raw water container can incorporate one or several filter elements depending on the flow required. The filters can also operate by siphonic action as shown in Figure 13.28. Complete units of upper and lower containers and filter elements can be purchased. Always order spare filter elements as they need replacing after long or heavy use. Spare filter elements can also be used to filter water in combination with a plastic bucket for the upper container and a jerry can for the filtered water.

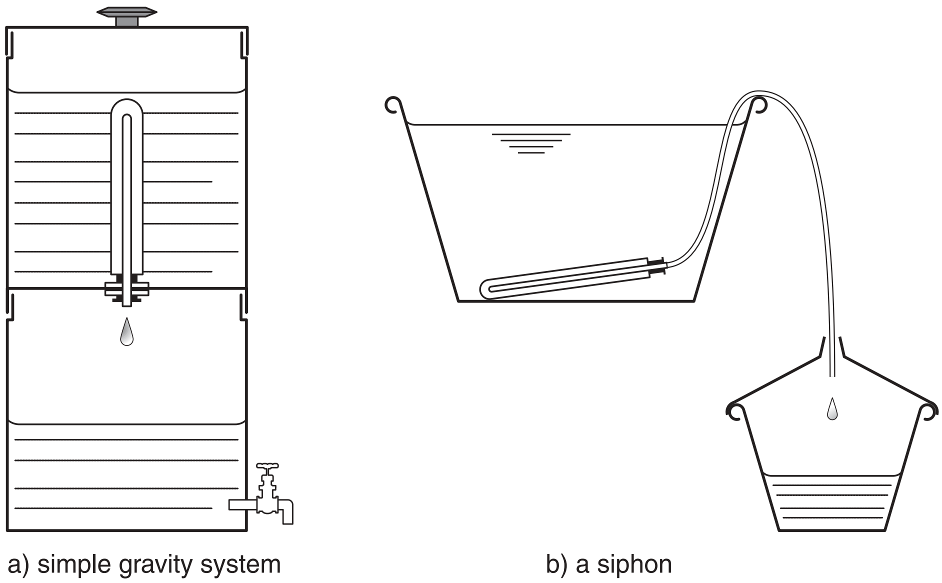

Figure 13.28 Ceramic candle filters

After some time the water flow diminishes as the candle becomes coated by the filtered out particles. The accumulated slime is cleaned off with a nylon brush in a bucket of water. Each brushing removes part of the ceramic candle so that the diameter of the candle is gradually reduced. A circular gauge should come with each filter – try not to lose it! The filter element needs replacing if the gauge can be slipped over the candle.

Silver acts as a bactericide, and candles are available which are silver impregnated for added protection.

13.3.3 Disinfection

Disinfection kills pathogenic organisms. It can be achieved by a variety of physical and chemical means. This section deals with the method most widely used in emergencies, chlorination. Some information is also given on two other methods: the use of iodine and boiling.

Chlorination

Chlorine is the most readily available and widely used chemical disinfectant for water supply. The aim of chlorination is the destruction of pathogens and the protection of the water supply. To achieve this, a chlorine dose must be sufficient to:

- Meet the chlorine demand of the water, that is, it must oxidize the contaminants (including reacting with any organic or inorganic substances).
- Leave a residual, in order to give protection against further contamination. This is achieved by ensuring a free residual of 0.2–0.5 mg/l of chlorine in the disinfected water, which inhibits any subsequent growth of organisms within the water supply system. Higher residuals may give an unpleasant taste.

A pre-condition for effective chlorination is that the turbidity of the water must be low. In an emergency water supply the aim is to have a turbidity of less than 5 NTU. Chlorination will function relatively effectively up to 20 NTU, but steps should be taken to reduce turbidities as soon as possible (see 13.3.1).

At high turbidity levels, large quantities of chlorine are needed to oxidize the organic matter present. This leaves a strong chlorine taste which may cause people to use other, possibly contaminated, sources of water for drinking. Furthermore, some pathogens inside particles of organic matter may survive the oxidizing effects of the chlorine.

Chlorine may be added to a water supply by:

- Dosing with a continuous flow of a one per cent solution of chlorine (see below and 13.3.4).
- Adding chlorine tablets or powder directly to a tank of water (for emergency chlorination only).

Table 13.14 outlines some of the advantages and disadvantages of using chlorine.

Chlorination and immunity to disease It has sometimes been suggested that the temporary provision of chlorinated water to people who normally have to

Table 13.14 Advantages and disadvantages of chlorine use as a disinfectant

Advantages	*Disadvantages*
It comes in several forms: powder, granules, liquid, gas	It is a powerful oxidizing agent which must be handled carefully – do not breathe chlorine fumes
It is usually readily available and relatively cheap in one form or another	It does not effectively penetrate particulate matter
It dissolves easily	It can give an unpleasant taste when slightly overdosed, which could dissuade people from drinking a safe water
Residual chlorine remaining in treated water provides some protection against further contamination	Its effectiveness against some pathogens – cysts, ova, viruses – requires higher chlorine concentrations and a longer contact time
It is effective against a wide range of pathogens	

drink polluted water can result in a reduction in immunity or resistance to disease, either because the chlorine affects the flora in the stomach or because the absence of pathogens in the water lowers subsequent immunity.

There is no evidence that any low level of residual chlorine that survives to the point of consumption is harmful. As an oxidizing agent, residual chlorine will react quickly with organic matter and it is therefore unlikely to survive long in the contents of the stomach (in which there are, in any case, high levels of naturally occurring hydrochloric acid). Current evidence suggests that there is very little likelihood that the absence of pathogens will have any effect on immunity to disease. Therefore, in crowded emergency situations, chlorination of the water supply is strongly recommended.

In other disaster situations, especially where populations are dispersed, chlorination of supplies may not be a priority. The decision on whether or not to chlorinate a water supply does not concern immunity. It concerns the balance of feasibility, cost and benefit to the health of the community as a whole (Feachem, 1993).

How much chlorine is required? Enough chlorine must be provided to meet the chlorine demand and to leave a free residual of 0.2–0.5 mg/l (WHO, 1984a) after a contact time of 30 minutes.

Chlorine residuals are of two kinds, combined residuals and free residuals. Combined residual chlorine is the proportion of the original chlorine dose which combines with ammonia and organic nitrogen compounds to form stable but less effective disinfectants than free chlorine. Free residual chlorine is that part of the chlorine dose which remains after the chlorine demand has been fully satisfied.

The actual dose will depend on the condition of the water. It can be expected to be in the range, 1–5 mg/l. Determine the optimum dose by trials on water samples.

To determine how much chlorine is required, it is necessary to analyse the water for the chlorine residuals. Simple colour comparator kits with reagents are available to indicate the free and combined residuals of chlorine in water.

The colour comparator shown in Figure 13.29 is used to indicate both chlorine residuals and pH concentrations.

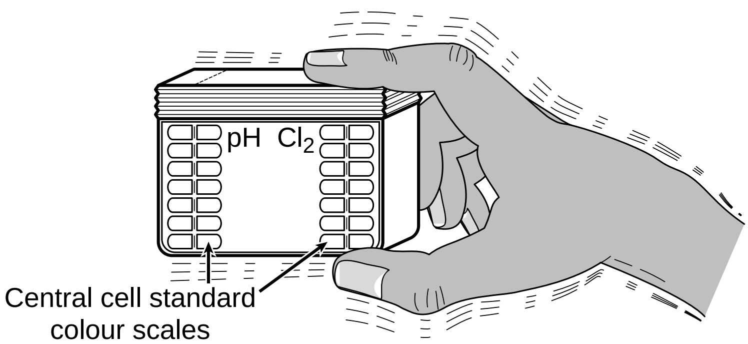

Figure 13.29 Colour comparator

Chlorine in water will form hypochlorous acid (HClO), at low pH values, or tend to dissociate into hydrogen (H^+) and chlorite (ClO^-) ions at higher pH values. Hypochlorous acid is the more active disinfectant and therefore chlorination is more effective in low pH (acidic) water. Chlorination is considerably less effective when the pH is greater than 8.

Disinfection using chlorine takes longer in cold than in warm water. Therefore, a normal contact time of 30 minutes may need to be increased to one hour. This implies that chlorination tanks may need to be increased in size or number to obtain the residence time for a particular throughput. Ensure all chlorination tests are conducted on samples that are at the correct temperature. For example, test samples in the outside temperature, not in a warm office or laboratory!

Box 13.5 gives a sample calculation for the chlorine requirement for a continuous process water supply system supplying a large community.

Box 13.5 Calculation of chlorine requirement

Task: to calculate how much chlorine is needed to chlorinate a water supply for 20 000 people receiving 15 litres/person/day of chlorinated water.

Water demand = 300 000 litres

If water is supplied by pump at a flow rate of 8 l/s then the total pumping time is about 10.5 hours/day.

In this case the water is of medium quality requiring a dose of 3mg/l of active chlorine to give a residual of 0.2 mg/l. This information was obtained by dosing small samples and analysing using a test kit.

For a pumping rate of 8 l/s the dosing rate must be $3 \times 8 = 24$ mg/s

Using a 1% chlorine solution, which contains 10 g chlorine/litre:
the rate of application required will be
$(24/1000) \times (100/1) = 2.4$ g/s (ml/s) or 144 ml/minute

For 10.5 hours pumping per day the amount of 1% chlorine solution required =
$144 \times 60 \times 10.5/1000 = 90.7$ litres/day

Therefore, a 200-litre drum of 1% chlorine solution would last two days.

Forms of chlorine Chlorine is available in the following forms:

- Chlorine gas is normally used in conventional water supply schemes of substantial size. Chlorine gas dosing equipment is expensive to install, complicated to operate and maintain, and it can be dangerous if not handled properly. Chlorine gas is unlikely to be used in an emergency water supply.
- High Test Hypochlorite (HTH) – calcium hypochlorite granules supplied in drums (70% available chlorine).
- Sodium hypochlorite – supplied in liquid form as:
  - Household disinfectant (Chloros, Parazone, Domestos, etc.) 5–15% available chlorine.
  - Laundry bleaches 3–5% available chlorine.

  - Antiseptic solutions (Milton, Javel) 1% or 2% solution.
- Electrolytic generators are available which generate sodium hypochlorite from common salt. They are powered by electricity from mains AC or solar photovoltaic cells.
- Bleaching powder or chlorinated lime – about 30 per cent available chlorine when fresh.
- Chlorine tablets – various relatively expensive types:
  - Small calcium hypochlorite tablets (60–70 per cent available chlorine) used in tablet chlorinators.
  - 'Swimming pool' tablets containing trichloroisocyanuric acid: these tablets can be suspended in a tank with a purpose-made float to give a slow release of chlorine.

Antiseptic solutions (such as Milton or Javel) are usually of one per cent (or two per cent) concentration. If chlorine is required in bulk, it is more economical to make up a one per cent solution from stronger solutions.

Making a 1 per cent chlorine solution A comparatively stable working solution is of 1 per cent available chlorine. This can be used to dose water in a water treatment plant. A 1 per cent solution contains 10 g of chlorine per litre, i.e. 10 000 mg/litre or 10 000 ppm (parts per million).

Small quantities of 1 per cent solution are suitable for dosing supplies to service centres such as clinics, and for relief worker compounds.

Take care when mixing bleaching powder, as it will form lumps if simply added to water. Add just enough water to the powder to form a cream. Use a wooden stirrer and gradually add water to make the required solution. Allow the sediment which forms to settle and decant the liquid before use.

Table 13.15 is an approximate guide to making 1 litre of a 1 per cent solution from various sources. Remember that if the chlorine source has been stored for some time, its strength will have reduced.

A 1 per cent chlorine solution can be used to dose commonly used containers as indicated in Table 13.16. See Section 13.3.4 on methods of dosing.

Table 13.15 Preparation of 1 litre of 1 per cent chlorine solution

Chlorine source	*Available chlorine, %*	*Quantity required*	*Approx. measure*
High Test Hypochlorite (HTH) granules	70	14 g	1 heaped tablespoon
Bleaching powder	34	30 g	2 heaped tablespoons
Stabilized tropical bleach	25	40 g	3 heaped tablespoons
Liquid household disinfectant	10	100 ml	7 tablespoons
Liquid laundry bleach	5	200 ml	14 tablespoons
Antiseptic solution (e.g. Milton)	1	1 litre	No need to adjust as it is a 1% solution

Table 13.16 Chlorine doses for common containers

Container size	1 gallon (4.5 litres)	20 litres	45 gallon drum (200 litres)
Volume of 1% solution required	8 drops	Half-teaspoon	1 tablespoon + 1 teaspoon

Guide based on the approximate measures: 1 teaspoon = 5 ml; 1 tablespoon = 15 ml

Storage and handling Both the liquid and powdered forms of chlorine reduce in strength over time, especially once containers are opened. Therefore, store dry chlorine in sealed containers, away from heat and out of sunlight, and keep liquid solutions in dark coloured bottles.

Chlorine is corrosive – handle with care, avoid skin contact and, when mixing a chlorine solution, wear protective clothes and gloves, protect the eyes and do not breathe the fumes.

Some other methods of disinfection

Iodine Iodine is an effective bactericide and kills spores, cysts and viruses. The recommended dose is 2 mg/l with a contact time of 30 minutes (WHO, 1989). It appears to be more effective than chlorine in penetrating suspended solids in water. This may be significant in an emergency in the absence of pre-treatment, and where iodine is available for small-scale use in clinics, etc. However, iodine is not appropriate for large scale use as it is far more expensive than chlorine and not so widely available.

Boiling Boiling is an effective physical method of complete sterilization. It is more reliable than chemical disinfection as it will destroy pathogens within suspended particulate matter. However, there are significant disadvantages:

- Energy is required to boil the water (about 1 kg of wood is needed to boil 1 litre of water).
- Boiling must continue for 5–10 minutes.
- Boiled water is de-aerated and has a flat, unattractive taste.
- There is a delay between boiling and cooling before the water can be drunk.
- There is nothing to hinder post-boiling re-contamination through poor handling and storage.
- It is only practical for small quantities of water.

13.3.4 Chemical dosing equipment

Methods for the dosing of liquid chlorine and coagulant solutions fall into the following categories:

- Batch dosing to a fixed volume of water.
- Constant rate dosing into water flowing at a steady rate.
- Proportional dosing at a rate proportional to a variable flow rate.

Figure 13.30 shows an improvised, gravity fed, constant rate method of chlorine dosing. The dose rate from the floating bowl is controlled by the driving head to the glass jet, which is controlled by the weight of the floating bowl. This driving head, and hence the dosing rate, may be adjusted by adding or removing stones from the floating bowl.

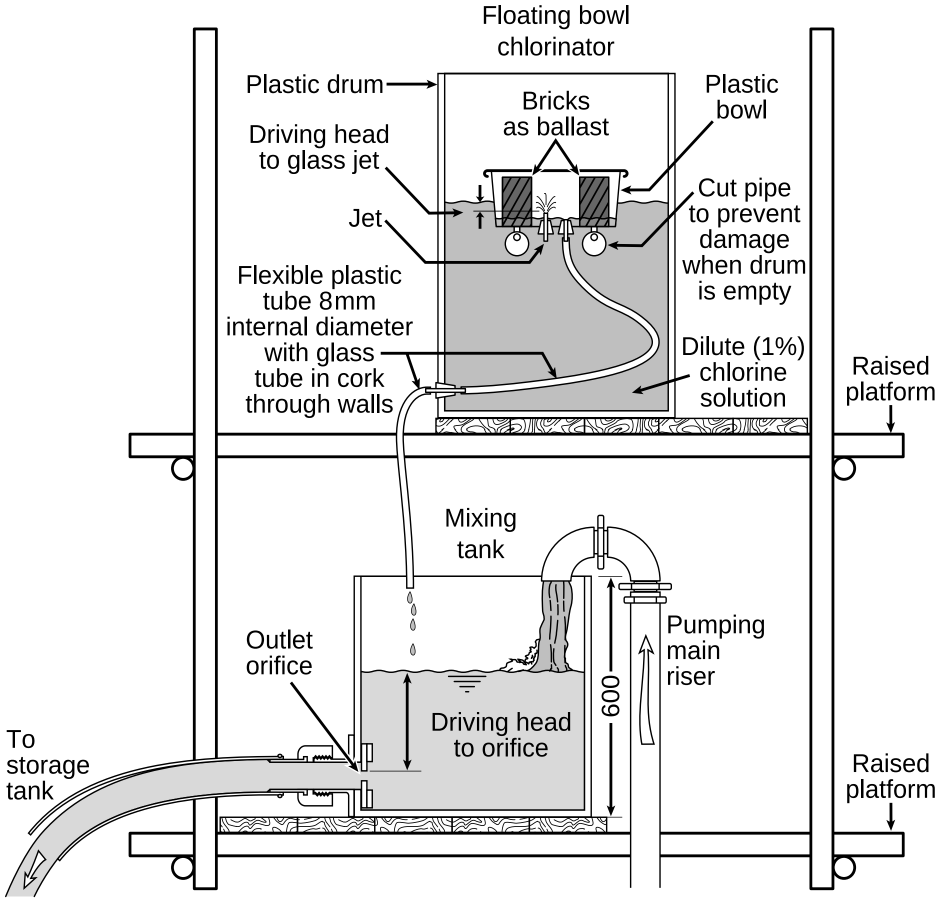

Figure 13.30 Gravity fed, constant rate chlorine solution dosing

The displacement doser (Figure 13.31) is a common method of proportional dosing used for small-scale community and institution supplies (such as hospitals). The differential pressure created across the orifice (or alternatively a venturi) displaces solution from the flexible bag and injects it into the flow.

13.3.5 Packaged water treatment plant

Portable packaged plants may be suitable in certain cases where appropriate expertise and a supply of consumables (fuel and chemicals) are available. They have been used to supply relief personnel during the installation of a larger system for the population as a whole. They are not normally appropriate for supplying water to large populations in an emergency because of the supply of

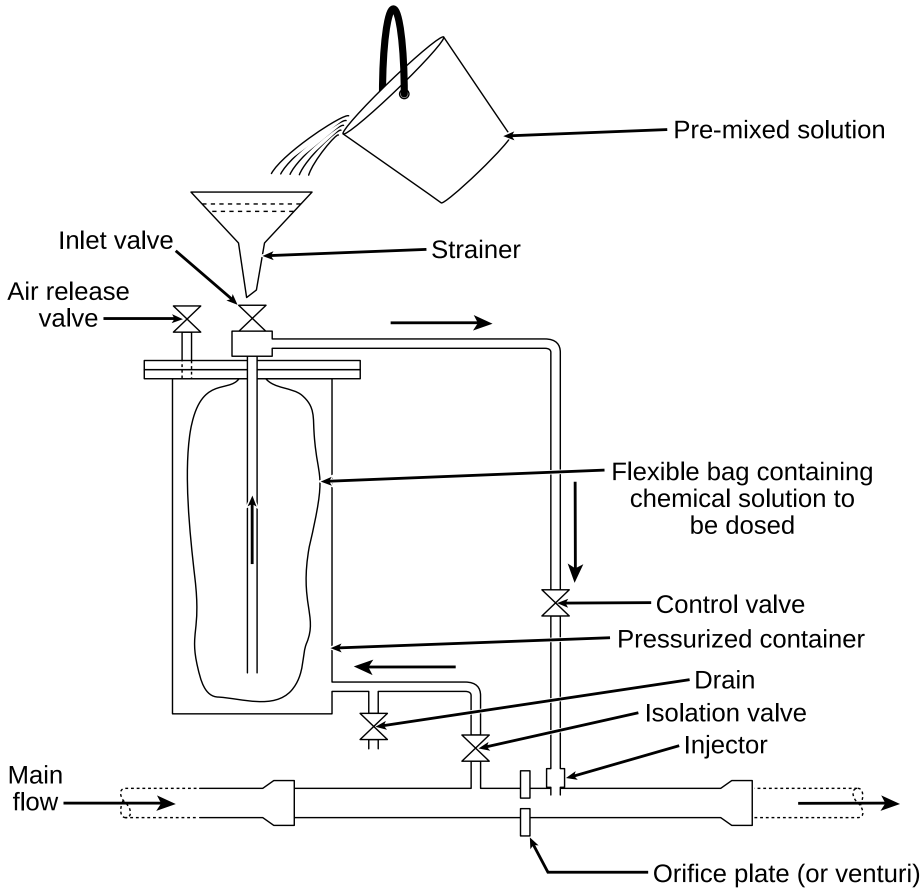

Figure 13.31 A displacement doser

consumables, and skilled operation and maintenance required. Units may be available from the military.

Portable treatment units generally consist of a water pump, a filtration unit and a method of chlorine dosing. Each section of the package may be supplied as a module, for ease of handling and independent use, or supplied as a self-contained unit for mounting on a trailer or skid. Typical capacities range from 2 to 22 m^3/h. Larger units are installed in standard freight (ISO) containers. When ordering, obtain guideline operational data from the supplier so that sufficient consumables (chemicals and fuel) can be ordered in advance.

Disinfection may be by superchlorination. The addition of a large dose of chlorine can rapidly disinfect water without the need for a long residence time. Excess residual chlorine is removed by a carbon filter and the water is then ready for immediate supply. A carbon filter may also remove bad tastes and odours.

Package filtration plant

There are several systems available:

- Small, high rate, pressurized sand filter with backwash. A carbon filter may also be incorporated.