

Providing clean water, keeping water clean: an integrated approach

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Millions of people, most of whom are children in developing countries, die of basic hygiene-related diseases every year. Interventions in hygiene, sanitation and water supply have been shown to control disease burden. Universal access to improved water sources and basic sanitation remains elusive but is an important long-term goal. Studies have shown that improving the microbiological quality of household water by on-site or point-of-use treatment and safe storage in improved vessels reduces diarrhoeal and other waterborne diseases in communities and households of developing and developed countries. The extent to which improving drinking water quality at the household level reduces diarrhoeal disease probably depends on a variety of technology-related and site-specific environmental and demographic factors that require further investigation, characterisation and analyses.

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Introduction

Around 2.2 million die of basic hygiene-related diseases, like diarrhoea, every year. The great majority are children in developing countries. Interventions in hygiene, sanitation and water supply make proven contributors to controlling this disease burden. For decades, universal access to safe water and sanitation has been promoted as an essential step in reducing this preventable disease burden. Nevertheless, the target of ‘universal access’ to improved water sources and basic sanitation remains elusive. The ‘Millennium Declaration’ established the lesser but still ambitious goal of halving the proportion of people without access to safe water by 2015. Achieving universal access is an important long-term goal. How to accelerate health gains against this long-term backdrop and especially amongst the most affected populations is an important challenge.

There is now conclusive evidence that simple, acceptable, low-cost interventions at the household and community level are capable of dramatically improving the microbial quality of household stored water and reducing the attendant risks of diarrhoeal disease and death. Many different water collection and storage systems and strategies have been developed, described and evaluated on the basis of various criteria for household and community use in developed and developing countries. A variety of physical and chemical treatment methods to improve the microbial quality of water are available and many have been tested and implemented to varying

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extents in developed and developing countries. Some of these water treatment and storage systems have been tested under controlled conditions in the laboratory and implemented in field to evaluate their ability to produce drinking water of acceptable microbiological quality and to maintain this quality during storage and use. Some of them have also been evaluated in the field for their ability to reduce diarrhoeal and other waterborne diseases among users.

Because of the importance of education, socio-cultural acceptance, changing people's beliefs and behaviours, and achieving sustainability and affordability in the provision of safe water, some of the most promising household water treatment and storage systems and their implementation strategies include efforts to address these considerations.

This paper reviews the data presented in a recently released report prepared by Dr Mark Sobsey for the World Health Organization, in which the various methods and systems for household water collection, treatment and storage in the home were critically evaluated, and recommendations for an integrated approach to water management presented. The review also presents and critically reviews data on the ability of these household water treatment and storage methods to provide water that has improved microbiological quality and lower risk of waterborne diarrhoeal and other infectious disease (WHO 2002).

The challenge in context

A large proportion of the World's population—around 1.1 billion people—does not have access to improved sources of water. For these and many others, contamination of water during transport and in the household presents a significant health risk. For this segment of the world's population, use of effective technologies for household water treatment and storage is likely to have direct beneficial effects in the form of reduced infectious diseases, and also contribute to greater productivity and other associated benefits from improved health. Household treatment can often provide these benefits to underserved populations much more quickly than it would take to design, install and deliver piped community water supplies.

Identifying the most accessible and effective methods for household water storage and treatment are matters of considerable importance. This paper summarises the findings of a critical review of the various candidate technologies and systems for providing microbiologically improved household water, and to identify the most promising ones based on their technical characteristics and performance criteria. The characteristics and performance criteria for these are: effectiveness in improving and maintaining microbial water quality, reducing waterborne infectious disease, technical difficulty or simplicity, accessibility, cost, socio-cultural acceptability, sustainability and potential for dissemination.

Systems for household storage of collected water to protect microbiological quality

A review of the existing literature on collection and storage of household water WHO (2002) revealed that such water often comes from faecally contaminated sources and therefore poses infectious disease risks to consumers. Furthermore, regardless of whether or not collected household water is initially of acceptable microbiological quality, it often becomes contaminated with pathogens of faecal origin during transport and storage due to unhygienic storage and handling practices.

Studies show that the use of containers with narrow openings for filling, and dispensing devices such as spouts or taps/spigots, protect the collected water during storage and household use. Many container designs also have handles, are lightweight, are made from durable, UV-

resistant plastic, and have a label fixed containing informational/educational messages on their cleaning and use. Other appropriate containers for safe storage are those in which water can be directly treated by the physical method of solar radiation and then directly stored and dispensed for household use. These improved containers protect stored household water from the introduction of microbial contaminants via contact with hands, dippers, and other faecally contaminated vehicles or the intrusion of vectors.

Treatment technologies to improve the microbiological quality of household waste

A variety of candidate technologies for treatment of household water has been described and many are widely used in different parts of the world. These are reviewed in more detail in the WHO report (WHO 2002). The technologies to improve the microbial quality of household water and reduce waterborne disease include a number of physical and chemical treatment methods. The physical methods include boiling, heating (fuel and solar), settling, filtering, exposure to UV radiation in sunlight, and UV disinfection with lamps. The chemical methods include coagulation–flocculation and precipitation, adsorption, ion exchange and chemical disinfection with germicidal agents (primarily chlorine). Some water treatment and storage systems use chemicals and other media and materials that cannot be easily obtained locally at reasonable cost and require relatively complex and expensive systems and procedures to treat the water. Such systems may be too inaccessible, complex and expensive to employ for treatment and storage of household water in some places and settings.

The efficacy of some treatment methods to physically remove particles that cause turbidity and microbes or to inactivate microbes in household water has been documented, primarily for indicator bacteria. Some treatment methods, such as boiling, solar disinfection, UV disinfection with lamps, chlorination and the combined treatments of chemical coagulation-filtration and chlorination have been evaluated for reducing counts of bacteria, viruses and in some cases protozoans. However, the ability of some of these methods to remove or inactivate a wide range of known waterborne pathogens has been inadequately investigated and documented. The differences in the technologies of candidate treatment and water storage systems, as well as the differences in the types, sizes and other properties of waterborne microbes that need to be removed or inactivated, have contributed to a lack of documentation of the efficacy of these methods for household treatment and storage of water.

With exception of chlorination and storage in a safe container and solar disinfection ‘SODIS’ (UV plus heat), most technologies for household water treatment and storage have not been studied for their ability to reduce diarrhoeal and other waterborne diseases in household use. Such epidemiological studies of an intervention are essential in establishing the performance of the technology and its acceptance and sustainability by users.

Several candidate technologies for household water treatment and storage appear to be accessible, simple and economical for use in both the developed and developing countries. Some of these systems have been characterised for microbial efficacy and reduction of waterborne disease, and for community acceptance sustainability and cost recovery. Of the systems now available, the following appear to be the most widespread and promising for further development, characterisation, implementation and dissemination:

- Solar disinfection by the combined action of heat and UV radiation.
- Solar disinfection by heat alone (‘solar cooking’).

- Chlorination plus storage in an appropriate vessel.
- Combined systems of chemical coagulation-filtration and chlorine disinfection.

The performance characteristics, advantages, disadvantages and estimated costs of these most promising technologies for household water treatment to improve microbial quality and reduce diarrhoeal diseases are presented in the report.

Treating turbid water: a special concern

For the most promising household water treatment systems of chlorination with an improved storage vessel, and solar disinfection with UV plus heat in clear bottles for sunlight penetration (SODIS), effective treatment of turbid water remains a challenge. This is because microbial reductions are decreased or prevented by turbidity particles that reduce access to target microbes or otherwise protect them from inactivation by other mechanisms. Suspended matter in water reduces the microbiocidal efficacy of chlorine and other chemical disinfectants, and it physically shields microbes from the UV radiation present in sunlight and responsible for much of its disinfection activity. There is a need to investigate, characterise and implement physical and physico-chemical technologies for practical and low cost pre-treatment of treatment of household water prior to chlorination and solar disinfection with UV plus heat.

Appropriate physical and physico-chemical methods for effective pre-treatment for household water need to be established, taking into consideration turbid waters of different quality with respect to particle characteristics and their removal efficiencies. In principle, some physical or physico-chemical methods may be highly effective for treatment of stored household water on their own. Pre-treatment technologies for removal of suspended matter that causes turbidity in water potentially include:

- Settling or plain sedimentation
- Fibre, cloth or membrane filters
- Granular media filters
- Slow sand filters.

These methods will vary in their ability to remove interfering turbidity from water, depending on the nature of the turbidity particles. Especially important in this regard is their size and density. Of the listed methods, slow sand filtration is the least likely to be implementable and sustainable at the household level. This is because the preferred filter designs and installations are often larger and capable of treating more water than needed by individual households, and because they require technical skills for maintenance and operation that may not be accepted by individual users.

Need for behavioural, motivational, and economic support

The use of technologies to treat and safely store household water is best accomplished if it is accompanied by, or supported with, economic incentives and other cost recovery methods, and with programmes designed to support community participation, education and efforts to achieve acceptance and sustainability. Where such additional socio-cultural, behavioural and economic components of household water treatment and storage technologies are absent or lacking, successful implementation and sustained use are unlikely to be achieved. The

importance of economic analyses and community participation, education and responsibility for household water treatment and safe storage cannot be over-emphasised in future efforts to establish and disseminate this intervention for water sanitation.

Conclusions

Studies have shown that improving the microbiological quality of household water by on-site or point-of-use treatment and safe storage in improved vessels reduces diarrhoeal and other waterborne diseases in communities and households of developing and developed countries. The extent to which improving drinking water quality at the household level reduces diarrhoeal disease probably depends on a variety of technology-related as well as site-specific environmental and demographic factors that require further investigation, characterisation and analyses. Reductions in household diarrhoeal diseases of 6–90% have been observed, depending on the technology and the exposed population and local conditions.

Further development, refinement, implementation, evaluation and comparison of household water treatment and safe storage technologies is both justified and encouraged. Furthermore, greater efforts to disseminate information about household water treatment and storage technologies and their benefits and advantages are merited.

The most promising and accessible of the technologies for household water treatment are filtration with ceramic filters, chlorination with storage in an improved vessel, solar disinfection in clear bottles by the combined action of UV radiation and heat, thermal disinfection (pasteurisation) in opaque vessels with sunlight from solar cookers or reflectors, and combination systems employing chemical coagulation–flocculation, sedimentation, filtration and chlorination. All of these systems have been shown to dramatically improve the microbiological quality of water. At least two of them: solar disinfection in clear plastic bottles (heat plus UV radiation) and chlorination plus storage in an improved vessel, have been shown in epidemiological studies of the intervention type to significantly reduce diarrhoeal and other infectious diseases, including cholera. These household water treatment and storage systems are considered the most promising and effective, based on their documented ability to improve the microbiological quality of water and reduce waterborne infectious disease risks.

All of the household water treatment technologies described here have been tested independently and so far none have been tested in combination. Historically and with renewed recent interest, water treatment technology and practice have focused on the use of two or more treatment technologies as a multiple barrier approach. There is considerable interest and potential merit in the use of two or more treatment systems in succession for improved treatment and the creation of multiple barriers. In particular, those treatments that provide no residual disinfectant, such as solar treatment and filtration could be followed by chlorination and storage in a protected or improved vessel to provide a multi-barrier approach that would result in appreciable microbial reduction, continued protection with a disinfectant residual and storage that is less prone to post-treatment contamination. Research and demonstration of such multi-barrier treatment and storage approaches deserve consideration and are recommended as next steps in the development, evaluation and implementation of improved treatment and storage of water at the household level.

The introduction of improved water treatment and storage at the household level, if done effectively, is likely to increase personal and community knowledge and awareness of the importance of water hygiene and sanitation and the benefits to be derived therefrom. It is likely that involvement in preparing and using safe water at the household level results in increased

knowledge of water hygiene and sanitation, recognition and appreciation of its contribution to infectious disease prevention and control and improved health. Such awareness of the role of safe drinking water in health promotion and disease prevention support and facilitate the ultimate goal of providing all of the world's population with community piped water that is accessible, safe and affordable.

Reference

WHO (2002). *Managing Water in the Home: Accelerated Health Gains from Improved Water Supply*. Geneva: World Health Organization, Document No. WHO/SDE/WSH/02.07.

