

# Household water storage, handling and point-of-use treatment

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## FORWARD

The burden of disease associated with unsafe drinking water is particularly trying, not only because it is borne most heavily by the poor, the very young and the immuno-deficient, but also because it is largely preventable. Providing reliable piped-in water must remain a priority, given its high return not only in health gains but also in economic productivity and overall human wellbeing (Hutton & Haller, 2004). At the same time, an increasing number of field trials have demonstrated that point-of-use treatment and safe storage of water in the home can be a cost-effective way to help vulnerable populations achieve the health benefits of safe water by taking charge of their own water security.

This review carefully summarises the growing body of research on storing, handling and treating water in the home. In doing so, it builds on the pioneering report on household water management prepared by Prof. Mark Sobsey for the World Health Organisation [3]. It provides compelling evidence that interventions to improve the microbial quality of water at the point of use are as effective as other environmental measures, such as hygiene and sanitation, in preventing diarrhoeal disease, thus helping refine the paradigm that has dominated watsan policy for the last 20 years [52, 53]. Moreover, by adopting a narrative approach, the review is a valuable complement to recent meta-analyses [80, 87] which have confirmed the effectiveness of household water treatment over traditional improvements at the source (protected wells and springs, tap stands, etc.), but have also found considerable heterogeneity in the study methods and results.

The review makes clear that additional studies, including longer-term, blinded trials, will be necessary to confirm the results to date, and to provide additional guidance on the circumstances under which household water treatment can be most effective. The ultimate impact of these interventions will also depend on overcoming challenges to their adoption by the target population on a scalable and sustainable basis. By summarising the research to date and identifying these remaining issues, however, the review provides a valuable guide on household water management that will be a useful tool to policy makers, donors, researchers and program implementers as they seek to ensure the benefits of safe drinking water for all.

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## SUMMARY

World Health Organisation (WHO) data on the burden of disease suggest that approximately 3.2% of deaths (1.8 million) and 4.2% of disability-adjusted-life years (61.9 million) worldwide are attributable to unsafe water, sanitation and hygiene. Of all deaths attributable to water, sanitation and hygiene, over 99.8% occur in developing countries, and 90% are of children. For decades, universal access to safe water and sanitation has been promoted as an essential step in reducing this preventable disease burden. Despite this, WHO/UNICEF estimate that up to 1.1 billion people still do not have access to “improved” sources of water for drinking, for example, a piped connection or a protected well. They also acknowledge that many of the remaining 5.2 billion people who use an “improved” water source nevertheless drink water which is unsafe, following contamination at source, in the piped distribution system or as a result of unhygienic handling during transport or in the home. Even in the European region it is estimated that 120 million people do not have access to safe drinking water. Consumption of unsafe water continues to be one of the major causes of diarrhoeal disease deaths.

Although it is accepted that diarrhoeal disease is a huge problem worldwide, obtaining reliable data on the extent of diarrhoeal illness, the causative organisms, and the extent to which this illness is water-borne is difficult. Although mortality from diarrhoeal disease in developing countries has declined, there is little change in morbidity rates compared with previously described incidences. It is estimated that residents of developing nations may experience between 5 and 20 episodes of diarrhoea per year. Drinking water quality is a problem, not only in developing countries but also in developed countries, most particularly Eastern European countries, but also in North America and elsewhere. In European countries and North America, there are now fewer risks of epidemics related to drinking water contaminated with pathogens such as cholera and typhoid or viral hepatitis, but numerous instances of water-borne disease resulting from contaminated drinking water are still reported. It is estimated that, even in developed countries, as much as 15-30% of community gastroenteritis may be attributable to municipal drinking water, despite state of the art technology for water treatment and no conventional evidence of unacceptable microbial contamination levels.

Although significant advances have been made globally in the provision of community water supplies, there is increasing concerns that the health gains from investment in water supply are being compromised by the fact that water often becomes contaminated during distribution or transport to the home, and during storage and handling within the home. One of the key options for dealing with this problem is promotion of point-of-use water treatment and safe storage in the home.

In this document we review a range of studies which show that improving the microbiological quality of household water by point-of-use treatment and safe storage reduces diarrhoeal and other water-borne diseases in communities and households. Opinions differ as to the relative extent to which diarrhoeal disease can be reduced by improving water quality at household level, rather than at source. Opinions also differ on the extent of the health impact achieved by improvements in water quality in the absence of programmes to improve sanitation, water quantity and promote hygiene measures such as handwashing. Nevertheless the evidence shows that provision of safe water alone at the household level can reduce diarrhoeal and other enteric diseases by 6 to 50%, even in the absence of improved sanitation or other hygiene measures. Importantly the data indicate that the health impact from promoting point-of-use water treatment and safe storage varies considerably from one community to another depending on a variety of technology-related as well as site-specific environmental and demographic factors. Thus the gains for some communities may be very significant, whilst in others they may be relatively modest.

A range of different simple, low-cost physical and chemical treatment methods, together with systems for safe collection, handling and storage, have been developed which can be used to improve household water quality. Increasingly the potential for use of two or more treatments in combination or in succession as a means of optimising water quality is being considered. Some of these methods have been tested in the laboratory and field trials to evaluate their ability to produce drinking water of acceptable microbiological quality, and maintain quality during storage and use. Some have also been evaluated in the field for their ability to reduce diarrhoeal and other water-borne diseases. For the interventions that have been shown to be effective, the focus has now shifted to scaling up programmes which achieve uptake within target populations.

For promotion of household water treatment and safe storage to be successful, it must also involve community education, participation and motivation. This means stressing the role of contaminated water and domestic hygiene in disease transmission, as well as teaching families how to implement water treatment and safe storage. Strategies for promoting hygiene behaviour change have been the subject of much recent research and a number of practical guides are now available which give guidance on how to implement hygiene promotion activities. It is possible that communities already sensitised by promotion of handwashing, who have observed first hand the health impact of handwashing behaviours, are more likely to respond to promotion of water treatment and safe storage. In the same way, promoting water treatment and safe storage at household level is likely to increase overall community awareness of the importance of water, sanitation and hygiene and its contribution to infectious disease prevention and improved health. Recent research suggests that “positive” perceptions rather than negative attitudes are better predictors of whether people are likely to consistently treat their water, which suggests that educational and promotional messages should focus on positive ideas, such as clarity, taste, good health, affordability, and ease of use.

A key argument for promoting household water treatment and safe storage is that it can provide safe water to underserved populations much more quickly and affordably than it takes to design, install and deliver piped community supplies. Promotion of “point of use” water treatment has the potential to provide immediate benefit to at risk populations until the long-term goal of providing community water supplies can be achieved. It is important however that point-of-use water treatment is not seen as an alternative to the provision of safe community water supplies, and an argument for decreased investment in such programmes.

Amongst public health scientists and practitioners, there is now widespread consensus that one of the past mistakes in tackling infectious disease has been to give greater priority to provision of community water supplies over provision of sanitation, and to sanitation over hygiene. In reality it is hygiene practices such as handwashing and household water treatment and safe storage, safe handling and cooking of food etc that reduces the burden of infectious disease. The neglect of hygiene goes a long way to explaining why community programmes to provide water supply and sanitation have often not brought the expected benefits. Although there is awareness of the importance of increased emphasis on hygiene promotion, this does not necessarily translate into commitment to action by national and international governments and by non-government agencies. One of the significant barriers to progress in developing and promoting hygiene is the fact that, in most countries, the separate aspects of hygiene (faeces disposal, food and water hygiene, handwashing, care of the sick, childcare etc) are dealt with by separate agencies. If hygiene promotion is to be effective ideally there should be a single lead agency in each country, and appropriate infrastructure at national, district and local level which is specific for actioning hygiene programmes that promote hygiene at household level. Unfortunately also, public health authorities usually focus on municipal services, hospitals, etc. There is a reluctance to acknowledge the home as a setting of equal importance in the chain of disease transmission.

Although the Millennium Development Goals (MDGs) demand that the emphasis is on disadvantaged communities, where the prevalence of diarrhoeal is highest, this review shows that the need to promote hygiene practices related to household water treatment, and provide effective, affordable treatment methods, is by no means confined to the poorest communities:

- In many developing countries, water quality is a significant problem even for the most prosperous communities that have access to piped water supplies. A significant proportion of families in developing countries live in this situation and are forced to rely on purchasing bottled water, which they can ill afford.
- Across Europe there are still areas where treated community water supplies of adequate microbiological quality are unavailable. This applies particularly in regions of Europe where political and economic upheaval have led to infrastructure deterioration.
- In the US, Europe and elsewhere, “small water systems” are a significant problem, because the communities often lack the resources to maintain facilities and provide continuous supplies.
- Emergency situations require a prompt response. In these situations, household or community treatment of drinking water and safe storage may play a special role in preventing large-scale diarrhoeal disease outbreaks attributable to contaminated water.

The 2002 World Health Report lists unsafe water and sanitation as “one of the top ten risks to health globally and regionally”. The report concludes “very substantial health gains can be made for relatively modest expenditures on interventions such as micronutrients supplementation, treatment of diarrhoea and pneumonia and disinfection of water at the point of use, as ways of reducing the incidence of diarrhoea”. The report suggests that “point-of-use” water treatment is particularly cost-effective in regions of high child mortality”, and that “a policy shift towards household water management appears to be the most attractive short term water-related health intervention in many developing countries”. “This would complement the continuing expansion of coverage and upgrading of piped water and sewerage services which is naturally a long-term aim of most developing nations”.





## I. INTRODUCTION

WHO data on the burden of disease suggests that approximately 3.2% of deaths (1.8 million) and 4.2% of disability-adjusted-life years (DALYs) (61.9 million) worldwide are attributable to unsafe water, sanitation and hygiene (WHO, 2004 [1]). This figure corresponds to 88% of diarrhoeal diseases worldwide which is considered to be the attributable fraction of diarrhoea due to unsafe water supply and sanitation plus the disease burden from trachoma, schistosomiasis, ascariasis, trichuriasis and hookworm disease. Several other water and sanitation-related diseases are not accounted in this figure, for example vector-borne diseases such as malaria and Japanese encephalitis which are linked to the development of water projects like dams or intensified irrigation schemes; and diseases related to chemical contamination such as unsafe concentrations of arsenic or fluoride in drinking water. An estimated 99.8% of such deaths occur in developing countries, and 90% are of children. For decades, universal access to safe water and sanitation has been promoted as an essential step in reducing this preventable disease burden. Despite this, a recent WHO/UNICEF report [2] estimates that up to 1.1 billion people still do not have access to “improved” sources of water for drinking, for example, a piped connection or a protected well. They also acknowledge that many of the remaining 5.2 billion people who use an “improved” water source nevertheless drink water which is unsafe, following contamination at source, in the piped distribution system or as a result of unhygienic handling during transport or in the home. Even in the European region it is estimated that 120 million people do not have access to safe drinking water. Consumption of unsafe water continues to be one of the major causes of diarrhoeal disease deaths [2].

In fact, the actual number of people who use microbiologically unsafe water is much higher than the estimated 1.1 billion. Although communities may have access to piped water at home, it may be contaminated by defects in the distribution system. Many communities have access to water that is microbiologically safe when collected or when it leaves a treatment plant. However, substandard water distribution systems, intermittent water pressure often lead to the introduction of faecal contamination resulting in microbiologically contaminated water at the consumer’s tap or collection point, even though the water may have been obtained from a high quality, protected and centrally treated source.

In addition water can become contaminated by unsafe consumer storage and handling practices at the household level. This can happen when:

- Water has to be collected from a communal source for domestic use. Many of the world's people continue to obtain their water on a daily or other frequent basis from any available source and either carry it or otherwise have it delivered to the home for personal use.
- The municipal water supply is intermittent and water has to be stored for significant periods in the home. Typically, this water is stored in containers of various designs, materials and sizes ranging from small earthenware or other vessels to relatively large underground or overhead tanks. Often, the water is not protected from subsequent contamination during use. Factors contributing to this problem are:
  - Inadequate protection (open, uncovered or poorly covered) of water collection and storage containers
  - Use of unhygienic methods to dispense water from household storage containers, including faecally contaminated hands and dippers
  - Lack of protection against contamination introduced by vectors (flies, cockroaches, rodents, etc.)
  - Inadequate cleaning of storage tanks to prevent biofilm formation and accumulation of sediments.

Studies which assess the extent and causes of microbiological contamination of household drinking water between source and point-of-use are reviewed by Sobsey [3] and Wright et al. [4].

In 2002, the UN Millennium Development Goals (MDGs) firmly established the issues of “water and sanitation” on the global agenda. However, there is widespread consensus that one of the past mistakes in tackling infectious disease, has been to give priority to water over sanitation and to sanitation over hygiene [5]. In reality it is keeping faecal matter away from hands, food and water, etc that reduces the burden of infectious disease (ID). The neglect of hygiene goes a long way to explaining why community programmes to provide water supply and sanitation have often not brought the expected health benefits. Where previously the emphasis has been on providing access to “water for all”, increasingly it is being argued that one of the keys to reducing the burden of water-borne ID is to incorporate promotion of hygiene practices such as handwashing and household water treatment and safe storage into programmes for provision of improved water supply and sanitation. It is suggested that a cost effective way to achieve “safe water for all” is through hygiene promotion,

whereby communities take responsibility for treatment and safe storage of water in their own homes. Given the present status of water quality of the municipal supplies in developing countries, it could be argued that for the underserved urban population, point-of-use treatment of water at the household level could provide more effective and prompt health benefits to the community.

Drinking water quality is a problem, in developing and developed country situations, most particularly in Eastern European countries, but also in North America and elsewhere. In European countries and North America, there are now fewer risks of epidemics related to drinking water contaminated with highly virulent pathogens such as cholera and typhoid or viral hepatitis, but it is worrying that there are still numerous instances of water-borne disease resulting from contaminated drinking water. Payment et al. [6,7] estimate that, even in developed countries, as much as 15-30% of community gastroenteritis is attributable to municipal drinking water, despite state of the art technology for water treatment, and no other evidence of unacceptable microbial contamination levels.

Although global investors such as World Bank and USAID focus on water, sanitation and hygiene promotion for the poorest communities, it is important to remember that hygiene promotion is a global concern affecting both developed and developing country situations. In the developed world, current concerns focus largely on foodborne, water-borne, and other infectious intestinal diseases, which remain at unacceptably high levels. They also relate to antibiotic resistance which compromises treatment of bacterial diseases, to viral agents which are not treatable by antibiotics, and to new agents (e.g SARS, avian flu) and their potential for rapid global spread. Pathogens are also now increasingly implicated as co-factors in cancers and some degenerative diseases.

Of particular concern, both in developed and developing countries, is the rising proportion of the population who are more vulnerable to infection [8, 9]. At risk groups cared for at home include not only the newborn whose resistance to infection is not fully developed, but also the rapidly increasing elderly population whose immune system is declining. It also includes patients recently discharged from hospital and family members who are immune-compromised resulting from treatment with immunosuppressive drugs. All of these groups, together with those who carry HIV/AIDS, are increasingly cared for at home by a home carer who may be a family member. A survey of 3 European countries, Germany, Netherlands and UK, suggests that up to 1 in 5 of the population in the home belongs to an “at risk” group. Immunocompromised patients are at risk of acquiring a wide range of potentially pathogenic micro-organisms from drinking water. This includes environmental strains such as pseudomonads and atypical mycobacteria. Ensuring that homecare is not accompanied by increased ID risks is key, otherwise cost savings gained by the trend towards shorter hospital stays are likely to be overridden by additional costs of re-hospitalisation. Colford et al. [10] recently conducted an intervention trial of home water treatment in San Francisco, California, from April 2000 to May 2001. Fifty HIV-positive patients were randomised to externally identical active (N = 24) or sham (N = 26) treatment devices. The active device contained a filter and UV light; the sham provided no treatment. There were 31 episodes of HCGI during 1,797 person-days in the sham group and 16 episodes during 1,478 person-days in the active group. The adjusted relative risk was 3.34 (95% CI: 0.99-11.21) times greater in those with the sham device. The authors also reported on an earlier trial which suggested an association (OR 6.76) between tap water and cryptosporidiosis among HIV positive persons.

As described more fully below, there is now conclusive evidence that simple, low-cost interventions at household level can significantly improve the microbial quality of household stored water. A range of different physical and chemical treatment methods, together with systems for safe water collection and storage, have been developed. Some have been tested in the laboratory and in field trials to evaluate their ability to produce drinking water of acceptable microbiological quality and to maintain this quality during storage and use. Some have also been evaluated in the field for their ability to reduce diarrhoeal and other water-borne diseases.

This report is a review of the ID risks related to water, with particular reference to “point-of-use” water in the household setting, and the health impacts of promoting water treatment and safe storage at the point-of-use. It reviews the various methods and systems for household water collection, treatment and storage, and critically assesses data on the ability of these systems, alone or in combination, to provide water of acceptable microbiological quality. Some of the formative research which is being carried out to better understand how to achieve behaviour change in the community with respect

to water handling, treatment and storage in the home, is also described. While toxic chemicals in drinking water are an important public health concern, the focus of this report is on strategies and systems for protection and improvement of the microbiological quality of household water and prevention and control of water-borne microbial diseases. However, some of the technologies that reduce water-borne microbes also reduce certain toxic chemicals, such as arsenic. Household water treatment and safe storage has also been recently reviewed by Mintz et al. [11] and Sobsey [3]. Further details on chemical contaminants in drinking water can be obtained from the WHO Guidelines for drinking-water quality. 3<sup>rd</sup> Edition, Vol.1 - Recommendations. 2004: [http://www.who.int/water\\_sanitation\\_health/dwq/gdwq3/en/print.html](http://www.who.int/water_sanitation_health/dwq/gdwq3/en/print.html).

Although this review focuses on the provision of “safe drinking water for all”, it is well accepted that this depends not only on the quality of the water source available to the community, but also on their hygiene practices (e.g. practices which keep faecal matter from re-entering water via hands etc). This in turn means that facilities for disposal of faeces and for handwashing are also likely to impact on household water quality: for homes where there is access to a latrine and a convenient source of water for handwashing, the risks of contamination of household water are lower than in homes where these facilities are not available. This means that sanitation and hygiene, as well as the quality of the community water source, are relevant to the problem of achieving and maintaining household water quality.

## 2. HOUSEHOLD WATER AND WATER-BORNE DISEASE: SITUATIONAL ANALYSIS

The vast majority of diarrhoeal disease in the world (88%) is attributable to unsafe water, sanitation and hygiene [12]. Although it is accepted that diarrhoeal disease is a huge problem worldwide, obtaining reliable data on the extent of diarrhoeal illness and the extent to which this illness is water-borne disease, is difficult. A recent estimate [13] suggested that residents of developed countries experience 1 episode of diarrhoeal illness every 2 years, whilst residents of developing nations may experience between 5 and 20 episodes per year. With a current global population 6.5 billion individuals this adds up to 5-60 billion gastroenteritis cases annually.

Diarrhoeal diseases, because they limit normal consumption of food and adsorption of nutrients can also cause malnutrition, leading to impaired physical growth and cognitive development, reduced resistance to infection and potentially long-term gastrointestinal disorders.

From a study of the global burden of diarrhoeal disease, as estimated from data published between 1992 and 2000, Kosek et al. [14] showed that, although mortality from diarrhoeal disease has declined, there is little change in morbidity rates compared with previously described incidences. They reported that, for children under 5 year of age in developing

**Table 1. Disease burden from diarrhoeal disease: total deaths and DALYs for 2000**

	Global	Africa	Americas	South East Asia	Europe	E. Mediterranean	W. Pacific
% of total deaths due to diarrhoeal diseases	3.2%	6.6%	0.9%	4.1%	0.2%	6.2%	1.2%
% of total DALYs lost due to diarrhoeal diseases	4.2%	6.4%	1.6%	4.8%	0.49%	6.2%	2.5%