A WELL FACTSHEET

Household water treatment

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Household-based approaches to water treatment may be more effective and cost-effective means of preventing diarrhoeal disease than conventional treatment at the source. This fact sheet summarizes the available evidence and some of the leading approaches.

Introduction

Diarrhoeal diseases kill an estimated 2.5 million people each year, the majority children under five. An estimated 4 billion cases annually account for 5.7% of the global burden of disease and place diarrhoeal disease as the third highest cause of morbidity and sixth highest cause of mortality. Among children under 5 years in developing countries, diarrhoeal disease accounts for 21% of all deaths.

Health authorities generally accept that safe water plays an important role in preventing outbreaks of diarrhoeal disease. Accordingly, World Health Organization (WHO) guidelines for water quality allow no detectable level of harmful pathogens at the point of distribution. However, in those settings in which diarrhoeal disease is endemic, much of the epidemiological evidence for increased health benefits following improvements in the quality of drinking water has been equivocal (Cairncross, 1989). Since many of these same waterborne pathogens are also transmitted via ingestion of contaminated food and other beverages, by person-to-person contact, and by direct or indirect contact with infected faeces, improvements in water quality alone may not necessarily interrupt transmission.

Water quality: refining the dominant paradigm

Two decades ago, Esrey and colleagues reviewed previous studies on the impact of environmental interventions on diarrhoea, and found improvements in water quality to be considerably less effective than those aimed at water quantity, water availability and sanitation. The review was subsequently updated and expanded to include hygiene interventions (Esrey et al., 1991). Ubiquitously cited in both professional journals and practical guides, the reviews have led to the dominant paradigm respecting water supply and sanitation interventions: that to achieve broad health impact, greater attention should be given to safe excreta disposal and proper use of water for personal and domestic hygiene rather than to drinking-water quality. The corollary has become equally established: that interventions aimed solely at improving drinking water quality would have relatively little impact in reducing diarrhoeal disease.

Recently, however, an increasing body of evidence has suggested the need to refine the dominant paradigm (Clasen & Cairncross, 2004). Much of this evidence arises from a relatively new approach to enhancing water quality as part of a public health initiative: improved household water management and storage. Esrey's conclusions that water quality improvements could reduce diarrhoeal disease by 15%-17% were based exclusively on studies involving interventions at the point of distribution, such as protected wells and springs. However, it is well known that even safe water becomes faecally contaminated during collection, transport, storage and drawing in the home (Wright et al., 2004). Accordingly, improving water quality at the point of distribution only may not secure the full health gains that are possible by ensuring that drinking water is microbiologically safe through the point of use. This distinction was suggested in a recent systematic review that demonstrated a 34% reduction in diarrhoea from higher quality studies of interventions at the point of use, fully twice the impact reported by Esrey of improvements at the source (Fewtrell et al., 2005).

The health impact of treating water at the point of consumption, however, is not universal or absolute. Except in the case of *Vibrio cholerae*, a reduction in waterborne pathogens is not clearly associated with a corresponding reduction in diarrhoea (Gundry et al., 2004). Moreover, while more than two dozen studies have shown household water treatment to be protective, the range of effects is quite broad. And a few studies, including one of the only blinded trials, have not demonstrated any statistically significant reduction in diarrhoea (Kirchoff et al., 1985). Such heterogeneous results can perhaps be anticipated, given the variety of interventions employed (some of which included hygiene instruction and other components), the diverse risk settings in which they are introduced, and the different methodological rigour of the studies themselves. A pending Cochrane review should clarify the apparent difference in health impact between interventions at point of distribution versus those at the point of use, and help explain the heterogeneous results observed for interventions at the household level.

Household water treatment and the WHO

As part of its Millennium Development Goals, the United Nations expressed its commitment by 2015 to reduce by one half the 1.1 billion people without sustainable access to improved water supply. Providing safe piped in, disinfected water, to each household may be the best solution to waterborne disease. The WHO acknowledges, however, that such a solution would entail an investment of tens of billions of dollars each year. Accordingly, it has called for other approaches while progress is made in improving infrastructure.

Interventions to treat and maintain the microbial quality of water at the point of use are among the most promising of these alternatives. In many settings, both rural and urban, populations have access to sufficient quantities of water, but that water is microbiologically unsafe. The up-front cost of treating such water at the point of use can be dramatically less than the cost of conventional water treatment and distribution systems. According to the 2002 World Health Report, point-of-use water treatment, such as household-based chlorination, is the most cost-effective environmental intervention to prevent diarrhoeal disease across a wide range of countries and settings (WHO, 2002). In 2003, the WHO helped organize the International Network for the Promotion of Safe Household Water Treatment and Storage, a global collaboration of UN and bilateral agencies, NGO's, research institutions and the private sector committed to improved household water management as a component in water, sanitation and hygiene programs. The Network's website, hosted by WHO, contains a considerable amount of information on household water management: www.who.int/household_water/en/

The WHO also commissioned a comprehensive review to identify the most promising POU treatment technologies based on selected technical characteristics and performance criteria, including effectiveness in improving and maintaining microbial water quality, health impact, technical difficulty or simplicity, accessibility, cost, acceptability, sustainability and potential for dissemination (Sobsey, 2002). After evaluating at least 37 different technologies, Sobsey concluded that 5 were the most promising: filtration with ceramic filters, chlorination with storage in an improved vessel, solar disinfection in clear bottles, thermal disinfection (pasteurization) in solar cookers or reflectors, and combination systems employing chemical flocculation and chlorination.

While this Fact Sheet will focus on these technology groups, readers are urged to explore other options which may be more suitable for a particular setting. Moreover, the potential commercial market for household-based water treatment has attracted private sector participants who attempting to adapt or develop new technologies. Accordingly, readers are encouraged to investigate these emerging technologies.

Certain technologies

1. Chemical disinfection.

Chemical disinfection is the most widely-practised means of treating water at the community level. It is also the method used most broadly in the home. While a wide range of oxidants are used in treating water, most household-based interventions employ free chlorine derived from liquid sodium hypochlorite or solid calcium hypochlorite which are usually available and affordable. Tablets formed from chlorinated isocyanurates (e.g., NaDCC), a leading emergency treatment of drinking water, and novel systems for on-site generation of oxidants such as chlorine dioxide, may also have a role in household water treatment in the future. At doses of a few mg/l and contact time of about 30 minutes, free chlorine inactivates more than 4 logs of enteric pathogens, the notable exceptions being *Cryptosporidium* and *Mycobacterium* species. The "Safe Water System", a programmatic intervention developed by the US Centers for Disease Control and Prevention that combines chlorination of water in the home with safe storage and hygiene instruction, has an estimated 5 million users in 19 countries (www.cdc.gov/safewater/default.htm) Its impact in reducing diarrhoeal diseases has been documented (Quick et al., 2002). Like most other household-based water interventions, however, the hardware must be accompanied by an extensive behavioural change program to stimulate adoption and continued utilization by householders.

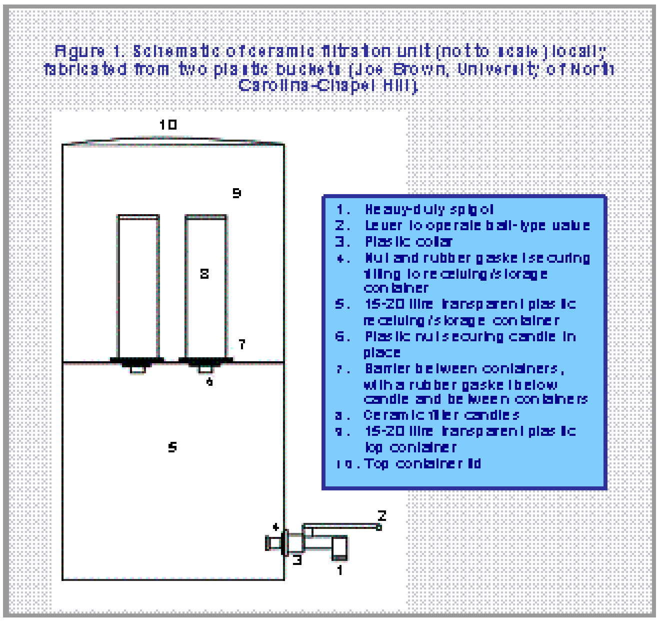

Figure 1. Schematic of ceramic filter system

Source: Joe Brown, University of North Carolina

2. Filtration.

Household filters potentially present certain advantages over other technologies. They operate under a variety of conditions (temperature, pH, turbidity), introduce no chemicals into the water that may affect use due to objections about taste and odour, are easy to use, and improve the water aesthetically, thus potentially encouraging routine use without extensive intervention to promote behavioural change. Higher quality ceramic filters treated with bacteriostatic silver have been shown effective in the lab at reducing waterborne protozoa by more than 3 logs and bacteria by more than 6 logs. Their potential usefulness as a public health intervention has been suggested in a recent field trial (Clasen et al., 2004). While the up-front cost of gravity systems employing such commercial ceramics is high (US$10 to US$25), their long life (up to 50,000L per ceramic "candle element") renders such systems comparable to chlorination on a per litre treated basis. The improving quality of locally-fabricated silver coated ceramics is particularly promising as a sustainable and low-cost alternative. Slow-sand filters, which remove suspended solids and microbes by means of a slime layer (*schmutzdecke*) that develops within the top few centimetres of sand, are capable of removing 2 logs or more of enteric pathogens if properly constructed, operated and maintained (Hijnen et al, 2004). A simpler but more advanced version, known as the "bio-sand" filter, was specifically designed for intermittent use and is more suitable for household applications. It has been tested (Palmeteer et al., 1999) and is being deployed widely in development settings with the help of CAWST, a Canadian NGO (www.cawst.org). Other filtration media, ranging from simple folded sari cloth for the removal of cholera-associated zooplankton (Colwell et al., 2003) to advanced but inexpensive carbon nanofibre membranes capable of removing even viruses at gravity pressure, demonstrate the broad range of opportunities for filtering water at the household level.

3. Thermal and solar disinfection.

Boiling or heat treatment of water with fuel is effective against the full range of microbial pathogens and can be employed regardless of the turbidity or dissolved constituents of water. While the WHO and others recommend bringing water to a rolling boil, this is mainly intended as a visual indication that a high temperature has been achieved. In fact, studies have demonstrated that heating to pasteurization temperatures (60º C) for 10 minutes will kill or deactivate most pathogens. However, the cost and time used in procuring fuel, and the environmental issues around denuding forests and adding especially to poor indoor air quality, have led to other alternatives. Solar disinfection, which combines thermal and UV radiation, has been repeatedly shown to be effective for eliminating microbial pathogens (Reed, 2004) and reduce diarrhoeal morbidity (Conroy et al., 1999). Among the most practical and economical is the "Sodis" system, developed and promoted by the Swiss Federal Institute for Environmental Science and Technology (EAWAG) (www.sodis.ch). It consists of placing low turbidity (<30NTU) water in clear plastic bottles (normally discarded 2L beverage bottles, preferably PET) after aerating it to increase oxygenation and exposing the bottles to the sun, usually by placing them on corrugated metal roofs. Exposure times vary from 6 to 48 hours depending on the intensity of sunlight. Like filters, thermal and solar disinfection do not provide residual protection against recontamination. Accordingly, householders must have a sufficient number of bottles to allow them to cool and maintain treated water in the bottles until it is actually consumed.

4. Combination flocculation and disinfection.

A particular challenge for most household-based water treatment technologies is high turbidity. Solids can use up free chlorine and other chemical disinfectants, cause premature clogging of filters, and block UV radiation essential in solar disinfection. While turbidity can often be managed by pre-treatment or even simple sedimentation, flocculation/coagulation using additives such as alum can be an effective and relatively low-cost option. Such forms of assisted sedimentation have been shown to reduce the levels of certain microbial pathogens, especially protozoa which may otherwise present a challenge to chemical disinfectants. However, disinfection is still required in most cases for complete microbial protection. Certain manufacturers have combined flocculation and time-released disinfection in a single product that is sold in sachets for household use. Proctor & Gamble's PUR® product, the most extensively tested, has been shown to reduce waterborne cysts by more than 3 logs, viruses by more than 4 logs and bacteria by more than 7 logs. Unlike the other methods of household water treatment discussed above, it has also been shown effective in reducing arsenic, an important non-microbial contaminant in certain settings, by more than 2 logs. Field studies have demonstrated such flocculation-disinfection products effective in preventing diarrhoeal diseases (Reller et al., 2003). While these products are relatively expensive on a per litre treated basis, they may have application in certain emergency and other settings. It may also be possible to achieve similar results by combining conventional and lower cost approaches to assisted sedimentation and subsequent disinfection at the expense of convenience.

Acceptability, affordability and sustainability

Household water treatment as an intervention against diarrhoeal disease is still at a nascent stage in its development. While there is considerable research to support the microbiological effectiveness of certain approaches, and a growing body of promising though not definitive research about its health impact, there is relatively little evidence about the potential uptake of such interventions. Questions about acceptability, affordability, long-term utilization and sustainability must still be addressed, particularly in programmatic settings. These issues will ultimately help determine the potential role of household water treatment in preventing diarrhoeal disease among vulnerable populations.

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