A WELL FACT SHEET

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Chlorination: a contribution to reducing diarrhoeal disease

This fact sheet examines the key issues in the use of chlorination within small-scale water supplies in developing countries.

To ensure a safe drinking water supply, the first priority is to protect and improve the source, if this is practicable. Even so, to completely eliminate waterborne diseases and other health-threatening organisms, disinfection may still be needed. Disinfection methods can be placed into two broad categories: chemical and physical. This report focuses on chlorination, a chemical disinfection process which aims to remove one of the major routes for transmission of diarrhoeal diseases.

Chlorination

Chlorination: the chemical process by which disease-causing organisms (pathogens) found in drinking water are killed or inactivated, is the most widely used method of disinfection of water supplies in developing countries. With diarrhoea being a leading cause of illness and death in children less than five years of age in these regions, chlorination and safe water storage makes a significant contribution to reducing diarrhoeal diseases. Much can be done to improve the quality of drinking water at community level, at the water source or in the treatment works and, on a more simple scale, at household level. This is aptly highlighted by current interventions to reduce HIV transmission from mother to child by the replacement of breast milk with infant formula milk. It is of paramount importance that safe water be used in the preparation of formula milk, so as to eliminate the risk of numerous episodes of diarrhoeal disease and potential death.

Chlorine, the chemical agent involved in the disinfection process, may be dosed in a number of forms, as a gas, in solution as sodium hypochlorite or as a solid in the form of powders and tablets (calcium hypochlorite). The stability and ease of use of each of these compounds differ widely. Proper storage prior to opening containers and between uses is essential to ensure that chlorine compounds retain their effectiveness. Even with good storage, some have a very limited shelf-life. Hypochlorite, for example, when stored in sealed containers in a cool, dark environment, looses half its efficacy in just one year.

Chlorine is a highly active agent and in the form of a chemical compound (usually in solution) needs to be well mixed with raw water to kill or inactivate pathogens. Sufficient chlorine should be added so that, after completion of any reactions with organic matter or chemical substances, there is enough free chlorine remaining to kill pathogens. This may give rise to a chlorine taste in the water, however, this alone does not indicate that a free chlorine residual exists. The more impurities in the water, the greater the *chlorine demand* (the amount of chlorine required over and above any residual free chlorine remaining in the water after the specified period of disinfection). Naturally, water quality will vary whether from different sources or from a single source and so variations in chlorine demand will occur. Clearly, a trained person is required to determine the correct chlorine dose and suitable equipment is required to regularly monitor and maintain the amount of active chlorine remaining in the water after treatment. Such equipment may be complicated, especially where variations in the flow rate of the water being treated exist.

Adverse health risks of chlorination by-products

In recent years, there has been some opposition to the use of chlorine for disinfection because of the perceived health risks (primary cancer) from disinfection by-products (DBPs) that arise from the disinfection of water with chemicals. The latest *Guidelines for drinking-water quality* (WHO, 2004, p.5) makes the following statement:

> *...the risks to health from these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection not be compromised in attempting to control such by-products.*

Recent developments in the small-scale production of sodium hypochlorite from the electrolysis of salt solution now mean that decentralized local production is often feasible, in developing countries. This approach has been used, for example in Peru and Bolivia, where, the *Safe Water System* has been promoted for the use of household chlorination and safe water storage (CDC, 2000).

Chlorine-resistant organisms

Two pathogens found in water - *Giardia duodenalis* and *Cryptosporidium parvum* - are highly resistant to normal levels of chlorination. Fortunately, if appropriate pre-chlorination treatment stages such as sedimentation (particularly after coagulation and flocculation) and filtration are used in the water treatment process, there is little risk of these pathogens reaching the chlorination stage. In very simple treatment systems used in rural areas of developing countries, it is often *not* possible to include these necessary treatment stages and so some risk from these pathogens will remain if they are present in the raw water. However, these organisms are unlikely to be present in groundwater if the collection point is properly protected and the water is hygienically handled.

Determining the chlorine dose

Many books offer advice on the procedures for determining the required chlorine dose (see Skinner, 2001 p.7). The actual strength of the source of chlorine does not have to be known to determine an appropriate dose (see the 'Modified Horrocks' method described in Parr et al., 1999).

It is important to realize that the chlorine demand of water sources will not necessarily remain constant. It will usually vary for surface water sources, depending on recent pattern of rainfall run-off contributing to the source, but pre-treatment stages to remove the additional suspended solids will limit the variation.

There are many factors that affect the efficiency of inactivation of microbial pathogens. The principal ones are the chlorine concentration around the organism, contact time (the period during which the chlorine is in contact with the pathogen), water temperature and pH. These and the other factors that will affect chlorination, such as the nature and flow rate of the water, the availability and use of chlorine compounds and testing equipment, and the chlorinator and its operation, are summarized by Skinner, 2001, p.9.

Contact time

The efficiency of chlorine in inactivating various pathogens is often specified by a 'Ct value' which is usually related to the 99% inactivation of a particular type of organism. The Ct value is a product of the concentration of chlorine in mg/l and the contact time in minutes. It takes into account that lower chlorine concentrations for longer periods will have similar effectiveness to higher concentrations for shorter periods as long as the Ct values for each situation are the same.

After a chlorine compound is applied, the water needs to be held in a tank (contact tank) or pipe system for sufficient time (usually at least 30 minutes) for the organisms to be inactivated before the water will be safe to drink. Where treated water is constantly flowing through a contact tank, the tank needs to be carefully designed to prevent water 'short circuiting' and passing through it faster than what might be anticipated from the ratio between the volume of the tank and the flow rate of the water.

Checking the residual chlorine

Regular testing is essential to ensure that adequate free residual chlorine is still present in the treated water, whatever changes take place in the raw water or in the strength of the chlorine compound being used. Standard methods of field-testing for chlorine concentrations in water are well explained elsewhere and are briefly discussed in Skinner, 2001, p.14-15. The DPD method is summarised in Parr et al, 1999.

Testing for chlorine residual

The most common test is the dpd (diethyl paraphenylene diamine) indicator test, using a comparator. This test is the quickest and simplest method for testing chlorine residual.

With this test, a tablet reagent 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 1, are available commercially. The kits are small and portable.

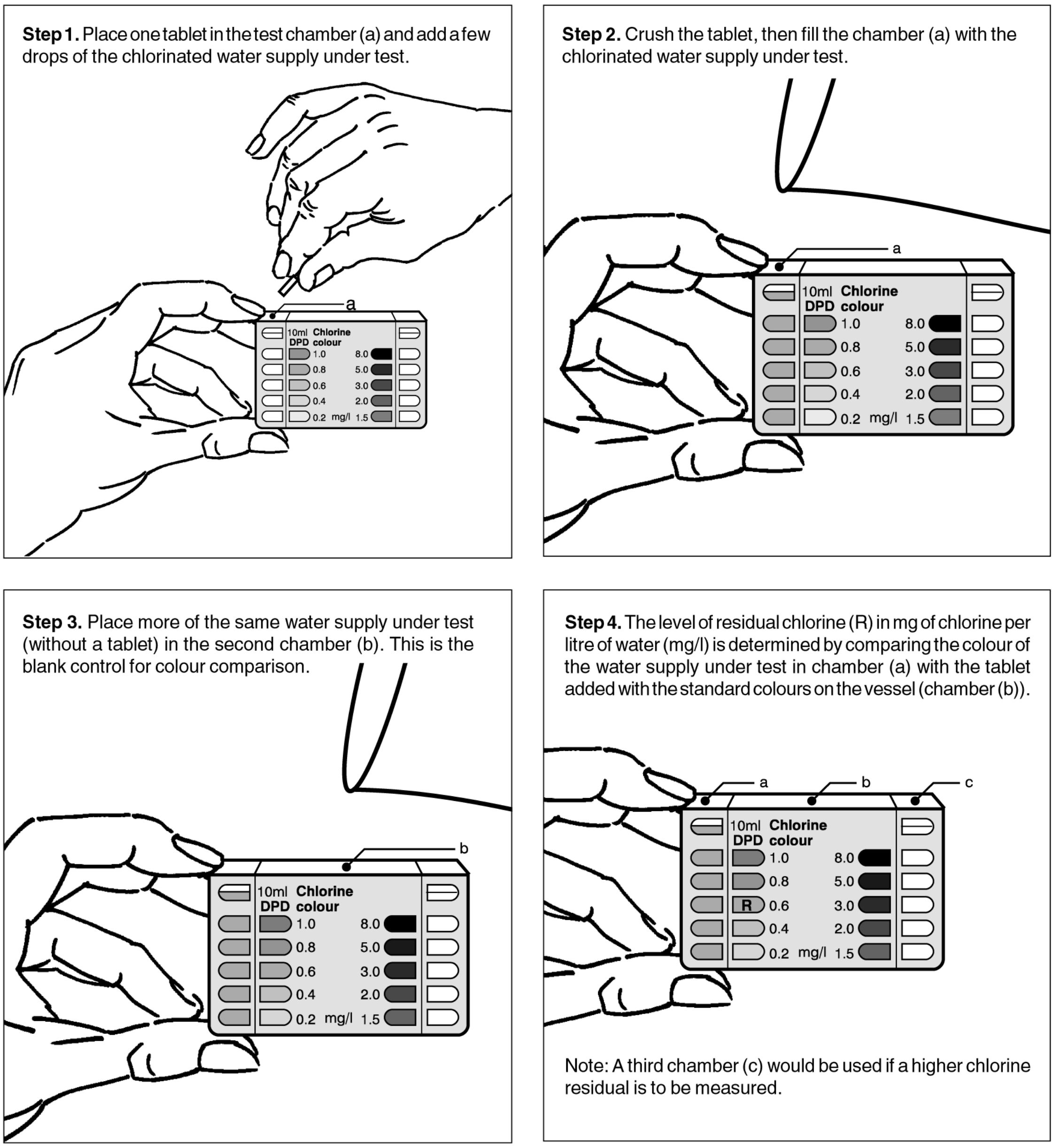

Figure 1. Procedure for testing for chlorine residual

Risks from contamination after treatment

Residual chlorine in water at the collection point will give some protection against subsequent contamination of the water, but users need to understand how to prevent subsequent contamination of the water or its quality may deteriorate, for example, though unhygienic practices used during collection, transportation, storage and withdrawal from storage. Many waterborne diseases are also carried by other routes. For the best health impact, sanitation and hygiene practices in the household and community will need attention as well as the quality of the water.

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Author: B Skinner   Quality assurance: P Moriarty, J Smet and S Cairncross   Design: S Plummer   Illustrations: R Shaw

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WELL Network Partners are developing regional annexes to a number of existing fact sheets. For details, refer to the WELL website: http://www.lboro.ac.uk/well/about-well/about-well.htm

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WELL at WEDC, Loughborough University, Leicestershire, LE11 3TU, UK.
Phone: +44 1509 222885   Fax: +44 1509 211079   E-mail: well@lboro.ac.uk
http://www.lboro.ac.uk/well/

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