Disinfectants

Water may be disinfected by physical or chemical means.

Physical disinfectants are treatments, like boiling or irradiation, applied to the water which is then safe to drink. After disinfection, water may be re-contaminated in household handling or storage (see Fact Sheet 2.34).

Some chemical disinfectants (such as chlorine and iodine) remain in the water after application. This residual of disinfectant in water is important because it can minimize bacterial re-growth and the effects of re-contamination. This is one of the reasons why chlorine is a very popular disinfectant for drinking water.

Each disinfectant is available under different trade names and requires specific safety measures, preparation and use. Every disinfectant has advantages and disadvantages.

Filtration may be considered a method of disinfection, but it differs in that bacteria are removed rather than inactivated. Removal of pathogens by filtration may not be complete,

thus filtered water is often also disinfected where this is possible. Filtration at household level is covered in Fact Sheet 2.34. Community water treatment is summarized in Fact Sheets 2.8 to 2.14.

Disinfection should be constant and should not be relied upon as the sole treatment for poor quality water for public distribution. This is because even a short-term fault with disinfection may lead to wide distribution of contaminated water. It is therefore important that disinfection is combined with source protection and, where appropriate, water treatment.

Selection of disinfectant

Under most circumstances, overwhelming factors will dictate the selection of disinfection method. The most common major factors are : availability and cost of disinfectant, logistics (especially transport costs), and cost of equipment. In most circumstances, chlorine in one of its forms has been found to be the disinfectant of choice. The choice of which form of chlorine will then largely be determined by the availability and cost of the product, along with transport costs.

Where there is a risk of cholera or an outbreak has occurred, the following chlorine residuals should be maintained :

- At all points in a piped supply 0.5 mg/l
- At standposts and wells 1.0 mg/l
- In tanker trucks, at filling 2.0 mg/l

In areas where there is little risk of a cholera outbreak, there should be a chlorine residual of 0.2 to 0.5 mg/l at all points in the supply. This means that a chlorine residual of about 1 mg/l when water leaves the treatment plant is needed. Chlorine residual can be tasted in water at 0.8 mg/l so, unless higher levels are vital for health reasons, it is recommended that levels above 0.8 mg/l are avoided at points of consumption. If the taste of chlorine is too strong, consumers may reject the water and use an alternative source which, although it may taste better, could be contaminated.

Chlorine

Chlorine is an effective disinfectant where water is not turbid (cloudy) and the water to be treated is not alkaline, that is, with a pH not above 8.0. Most natural waters have a pH below 8.0.

As disinfection with chlorine is less effective in turbid water, water to be chlorinated should be clarified. This can be done by natural filtration, as is the case with groundwater from wells and springs, or by filtration during water treatment. Filtration should also remove the cysts and eggs of protozoa and helminths which are resistant to chlorine.

Chlorine persists in water as residual chlorine after dosing. This helps to minimize the effects of re-contamination during storage and distribution. When chlorine is added to water, some of it reacts with substances in the water and is inactivated as a disinfectant (chlorine demand). For this reason, more chlorine than is required will need to be added. This should be taken into account when estimating chlorine requirements. The estimation of requirements for chlorination of water supplies is covered in Fact Sheet 1.8.

Chlorine is easily, rapidly and cheaply measured in water, and this can be done on-site using simple, hand-held colour comparators. Chlorine is available in various forms, including calcium hypochlorite, sodium hypochlorite and as pure chlorine gas in cylinders.

Calcium hypochlorite (chlorinated lime, tropical bleach, bleaching powder, HTH) is a powder containing between 30 and 70 per cent available chlorine. It must be stored carefully to prevent deterioration, and although it can cause burns, is generally safe to handle and transport. The capital (equipment) costs of using calcium hypochlorite for disinfection are generally low. Calcium hypochlorite is most commonly used in solution for the disinfection of rural and small community water supplies and in diffusion hypochlorinators or in tablet form for household use. Technical details regarding calcium hypochlorite are given in Fact Sheet 2.19.

Sodium hypochlorite (including household bleaches) is a solution. Sodium hypochlorite solutions contain about 1 to 18 per cent chlorine and are thus mostly water. The solution must be stored carefully to prevent deterioration, it can cause burns and is inefficient to transport, since it is mostly water. Sodium hypochlorite is most commonly used for disinfection in the home and in water supplies where transport of the solution is not a problem. Technical details of sodium hypochlorite are given in Fact Sheet 2.20.

Pure chlorine gas, in cylinders, is used widely. Specialized transport, handling and dosing equipment are needed. As chlorine in cylinders is not normally subject to deterioration, gas cylinders are an efficient means of storing and dosing chlorine. Leaks of chlorine gas are, however, very dangerous and installations storing cylinders should be well designed, monitored and maintained. Chlorine in cylinders is most commonly used for dosing at water treatment plants, at the head of wells from which water is pumped mechanically, and at re-chlorination plants in large distribution networks. Technical details of chlorine in cylinders are given in Fact Sheet 2.18.

Chlorine dioxide

Chlorine dioxide is a more powerful oxidizing agent than chlorine, and its disinfectant action is less pH-dependent than that of chlorine. It leaves a long-lasting residual.

Chlorine dioxide is mainly used for the control of tastes and odours. It does not combine with ammonia to a significant extent and therefore is more efficient than chlorine in waters with raised levels of ammonia.

Chlorine dioxide is unstable and must be generated on-site by the action of chlorine or an acid on sodium chlorite. In general, the two chemicals are dosed together into the water. This process requires constant, vigilant monitoring and control. Chlorine dioxide is much more expensive than chlorine.

Iodine

Where water is not turbid, iodine is an effective disinfectant and is more stable than chlorine in storage. Iodine is mostly used for disinfecting small volumes of water for personal use. It is generally too costly for dosing into community water supplies. Iodine reacts less with organic matter than chlorine and does not react with ammonia.

A dose of two drops of a 2 per cent solution of iodine in ethanol per litre of clear water has been recommended for disinfecting small volumes of water for personal use.

For public water supplies, however, 1-2 mg/l with a contact time of not less than 30 minutes is normally recommended. Most people begin to detect the taste and odour of iodine at concentrations in the range 1-2 mg/l.

Iodine in solid form is easy to store and deteriorates less rapidly than chlorine. If dissolved in ethanol, however, iodine will deteriorate rapidly. Stable iodine compounds for dosing into water supply systems, such as tetraglycine potassium tri-iodide, are available as tablets.

Commercial iodine preparations include Globaline, PotableAqua and Individual Water Purification Tablets. Commercial preparations are sold with recommendations concerning dosage and contact time.

Iodine is rarely appropriate as a disinfectant for long-term use in community water supplies, especially because of its cost. Nevertheless, because of its stability and effectiveness, it is very useful for the disinfection of drinking water, especially in small volumes, in emergency or disaster situations.

At high doses (above 4 mg/l), iodine may produce allergic reactions in some individuals and doubts exist regarding the advisability of long-term use of iodine for drinking water disinfection.

Ozone

Ozone (O_3) is an unstable gas which is only slightly soluble in water. It is an efficient disinfectant, but because it is unstable does not leave a residual in water (unlike chlorine, for example). For this reason it is effectively impossible to over-dose with ozone. Ozone contributes to the bleaching of colour and removal of tastes and odours.

Ozone is produced by passing dry oxygen or air through an electrical discharge. It is manufactured on-site using specialized equipment.

Ozonation is much more expensive than chlorination. It would not normally be considered unless cheap electricity were available and/or chlorination very expensive.

Ultraviolet radiation

Ultraviolet (UV) radiation has been used fairly extensively for disinfection of small community water supplies.

The efficiency of UV disinfection is dependent on the intensity and wavelength of the irradiation and the exposure of the microorganisms to the radiation. UV radiation therefore decreases in efficiency as contamination (especially turbidity and some substances in solution, such as iron and organic compounds) increases.

UV disinfection of water is normally achieved by passing the water through tubes lined with UV lamps. This gives efficient disinfection after a contact time of a few seconds. A typical power requirement would be within the range 10-20 W/m^3h. The UV lamps disinfect using a wavelength of light around 254 nm. The lamps may continue to produce blue light when they are worn out and are no longer producing disinfecting irradiation. The manufacturer's recommendations regarding replacement should be observed.

Disinfection with UV irradiation does not give rise to tastes and odours. There is no requirement for consumable chemicals, maintenance is straightforward and there is no danger of over-dosing. UV irradiation does not leave a residual effect in the water. The equipment and consumables are expensive, and water to be treated must be of consistently high clarity.

Mixed oxidizing gases generated on-site

Since 1982, considerable work has been undertaken, particularly in a number of Latin American countries with the support of the Pan American Health Organization, in the development of mixed oxidizing gases generated on-site for disinfection (MOGGOD).

A MOGGOD device comprises essentially two electrodes separated by a semi-permeable membrane. One electrode is in a saturated solution of sodium chloride. Hydrogen gas is released, which is vented to waste. At the other electrode, a mixed oxidizing gas is produced. The mixture may contain ozone, hydrogen peroxide and chlorine. Whether all of these are produced, and in what proportions, depends on electrode composition, configuration and operating conditions.

In theory, the only consumable items are sodium chloride (salt) and a small amount of electricity. The equipment is still being developed, however, and problems, such as membrane clogging if the salt is not pure, are yet to be overcome. The membranes and electrodes wear out at variable rates which depend on initial quality and operating conditions ; their cost is a significant component of the cost of disinfection with MOGGOD. MOGGOD may become useful for small community water supplies. Larger units are not more cost-effective and so MOGGOD is unlikely to be favoured for larger supplies.

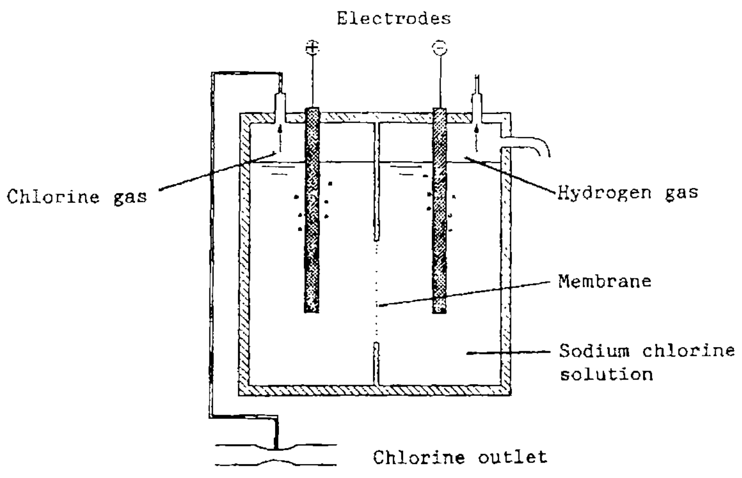

Figure 1. MOGGOD device

Boiling and household filters

Disinfection of water using methods such as boiling or household filters are covered in Fact Sheet 2.34.