Measuring chlorine levels in water supplies

As the quality of water can be seriously affected by a disaster or an emergency, it is best practice to disinfect all emergency water supplies. The most common way of disinfecting is with chlorine. This technical note explains why disinfection is important, why chlorine is used, how it works, how to test for its presence and where and when to test.

Why should emergency water supplies be disinfected?

When disaster strikes a stable community with access to drinking-water of a certain quality, their situation changes:

- Disasters often damage existing water supplies leading to contamination or further contamination of the supply.

- People sometimes have to move to new locations and are forced to drink water from new sources for which they have no natural immunity to its contamination.

- Disasters frequently affect people's physical and psychological health, making them more susceptible to infection and disease.

It is important, therefore, that all people affected by a disaster are provided with access to safe drinking-water. There is a wide variety of methods for improving the quality of drinking-water, many of which are discussed in Technical Notes 4 and 5. Most of these treatment processes are designed to prepare the water for disinfection, which is the final stage in the treatment process.

What is disinfection?

Many of the diseases that affect traumatized communities are caused by micro-organisms carried in drinking-water. Hence the reference to water-borne diseases. Disinfection is the process of destroying these organisms to prevent infection. There are a number of methods of disinfecting water, but chlorination is by far the most common. Table 11.1 lists the advantages and disadvantages of using chlorine for disinfection.

How does chlorine work?

When chlorine is added to water, it destroys the membrane of micro-organisms and kills them. The process only works, however, if the chlorine comes into direct contact with the organisms. If the water contains silt, the bacteria that reside within it may not be reached by the chlorine. Chlorine disinfects water but does not purify it: there are some contaminants it cannot remove (see Box 11.1 overleaf).

Chlorine takes time to kill organisms. At temperatures of 18°C and above, the chlorine should be in contact with the water for at least 30 minutes. If the water is colder then the contact time must be increased.

It is normal, therefore, to add chlorine to water as it enters a storage tank or a long delivery pipeline to give the chemical time to perform its disinfecting action before it reaches the consumer.

Table 11.1. Advantages and disadvantages of using chlorine as a disinfectant

Advantages	Disadvantages
It comes in several forms: powder, granules, tablets, liquid and gas.	It is a powerful oxidizing agent which must be handled with care and breathing chlorine fumes must be avoided.
It is usually readily available in one form or another and relatively inexpensive.	It does not effectively penetrate silt and organic particles suspended in the water.
It dissolves easily in water.	It can give an unpleasant taste if slightly overdosed, which can dissuade people from using the supply.
It provides residual disinfection (see Box 11.2).	
It is effective against a wide range of disease-causing micro-organisms.	Its effectiveness against some organisms requires higher concentrations of chlorine and longer contact times.

Source: Adapted from Davis and Lambert (2002)

Box 11.1. Chlorine is not a perfect solution

Although chlorine does not destroy all micro-organisms, it is still considered to be the most effective emergency disinfectant available because the vast majority of organisms are destroyed. Chlorine will not remove chemical contaminants from the water. Chemical contamination is more difficult to remove and requires specialist knowledge and equipment.

Box 11.2. Residual protection

Most disinfection methods kill micro-organisms effectively but do not provide any protection against recontamination further along the supply system.

Chlorine has the advantage of being both an effective disinfectant and its residual can protect the supply downstream from the disinfection point.

The turbidity and the acidity (pH) of the water have a significant effect on the efficiency of chlorine as a disinfectant. The turbidity should be < 5NTU and the pH level between 7.2 and 6.8. See Technical Note 1 for advice on how to change the pH level of water and measure turbidity.

Consult the references given under "Further information" page 11.4 on how to add chlorine to water.

Chlorine residual

When chlorine is added to water, it will attack organic matter and attempt to destroy it. If enough chlorine is added, some will remain in the water after all possible organisms have been destroyed. What is left is called *free chlorine* (Figure 11.1). Free chlorine will remain in the water until it too dissipates or is used to destroy new contamination.

So if water is tested and found to contain some free chlorine, it proves that the most dangerous organisms in the water have been removed and it is likely to be safe to drink. This process is called *measuring the chlorine residual* (see Figure 11.2).

Testing for chlorine residual

The quickest and simplest method for testing for chlorine residual is the dpd (diethyl paraphenylene diamine) indicator test, using a comparator. A tablet of dpd is added to a sample of water, colouring it red. The strength of colour is measured against standard colours on a chart to determine the chlorine concentration. The stronger the colour, the higher the concentration of chlorine in the water.

Several kits for analysing the chlorine residual in water, such as the one illustrated in Figure 11.2, are available commercially. The kits are small and portable.

When and where to test water

Continuous chlorination is most commonly used in piped water supplies. Regular chlorination of other water supplies is difficult and usually reserved for disinfection after repair and maintenance. It is common to test for chlorine residual at the following points:

*   Just after the chlorine has been added to the water to check that the chlorination process is working.

*   At the outlet of the consumer nearest to the chlorination point to check that residual chlorine levels are within acceptable levels.

*   At the furthest points in the network where residual chlorine levels are likely to be at their lowest. If chlorine levels are found to be below minimum levels (see Box 11.3) it might be necessary to add more chlorine at an intermediate point in the network.
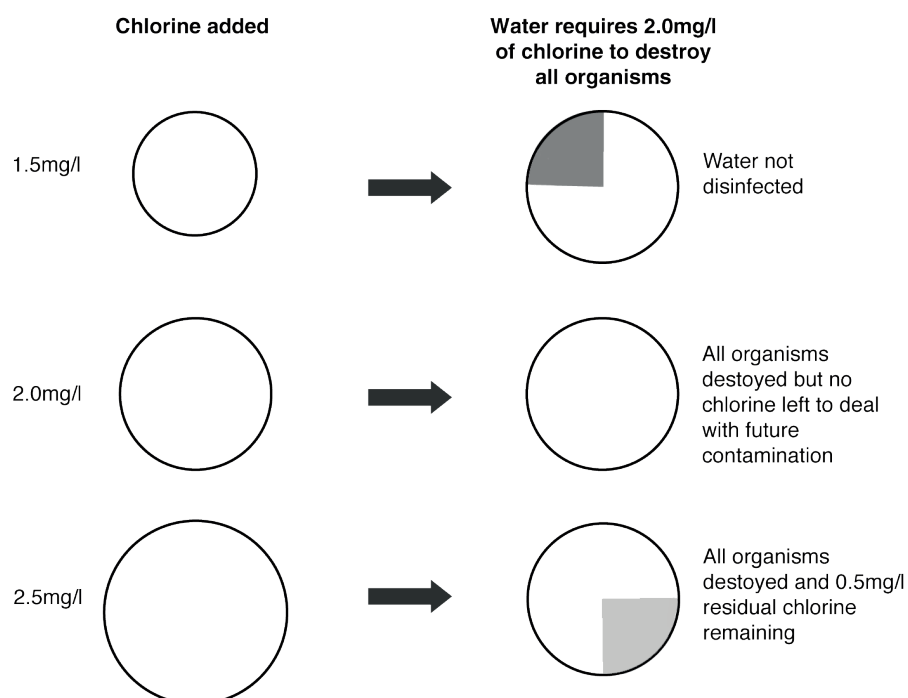
Chlorine added

**Water requires 2.0mg/l of chlorine to destroy all organisms**

1.5mg/l → Water not disinfected

2.0mg/l → All organisms destoyed but no chlorine left to deal with future contamination

2.5mg/l → All organisms destoyed and 0.5mg/l residual chlorine remaining

Figure 11.1. The effect of chlorine residual

Step 1.

Place one tablet in the test chamber (a) and add a few drops of the chlorinated water supply under test.

a

10ml **Chlorine DPD colour**
1.0   8.0
0.8   5.0
0.6   3.0
0.4   2.0
0.2 mg/l 1.5
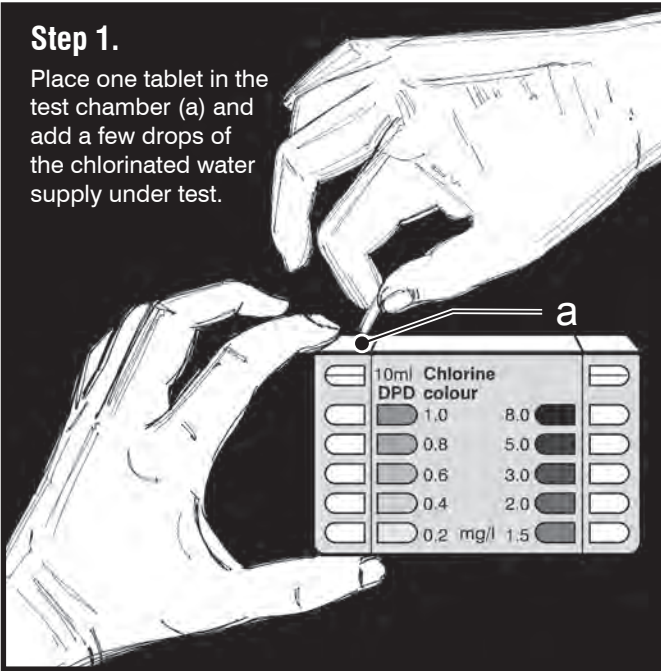
Step 2.

Crush the tablet, then fill chamber (a) with the chlorinated water supply under test.

a

10ml **Chlorine DPD colour**
1.0   8.0
0.8   5.0
0.6   3.0
0.4   2.0
0.2 mg/l 1.5
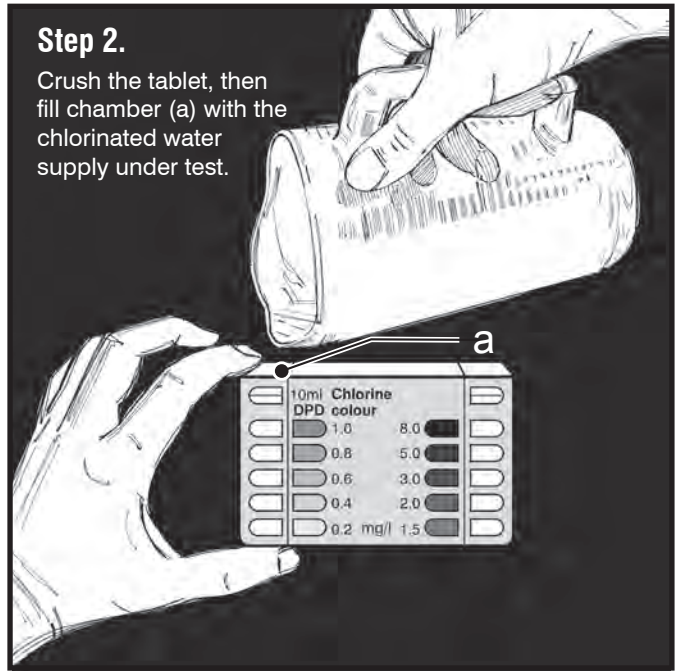
Step 3.

Place more of the chlorinated water supply under test (without a tablet) in the second chamber (b). This is the blank control for colour comparison.

b

10ml **Chlorine DPD colour**
1.0   8.0
0.8   5.0
0.6   3.0
0.4   2.0
0.2 mg/l 1.5
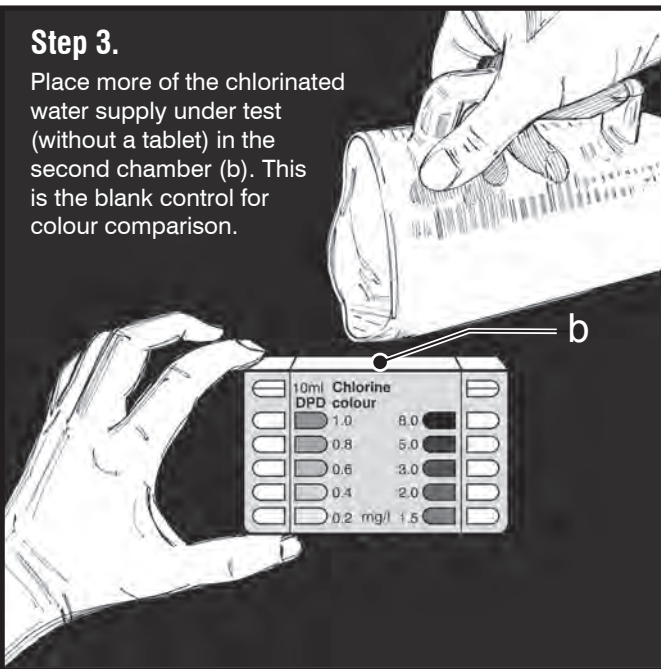
Step 4.

The level of residual chlorine (R) in mg of chlorine per litre (mg/l) is determined by comparing the colour of the water supply under test in chamber (a) with the tablet added with the standard colours on the vessel (chamber (b)). Note that chamber (c) would be used if a higher chlorine residual is to be used.
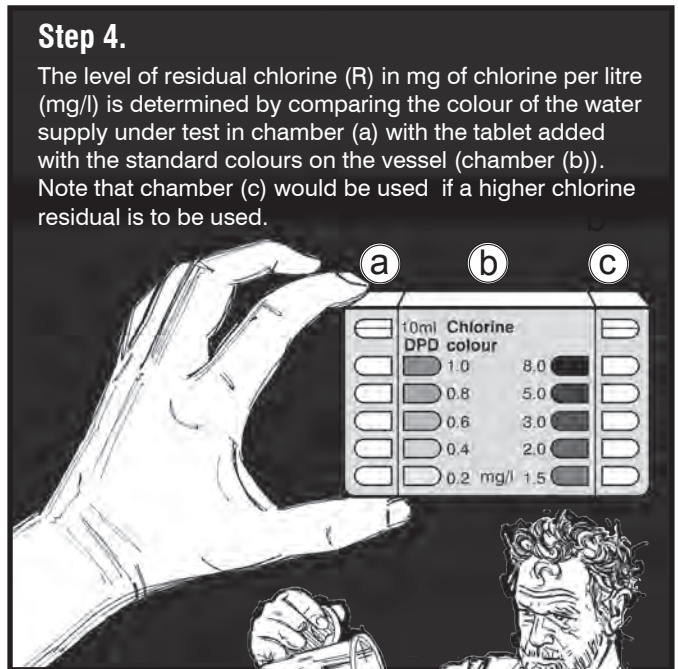
a   b   c

10ml **Chlorine DPD colour**
1.0   8.0
0.8   5.0
0.6   3.0
0.4   2.0
0.2 mg/l 1.5

Figure 11.2. Steps in determining the chlorine residual in water using a comparator

The amount of chlorine residual changes during the day and night. Assuming the pipe network is under pressure all the time (see Box 11.4) there will tend to be more residual chlorine in the system during the day than at night. This is because the water stays in the system for longer at night (when demand is lower) and so there is more opportunity for the water to become contaminated which reduces the residual chlorine through disinfection of the contaminants.

Chlorine residual should be checked regularly. If the system is new or has been rehabilitated then check daily until you are sure that the chlorination process is working properly. After that, check at least once a week.
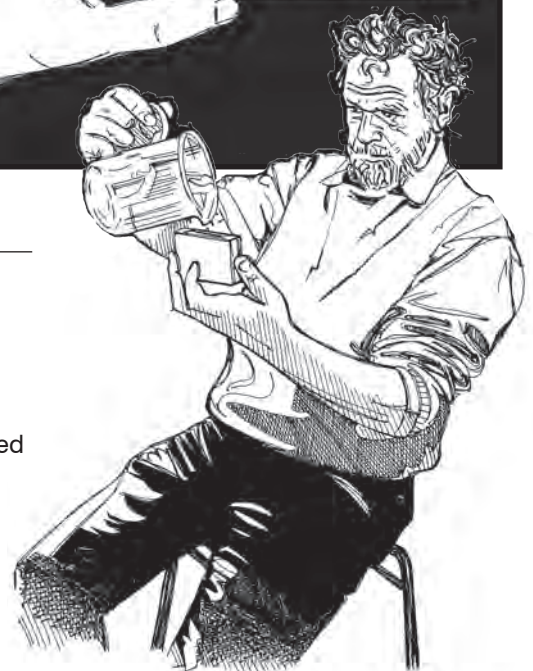
Box 11.3. Recommended residual chlorine levels

The higher the residual chlorine levels in the supply, the better and longer the chemical will be able to protect the system from contamination. However, high levels of chlorine make the water smell and give it a bad taste, which will discourage people from drinking it.

For normal domestic use, residual chlorine levels at the point where the consumer collects water should be between 0.2 and 0.5 mg/l. The higher level will be close to the disinfection point and the lower level at the far extremities of the supply network.

Box 11.4. Chlorination and intermittent supplies

There is no point in chlorinating pipe networks if the water supply is intermittent. All pipe systems leak and when the water supply is switched off, the pressure will drop and contaminated water will enter the system through the breaks in the pipe wall. No level of residual chlorine acceptable to consumers will be able to deal with such high levels of contamination. All intermittent water supplies should be assumed to be contaminated and measures taken to disinfect water at the point of use.

A chorination checklist

- Chlorine needs at least 30 minutes contact time with water to disinfect it. The best time to apply chlorine is after any other treatment process, and before storage and use.

- Never apply chlorine before slow sand filtration or any other biological process, as the chlorine will kill off the bacteria which assist treatment, making the treatment ineffective.

- Never add any solid form of chlorine directly to a water supply, as it will not mix and dissolve. Always make up as a paste first, mixing the chlorine compound with a little water.

- Disinfection is only one defence against disease. Every effort should be made to protect water sources from contamination, and to prevent subsequent contamination during collection and storage.

- The correct procedure for applying a disinfectant to water should be strictly adhered to, and water supplies should be monitored regularly to ensure that they are free from bacteria. Otherwise, people may be misled to believe that the water is safe to drink when, in fact, it is hazardous to do so.

- The optimum chlorine residual in a small, communal water supply is in the range of 0.2 to 0.5mg/l.

Further information

WHO (2004) *Guidelines for drinking water quality*, 3rd ed., WHO, Geneva.

Davis J, Lambert R. (2002) *Engineering in Emergencies* 2nd edition, chapter 13. ITDG UK.

CDC (Undated) *Chlorine residual testing.* http://www.cdc.gov/safewater/publications_pages/chlorineresidual.pdf

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