TREATMENT AND SAFE STORAGE OF WATER IN HOUSEHOLDS WITHOUT PIPED SUPPLIES OF TREATED WATER

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Contents

1. Introduction
2. Boiling
3. Chlorination
4. Solar Disinfection
5. Ceramic Filtration
6. Biosand (Intermittent Sand) Filters
7. Flocculation-Disinfection
8. Safe Storage
9. Cost and Affordability
10. Acceptability, Affordability and Sustainability
Glossary
Bibliography and Suggestions for further study
Biographical Sketch

Summary

While piped-in access to safe and reliable water supplies at the household level are an important goal, simple and affordable means of treating water in the home offer a means of achieving the health gains associated with safe drinking water. The World Health Organization and others are therefore promoting household water treatment and safe storage as means of allowing householders to take charge of their own water security. This chapter summarizes the leading approaches used for treating water at the household level and the research concerning the microbiological effectiveness, health impact, use and cost of these approaches.

1. Introduction

In the early 1970s, a landmark study on domestic water reported that 950 million people—one-quarter of the world’s then 3.7 million population—lacked access to safe drinking water supplies. Substantial efforts have been undertaken during the ensuing years to make safe water supplies available, including the poor in low-income countries. International policy makers have also drawn attention to the sector, even designating the 1980s as the United Nations “Water and Sanitation Decade”. But while the proportion of the population that still relies on unimproved sources of drinking water has shrunk over this period, the absolute number of people without coverage has actually increased, from 950 million in 1970 to an estimated 1.1 billion in 2000. Moreover, the current definition of “improved” supplies addresses only to the type of supply (protected well, borehole, etc.), not the microbial quality of that supply. Thus, millions of those whose supplies meet the definition of “improved” nevertheless rely on water that is unsafe for consumption.

As part of its Millennium Development Goals (MDGs), the United Nations expressed its commitment by 2015 to reduce by half the proportion of people without sustainable access to safe drinking water. Once again, progress is being made with many countries on track to meet the targets. Nevertheless, current trends will leave more than 900 million unserved by the target date. Three quarters of these will live in rural areas where poverty is often most severe and where the cost and challenge of delivering safe water is greatest. In sub-Saharan Africa, current trends will actually result in a 47 million increase in the number of the unserved. Moreover, even if this goal could be met, it would still leave hundreds of millions without such access. Thus the health benefits of safe drinking water—especially in preventing diarrhea which kills 1.8 million annually including 17% of children under 5 years in developing countries--will remain elusive for vast populations for years to come.

Filtering and disinfecting water at conventional treatment facilities and distributing it to households reliably and in sufficient quantities is the ideal solution for minimizing waterborne disease. Meeting the MDG for safe water access, however, would entail an investment of tens of billions of dollars each year to connect households at the rate of 300,000 per day, about a third more than the current pace. While careful not to encourage diversion of resources away from connected taps, public health officials have called for other approaches that will provide some of the health benefits of safe drinking water while progress is made in improving infrastructure.

One such alternative is household water treatment and safe storage (HWTS). In many settings, both rural and urban, populations have access to sufficient quantities of water, but that water is microbiologically unsafe. This is increasingly true even for piped-in water, since supplies are rarely provided on a 24 hour / 7day basis, forcing householders to store more water in the home and leading to microbial infiltration of poorly maintained systems. Effective treatment at the household level--often using the same basic approaches of filtration, disinfection and assisted sedimentation or a combination thereof as characterize conventional water treatment—can remove, kill or deactivate most microbial pathogens. Moreover, by focusing at the point of use rather than the point of delivery, treating water at the household level minimizes the risk of recontamination that even improved water supplies can present. There is compelling evidence that HWTS is more effective in preventing diarrheal disease than conventional improvements at the source, such as wells, boreholes and communal tap stands. HWTS is also been shown to be highly cost-effective.

While HWTS is not new, its potential as a focused health intervention strategy is just emerging. For centuries, householders have used a variety of methods for improving the appearance and taste of drinking water, including filtering it through sand and other media, or using natural coagulants and flocculants to remove suspended solids. Even before the germ theory was well-established, successive generations were taught to boil water, expose it to the sun, filter it through porous stone, or store it in copper containers, all in an effort to make it safer to drink. In 2000, the World Health Organization (WHO) commissioned a comprehensive study to review these household water treatment and storage practices. The review identified 37 different options for household-based water treatment and assessed the available evidence on their microbiological effectiveness, health impact, acceptability, affordability, sustainability and scalability. Seeking to create a forum and clearinghouse for advancing HWTS, a variety of organizations met in Geneva in 2003 and launched the WHO-backed International Network to Promote Household Water Treatment and Safe Storage (http://www.who.int/household_water/en/). The Network now claims more than 100 members from government, UN agencies, international organizations, research institutions, NGOs and the private sector; it meets regularly, rotating among continents. Some of the principles are related to those also applied in systems intended for different purposes and markets (see *Point-of-use Water Treatment for Home and Travel*).

2. Boiling

Boiling or heating with fuel is perhaps the oldest means of disinfecting water at the household level. It is certainly the most common, with household surveys showing boiling to be the preferred means of treating water, especially in Asia. If practiced correctly, boiling is also one of the most effective, killing or deactivating all classes of waterborne pathogens, including bacterial spores and protozoan cysts that have shown resistance to chemical disinfection and viruses that are too small to be mechanically removed by microfiltration. Heating water to even 55° C has been shown to kill or inactivate most pathogenic bacteria, viruses, helminths and protozoa that are commonly waterborne. Moreover, while chemical disinfectants and filters are challenged by turbidity and certain dissolved constituents, boiling can be used effectively across a wide range of waters. In rural Kenya, pasteurization of water using a simple wax indicator to show householders when water reached 70° C increased the number of households whose drinking water was free of coliforms from 10.7% to 43.1% and significantly reduced the incidence of severe diarrhea compared to a control group.

Governments, NGOs and others have promoted the practice, both in developing countries where water is routinely of uncertain microbial quality and in developed countries when conventional water treatment fail or water supplies are interrupted due to disasters or other emergencies. The WHO Guidelines for Drinking Water Quality simply recommend bringing water to a rolling boil as an indication that a disinfection temperature has been achieved.

Despite its extensive use, however, boiling water presents certain disadvantages that may limit its scalability as a means of routinely treating drinking water. First, there is increasing evidence suggesting that as actually practiced in the home, boiling and storing water often does not yield microbiologically safe drinking water. Once the water begins to cool, it is immediately vulnerable to recontamination from hands and utensils since it contains no residual disinfectant and is often stored in open vessels without a tap. Recent studies have shown that the stored drinking water in the home of families who report that boiling it often contains high levels of fecal contamination. Second, more than half of the world's population relies chiefly on wood, charcoal and other biomass for their energy supplies. In some of Sub-Saharan Africa, Southeast Asia and the Western Pacific regions, the figures are 77%, 74% and 74%, respectively. The procurement of these fuels represents a substantial commitment of time and energy, primarily for women and girls, and may detract from other productive and potentially health-promoting activities. An alternative means of treating water that does not require the use of such fuel may reduce the time spent collecting the same. Third, boiling can be an important cause of other health hazards, including respiratory infections, anemia and stunting associated with poor indoor air and accidents, especially among young children. Fourth, depending on the fuel used, boiling may be environmentally unsustainable and contribute to greenhouse gases. Finally, the long-term cost of boiling is greater than some alternatives (Section 9 below), and may be principal reason why the practice is not even more widespread. Research on the affordability of boiling in a village in Bangladesh found that families in the lowest income quartile would have had to spend 22% of their yearly income on fuel; even those in the highest income bracket would have spent 10%. For a typical family in the lowest income quartiles, boiling of drinking water would require an 11% increase in household budget.

3. Chlorination

Chemical disinfection is the most widely-practiced means of treating water at the community level. While most conventional systems in developed countries treat water with chlorine gas (delivered as a liquid in pressurized systems), other common alternatives include calcium hypochlorite, sodium hypochlorite, lithium hypochlorite and chloroisocyanurates (sodium dichloroisocyanurate or trichloroisocyanuric acid). All of these compounds disinfect water by releasing free available chlorine (FAC) in the form of hypochlorous acid (HOCl). At doses of a few mg/l and contact time of about 30 minutes, free chlorine kills or inactivates more than 4 logs of enteric pathogens, the notable exceptions being *Cryptosporidium* and *Mycobacterium* species.

Apart from boiling, chlorination is also the most common method for treating water in homes without piped water supplies. Most householder use free chlorine derived from liquid sodium hypochlorite which is usually available in the form of household bleach and is comparatively affordable (Section 9). 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, is one of the most successful efforts to encourage effective water treatment at the household level; as of 2006, it was practiced by an estimated 5 million users in 19 countries (http://www.cdc.gov/safewater/default.htm). The impact of the approach in reducing diarrheal diseases has been documented in a series of rigorous randomized, controlled trials (RCTs), and because of its relatively low cost, it has been shown to be the most cost-effective of HWTS options. Like most other household-based water interventions, however, the hardware must be accompanied by an extensive behavioral change program to stimulate adoption and continued utilization by householders.

One alternative to sodium hypochlorite is sodium dichloroisocyanurate (NaDCC), also known as sodium dichloro-s-triazinetrione or sodium troclosene. Widely used for decades in household and commercial laundry bleaches, scouring powders and industrial and recreational water disinfection, NaDCC has recently found applications ranging from the sanitation of medical instruments to the cleaning of baby bottles and contact lenses. For more than 30 years, the effervescent tablet version of NaDCC has been used for the emergency treatment of water; tens of millions of Aquatabs™ NaDCC tablets were used in connection with the response to the 2004 Indian Ocean tsunami. Its widespread use in non-emergency household water treatment applications began after review of the chlorinated isocyanurates by the United States Environmental Protection Agency (USEPA) and the WHO/FAO for the routine treatment of drinking water following the submission and review of extensive test data on the products safety and effectiveness. While still not widely available, NaDCC tablets offer certain advantages over sodium hypochlorite in terms of convenience and shelf-life and are not more costly even over the longer term (Section 9). As householders can buy as little as one or two tablets, NaDCC can also be more affordable.

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Biographical Sketch

Thomas F. Clasen, an epidemiologist, is Lecturer in Household Water Management, Department of Infectious and Tropical Diseases, London School of Hygiene & Tropical Medicine. His research focuses on waterborne diseases affecting low-income populations, including household-based interventions to improve the microbiological quality of drinking water in development and emergency settings. Recent publications include field trials of point-of-use filtration and disinfection products, a systematic review and meta-analysis of water quality interventions to prevent diarrheal disease, and a cost-effectiveness analysis of water quality interventions in developing countries. He received his MSc (Control of Infectious Diseases) and PhD from the University of London.