company www.hach.com Approximately \$40

3. Digital Colorimeters

Digital colorimeters are the most accurate way to measure free chlorine and/or total chlorine residual in the field in developing countries. These colorimeters use the following method: 1) addition of DPD tablets or powder into a vial of sample water that causes a color change to pink; and, 2) insertion of the vial into a meter that reads the intensity of the color change by emitting a wavelength of light and automatically determining and displaying the color intensity (the free and/or total chlorine residual) digitally. The range of the meter is 0 - 4 mg/L, equivalent to 0 - 4 ppm (parts per million).

Benefits of the digital colorimeters are:

- Highly accurate readings
- Fast results

Drawbacks of the digital colorimeters are:

- Expense
- Necessity of calibration with standards

How to order and cost information:

Lamotte Company www.lamotte.com

Approximately \$325, plus \$65 for standards

Hach Company www.hach.com

Approximately \$350, plus \$50 for standards



SUMMARY STATEMENT

The selection of which methodology to use to measure free and total chlorine can be complicated and is dependent on a number of factors in a program, including: need for accuracy, cost, and number of samples you would like to collect. The choice is also highly dependent on what you would like to use the data for. Some recommendations for which methodology to use based on different sampling goals are detailed below:

Dosage Testing in a New Project:

If your goal is to dosage testing for a national scale project, the SWS Project highly recommends the use of the digital colorimeters. The accuracy of the meters is necessary to ensure the correct dose is obtained.

Program Monitoring:

If your goal is to determine whether users are using the chlorine in their homes, spot-checks in the home to sample the household water with pool test kits is sufficient and provides a simple indicator of the presence or absence of chlorine.

Project Evaluation:

If your goal is to determine if users are adding the correct amount of chlorine and using the chlorine solution in the home, spot-checks in the home to sample the household water with the Hach Color-wheel kit provides more information than the pool test kits, while remaining relatively inexpensive and easy to use.

If you have questions about chlorine residual testing, please contact safewater@cdc.gov.

CDC as a branch of the federal government does not endorse products from specific companies. The above information is for reference purpose only to describe the SWS project experience and represents, to the authors current knowledge, a range of available products to complete this sampling.