Centre for Affordable Water and Sanitation Technology

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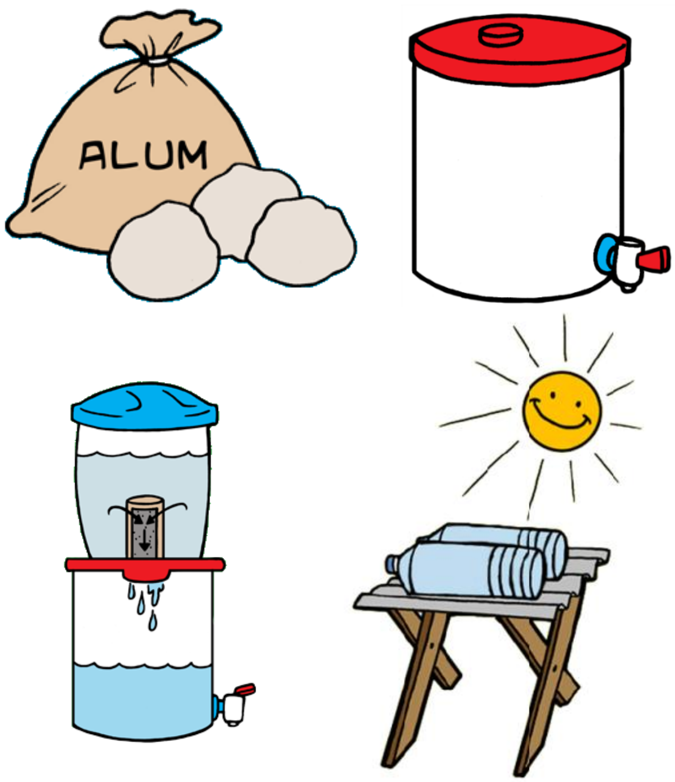
Manual

Introduction to Household Water Treatment and Safe Storage



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CAWST is a Canadian non-profit organization focused on the principle that clean water changes lives. Safe water and basic sanitation are fundamentals necessary to empower the world's poorest people and break the cycle of poverty. CAWST believes that the place to start is to teach people the skills they need to have safe water in their homes.

CAWST transfers knowledge and skills to organizations and individuals in developing countries through education, training and consulting services. This ever expanding network can motivate individual households to take action to meet their own water and sanitation needs.

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Acronyms

CAWST	Centre for Affordable Water and Sanitation Technology
CBO	community based organization
DALY	disability-adjusted life years
HIV/AIDS	human immunodeficiency virus/acquired immunodeficiency syndrome
HWT	household water treatment
HWTS	household water treatment and safe storage
MDG	Millennium Development Goal
NGO	non-governmental organization
PAC	polyaluminium chloride
POU	point of use
SODIS	solar water disinfection
TDS	total dissolved solids
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNICEF	United Nations Children’s Fund
UV	ultraviolet
WHO	World Health Organization
JMP	Joint Monitoring Programme for Water Supply and Sanitation

Abbreviations

L	litre
mg	milligram

1 The Case for Managing Water in the Home

Household water treatment and safe storage (HWTS) is an essential component of a global strategy to provide safe water to the 884 million people who currently live without it and the millions more who suffer from contamination of their improved water sources.

Health can be compromised when pathogens (microorganisms that cause disease) contaminate drinking water. This contamination can occur at the source or within a piped distribution system. Even unhygienic handling of water during transport or within the home can contaminate previously safe water. For these reasons, many of those who have access to improved water supplies through piped connections, protected wells or other improved sources are still, in fact, drinking contaminated water (WHO, 2007).

At any given time close to half the people in the developing world are suffering from one or more of the main diseases associated with inadequate provision of water and sanitation, such as diarrhea, guinea worm, trachoma and schistosomiasis (UNDP, 2006). Diarrhea occupies a leading position among infectious diseases as a cause of death and illness – killing more people than tuberculosis or malaria each year.

Evidence from both research and implementation experience suggests that HWTS:

- Dramatically improves microbiological water quality
- Significantly reduces diarrheal disease
- Is among the most effective water, sanitation and health interventions
- Is highly cost-effective
- Can be quickly implemented and taken up by vulnerable populations

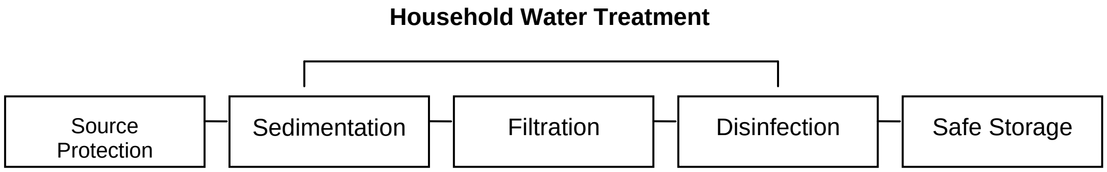
This Sectiondefines household water treatment and safe storage and presents the evidence of its effectiveness. It also discusses the circumstances under which HWTS is most applicable and how it contributes to the Millennium Development Goals (MDG).

1.1 What is Household Water Treatment and Safe Storage?

Household-level approaches to drinking water treatment and safe storage are also commonly referred to as managing the water at the point of use (POU). The family members gather water, preferably from an improved source, and then treat and store it in their home.

Using the **multi-barrier approach** is the best way to reduce the risk of drinking unsafe water. Each step in the process, from source protection, to water treatment and safe storage, provides an incremental health risk reduction. Both community and household systems follow the same basic water treatment process: sedimentation, filtration and disinfection. The main difference is the scale of the systems that are used by individuals and communities.

Figure 1.1: Multi Barrier Approach to Safe Water



Household water treatment technologies that will be discussed further in Section 2 include: sedimentation (settling, coagulation), filtration (straining through a cloth, biosand filters, ceramic filters, membrane filters) and disinfection (chlorine, solar, ultraviolet, pasteurization, boiling).

The money and resources needed to construct, operate and maintain a community water treatment system are not always available in many countries. To reach the MDG target for safe water using community systems would necessitate an investment of tens of billions of dollars each year to connect households (Hutton and Bartram, 2008).

The main advantage of household water treatment and safe storage (HWTS) is that it can be adopted immediately in the homes of poor families to improve their drinking water quality. It is proven to be an effective way to prevent diseases from unsafe water. HWTS lets people take responsibility of their own water security by treating and safely storing water themselves.

HWTS is also less expensive, more appropriate for treating smaller volumes of water, and provides an entry or starting point for hygiene and sanitation education. There are a wide range of simple HWTS technologies that provide options based on what is most suitable and affordable for the individual household. By adopting HWTS, households are empowered to take charge of their own water quality.

Some limitations of HWTS are that it requires families to be knowledgeable about its operation and maintenance, and they need to be motivated to use the technology correctly. As well, most HWTS technologies are designed to remove pathogens rather than chemicals. There are household-scale technologies that can remove substances such as iron, manganese, undesirable odors, and turbidity, and in many cases these need to be reduced first anyway before pathogen-removal technologies can work.

An increasing amount of research suggests household water treatment and safe storage (HWTS):

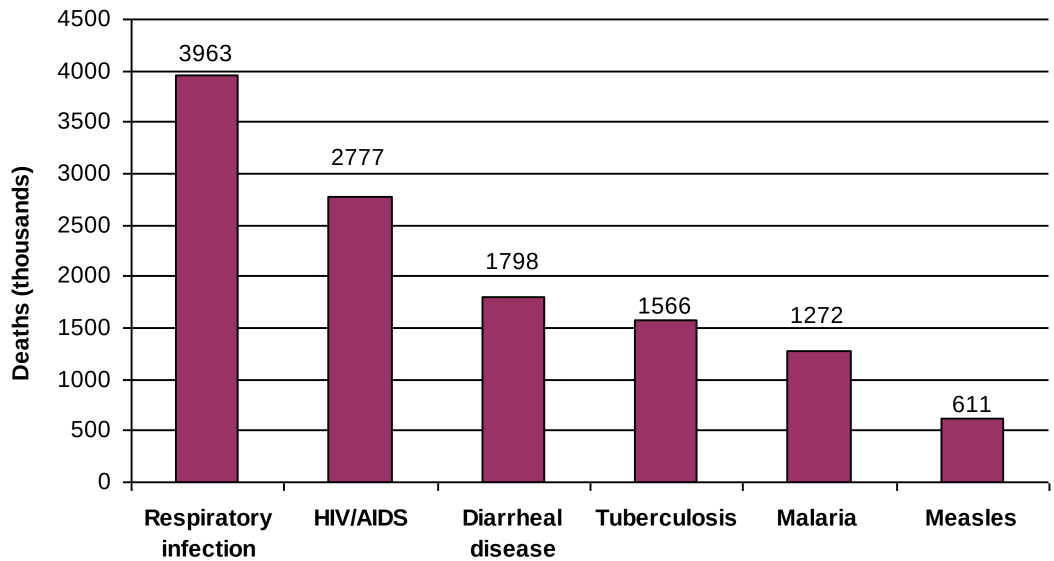
- Dramatically improves microbial water quality
- Significantly reduces diarrhea
- Is among the most effective of water, sanitation and health interventions
- Is highly cost-effective
- Can be quickly implemented and taken up by vulnerable populations

(WHO, 2007)

1.2 Preventing Diarrhea

Diarrhea occupies a leading position among diseases as a cause of death and illness, killing 1.8 million and causing approximately 4 billion cases of illness annually. 90% of diarrheal deaths are borne by children under five, mostly in developing countries (WHO, 2004).

Figure 1.2.1: Leading Causes of Deaths from Infectious Diseases



(WHO, 2004)

For every child that dies, countless others suffer from poor health and lost educational opportunities leading to poverty in adulthood. Every episode of diarrhea reduces their calorie and nutrient uptake, setting back growth and development. The UNDP (2006) estimates that parasitic infections retards the learning potential for more than 150 million children and water-related illness causes the loss of 443 million school days each year.

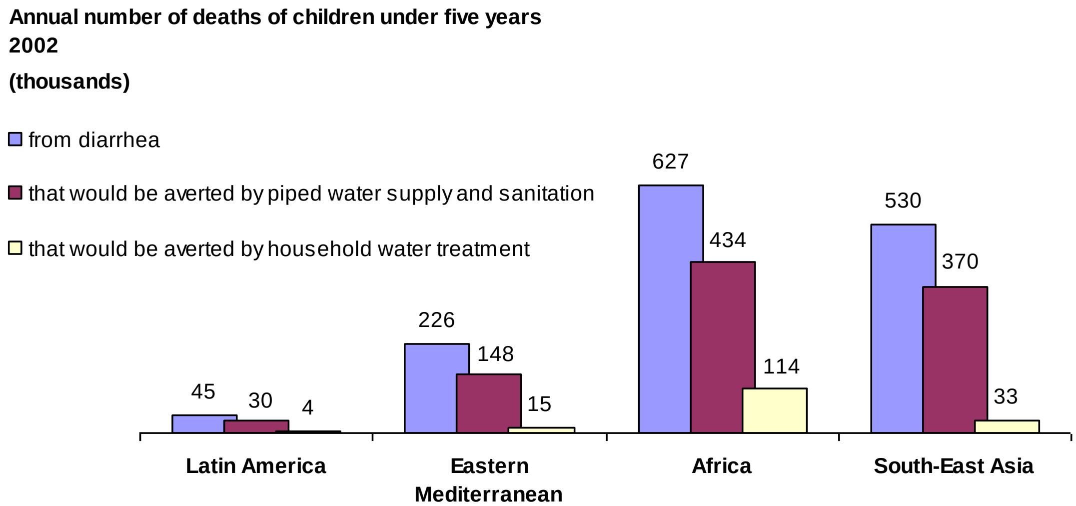
Having safe drinking water is essential in breaking the cycle of disadvantage and poverty by improving health, ability go to school, and strength to work. The WHO estimates that 94% of diarrheal cases are preventable through modifications to the environment, including interventions to increase the availability of clean water, and to improve sanitation and hygiene (Prüss-Üstün and Corvalan, 2006).

In addition, Fewtrell et al. (2005) conducted a systematic review and concluded that diarrheal episodes are reduced by 25% through improving water supply (e.g. increasing access to more water can enable better hygiene), 32% by improving sanitation, 45% through hand washing, and 39% via household water treatment and safe storage.

A more recent Cochrane review of controlled trials confirmed the key role that POU quality interventions at the household level could play in reducing diarrhea episodes. The authors reported a reduction in diarrheal disease by roughly half, on average, with some studies resulting in disease reductions of 70% or more (Clasen et al, 2006).

"There is increasing recognition that simple household-based approaches to ensuring drinking water safety should be incorporated into country strategies to reduce waterborne disease."
(WHO, 2007)

Figure 1.2.2: Preventing Diarrhea



(Adapted from WHO, 2004)

1.3 Reaching the Vulnerable

Many of these people are among the most vulnerable and those hardest to reach: families living in remote rural areas and urban slums, families displaced by war and famine, and families living in the poverty-disease trap, for whom improved drinking water could offer a way out.

For millions of poor households, daily water use can vary temporally and seasonally, due to changes in water quality and availability. Low pressure and irregularity of supply in a piped network mean that households in urban slums seek a back up source – such as a shallow well. In rural villages, people might draw water from a protected well or standpipe for part of the year but then be forced to fetch water from a river during the dry season. The use of water sources constantly adjusts to take into account factors ranging from water quality, proximity, price and reliability (UNDP, 2006).

Household water treatment allows people to use a wide array of water sources which may be more convenient and accessible, even though they are of poor quality, such as rivers, ponds, streams and canals. Treating water in the home allows people to adapt to the temporal and seasonal variations in their water supply. In some cases, HWTS may be the only option for remote and isolated homes to have safe water.

Even if water is drawn from an improved source, it may be subject to fecal contamination during collection, storage, and use in the home. Contamination of water between source and point-of-use is widespread and often significant, particularly in urban areas that have safe water sources to begin with (Wright et al., 2004). A WHO 2007 assessment found that in one country more than half of the household samples showed post-source contamination. The research implies that treating and storing drinking water in the home just before it is consumed will improve its quality. Water treatment also needs to be accompanied by safe storage.

To reach the vulnerable, drinking water provision must meet the criteria for the poor, namely being simple, acceptable, affordable and sustainable – all of which household water treatment is able to do.

A variety of simple household treatment technologies and methods are available. Many have been tested and successfully implemented in a variety of settings and for a diverse range of populations. Many of these technologies are convenient and easy to use, minimizing the need for significant behaviour change in people's daily routines and habits.

Field studies show that taste and other aesthetic properties of water are important factors for its acceptability (WHO, 2007). Every person, regardless of being poor or wealthy, wants their water to look, taste and smell good. And in this regard, household water treatment provides a range of options for people to immediately and consistently improve the aesthetics of their water, while at the same time making it safe to drink.

Affordabilityhas a significant influence on the use of water and selection of water sources. Households with the lowest levels of access to safe water supply frequently pay more for their water than do those connected to a piped water system. The high cost of water may force households to use alternative sources of water of poorer quality that pose a greater risk to their health (WHO, 2005). Treating water at home can therefore be a low cost option for these households to provide safe drinking water, even if they are using contaminated sources.

In addition to these cost savings, there are health costs that can be averted by both individuals and governments from household water treatment. Direct cost offsets more than cover the costs of implementing most household water treatment interventions. This means that governments, who are chiefly incurring such costs, would reduce their overall outlays by investing in household water treatment rather than in the treatment of cases of diarrheal disease (Clasen and Haller, 2008).

At the global level, a WHO report suggests that household water interventions can lead to a benefit of up to US$60 for every US$1 invested (Hutton and Haller, 2004).

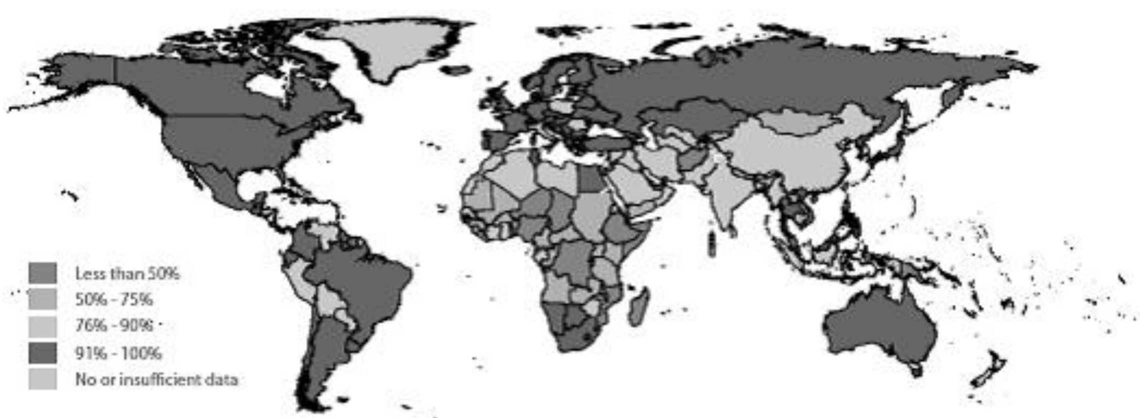
Reaching the vulnerable, however, implies much more than developing simple and affordable HWTS products. These interventions are most effective in preventing disease only if they are used correctly and consistently. Identifying and implementing successful approaches to increase the uptake of HWTS on a sustainable basis is essential for this intervention to achieve widespread and long-term success (WHO, 2007).

1.4 Contributing to the Millennium Development Goals

MDG 7, Target 10, calls for reducing by half the proportion of people without sustainable access to safe drinking water by 2015. Reaching this target implies tackling both the quantity (access) and quality (safety) dimensions of drinking water. Progress towards meeting the target is tracked by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP).

The WHO/UNICEF JMP estimates that globally 884 million people do not use improved sources of drinking water. However, the percentage of people worldwide who have access to an improved water supply has risen from 77% in 1990 to 87% in 2008, an increase of 1.8 billion people. All regions of the world have succeeded in reducing the proportion of the population using unimproved sources for drinking water. At the current rate of progress, the world is expected to exceed the MDG safe drinking water target. Even so, 672 million people will still lack access to improved drinking water sources in 2015, especially in rural areas (WHO/UNICEF JMP, 2010).

Figure 1.4: Worldwide Drinking Water Coverage, 2006



(WHO/UNICEF JMP, 2008)

It is important to distinguish between “improved” and “safe” drinking water. Safe water does not have any detectable fecal contamination in any 100 ml sample and meets the WHO Guidelines for Drinking Water Quality (2006). Improved water, on the other hand, is defined by WHO/UNICEF JMP (2010) as a drinking water source that by nature of its construction adequately protects the source from outside contamination, in particular fecal matter. Examples of improved water sources are listed in the following table.

It is assumed that certain sources are safer than others, but **not all improved sources in actual fact provide drinking water that is safe.** Many people who have access to improved water are still, in fact, drinking contaminated water (WHO, 2007). This contamination can occur at the source or within a piped distribution system. Even unhygienic handling of water during transport or within the home can contaminate previously safe water.

Table 1.4.1: What Are Improved Drinking Water Sources?

Improved Sources	Unimproved Sources
• Piped water into dwelling, yard or plot • Public tap or standpipe • Tubewell or borehole • Protected dug well • Protected spring • Rainwater collection	• Unprotected dug well • Unprotected spring • Vendor-provided water • Tanker truck water • Surface water (e.g. river, stream, dam, lake, pond, canal) • Bottled water[1]

[1] Bottled water is a source of improved drinking water only when another improved source is also used for cooking and personal hygiene; where this information is not available, bottled water is classified on a case by case basis.
[2] Shared or public facilities are not considered to be improved. (WHO/UNICEF, 2010)

The MDG target for safe water is indicated by the proportion of households reporting the use of "improved" water supplies. The statistics about the number of people who drink unsafe water in the world today, and consequently the progress in achieving the MDG targets, are approximate. The WHO/UNICEF JMP household surveys and censuses do not provide specific information on the quality of water. Assessing drinking water quality through national health and demographic surveys is considered to be too costly and time consuming to be practical. The WHO/UNICEF JMP relies, instead on proxy indicators such as "improved" water sources to indicate water quality.

It is also worth noting that the household surveys and censuses on which the JMP relies also measure "use" and not "access". The proportion of the population that uses an improved drinking water source is a proxy indicator for access to improved drinking water. Access involves many additional criteria other than use, such as time taken or distance to collect water. Some argue that the time needed to collect water should be considered when determining whether a source is "improved'' or not because it is a factor in use (WHO/UNICEF, 2008).

Household-level interventions can make an immediate contribution to the safety component of this target, and would significantly contribute to meeting the MDGs in situations where access to water supplies is secure, but household water quality is not assured (WHO, 2007).

The two main household surveys used by the JMP now include questions on household water treatment. The purpose of the questions is to know whether drinking water is treated within the household and, if so, what type of treatment is used. The questions provide an indication of the drinking water quality used in the household. Results from recent surveys conducted in 35 countries show that a variety of household treatment methods are used. Additional evidence can be obtained and a trend analysis carried out as more surveys become available over time (WHO/UNICEF, 2008).

As shown in the following table, safe drinking water is a complex issue that is interlinked to achieving other targets set under the Millennium Development Goals, ranging from the reduction of extreme poverty to gender equality to health and education. A lack of progress in achieving the safe drinking water target will hold back improvements across the board.

Table 1.4.2: Safe Water and the Millennium Development Goals

Millennium Development Goal	Importance of Safe Drinking Water
Goal 1 Eradicate extreme poverty and hunger	• The absence of clean water is a major cause of poverty and malnutrition • Diseases and productivity losses linked to water and sanitation in developing countries amount to 2% of GDP • The poorest households pay as much as 10 times more for water as wealthy households
Goal 2 Achieve universal primary education	• Collecting water and carrying it over long distances keeps millions of girls out of school, consigning them to a future of illiteracy and restricted choice • Water-related diseases such as diarrhea and parasitic infections cost 443 million school days each year and diminish learning potential • The absence of adequate sanitation and water in schools is a major reason that girls drop out • Parasitic infection transmitted through water and poor sanitation retards learning potential for more than 150 million children
Goal 3 Promote gender equality and empower women	• Women bear the brunt of responsibility for collecting water which is a major source of time poverty • The time women spend caring for children made ill by waterborne diseases diminishes their opportunity to engage in productive work
Goal 4 Reduce child mortality	• Unsafe water accounts for the vast majority of the 1.8 million child deaths each year from diarrhea, making it the second largest cause of child mortality • Access to clean water can reduce the risk of a child dying by as much as 50%
Goal 5 Improve maternal health	• Provision of water reduces the incidence of diseases and afflictions—such as anaemia, vitamin deficiency and trachoma—that undermine maternal health and contribute to maternal mortality
Goal 6 Combat HIV/ AIDS, malaria and other diseases	• Inadequate access to water restricts opportunities for hygiene and exposes people with HIV/AIDS to increased risks of infection • HIV-infected mothers require clean water to make formula milk

(Adapted from UNDP, 2006)

1.5 Summary of Key Messages

- Household water treatment and safe storage (HWTS) is an essential component of a global strategy to provide safe water to the 884 million people who currently live without it and the millions more who suffer from contamination of their improved water sources.

- Research and implementation experience suggests that HWTS:
  - Dramatically improves microbiological water quality
  - Significantly reduces diarrheal disease
  - Is among the most effective of water, sanitation and health interventions
  - Is highly cost-effective
  - Can be quickly implemented and taken up by vulnerable populations

- The Millennium Development Goals (MDGs) commits to reduce by half the proportion of people without sustainable access to safe drinking water by 2015. While progress is being made, current trends will still leave hundreds of millions without access to improved water sources by the target date.

- There is a difference between “improved” and “safe” drinking water. Not all improved sources in actual fact provide drinking water that is safe. Many people who have access to improved water are still, in fact, drinking contaminated water.

- Providing safe, reliable, piped-in water to every household is an essential goal. However, the resources needed to construct, operate and maintain a community water supply system are not always available. HWTS can provide the health benefits of safe drinking water while progress is being made in improving water supply infrastructure.

- HWTS should be targeted to the most vulnerable populations, including those with:
  - Underdeveloped or impaired immune systems – children under five, the elderly, people living with HIV/AIDS
  - High exposure to contaminated water – families living in remote rural areas and urban slums or those displaced by war and famine

- HWTS is highly cost effective compared to conventional water supply interventions. In addition to cost savings, there are health costs that can be avoided by both individuals and governments through the use of HWTS. When health care savings are included, governments could reduce their overall expenditures by investing in HWTS rather than treating diarrheal disease.

- To realize the full potential of HWTS, it is essential that technologies perform well and are affordable. As well, they need to reach the most vulnerable populations at scale (coverage) and these populations need to use HWTS correctly and consistently over the long-term (adoption).

2 Water Contamination and HWTS Options

The first priority is to ensure that drinking water is free of pathogens that cause disease, even though there are several chemical and physical contaminants that may also be harmful to humans. Household water treatment is primarily focused on removing pathogens– the biggest public health threat.

Using the multi-barrier approach in the home is the best way to reduce the risk of drinking unsafe water. Each step in the process, from source protection, to water treatment and safe storage, helps reduce health risks incrementally. Both community and household systems follow the same basic water treatment process: sedimentation, filtration and disinfection.

More often than not, people focus on a particular HWTS option rather than considering the water treatment process as a whole. While individual technologies can incrementally improve drinking water quality, the multi-barrier approach is essential in providing the best water quality possible.

Many people simply want to be told the “best” technology for household water treatment. Unfortunately, there is no easy formula that will answer this question since there are many factors to consider, including treatment effectiveness, appropriateness, acceptability, affordability and implementation requirements. Each of these criteria for selection is described further in this Section.

To select the most appropriate HWTS option, implementers need to know about water quality, as well as how different HWTS options work and their effectiveness against different contaminants. This Section presents the different biological, chemical and physical contaminants commonly found in unsafe water. As well, detailed fact sheets that summarize field experience and research evidence on the operation and treatment efficiency of various HWTS options are provided in Appendix B.

2.1 How Much Water Do People Need?

There are basic things that we all need water for: drinking, personal hygiene, cooking, laundry and cleaning. There is no rule about how much water is enough for each person. On average, people need to drink between 2 to 4.5 litres of water a day just to survive; the higher number being for people who do manual work in hot climates.Women who are breast feeding and doing even moderate physical activity should have about 5.5 litres of drinking water each day, and may even require up to 7.5 litres if they are working in hot climates (WHO, 2003).

In total, every person should have at least 20 litres of safe water each day to meet their basic needs for drinking and personal hygiene. Below this level people are constrained in their ability to maintain their physical wellbeing and the dignity that comes with being clean. 20 litres is the minimum requirement for respecting the human right to water – and a minimum target for governments. Factoring in bathing and laundry needs would raise the personal threshold to about 50 litres a day (UNDP, 2006).

The 884 million or so people in the world who live more than 1 kilometre from a water source often use less than 5 litres a day of unsafe water (UNDP, 2006).

Every person should have at least 20 litres of water each day to meet their basic needs.

2.2 What is Safe Drinking Water?

As water moves through the water cycle, it naturally picks up many things along its path. Water quality will naturally change from place to place, with the seasons, and with the kinds of rocks and soil which it moves through.

Water can also be polluted by human activities, such as open defecation, inadequate wastewater management, dumping garbage, poor agricultural practices (e.g. use of fertilizers or pesticides near water sources), and chemical spills at industrial sites. In developing countries, 75% of all industrial waste and up to 95% of sewage is discharged into surface waters without any treatment (Carty, 1991).

Even though water may be clear, it does not necessarily mean that it is safe for us to drink. It is important to judge the safety of water by taking the following three qualities into consideration:

1. **Biological** – bacteria, viruses, protozoa, and worms
2. **Chemical** – minerals, metals and chemicals
3. **Physical** – temperature, colour, smell, taste and turbidity

Different household water treatment technologies remove different types of contaminants. Understanding the local water quality and contaminants will influence the selection of appropriate household water treatment options. The focus of household water treatment is on removing biological pathogens. However some household water treatment options can also remove chemicals and improve physical qualities of drinking water.

Microbiology versus Epidemiology

Microbiology – The study of organisms that are too small to be seen with the naked eye, such as bacteria, viruses and protozoa.

Epidemiology – The study of the causes, distribution, and control of disease in populations. It focuses on groups rather than individuals. Epidemiology developed out of the search for causes of human disease in the 19th century. One of its main purposes is to identify populations at high risk for a given disease, so that the cause may be identified and preventive measures can be taken. Epidemiologists use their understanding of microbiology when they are studying diseases.

2.2.1 Biological Quality

Water naturally contains many living things. Most are harmless or even beneficial, butothers can cause illness. Living things that cause disease are also known as **pathogens**. They are sometimes called other names, such as microorganisms, microbes or bugs, depending on the local language and country.

There are four different categories of pathogens: **bacteria, viruses, protozoa and helminths**. Their microbiology and epidemiology will be discussed in the following sections.

Table 2.2.1: Water-Related Diseases

Type	**How People Get Sick**	**Possible Diseases**	**How to Prevent Illness**
Water-borne	Drinking water with pathogens	Diarrhea, cholera, typhoid, shigellosis, hepatitis A and E	Improve drinking water quality by removing or killing pathogens.
Water-washed	Pathogens touch the skin or eye	Trachoma, scabies	Provide enough water needed for basic hygiene. Improve basic hygiene practices.
Water-based	Pathogens go through the skin	Schistosomiasis, guinea worm	Do not bath or swim in water that is known to be contaminated. Improve water quality by removing or killing source of pathogens.
Water-insect vector	Pathogens are passed on by insects that breed or live in water, such as mosquitos	Malaria, dengue, yellow fever, filariasis, river blindness, sleeping sickness	Prevent insects from breeding in water. Use pesticides to control insects. Prevent insects from biting by using bed nets and wearing long clothes.

2.2.1.1 Pathogenic Bacteria

Bacteria are very small single-celled organisms that are present everywhere and are the most common living things found in human and animal feces. Drinking water that contains feces is the main cause of water-related diseases.

The most common water-related diseases caused by pathogenic bacteria have **diarrhea** as a major symptom, including **cholera, shigellosis** (also known as bacillary dysentery) and **typhoid**. About 1.8 million people die every year from diarrheal diseases, about 90% are children under the age of five (WHO/UNICEF, 2008).

Cholera is no longer an issue in countries that have basic water, hygiene and sanitation standards. However, it is still a problem where access to safe drinking water and adequate sanitation practices are limited. Almost every developing country in the world has cholera outbreaks or the threat of a cholera epidemic (WHO, 2007).

Typhoid is also common in places that do not have safe drinking water and proper sanitation. There are an estimated 17 million cases of typhoid worldwide resulting in 600,000 deaths (WHO, 2007).

2.2.1.2 Pathogenic Viruses

Viruses are the smallest of microorganisms. Viruses are unable to reproduce by themselves and must use another living thing to make more viruses. It is difficult and expensive to study viruses so less is known about them than other pathogens.

Some pathogenic viruses that are found in water can cause **hepatitis A** and **hepatitis E**. Hepatitis A is common throughout the developing world with 1.5 million people getting sick every year (WHO, 2004).

There are other viruses that are passed on by certain mosquitoes, which breed or live in water. For example, they can spread viral diseases such as **Dengue Fever**, **Japanese Encephalitis** and **West Nile Fever**. Most of these diseases occur in tropical places where there is standing water for mosquitoes to breed.

Water cannot spread the human immunodeficiency virus (HIV) and other viruses that cause the common cold. Water does not provide the environment needed for these viruses to survive.

2.2.1.3 Pathogenic Protozoa

Protozoa are larger than bacteria and viruses. Some protozoa are parasites that need a living host to survive. They weaken the host by using up their food and energy, damage internal organs, or cause immune reactions.

Amoeba, cryptosporidium and giardia are some of the pathogenic protozoa that are found in water, mainly in tropical countries. Amoebic dysentery is the most common illness and it affects around 500 million people each year.

Some protozoa like cryptosporidium are able to form cysts which let them stay alive without a host and survive in harsh environments. The protozoa cysts become active once the environmental conditions are optimal for their development.

Malaria is another protozoa that is passed on by mosquitoes. About 1.3 million people die each year of malaria, 90% are children under the age of five. There are 396 million cases of malaria every year, most of them happening in sub-Saharan Africa (WHO, 2004).

2.2.1.4 Pathogenic Helminths

Helminths are worms. Pathogenic helminths are generally passed through human and animal feces. Some spend part of their life in hosts that live in water before being passed on to people through the skin. For others, the infection route is by ingestion or by vectors such as mosquitoes.Many can live for several years in our bodies. The WHO estimates that 133 million people suffer from worms and about 9,400 people die each year (WHO, 2000).

Common types of pathogenic helminths that cause illness in developing countries are **round worms**, **pin worms**, **hook worms** and **guinea worms**. **Schistosomiasis**, also known as bilharzia, is caused by the trematode flatworm. This disease affects about 200 million people worldwide and it causes severe symptoms. Schistosomiasis is often associated with large water resource projects, such as the construction of dams and irrigation canals, which provide an ideal breeding ground for the worm.

2.2.1.5 Infective Dose

The minimum number of pathogens needed to make somebody sick is called the infective dose. The presence of a pathogen in water does not always mean that it will make someone sick. The infective dose is different depending on the type of pathogen. Generally, bacteria have a higher infective dose than viruses, protozoa and worms. This means that with some bacteria, larger numbers need to be ingested to cause illness relative to other pathogens.

Infants, young children, the sick and elderly generally have a lower infective dose than an average adult. This means that they are most at risk and more likely to die from water related diseases. Over 90% of deaths from diarrheal diseases in developing countries occur in children under 5 years old (WHO, 2007).

Table 2.2.2: Dose of Microorganisms Needed to Produce Infection in Humans ID50[1]

Disease	Pathogen	Type of Pathogen	Disease-Producing Dose
Shigellosis	*Shigella spp.*	Bacteria	10 – 1,000
Typhoid fever	*Salmonella typhi*	Bacteria	100,000
Cholera	*Vibrio cholerae*	Bacteria	100,000,000

(Adapted from Ryan et al., 2003)

2.2.1.6 Indicator Organisms

Testing for every pathogen in water would be time consuming, complicated and expensive. Alternatively, the presence or absence of certain bacterial indicator organisms is used to determine the safety of the water, especially since there are no routine testing techniques available for viruses, protozoa and helminths. Bacterial indicator tests have been found to be cheaper, easier to perform and yield faster results, compared to direct pathogen testing.

There is no universal indicator to ensure that water is pathogen free, but there are several types of indicators, each with certain characteristics. Coliform bacteria are most commonly used as indicators because they exist in high numbers making them easier to detect in a water sample.

The WHO Guidelines for Drinking Water Quality (2006) recommend using *Escherichia coli* (also commonly known as *E. coli*) as the indicator organism of choice for fecal contamination. Thermotolerant coliforms (TTC) can be used as an alternative to the test for *E. coli* in many circumstances. According to the WHO Guidelines, water intended for human consumption should contain no indicator organisms. See Section 3.4 for further information about the WHO Guidelines for Drinking Water Quality.

[1]Infective dose is the dose necessary to cause disease in 50% of the exposed individuals, hence ID50. These numbers should be viewed with caution and cannot be directly used to assess risk since they are often extrapolated from epidemiologic investigations, best estimates based on a limited data base from outbreaks, worst case estimates, or other complex variables (US FDA).

2.2.2 Chemical Quality

Water may also contain chemicals which can be helpful or harmful to our health. There are different ways that chemicals get into drinking water. Some are found naturally in ground water, such as arsenic, fluoride, sulphur, calcium and magnesium. Human activities such as agriculture, industry and our daily lives can also add chemicals such as nitrogen, phosphorous and pesticides to water. Many countries are experiencing a rise in industrial activity with no strict compliance to environmental rules and regulations. As a result, water sources are increasingly becoming contaminated with industrial chemical waste.

There are many chemicals that may be in drinking water, but only a few make people sick right away. There are only a few chemicals that can lead to health problems after a single exposure, except through massive accidental contamination of a drinking water supply (WHO, 2006). The main problems are the chemicals that cause illness after drinking contaminated water over a long time.

Even though there are many chemicals that may occur in drinking water, only a few cause health effects on a large-scale. Arsenic and fluoride are usually the chemicals that are most concerning. Other chemicals, such as nitrates and nitrites may also be an issue in certain situations (WHO, 2006).

HWT technologies are generally targeted towards improving the microbiological quality and may not be able to remove all chemical contaminants from drinking water. Therefore, water quality testing carried out at the water source can help to identify an effective and appropriate HWT technology for a particular area.

While microbiological contamination is the largest public health threat, chemical contamination can be a major health concern in some cases. Water can be chemically contaminated through natural causes (e.g. arsenic, fluoride) or through human activity (e.g. nitrate, heavy metals, pesticides).

(UNICEF, 2008)

2.2.2.1 Arsenic

Arsenic can naturally occur in ground water and some surface water. It is one of the greatest chemical problems in developing countries. The WHO considers arsenic to be a high priority for screening in drinking water sources (WHO, 2006).

High levels of arsenic can be found naturally in water from deep wells in over 30 countries, including India, Nepal, Bangladesh, Indonesia, Cambodia, Vietnam, Lao PDR, Mexico, Nicaragua, El Salvador and Brazil. In south Asia alone, it is estimated that 60 to 100 million people are affected by unsafe levels of arsenic in their drinking water. Bangladesh is the most severely affected country, where 35 to 60 million of its 130 million people are exposed to arsenic-contaminated water. It is possible that arsenic may be found in other locations as more extensive testing is done.

Arsenic is poisonous, so if people drink water or eat food contaminated with arsenic for several years, they develop chronic health problems called arsenicosis. According to the UNDP (2006), the projected human costs over the next 50 years include 300,000 deaths from arsenic associated cancer and 2.5 million cases of arsenic poisoning.

There is currently no effective cure for arsenic poisoning, however the health effects may be reversed in the early stages by removing the exposure to arsenic. The only prevention is to drink water that has arsenic levels within the safe limit. There are different HWT technologies that are able to remove arsenic from drinking water to safe levels.

More information about arsenic is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.2.2 Fluoride

Fluoride is also a naturally occurring chemical that may be found in groundwater and some surface water.

High levels of fluoride can be found naturally in many areas of the world including, Africa, the Eastern Mediterranean and southern Asia. One of the best known high fluoride areas extends from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. It is possible that fluoride may be found in other locations as more extensive testing is done.

Small amounts of fluoride are generally good for people's teeth. But at higher amounts over time, it can damage people's teeth by changing colour and pitting. Eventually, fluoride can build up in people's bones and cause crippling skeletal damage. Infants and young children are most at risk from high amounts of fluoride since their bodies are still growing and developing.

There is currently no effective cure for fluoride poisoning. The only prevention is to drink water that has safe levels of fluoride. There are emerging household water treatment technologies that are able to remove fluoride from drinking water. More research is needed to find a simple, affordable and locally available technology that can be easily used by households.

More information about fluoride is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.2.3 Nitrate and Nitrite

Nitrate and nitrite are naturally occurring chemicals in the environment. Nitrate is commonly used in fertilizers and for agriculture and nitrite is used as food preservatives, especially in processed meat.

Nitrate in ground water and surface water is normally low but can reach high levels if there is leaching or runoff from agricultural fertilizers or contamination from human and animal feces (WHO, 2006). High nitrate levels are often associated with higher levels of microbiological contamination since the nitrates may have come from feces.

High levels of nitrate and nitrite in drinking water can cause methaemoglobinaemia, commonly called blue baby syndrome. This occurs in infants that are bottle fed with formula prepared with drinking water. It causes them to have difficulty breathing and their skin turns blue from a lack of oxygen. It is a serious illness that can sometimes lead to death.

More information about nitrate and nitrite is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.2.4 Iron

Iron can be naturally found in groundwater and some surface water (such as creeks, rivers and some shallow dug wells). There are areas of the world that have naturally high amounts of iron in their groundwater. Iron can also be found in drinking water that is passed through rusty steel or cast iron pipes.

Drinking water with high concentrations of iron will not make people sick. Iron, however, can turn water a red-orange colour and it may cause people to not use it and choose another, possibly contaminated, water source instead.

Iron is a nuisance – high levels can cause an objectionable colour and taste and can stain cooked food, water pipes and laundry. As well, some types of bacteria feed on iron and leave slimy red deposits that can clog water pipes.

More information about iron is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.2.5 Manganese

Manganese can be naturally found in groundwater and surface water, and it usually occurs with iron. However, human activities may also be responsible for manganese contamination in water in some areas.

People need small amounts of manganese to keep healthy and food is the major source for people. However, too little or too much manganese can cause adverse health effects.

Manganese causes similar issues as iron. High concentrations can turn water a black colour and it may cause people to not use it and choose another, possibly contaminated, water source instead. It also causes an objectionable taste, stains water pipes and laundry, and also forms coatings on water pipes. As well, some types of bacteria feed on manganese and leave black-brown deposits that can also clog pipes.

More information about manganese is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.2.6 Total Dissolved Solids

Total dissolved solids (TDS) are made up of inorganic salts (mainly sodium chloride, calcium, magnesium, and potassium) and small amounts of organic matter that are dissolved in water. TDS in drinking water comes from natural sources, sewage, urban runoff and industrial wastewater. There are areas of the world that have naturally high amounts of TDS in their drinking water.

Water with very high or low levels of TDS is often called “hard” or “soft” water, respectively. Hard water received this name because it requires more soap to get a good lather and makes the water “hard” to work with. Soap is less effective with hard water due to its reaction to the magnesium and calcium; leading to high use of soap for laundry and bathing. As well, hard water can leave a residue and cause scale to build up on cooking pots and water pipes. People generally prefer the taste of hard water due to the dissolved minerals, however very high concentrations of TDS can cause a bitter or salty taste.

Soft water is usually preferred for laundry, bathing and cooking. However, water with extremely low TDS concentrations (e.g. rainwater) may be unacceptable because of its flat taste.

More information about total dissolved solids is provided in **Appendix A: Chemical Contaminants in Drinking Water Fact Sheets**.

2.2.3 Physical Quality

The physical characteristics of drinking water are usually things that can be measured with our senses: turbidity, colour, taste, smell and temperature. In general, drinking water is judged to have good physical qualities if it is clear, tastes good, has no smell and is cool.

2.2.3.1 Turbidity

Turbid water looks cloudy, dirty or muddy. Turbidity is caused by sand, silt and clay; and suspended precipitates of iron that are floating in the water. Drinking turbid water will not make people sick by itself. However, viruses, parasites and some bacteria can sometimes attach themselves to the suspended particles in water. This means that turbid water usually has more pathogens so drinking it increases the chances of becoming sick.

It is also important to remember that clear water does not necessarily mean that it is free of pathogens and safe to drink.

High turbidity levels reduce the efficiency of some household water treatment technologies such as chlorination, solar disinfection (SODIS) and ultraviolet disinfection. Sand in water can also wear out pipes, valves and pumps ahead of their time.

2.2.3.2 Colour

Coloured water will not usually make people sick. Although, it may cause people to not use the coloured water and choose another, possibly contaminated, water source instead.

The following explain some of the different colours that may be found in water:

- Vegetation such as leaves, bark and peat can cause dark brown or yellow colour
- Sand, silt and clay usually cause brown or red colour
- Iron can cause orange or brown colour that can stain laundry and plumbing fixtures and gives water a bad taste
- Manganese can turn water black and cause the same problems as iron
- Algae can make water look bright green or blue-green and some forms produce toxins which can be harmful
- Bacteria growth can also turn water black. These bacteria can also cause illness.

2.2.3.3 Taste and Smell

Most people like to drink water that tastes and smells good. A bad taste or smell may indicate some sort of contamination, especially when a change happens quickly. In most cases, an unpleasant taste or smell will not make people sick. However, it is next to impossible to convince people that water is safe to drink if it tastes or smells bad.

The following explain the cause of different tastes and smells that may occur in water:

- Algae and some bacteria may cause an unpleasant taste and smell
- High level of sulphate (SO_4) may cause a bitter or medicinal taste
- Some bacteria can convert sulfate (SO_4) to form hydrogen sulphide (H_2S) which has a rotten egg smell
- Iron can combine with tea, coffee and other beverages, to produce a harsh, unacceptable taste
- Chlorine has a distinct taste and may be present in treated water
- Rain water has less taste than ground water or surface water

2.2.3.4 Temperature

Most people like to drink cool water instead of warm water. The desirable temperature is between 4^oC to 10^oC ($39-50^oF$); people generally do not like to drink water that has a temperature above 25^oC (77^oF). Some bacteria can grow in warm water and may cause the water to taste, smell and look bad over time.

2.2.4 Drinking Water Quality Guidelines and Standards

What is the Difference between Guidelines and Standards?

Standard – A mandatory limit that must not be exceeded; standards often indicate a legal duty or obligation.

Guideline – A recommended limit that should not be exceeded; guidelines are not intended to be standards of practice, or indicate a legal duty or obligation, but in certain circumstances they could assist in evaluation and improvement.

The WHO writes the **Guidelines for Drinking Water Quality** (2006) to help make sure that people are drinking safe water around the world.

The WHO Guidelines explain that safe drinking water will not make people sick at any time throughout their life, including when they are young, old or sick. Safe drinking water should be good to use for all of our personal needs, including drinking, cooking, and washing.

The WHO Guidelines cover microbiological, chemical and physical qualities. However, it is stressed that microbiological quality is the most important since this is biggest cause of illness and death around the world.

> Although there are several contaminants in water that may be harmful to humans, the first priority is to ensure that drinking water is free of pathogens that cause disease.
>
> (WHO, 2006)

The implementation of the WHO Guidelines for Drinking Water Quality varies among countries. There is no single approach that is used worldwide. The Guidelines are recommendations to work towards and they are not mandatory limits.

Countries can take the WHO Guidelines into consideration along with the local environmental, social, economic and cultural conditions. This may lead to countries developing their own national standards that are quite different from the WHO Guidelines. For example, in 2007 Nepal developed national drinking water standards where total coliform should be zero at least 95% of the time.

The following table summarizes the WHO Guidelines for Drinking Water Quality.

Table 2.2.4: Summary of WHO Guidelines for Drinking Water Quality

Parameter	**Guideline Value**
Aluminum	No health based value is proposed
Ammonia	No health based value is proposed
Antimony	0.02 mg/L
Arsenic	0.01 mg/L
Barium	0.7 mg/L
Boron	0.5 mg/L
Cadmium	0.003 mg/L
Calcium	No health based value is proposed
Chloride	No health based value is proposed
Chlorine	5 mg/L
Chromium	0.05 mg/L
Copper	2.0 mg/L
Cyanide	0.07 mg/L
Fecal contamination	0 *E. coli* or thermotolerant coliforms in any 100 ml sample
Fluoride	1.5 mg/L (Recommended to have 0.5 - 1.0 mg/L for artificial fluoridation of drinking water)
Iron	No health based value is proposed
Lead	0.01 mg/L
Manganese	0.4 mg/L
Mercury	0.006 mg/L (for inorganic mercury)
Molybdenum	0.07 mg/L
Nickel	0.07 mg/L
Nitrate	50 mg/L
Nitrite	3 mg/L (short-term exposure) 0.2 mg/L (long-term exposure)
pH	No health based value is proposed
Potassium	No health based value is proposed
Silver	No health based value is proposed
Sodium	No health based value is proposed
Total dissolved solids (TDS)	No health based value is proposed
Uranium	0.015 mg/L
Zinc	No health based value is proposed

(WHO, 2006)

2.3 The Multi-Barrier Approach

Household water treatment is primarily focused on removing pathogens from drinking water – the biggest water quality issue around the world. While improving the microbiological quality, there are some technologies that may also be able to remove certain chemicals as a secondary benefit, such as arsenic and iron.

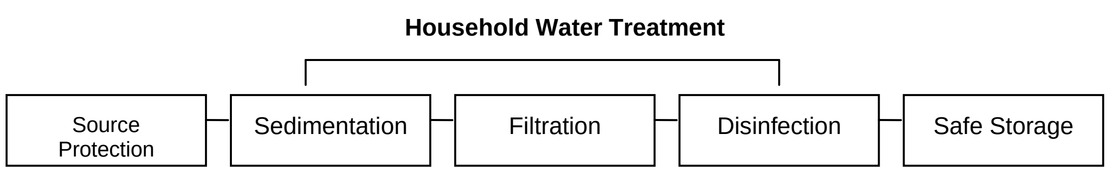
Using the multi-barrier approach is the best way to reduce the risk of drinking unsafe water.

Each step in the process, from source protection, to water treatment and safe storage, helps reduce health risks incrementally. The concept of the multi-barrier approach is also addressed as part of water safety plans, the principles of which can be applied at both community and household levels. The WHO provides additional information about water safety plans on their website.

Both conventional and household systems follow the same basic water treatment process: sedimentation, filtration and disinfection. The main difference is the scale of the systems that are used by individuals and communities.

More often than not, people focus on a particular technology that is directed towards one step rather than considering the whole water treatment process. While individual technologies can incrementally improve drinking water quality, the entire process is essential in providing the best water quality possible.

Figure 2.3: The Multi-Barrier Approach to Safe Water



- Sedimentation removes larger particles and often > 50% of pathogens
- Filtration removes smaller particles and often > 90% of pathogens
- Disinfection removes, deactivates or kills any remaining pathogens

2.3.1 Water Source Protection

There are many ways in which pollution may threaten drinking water quality at the source, or point of collection. These risks include the following:

- Poor site selection
- Poor protection of the water source against pollution
- Poor structure design or construction
- Deterioration or damage to structures
- Lack of hygiene and sanitation knowledge and practice in the community

Protecting the water source reduces or eliminates these risks and can lead to improved water quality and health. Actions that can be taken at the community level can include some of the following:

- Regularly cleaning the area around the water source
- Moving latrines away from and downstream of water sources
- Building fences to prevent animals from getting into open water sources
- Lining wells to prevent surface water from contaminating the ground water
- Building proper drainage for wastewater around taps and wells
- Stabilizing springs against erosion and protection from surface run-off contamination
- Ensuring watershed use is non-polluting

Further information is provided in the **Fact Sheet: Source Protection** found in **Appendix B**.

2.3.2 Sedimentation

Sedimentation is a physical treatment process used to reduce the turbidity of the water. This could be as simple as letting the particles in the water settle for some time in a small container such as a bucket or pail.

The sedimentation process can be quickened by adding special chemicals or native plants, also known as **coagulants**, to the water. Coagulants help the sand, silt and clay join together and form larger clumps, making it easier for them to settle to the bottom of the container.

The common chemical coagulants used are aluminium sulphate (alum), polyaluminium chloride (also known as PAC or liquid alum), alum potash and iron salts (ferric sulphate or ferric chloride).

Native plants are also traditionally used in some countries, depending on the local availability, to help with sedimentation. For example, prickly pear cactus and moringa seeds have been used to help sediment water.

Further information on different sedimentation options is provided in the **Fact Sheets** found in **Appendix B.**

2.3.3 Filtration

Filtration is commonly used after sedimentation to further reduce turbidity and remove pathogens. Filtration is a physical process which involves passing water through filter media. Some filters are also designed to grow a biological layer that consumes pathogens and improves the removal efficiency.

Sand and ceramic are the most common filter media, although cloth and membranes can also be used. There are various types of filters that are used by households around the world, including:

- Straining through a cloth
- Biosand filter
- Ceramic pot filter
- Ceramic candle filter
- Membrane filters

Further information on the different filtration options is provided in the **Fact Sheets** found in **Appendix B.**

2.3.4 Disinfection

The last step in household water treatment is to remove or kill any remaining pathogens through **disinfection**. The most common methods used by households around the world to disinfect their drinking water are:

- Chlorine disinfection
- Solar disinfection (SODIS)
- Solar pasteurization
- Ultraviolet (UV) disinfection
- Boiling

When water has high levels of turbidity, pathogens “hide” behind the suspended particles and are difficult to kill using chemical, SODIS and UV disinfection. Reducing turbidity by sedimentation (see Step 2) and filtration (see Step 3) will improve the effectiveness of these disinfection methods.

Distillation is another method of using the sun’s energy to treat drinking water. It is the process of evaporating water into vapour, and then capturing and cooling the vapour so it condenses back into a liquid. Any contaminants in the water are left behind when the water is evaporated.

Further information on the different disinfection options and distillation is provided in the **Fact Sheets** found in **Appendix B.**

2.3.5 Safe Water Storage

Households do a lot of work to collect, transport and treat their drinking water. Even after the water is treated, it should be handled and stored properly to keep it safe. If it is not stored safely, the treated water quality could become worse than the source water and may cause illness.

Recontamination of safe drinking water is a significant issue. The risk of diarrhea due to water contamination during household storage, first noted in the 1960s, has since been repeatedly observed by others (Mintz et al., 2001).

Distributing and using safe storage containers has shown substantial reductions in diarrheal disease (Roberts et al., 2001). Safe storage means keeping treated water away from sources of contamination, and using a clean and covered container. It also means drawing water from the container in a way that won't recontaminate the water and cause sickness. The container should prevent hands, cups and dippers from touching the water.

There are many designs for water containers around the world. A safe water storage container should be:

- With a strong and tightly-sealing lid or cover
- With a tap or narrow opening at the outlet
- With a stable base so it does not tip over
- Durable and strong
- Not transparent or see-through
- Easy to clean

A good safe storage container should also have instructions on how to properly use and maintain it.

Other safe water handling practices include:

- Using a container for collecting and storing only untreated water
- Using a separate container for storing only treated water
- Frequently cleaning out the storage container with soap or chlorine
- Storing treated water off the ground in a shaded place in the home
- Storing treated water away from small children and animals
- Pouring treated water from the container instead of scooping the water out of it
- Using the water as soon as possible after it is treated, preferably on the same day

Sometimes it is difficult for rural and poor households to find or buy good storage containers. The most important things are to make sure that they are covered and only used to store treated water.

Further information is provided in the **Fact Sheet: Safe Storage and Handling** found in **Appendix B**.

2.4 Technology Selection

Decision making and technology selection can take place at many levels, ranging from central government to independent program implementers to the individual households.

There is no one right way to make decisions and they are often made pragmatically based on the information and resources available. Decision making can be a formal process undertaken by the stakeholders or be done informally and subconsciously by individuals. .

2.4.1 What is the Best Technology?

Many people simply want to be told the "best" technology for household water treatment. Unfortunately, there is no easy formula that will answer this question since there are many factors to consider.

First of all, it is important to remember that household water treatment is a process (i.e. sedimentation, filtration and disinfection), not just a single technology. It is not easy to know which combination of technologies is the most appropriate. Many measures have the potential to seriously reduce diarrheal disease, each with its advantages and limitations depending on the local circumstances. Different technologies have varying suitability in each local situation.

The "best process" ought to be driven by a number of factors, including treatment effectiveness based on the source water quality and local contaminants, appropriateness, affordability, and acceptability for sustainable use by poor households.

Since the household water treatment process is dependent on so many different factors, there can be no standard solution. However, decision making tools are available to help identify the HWTS process that is best suited for the local context. Several decision making tools have been provided in **Appendix C** to compare different HWTS options against criteria which are important to the stakeholders.

The tools are participatory activities which encourage the involvement of different stakeholders in a group process. Participants can actively contribute to decision making, rather than passively receiving information from outside experts, who may not have an understanding of the local context and issues.

Participatory activities are designed to build self-esteem and a sense of responsibility for one's decisions. Experience shows that when everyone contributes to the decision making process, people feel more ownership of the problem and develop more appropriate solutions for their situation. Participatory decision making can empower communities to implement their own HWTS improvements.

2.4.2 Criteria Influencing Technology Choice

There are five main criteria that should take into consideration when deciding which household water treatment technologies are most suitable:

1. **Effectiveness** – How well does the technology perform?
2. **Appropriateness –** How well does the technology fit into people's daily lives?
3. **Acceptability** – What will people think of the technology?
4. **Cost** – What are the costs for the household?
5. **Implementation –** What is required to get the technology into people's homes?

Each of these criteria is described in the following sections. Other criteria which are important to the stakeholders can also be added.

2.4.2.1 Effectiveness

Effectiveness is the ability of the technology to provide sufficient water quality and quantity. There should be enough safe drinking water for a household to meet their basic needs. Criteria that show the technology's effectiveness include the following:

Water Quality

- Which microbiological, physical and chemical contaminants can be removed by the technologyand how much?

Water Quantity

- How much water can be provided every day?
- Is it sufficient to meet the household's daily needs?

Local Water Source

- Will the technology be able to treat the specific microbiological, physical and chemical contaminants of the local water source?
- Will it treat water from different sources to the same level?

2.4.2.2 Appropriateness

Some technologies will be more suitable than others depending on the needs and conditions of the community. Answering the following criteria can help to match a technology with a particular community:

Local Availability

- Can the technology be manufactured in or near the community using local materials and labour?
- Does the technology need imported spare parts or consumables?
- Is it possible to buy spare parts or consumables locally?
- Is the supply chain reliable?

Time

- How long does it take for a household to treat enough water to meet their daily needs?
- Does it significantly add to the household's labour burden?

Operation and Maintenance

- What are the household's responsibilities to operate and maintain the technology?
- Is it easy and convenient for women and children to use the technology?

Lifespan

- How long will the technology last before it needs to be fixed or replaced?

2.4.2.3 Acceptability

People's opinion about the technology will affect its widespread adoption and consistent use. It is difficult for many people to accept a new technology until they personally experience the benefits. People's acceptance of a technology is affected by the following criteria:

Taste, Smell and Colour

- How will the treated water look, taste and smell?

Needs and Motivations

- What benefits will the technology give to people?
- Will it provide convenience, health improvement, social status, time or money savings?

2.4.2.4 Cost

Most HWTS options are not free. The following costs need to be considered:

Capital Costs

- Initial purchase of a durable product
- Transportation

On-Going Costs

- Continuing purchase of consumable products
- Operation and maintenance
- Potential repair and replacement parts

Willingness to Pay and Affordability

- Can households afford the full cost of the technology?
- Are households willing to pay for capital costs?
- Are households willing to pay for on-going operation and maintenance costs?
- How is technology subjected to household income fluctuations?
- Do durable or consumable items need to be subsidized?

Implementation Costs

- Cost to run the program (e.g. staff, office space, etc.)
- Cost to raise awareness in the community
- Cost to educate people about how to use the technology
- Cost to provide on-going support for households

Successful cost recovery is an important part of the program sustainability. Implementers need to consider how the costs can be recovered - whether from households, donors, government or others. It is important to figure out who is financially responsible for which costs, and over what period of time.

2.4.2.5 Implementation

There are several factors to consider about how the technology is implemented:

- How is the technology manufactured and distributed to the households?
- Are local manufacturing and repair skills and spare parts available? If not, can these be made available?
- How fast can the technology be implemented?
- What training will the household require to properly use the technology?
- Who will help a household if they have a problem or question?
- What monitoring is required for the technology?
- What additional support is needed?
- Do households perceive the technology to be of benefit to them?
- How well can the technology be integrated into current government programs?

2.5 Summary of Key Messages

- The first priority is to ensure that drinking water is free of pathogens that cause disease. Household water treatment is primarily focused on removing pathogens– the largest public health threat. Some household water treatment options can also remove chemicals and improve physical qualities of drinking water.

- There are four different categories of pathogens: bacteria, viruses, protozoa and helminths. Different household water treatment technologies have varying levels of effectiveness in removing, inactivating or killing the different types of pathogens.

- Many chemicals may be found in drinking water, however only a few cause health effects on a large-scale, such as arsenic and fluoride. Water quality testing of the source can help to identify mitigation and treatment options for particular chemicals.

- The implementation of the WHO Guidelines for Drinking Water Quality varies among countries. There is no single approach that is used worldwide. The Guidelines are recommendations to work towards and they are not mandatory limits.

- Safe water and improved water do not mean the same thing. Improved water is a source that by nature of its construction adequately protects it from outside contamination, in particular fecal matter. It is assumed that certain sources are safer than others, but not all improved sources in actual fact provide safe drinking water.

- Using the multi-barrier approach is the best way to reduce the risk of drinking unsafe water. Each step in the process, from source protection, to water treatment and safe storage, helps reduce health risks incrementally. Water safety plans use the concept of the multi-barrier approach, the principles of which can be applied at both community and household levels.

- Both community and household systems follow the same basic water treatment process: sedimentation, filtration and disinfection.

- People often focus on a particular HWTS option rather than considering the water treatment process as a whole.

- There is no “best” technology for HWTS. There are many criteria to consider for the local context, including treatment effectiveness for the water source, appropriateness, acceptability, affordability and implementation requirements.

- There is no one right way to make decisions about HWTS selection. They are often made pragmatically based on the information and resources available.

3 Implementation of HWTS

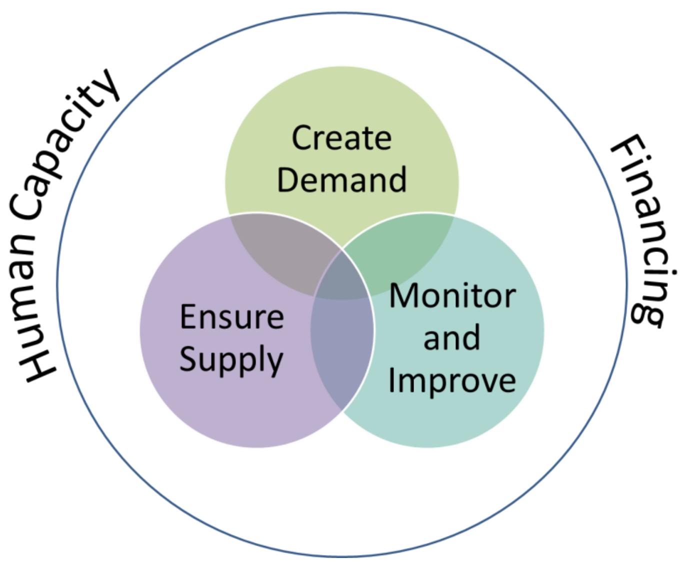
The objective of this Section is to illustrate the diversity of HWTS implementation and explain the components shared by successful programs. Understanding what it takes to implement a HWTS program will help governments promote and support best practices in their country.

A review of the implementation programs worldwide shows that **there is no standard approach for getting HWTS into people's home**. There are a wide variety of organizations using different HWT options and a diverse range of programs, from emergency response to long term development. While there is no one standard implementation model, many of the programs do address the following key components, which make them more likely to succeed:

1. Creating demand for HWTS
2. Supplying the required HWTS products and services to meet the demand
3. Monitoring and continuous improvement of program implementation

The organization's ability to plan and implement these components is determined by their **human capacity (people)** and **financing (money).** Successful programs understand and integrate these supporting components into their planning and implementation.

Figure 3: Framework for HWTS Implementation



The following sections discuss each of these framework elements in more detail. Case studies are also used to illustrate the diversity of implementers and their approaches.

Implementation… is the process of creating and following a plan to execute a HWTS program. It also includes monitoring day to day activities and evaluating the results of the program.

3.1 Creating Demand

Creating demand requires awareness and education to convince households of the need and benefits of HWTS so that it is desired and sought after. Demand exists when people need and want HWTS and have the opportunity and ability to bring it into their homes. It is critical that households actually want and value HWTS; this ensures it will be used over the long term.

Ultimately all implementation programs want to make a change – an increase in the number of people who have safe drinking water. For anything to change, one has to start acting differently, such as treating water in their home. The challenge of changing people's behaviour, and subsequently creating demand for HWTS, is significant for implementers – requiring time, sustained investment, and a range of strategies.

Many successful implementers use the following steps to create demand for HWTS:

Plan	1. Identify an appropriate target population. 2. Select a suitable and feasible HWTS option
Initiate and Pilot	3. Increase awareness of HWTS as a solution for safe water and educate people on the relationship between water and health. 4. Use demonstration projects to convince people of the benefits of HWTS. 5. Engage government agencies to give credibility to HWTS.
Sustain and Expand	6. Provide positive reinforcement to households so they continue using HWTS.

Each step is discussed in more detail in the following sections.

The piloting phase is especially important. Before scaling up, many organizations gain significant benefit from first implementing a small pilot project to establish their processes, learn from experience, get household feedback, ensure quality of service, and demonstrate results and their capability to potential funders.

3.1.1 Identify the Target Population

Implementers should identify a target population during their program planning. They can often find initial success by working with households that are more likely to adopt HWTS, and working within their organizational capacity.

It is easier to start implementation in an area where people already have self-identified a need and motivation to adopt healthier behaviours. Implementers can also strategically focus on people who are most vulnerable from unsafe water, including those who:

- Have low immune systems, such as children under the age of five, the sick (including people living with HIV/AIDS), and the elderly
- Suffer from diarrheal diseases and other illnesses which can be prevented through water, hygiene and sanitation programs

- Use surface water and shallow wells which are more likely to be contaminated by pathogens
- Live in areas susceptible to flooding, in areas of poor hygiene and sanitation, and in places experiencing conflict or other emergencies

3.1.2 Select HWTS Options

The majority of organizations select only one HWTS option within the multi-barrier approach to implement. This is frequently due to their limited resources and capacity to provide more than one option to households.

Implementers often make their decision using the criteria presented in Section 2:

1. **Effectiveness** – How well does the technology perform?
2. **Appropriateness** – How well does the technology fit into people's daily lives?
3. **Acceptability** – What will people think of the technology?
4. **Cost** – What are the costs for the household?
5. **Implementation** – What is required to get the technology into people's homes?

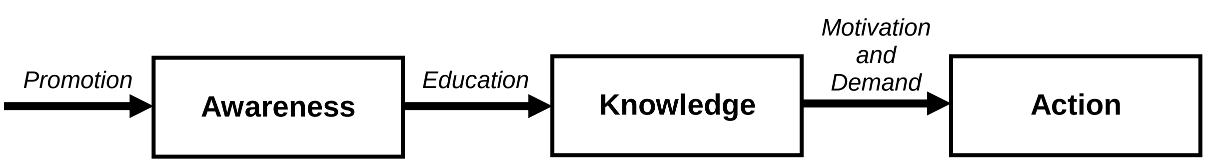
It is believed that demand can be increased by providing more HWTS options; allowing household to choose from a range of products at a number of price points (WSP, 2002; UNICEF, 2008; Clasen, 2009). Generally, the greater involvement households have in selecting their HWTS, the greater their understanding and motivation for using it.

People can, however, be easily overwhelmed if there are too many choices. Difficulty in making a decision may lead to people not taking any action at all and continuing to drink unsafe water. Households often need someone to help them make a decision by suggesting a good place to start. Some implementers help people decide what is most appropriate for their situation through education and training and proposing a small selection of options.

3.1.3 Increase Awareness and Knowledge

Implementers need to increase awareness and knowledge to motivate people to take action against their poor water conditions. Promotion activities are used to create awareness and encourage people to learn more about the solutions for getting safe drinking water. Education increases their knowledge on the relationship between water and health and the available HWTS options. Both are needed to motivate individuals to act differently and integrate HWTS into their daily routine. Promotion and education efforts must be designed specifically for the target population.

Figure 3.1.3 Increasing Awareness and Knowledge



3.1.3.1 Promotion to Create Awareness

Promotional activities are generally targeted at a wide range of individuals, with the understanding that those most interested will step forward. It lends itself to using of mass media communication channels such as television, radio, newspaper, billboards, street dramas, etc. Mass media campaigns usually focus on a few key messages for the general public, such as:

- "Dirty water can make you sick."
- "Clean water makes you healthy."
- "You can treat dirty water at home to get clean water."

Mass media can be very timely (e.g. raising awareness about cholera just before the rainy season) and can reach a large audience with limited human resources. However, mass media should be quickly followed by **education** to further motivate people to take action. Mass media alone is less effective for long-term change because it provides only one way communication. As well, it may only reach select audiences, such as wealthy households, who may be the only ones owning a television or radio (Namsaat, 2001).

3.1.3.2 Education to Increase Knowledge

People need to be educated on three things in order to begin treating water in their home:

1. Why use HWTS
2. What to do to get HWTS
3. How to use HWTS

Community health promoters are critical to successful implementation by helping households learn about the need for safe water and HWTS. They are local people who are trusted and respected, giving credibility to HWTS, such as nurses, teachers, women's leaders, community leaders, and elders.

Education as a First Approach to Safe Water – Ceramic Filters, Thirst-Aid, Myanmar

Thirst-Aid's goal is to make knowledge of household water treatment as common as how to cook rice or fry an egg. They use education and knowledge to inspire the drive for safe water to come from within the community before introducing HWTS.

The organization creates demand by using education and knowledge as investment capital. Their approach is based on the assumption that educated people do not willingly drink contaminated water – much less give it to their children.

Thirst-Aid provides the currency for community buy-in by issuing *Certificates of Knowledge* upon successful completion of their educational program. These certificates serve as legal tender that can be later used for the purchase of HWTS.

(Bradner, C., Personal communication, July 2010)

Studies show that people are more likely to treat water if they understand the relationship between water and health and have some knowledge of safe water practices (Kraemer and Mosler, 2010; Brown et al., 2007). However many, many people around the world do not understand the relationship between water and health.
Traditional norms, and beliefs that diarrhea is not a disease or that it is caused by supernatural powers, are often mentioned by implementers as reasons for the lack of demand. Other implementers have found that people believe that since they have been drinking the water for a long time, they have immunity and do not need to treat it (Heri and Mosler, 2008; Graf et al., 2008; Clasen, 2009).

Choosing the most appropriate key messages and communication channels are essential for appealing to the beliefs and motivations of the target audience. For example, community health promoters may arrange for house-to-house visits and meetings with women's groups to reach mothers, while street theatre may be more effective in reaching fathers and youth.

Some argue that person to person communication is too resource intensive and not scalable and should therefore be limited to areas where the reach of mass media is unavailable (Parker, 2009). However, many implementers report that group meetings and household visits done by community health promoters is the most successful strategy to educate people and support them to adopt HWTS. Acceptance, adoption and long term use is more likely and, in addition, it helps create a "word-of-mouth education" beyond the investment of the project – resulting in further potential scale-up.

Using Appropriate Communication Channels – Chlorine, Afghanistan

In Afghanistan, men primarily learn about safe water though mass media channels such as television and radio. Women, however, generally learned about PSI's chlorine products through friends, neighbours, and other person-to-person interactions. Given that men often control a family's finances and that women usually prepare the household's water, targeting both genders was critical for program success.

(POUZN Project, 2007)

3.1.4 Use Demonstration Projects

Seeing is believing. A demonstration project allows people to see and experience the benefits of HWTS for themselves. Doing a small demonstration project at the beginning of a program is a good strategy for implementers. This helps to generate interest and create demand before the program is scaled up.

Seeing is Believing

Implementers have reported that when people observe the benefits their neighbours have with HWTS, they want the same thing forthemselves.

A study done by Moser et al. (2005) showed that the more people that someone has seen using SODIS, the higher the percentage of SODIS use.

Clean Water for Haiti initially placed biosand filters in schools, health centres, churches and in the homes of community leaders to demonstrate the technology. People were able to see for themselves that the filtered water was better, and that there were improvements in people's health. The success of their demonstration helped convince people to adopt filters. To date over 10,000 households have biosand filter installed and demand outstrips the organization's ability to supply (Dow Baker et al., 2008).

The best locations to set up a demonstration are generally public and community institutions, such as schools and health clinics. These locations highlight leadership from those in authority and gives credibility to the program. It is also a way for implementers to gain access to some of the most vulnerable populations – young children and the sick.

In a school situation, the effectiveness of HWTS can be demonstrated and teachers can also receive training in safe drinking water, hygiene and HWTS to share with their students. Once youth have knowledge about the importance of safe drinking water and the solutions available, they pass the messages onto their parents and encourage action at home.

Similarly, demonstrations in health clinics can be coupled with education for health workers, who pass the information on to their patients and clients. Outreach through clinics directly reaches the children under five years of age who experience the highest rates of illness and death from diarrhea, and mothers who are concerned about their family's health and looking for solutions.

HWTS options are usually given to schools and clinics at no cost. Letters of agreement or contracts have been used successfully to ensure that they agree and comply to the proper operation and maintenance of the HWTS products. Some programs also provide free HWTS for teachers and health workers to use at home.

Educating Communities through Schools and Health Clinics – Chlorine, Kenya

CARE-Kenya implemented a school-based safe water and hygiene intervention in rural schools. Schools were provided with safe water storage containers, WaterGuard (chlorine), and hand washing stations. The program was evaluated to assess its impact on students' knowledge and on parents' adoption of safe water and hygiene practices in the home. The approach showed promise for passing on messages from student to parent to promote water and hygiene interventions at home (O'Reilly et al., 2006; O'Reilly et al., 2008).

In another study, nurses in a maternal and child health clinic were trained in chlorination using WaterGuard and proper hand washing. They were asked to communicate this information to their clients. Interviews immediately following the training were conducted with the health clinic clients - 76% reported being taught both chlorination and hand washing during their clinic visit (Parker et al., 2006).

3.1.5 Engage Government Agencies

Acknowledgement and support from government is required to help increase demand over time. Endorsements from government agencies give credibility to HWTS and implementers.

Implementers should be proactive and take steps to engage all levels of government – local, regional and national. HWTS can cross a range of sectors (such as health, water and sanitation, rural development, and education), so officials from each of these areas should be involved. Engaging government officials can be done by educating them about the benefits of HWTS and showing how it can leverage their own efforts in providing services (Clasen, 2009).

In Nepal, the government is very active in HWTS promotion. They coordinate the development of HWTS promotion materials and messaging with implementing organizations. The government of Lao PDR also works closely with implementers to promote various HWTS options, including boiling, chlorine, SODIS, and the biosand filter. They also provide training through their government extension system and are involved in the joint production of education materials with implementers (SODIS, 2010).

A number of country governments (including Haiti, Tanzania, Viet Nam, Cambodia, Indonesia, Nepal and the Philippines) have also drafted HWTS guidelines to encourage implementation and endorse product quality.

The Success of Boiling

Boiling is the predominant method of HWT with 21% of low- and middle-income households reporting the practice. Boiling is almost universal in Mongolia (95.1%), Vietnam (91%) and Indonesia (90.6%), and also quite high in Timor-Leste (73.4%), Cambodia (60.1%), and Laos (62.7%). In some countries, the success of boiling is due to government recommending it as part of their overall health or hygiene campaigns. As well, many governments have trained health and community workers to promote the practice in villages and communities.

(Clasen, 2009; Rosa and Clasen, 2010)

3.1.6 Provide Positive Reinforcement

Positive reinforcement is critical after HWTS has been first introduced in the home.People need encouragement and support as they learn to incorporate HWTS into their daily routines. They often have questions or need reminding on how to properly use and maintain their HWTS product.

One of the greatest challenges for implementers is to follow up with households in a timely manner to monitor and reinforce the use of HWTS. Many implementers have successfully used community health promoters to reinforce key messages and practices. Community health promoters visit with households and organize group activities to help people treat their water, provide troubleshooting, and answer questions.

Need for Continuous Reinforcement – SODIS, Bolivia

A study of SODIS in Bolivia observed that altering existing habits and developing new ones is a difficult and long process. It recommended regular monitoring and follow-up with new users over a long period of time to support and reinforce using SODIS

(Moser et al., 2005).

3.2 Supplying Required Products and Services

Households need both the HWTS product and support services to ensure its proper and consistent use over the long term. This requires significantly more effort on the service component or “software” than has traditionally been the case in the water and sanitation sector.

Implementers must work towards supplying both high quality products and services to create demand and then meet that demand. Many organizations choose to do a small pilot project to establish their processes, learn from experience and ensure quality control of product and service before scaling up their program.

While there are successful stories of large scale supply of HWT products, many organizations rely on localized supply. Supply chains which use locally available resources, supply routes, fabrication and people (for labour, education and follow up) are often successfully used as they can:

- Create local knowledge skills which empower beneficiaries to meet their own needs
- Aid demand creation and sustainable supply
- Allow more gradual expansion, since implementation can be limited to a predefined area
- Reach areas which are difficult to access via existing commercial means

3.2.1 Products

Affordability and availability are the two key considerations to ensure the supply of household water treatment and safe storage products. Safe water storage containers are critical products that also need to be supplied to households.

HWTS options can be divided into consumable and durable products, each requiring different implementation strategies to make them affordable and available.

Consumable products, such as alum or chlorine, need to be replenished on a regular and continuing basis (e.g. weekly or monthly). As such, they have recurrent costs, but generally no capital costs.

Durable products are an occasional or one-time purchase (e.g. ceramic filter elements need to be replaced every 1-2 years, biosand filters can potentially last a lifetime). They have a relatively higher capital cost than consumable products, butminimal recurrent costs.

Table 3.2.1 Comparison of Consumable and Durable HWTS Products

Consumable Products	Durable Products
• Need to be constantly replenished • Has little to no capital costs, however has regular, recurrent costs • Should be self-sustaining without subsidies • Implementation is similar to commercial products • Lends to private sector implementation	• One-time or infrequent purchase • Has relatively high capital costs, but minimal recurrent costs • Initial capital costs may be subsidized • Implementation is similar to community development or infrastructure programs • Lends to NGO and government implementation

3.2.1.1 Affordability

Many programs target poor populations because they often derive the most benefit from HWTS. Consequently, both the initial capital cost and the on-going recurrent costs need to be affordable to the poor, especially those who live on US$1-2 a day.

It is generally agreed and widely accepted that for programs to be sustainable, recurrent costs should be affordable and not subsidized. Households need to be able to afford the full cost of purchasing consumable products on a continuous and long-term basis. In the case of durable products, people should be able to pay for the minimal recurrent costs associated with replacement parts and the on-going operation and maintenance.

Subsidies for the capital cost of durable products may be required to make it affordable to the poor. The high up-front purchase cost of durable products, like a biosand filter, often makes it impossible for the poorest of households to afford. Similar to other infrastructure projects, some form of cost sharing is usually required.

The majority of implementers recommend that households should contribute to the initial purchase of durable products in some way. Experience has shown that people place more value on their HWTS product and use it over the long term when they have invested at some level. Free distribution is not recommended.

Several different types of schemes have emerged to enable the poor to contribute to the capital costs. Householders often contribute in kind, by providing voluntary labour for construction or transport, or by providing local materials. Household may also be offered the option of paying smaller amounts in installments, rather than having to pay the full cost all at once.

Microfinance institutions can also have a useful role in financing the capital cost of durable HWTS products. Pilot microfinance projects in India have reported nearly 100 percent repayment on loans by lower income populations for purchase of filters that are usually only affordable to middle-income households. Safe water saves money from reduced illness and increased productivity, making it easier to repay loans over time. Even with this success, current access to small loans for non-income generating products (such as HWTS) is limited. It will be important for implementers who wish to use microfinancing to educate these institutions on the benefits of HWTS (IFC, 2009).

Household Investment in HWTS – Biosand Filters, Cambodia

Biosand filters are subsidized by Clear in Cambodia to support those who are unable to purchase them at full cost. Households pay a nominal amount and contribute labour to help construct and transport their filters home. As such, people have made a personal investment and Clear has experienced a high adoption rate with over 67,000 biosand filters implemented in the country.

(Heng, K. Personal communication, July 2010.)

3.2.1.2 Availability

A supply chain is needed to ensure that HWTS products are available to respond to the demand. As part of the supply chain, implementers need to consider how the product is going to be manufactured, packaged, distributed and priced (cost recovery and financing is discussed further in Section 4). The complexity of the supply chain depends on many factors, including:

- Type of HWTS product (i.e. durable or consumable)
- Availability of local materials and labour
- Strength of the private sector
- Transportation
- Shelf life
- Quality assurance
- Scale and capacity of the program

Consumable products require an uninterrupted and long-term supply chain. Product shelf life and quality assurance are critical factors to consider when manufacturing and distributing consumable products. For example, consumable products which have a short shelf life, like chlorine solution, are best made by local manufacturers and distributed through small networks. Whereas, products with a long shelf life, such as Aquatabs® or Pur®, lend themselves to international manufacturing and global distribution.

Durable HWTS products are usually more appropriate for local manufacture. Both biosand filters and ceramic filters can be built using locally available materials. They have established production processes which allow them to be built to consistent standards in diverse communities with lower costs than importing them. Also, these products are difficult to transport over long distances, due to the weight or fragility, so it is better to manufacture them as close to the end users as possible.

A variety of roles are needed to implement a supply chain. Manufacturing and distribution may be carried out within one organization or across multiple organizations. The implementing organization first needs to decide which parts of the supply chain they are going to manage themselves and which can be handled by another organization or the private sector. We will consider manufacturing and distribution separately in the following sections.

(a) Manufacturing

Implementers who do the manufacturing and distribution themselves have more control over the product's quality as they control the entire process from beginning to the introduction to the household. It may however require them to have special skills and training, and an increased financial and human resource base.

Implementers who do their own manufacturing need to decide if they want to have centralized or decentralized production. For example, RDI in Cambodia and FilterPure in Haiti use a centralized factory to construct ceramic filters and then distributes them across the country. Alternatively, Clear Cambodia uses a decentralized model to build biosand filters. They have travelling teams that transport the filter molds and tools to a temporary work site in the village. The team spends several weeks there until the demand has been satisfied before moving onto the next village.

If the implementer decides to purchase HWTS products from another organization or the private sector, then the decision is one of whether to use local or imported products from national or international companies. While there are successful stories of large scale, imported supply, many organizations rely on a local supply of HWTS products.

Supply chains which use locally available resources, supply routes, fabrication and people (for labour, education and follow up) are often used since they can:

- Build local knowledge and skills which empowers beneficiaries to meet their own needs
- Create jobs and support the local economy
- Allow for more gradual scale up, since implementation can be limited to a predefined area
- Reach areas which are difficult to access via existing commercial means

Leveraging the resources of the local entrepreneurs or other organizations has many benefits. However, some implementers have found that working with local entrepreneurs was difficult and time consuming in the early stages of implementation. But in the end they report that it is essential for program sustainability and cost-effectiveness.

Reputable regional and international manufacturers, such as Medentech, Proctor & Gamble and Hindustan Unilever Limited, have the advantage of high quality control standards and product manufacturing consistency. However, HWTS products that depend on international supply chains may be subject to importation taxes and storage and handling fees, potentially resulting in delays and expenses.

Even with outsourcing to the private sector, experience has shown that implementers may still need to be involved in the product development, sourcing of raw material suppliers, product registration, product testing, and ensuring quality control (POUZN Project, 2007; Ngai, 2010).

(b) Distribution

There are also many strategies used by implementing organizations for distributing HWTS products. Depending on the strength of the private sector, some implementers choose to distribute their product through traditional commercial outlets, such as retail shops and pharmacies. Others also use non-traditional outlets to sell HWTS products, such as through community volunteers and mobile sales teams. In some programs, households must purchase their HWTS product directly from the factory or implementing organization.

Partnerships in Manufacturing and Distribution – Chlorine, AmanTitra, Indonesia

AmanTirta, Safe Water Systems (SWS), a five-year project funded by USAID, aimed to ensure widespread access in Indonesia to an affordable chlorine solution (Air RahMat) for low income families with children less than five years old. Led by Johns Hopkins University, in partnership with the Ministry of Health, CARE International Indonesia, PT Tanshia Consumer Products and Ultra Salur, the project used a public-private partnership (PPP) model to create the first fully sustainable commercial model for SWS.

The PPP combined commercial manufacturing and distribution of Air RahMat by PT Tanshia, with community participation and media promotion to create demand. The project negotiated and supported extensive distribution of Air Rahmat through traditional channels (e.g. stores and kiosks), as well as non-traditional retail outlets (e.g. community based organizations, microcredit organizations, community volunteers).

(Johns Hopkins University, 2009)

3.2.2 Services

Implementers need to set up a system to support households with the proper and consistent use of HWTS over the long term. Households need a contact point for follow up service, purchase of replacement parts, and queries.

> *"Ceramic water filters are not a passive resource; they require ongoing management and maintenance by users. Therefore, like computers, after sales support is essential for on-going and appropriate use of ceramic water filters."*
>
> (Hagan et al, 2009)

Organizations need to identify the level of service required and how it will be financed as part of the program to ensure that it is actually done. Delivering long-term services, even after the implementation program may have ended, generally involves using community health promoters, local institutions (e.g. health clinics) and government agencies.

For consumable products that are sold commercially, the private sector has incentive to provide follow-up support to households, ensuring that they are satisfied and will purchase the product again. However, businesses which sell durable products that are a one-time purchase and much less likely to be replaced, have little incentive to provide support to households since it will cut into their profit margins.

3.3 Monitoring and Continuous Improvement

Monitoring is essential for on-going improvement of implementation programs. It helps to create a feedback loop within a program. It is particularly important for making improvements to the program as well as measuring the impact and success of a program, especially if an organization wants to scale up their activities.

The key to successful monitoring is to keep it simple and within the means of the organization. The tendency for many implementers is to collect too much data which is overwhelming and often not of practical use. It is ideal to use a small set of indicators that can be collected without becoming an additional burden to the program.

The extent of monitoring will vary depending on the implementer's capacity and nature of their activities. There is no specific formula for implementers to follow, however programs often monitor the following elements:

- Management
- Product quality
- Distribution systems
- Household education
- Performance and use of the HWTS option
- Impact

Good monitoring systems share the following characteristics:

- Has a clearly defined purpose
- Collects specific information on a small but well-defined set of indicators
- Fully integrated into the program activities
- Simple and within the means of the organization
- Analyzed on a regular schedule to determine lessons learned
- Focused on factors within complete control of the program
- Results in program modifications and improvements, based on lessons learnt and information collected

3.3.1 What Should be Monitored

There are two broad categories of monitoring that can be used during implementation: process monitoring and impact monitoring.

Process monitoring looks at the processes that contribute to the functioning of the program. This includes production, quality control, distribution systems, financial control, use of materials, and program management. Process monitoring helps implementers to answer the question "Are we doing things right?" Depending on the implementation approach, there are many different process indicators that could be used to monitor the program. A few indicators to consider include:

- Number of products manufactured
- Number of products distributed
- Cost per product
- Number of people trained (e.g. promoters, technicians, staff)
- Number of education material distributed
- Number of household visits conducted

Impact monitoring looks at the impact the program has on the target population and can look at the following: number of people with improved water as a result of HWTS implementation; proper and consistent use of HWTS; effectiveness of HWTS; adequacy of promotion and education efforts; and usefulness of training and education material. Impact monitoring helps implementers to answer the question "Are we doing the right things?" A few impact indicators to consider include:

- Percentage of products meeting basic operating parameters
- Percentage of products still in use after a given time period
- Percentage of products being used correctly after a given time period
- User perception of the product's benefits and limitations
- Number of people with access to safe water
- Number of people experiencing health benefits, such as reduced diarrhea

3.3.2 Who Should be Involved

Process monitoring is usually internal to an organization and carried out by staff through record keeping, spot checks and regular reviews and appraisals.

Impact monitoring is usually initially done by the implementer and then should be transitioned to an activity done by the local community to ensure that it continues beyond the length of the program. Community health promoters are an excellent mechanism to monitor behaviour change and encourage proper and consistent use of HWTS. In most instances, local government is also better placed than implementers to ensure long-term monitoring and support.

In addition, project evaluations are a form of impact monitoring, and normally include a review of the process monitoring to ensure that it is sufficient and being done correctly and consistently. These are often done by people who are not involved in the process monitoring to reduce the potential for overlooking problems.

Project evaluations are also a form of impact assessment. Evaluations normally include a review of the process and impact monitoring indicators as well as a more in depth look into the long term impact of the program. This is to ensure that the program is being done correctly and consistently. Evaluations are often done by people who are not involved in monitoring to reduce the potential for overlooking problems.

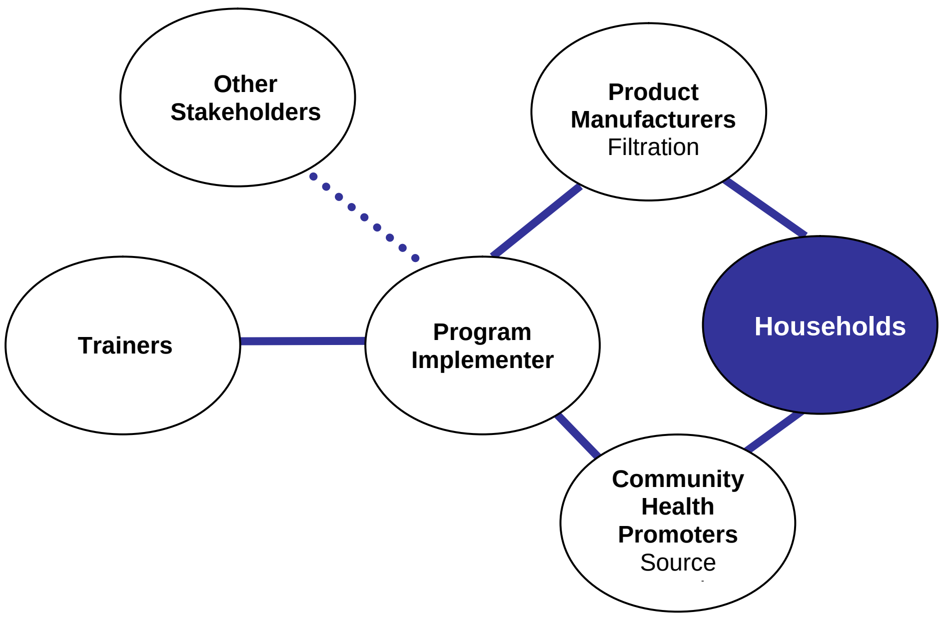
3.4 Human Capacities Required for Implementation

Developing individual people's knowledge and skills is part of building the overall organizational capacity required for implementation. A capacity building process with competency validation can be used to increase both individual and organizational capacity. The ultimate objective of HWTS programs should be to build the capability of local populations to meet their own needs.

A variety of roles are needed to implement HWTS programs. The following roles may be carried out within one organization, or more commonly across multiple organizations:

- **Program Implementers:** Individual or organization who plans and implements a HWTS program.
- **Community Health Promoters:** Raise awareness and educate households about the need for safe water and HWTS solutions.
- **Product Manufacturers:** Construct and distribute the HWTS product.
- **Trainers:** Provide training and consulting to support implementers.
- **Other Stakeholders:** Donors, government, universities and education institutions

Figure 3.4: Roles Required for HWTS Program Implementation



Smooth transfer of knowledge from one role to another is vital and occurs best when:

- All stakeholders contribute to defining the program goals and objectives
- All stakeholders agree on and understand their roles and responsibilities
- The needs of each stakeholder are understood by others (e.g. information, resources and support)
- Communication channels remain continually open
- Formal and informal systems and tools are in place to aid knowledge transfer
- Communication and knowledge transfer occurs in both directions
- Plans and tools are available for building competency and capacity

3.4.1 Program Implementers

There is no standard type of program implementer. A review of HWTS programs globally highlights the diversity of implementers, profiled in the following table. However, successful implementers do share common characteristics such as excellent planning, management, organizational and communication skills.

Table 3.4.1: Characteristics of Implementing Organizations

Type of Organization	**Characteristics**
Indigenous NGOs	• Initiated and managed in-country by local people • Have strong relationships with the target population • Builds local ownership and capacity to solve own problems • Often have simpler processes to implement projects • Can react quickly to lessons learned and make changes • May need external support with technical expertise and institutional capacity building • May depend on external funding support
International and Multinational NGOs	• From developed countries who initiate programs, often in partnership with an in-country organization • Range from small international to large, multinational organizations • Often have good access to funding • Have enormous technical expertise and often well connected to the latest research • Knowledge and capacity often remains with foreign experts, needs to be transferred to the local community • Much of the experiences and lessons learned may be lost once the program is completed
UN agencies	• UNICEF is the main agency implementing programs and supporting governments with HWTS in various countries • WHO and UNHABITAT are promoting HWTS with governments and supporting training • Often have good access to funding • Have enormous technical expertise and often well connected to the latest research • Bureaucracy may limit implementation and delay planned activities
Government	• May be local, regional or national levels responsible for health, rural development, water or environment • Lends political will to change • Gives credibility to HWTS and leads to higher acceptance by households • Can support implementation by incorporating HWTS in public health and education programs, may also be a source of funding • Bureaucracy may limit formal cooperation with other organizations and delay implementation of planned activities

Type of Organization	Characteristics
Private sector	• May be local entrepreneurs or national and international companies • Has the expertise, incentive and resources to manufacture, distribute and promote HWTS products • In many cases, able to provide long-term financial and institutional sustainability to HWTS programs • Market-driven, full cost-recovery models used by private sector are not likely to reach the poorest of the poor

3.4.2 Community Health Promoters

Community health promoters are essential for the successful implementation of any HWTS program. Their main role is to facilitate the learning process and help others improve their water, hygiene and sanitation practices through community activities and household visits.

Community health promoters usually report to the implementer. They can either be paid or act as volunteers, and may spend their whole day or only a few hours a week on the job. Depending on the organization, there may be additional responsibilities that are assigned, such as performing monitoring activities.

Almost anyone with the following capacities can become a community health promoter:

- Is trusted and respected by the community
- Speaks the local language
- Understands the local culture
- Communicates effectively and listens to others
- Demonstrates good water, hygiene and sanitation practices within their household
- Is committed to addressing water, hygiene and sanitation needs in their community

Community health promoters don't necessarily have to be experts in water, hygiene and sanitation. This is knowledge that they can learn through training. It is more important for them to have the capacity to learn new skills and communicate.

3.4.3 Trainers

Training and consulting support is often required to build human capacity for the different implementation roles. On-the-ground assistance can be a significant factor that contributes to successful programs. For many people, training helps build their knowledge and skills, and gain confidence, to meet the numerous challenges which must be overcome on a regular basis.

"*Interaction with high level experts from different organizations can be difficult as we feel we are lacking in knowledge and expertise to be able to talk at the same level, despite the fact that we have constructed and installed many filters which are operating properly and supplying people with safe water. We need additional professional training and support,*" reports Koshish, a biosand filter implementer in Pakistan.

(Dow Baker et al., 2008)

Any training needs to be practical and help address the real challenges that implementers face. Often implementers focus on technology training and on theory, which is usually not enough. Depending on their human capacity, organizations shouldalso learn how to plan, implement and monitor their programs.

External training organizations can provide professional training, consulting services, and networking to implementers through highly skilled advisors and volunteers. Experienced in-country organizations can also act as local trainers and are capable of training other community organizations in the various roles required to implement HWTS programs.

Technical Training and Education Organizations

CAWST, the Centre for Affordable Water and Sanitation Technology, based in Canada, provides technical training and consulting services on HWTS to implementing organizations around the world. CAWST starts with education and training to build local capacity. They deliver training that is customized for the different implementation roles. After training, CAWST provides on-going support to help organizations with program development, overcome barriers to implementation, and make connections with other implementers.

The Swiss Federal Institute of Aquatic Science and Technology (Eawag), based in Switzerland, provides technical assistance, support and education programs to NGOs and governments in developing countries. They focus on the worldwide promotion and implementation of SODIS programs.

3.4.4 Other Stakeholders

It is important for implementers to work with and create effective relationships with other stakeholders. There are different types of stakeholders that play a role at various times, including donors, government, universities and education institutes.

- **Donors**include local and international individuals, community organizations, foundations, and government agencies. Implementing organizations need long-term, consistent funding to ensure that their activities can be executed without disruption. Implementers have a role to play in educating donors who may not be familiar with HWTS and implementation best practices. It is helpful for donors to understand why and what they are funding when they are reviewing and approving proposals, providing advice, and conducting program evaluations.

- **Governments**have the mandate for providing safe water and can benefit from HWTS implementation programs. Some governments have drafted national HWTS guidelines. Support and endorsement from the government gives credibility to HWTS and implementers. Governments may be a source of funding and can provide in-kind resources to support implementers, such as workspace or transportation.
- **Universities and education institutes** provideresearch which can build the case for HWTS as an intervention worthy of support by policy makers and donors (Clasen, 2009). Universities and other institutes can conduct research on technology development and program implementation. Universities can also help implementers conduct program evaluations.

3.4.5 Use a Capacity Building and Competency Validation Process

A **competency** is a knowledge, skill or attitude that is a standardized requirement for somebody to properly perform a specific job or role. A list of competencies can be created by implementers for each role within their organization, such as trainer, product manufacturer or community health promoter.

Validation is the process of checking people's knowledge, skills and attitudes to confirm that they are competent in their role. Validators can be from within the implementing organization or from external training organizations.
Implementers may use a capacity building and competency validation process for several reasons:

- Provides an opportunity and framework by which individuals and organizations can improve their knowledge, skills and attitude with respect to a specific process or task
- Brings credibility to the organization by giving justifiable confidence in their capacity to provide high quality products and service
- Allows the implementer to pursue opportunities for financing or funding since they can demonstrate the quality of their products and services
- Distinguishes those who are trained to provide a good quality product and service from those who do not

Implementers need to ensure that time and resources are available to support individuals in improving existing capacities and developing new ones. A needs assessment can be conducted to help organizations identify gaps in people's competencies and create a plan to address the gaps and build their capacity. The length of time required for the capacity building and competency validation process is individual specific and depends on the baseline of the individual's knowledge and skills.

There is no standard way to build capacity. Often people participate in trainings, and later by apprenticing with qualified staff or external experts to gradually take on more responsibility as they build their confidence, knowledge and skills. Building capacity and competencies takes more than just a one-time training event. It is important to provide on-going coaching and mentoring to provide feedback and support as people develop and practice their new skills.

Example Competencies for Community Health Promoters

A Community Health Promoter should be able to:

- Describe their role as a Community Health Promoter
- Identify local water and sanitation issues in the community
- Describe water-related disease transmission routes
- Describe the multi-barrier approach to safe water
- Demonstrate active listening and effective questioning skills
- Demonstrate how to facilitate participatory learning activities
- Demonstrate how to properly use and maintain various HWTS options
- Demonstrate how to effectively conduct a household visit

3.5 Program Financing

Implementers need consistent and long-term funding to ensure that all of their program activities are executed without disruption. Adequate financing is essential to ensure that implementation efforts are sustained and that they can be scaled up. Given the numbers of independent organizations operating at different levels, the success of scaling up HWTS will rely on providing varying amounts of funding to numerous implementers, including the often neglected smaller organizations.

The costs of implementation are highly program specific. At a minimum, the following costs should be considered:

- Program planning and administration
- Promotion and education activities
- Product manufacturing and distribution
- Monitoring for improvement
- Evaluation

Implementers often need a combination of funding sources to cover their expenses. It is important to figure out who is financially responsible for each cost, and over what time period. Financing also depends on the organization's legal structure (e.g. for profit, NGO status) and its implementation strategy (e.g. subsidized products, retail sales). Potential funding sources may include:

- Local and international donors
- Implementing organization
- Earned revenue from households
- Government partnerships

The key for implementers to obtain funding is to know who to ask for support, to clearly state the reasons why this financial support is needed, and to explain how it will lead to more effective HWTS programs. Typically, funding begins with small costs to start a demonstration project, with larger amounts made available based on the results and plans.

While there are no fixed models for financing there are several lessons that have been learned through HWT implementation, including:

- Raising awareness, education and capacity building for HWTS are almost always a public sector activity, and are highly subsidized
- Users need to pay for their own long term operation and maintenance whereas initial capital costs can (and in some cases should) be subsidized
- Durable products often need to be subsidized to enable access by the poorest
- Households need to invest in HWTS at some level, whether in kind or small financial contributions

These lessons will be discussed further in the following sections.

3.5.1 Program Planning and Administration

Program planning and administration need adequate attention and funding to increase the chance of implementation success. Those who fail to plan, plan to fail.

Many implementers underestimate the time and financial resources required to make comprehensive plans, and thus fail to seek or allocate sufficient resources to planning activities. As a consequence, many essential elements of planning are bypassed, and the overall program design becomes fragmented. The different components (e.g. creating demand, supplying products and services, and monitoring) are not thoroughly considered, and coordination and communications with stakeholders are weak. The end results are often ineffective or unsuccessful HWTS implementation.

Funding for program planning and administration is commonly provided by donors or from within the implementing organization. The level of funding is dependent on many factors, such as the organization's internal financial and institutional capacity, the knowledge and commitment to HWTS among donors, and the perceived reputation of the implementing organization.

3.5.2 Promotion and Education Activities

In many cases, implementers have found the cost of promotion and education activities (i.e. software) to be far greater than the cost of manufacturing the HWTS product (i.e. hardware).

As discussed previously, creating demand through behaviour change is a long and demanding process. To create real and lasting change in the perception and practice of HWTS, it is important to have a long-term investment of human and financial resources required for promotion and then followed up with education.

Raising awareness, education and capacity building for HWTS are almost always a public sector activity, and highly subsidized. These expenses are often covered through donor funding and government partnerships to generate widespread acceptance and adoption of HWTS. For example, the social marketing strategy used by PSI is designed to recover the cost of product manufacture and distribution, but not the promotion costs which are covered by donor funding from USAID.

3.5.3 Product Manufacturing and Distribution

For most of the HWTS options, there are capital and recurrent costs associated with manufacturing, distribution, operation, and maintenance. Consumable products need to be replenished on a regular basis and therefore have on-going recurrent costs; they generally have no capital costs. Durable products havecapital costs and minimal recurrent costs.

The relationship between what the households are expected to pay and the actual production and distribution costs can be divided into the following four categories:

- **Fully subsidized as a public good:** Households receive the HWTS product without paying any money.
- **Subsidized with partial cost recovery:** Households pay for a portion of the HWTS product cost.
- **Full cost recovery:** Households pay for the full cost of the HWTS product.
- **Full cost recovery with profit:** Households pay for the full cost of the HWTS product plus an additional cost allowing it to be sold on a commercial basis.

It is generally agreed and widely accepted that for programs to be sustainable, households should pay the full cost of consumable products and recurrent costs.

However, some form of cost sharing is usually required to make the capital cost of durable products accessible to the poor. Durable products are often partially subsidized so that households contribute a small portion of the product cost, whether it is monetary or in-kind. It is important to consider both the ability and the willingness of the households to pay. Implementers have also set different prices for the technology depending on the wealth of the household in the community. This way, richer households pay more and cross-subsidize the costs for poorer families. Research has shown that the poor will pay, but payment needs to be flexible to their situation.

Implementers must engage donors to provide the necessary funding to cover the product subsidies given to households.

Moving from Subsidies to Full Cost Recovery – Ceramic Filters, Cambodia

International Development Enterprises Cambodia (IDE) and Resource Development International-Cambodia (RDI) have been manufacturing and distributing ceramic pot filters in Cambodia since 2001 and 2003, respectively. Their production is evolving from subsidized NGO-based implementation to market-based, full cost recovery programs. The ceramic filters are accessible to all but the very poorest households.

IDE has four regional distributors covering 131 retailers in 19 provinces, operating on a full cost recovery basis. They ended subsidized distribution of filters in 2005. IDE sells about 22,000 filters each year at full cost (US$7.50-US$9.50) – about half to NGO partners and the other half through retailers.

RDI is able to sell about 23,000 filters a year at full cost (US$8.00) through direct sales to users, local contract vendors, and sales to NGOs and government agencies. A relatively small number of filters are also distributed at subsidized cost to villages in an NGO-led program. The subsidies are targeted to the poorest households, as determined by a means assessment, and the costs vary from US$1 -7.

(Brown et al., 2007)

3.5.4 Monitoring and Evaluation

Monitoring and follow up visits are essential to support people as they learn to incorporate HWTS into their daily routines. This helps to ensure its proper and consistent use over the long-term.

The cost of monitoring and follow up is not limited to household visits. Other expenses such as water quality testing, technical troubleshooting, reinforcement education and training, as well as program evaluation are important and should be considered as well.

There are a range of options to fund monitoring and evaluation activities. In some cases, donors support monitoring during the program period and an evaluation at the end of the fuding period, after which the funding must come from other sources. Local government institutions and/or community health promoters are often encouraged to conduct monitoring and follow up well beyond the program period so the costs are essentially shifted over to their agencies or organizations. In other cases, the cost of monitoring and follow up is incorporated into the overall product cost to be recovered at the time of sale. Occasionally, some implementers may charge a service fee to households for monitoring, troubleshooting, and technical repair services.

3.6 Implementation Case Studies

A review of HWTS programs highlights the diversity of implementers and the wide range of strategies they use to create their own unique approaches to implementation.

Even within the same country, there is an assortment of implementers, situational contexts, and strategies. This level of complexity makes it difficult to simplify implementation into typical approaches. However, social and commercial marketing are two approaches which are emerging and being used by a variety of implementers.

Implementation case studies are provided in **Appendix D** to illustrate the variety of approaches that are used by different types of organizations. In particular, the case studies highlight the strategies used by the implementer to address the following:

- Creating demand for HWTS
- Supplying HWTS products and services
- Monitoring and continuous improvement
- Building human capacity
- Program financing

3.7 Summary of Key Messages

- There is no standard approach for getting HWTS into people's homes. There are a variety of organizations implementing different HWTS options in different ways. This level of complexity makes it difficult to simplify implementation into typical approaches.
- Implementers should address three key components to make them more likely to succeed:
    1. Creating demand for HWTS
    2. Supplying the required HWTS products and services to meet the demand
    3. Monitoring and continuous improvement of program implementation
- The organization's ability to plan and implement the key components is determined by their human capacity (people) and financing (money).
- Awareness and education are needed to create demand and convince households of the need and benefits of HWTS. The following steps can be used to create demand:
    1. Identify an appropriate target population.
    2. Select appropriate and feasible HWTS options.
    3. Increase awareness of HWTS as a solution for getting safe water, and educate people on the relationship between water and health.
    4. Use demonstration projects to convince people of the benefits of HWTS.
    5. Engage government agencies to give credibility to HWTS.
    6. Provide positive reinforcement to households so they continue using HWTS.
- Households need both the product and support services to ensure the proper and consistent use of HWTS over the long term.
- HWTS options can be divided into consumable and durable products. Consumable products require an uninterrupted and long-term supply chain, and their recurrent costs should not be subsidized. For durable products, the capital cost may require partial subsidies to make it affordable.
- The key to successful monitoring is to keep it simple and within the means of the organization.
- Developing individual people's knowledge and skills is part of building the overall organizational capacity required for implementation. A competency building and validation process can be used to increase both individual and organizational capacity.
- A variety of roles are needed to implement HWTS programs, including Program Implementers, Community Health Promoters, Trainers and other Stakeholders.
- Implementers need consistent and long-term funding to ensure their program activities are executed without disruption. Costs are highly program specific and implementers often need a combination of funding sources to cover their expenses.

4 Additional Resources

Akvopedia
www.akvo.org/wiki/index.php/Main_Page

Akvopedia is an open water and sanitation resource that anyone can edit. The goal of Akvopedia is to improve water and sanitation projects through knowledge exchange on smart and affordable technical solutions and effective approaches. The Water Portal contains explanations on various household water treatment technologies.

Centers for Disease Control and Prevention (CDC)
Website: www.cdc.gov/safewater

CDC promotes the Safe Water System (SWS) – a water quality intervention that employs simple, robust, and inexpensive technologies appropriate for the developing world. The objective is to make water safe through disinfection and safe storage at the point of use. CDC provides various publications including the Safe Water System Handbook and fact sheets on their programs and various household water treatment options.

CAWST, the Centre for Affordable Water and Sanitation Technology
Website: www.cawst.org

CAWST is a Canadian non-profit organization focused on the principle that clean water changes lives. CAWST believes that the place to start is to teach people the knowledge and skills they need to have safe water in their homes. CAWST transfers knowledge and skills to organizations and individuals in developing countries through education, training and consulting services. One of CAWST's core strategies is to make water knowledge common knowledge. This is achieved, in part, by developing and freely distributing education materials with intent of increasing its availability to those who need it the most. CAWST provides free open content training manuals, posters, learning activities, and HWTS fact sheets. These materials are provided to workshop participants, interested organizations upon request, and are available online.

International Network to Promote HWTS
Website: www.who.int/household_water/network/en/index.html

The Network was set up to accelerate health gains to those without reliable access to safe drinking water. It was established by the World Health Organization and is aimed at promoting HWTS. The network format optimizes flexibility, participation and creativity to support coordinated action. Membership in the Network is open to all interested stakeholders that agree with the Network mission and guiding principles and who are willing to commit themselves to working toward achieving the objectives of the Network. The World Health Organization provides the Secretariat for the Network.

International Water and Sanitation Centre (IRC)
Website: www.irc.nl

IRC bridges the knowledge gap and joint learning with partners for improved, low-cost water supply, sanitation and hygiene in developing countries. IRC offers public access to a bank of information and interactive tools. In addition to more than 100 documents on water and sanitation, they provide the Source Water and Sanitation News Service, the Source Bulletin, a digital library, InterWater Thesaurus, and a question and answer service.

Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs
Website: www.jhuccp.org/

CCP advances the science and art of strategic communication to improve health and save lives. They are a recognized leader in the field of health communication, with extensive technical expertise and program experience in social and behaviour change communication. Researchers have published documents on social, cultural and behavioral correlates on household water treatment.

London School of Hygiene and Tropical Medicine (LSHTM)
Website: www.lshtm.ac.uk

The LSHTM's mission is to contribute to the improvement of health worldwide through the pursuit of excellence in research, postgraduate teaching and advanced training in national and international public health and tropical medicine, and through informing policy and practice in these areas. LSHTM conducts extensive academic research on household water treatment and safe storage in developing countries.

Massachusetts Institute of Technology (MIT)
Website: http://web.mit.edu/watsan/tech_hwts.html

This MIT website offers information on HWTS and technologies, global water mapping, International HWTS Network, methods for water quality field testing, and open content courses on Water and Sanitation Infrastructure in Developing Countries.

Oxfam
Website: www.oxfam.org.uk/resources/learning/humanitarian/watsan.html

Oxfam is a humanitarian organization that acts as a catalyst for overcoming poverty. To achieve the greatest impact, they work on three fronts: saving lives by responding swiftly to provide aid, support and protection during emergencies; developing programs and solutions that empower people to work their way out of poverty; and campaigning to achieve lasting change. Oxfam has developed emergency manuals and guidelines, as well as technical briefing notes on public health engineering topics, including household water treatment and storage.

Swiss Agency for Development and Cooperation (SDC)
Website: www.poverty.ch/safe-water.html

SDC's 2008 document "Marketing Safe Water Systems" provides unique insights – from the varied perspectives of users, disseminators, producers and retailers – into the marketing challenges of point-of-use treatment devices. It discusses the 5 Ps of marketing: Product, Price, Place, Promotion and People. As well, the document puts forward a mix of marketing and social marketing strategies which can raise the dissemination of household water treatment systems to the levels required for achieving the Millennium Development Goals.

United Nations Children's Fund (UNICEF)
Website: www.unicef.org/wes/
www.unicef.org/wes/files/Scaling_up_HWTS_Jan_25th_with_comments.pdf

UNICEF works in more than 90 countries around the world to improve water supplies and sanitation facilities in schools and communities, and to promote safe hygiene practices. In emergencies, UNICEF provides urgent relief to communities and nations threatened by disrupted water supplies and disease. Their 2008 publication "Promotion of Household Water Treatment and Safe Storage in UNICEF WASH Programmes" summarizes some of the leading approaches for treating water in the home, provides evidence of their effectiveness and cost effectiveness in development and emergency settings and it outlines how the promotion of HWTS can be incorporated with UNICEF programs.

United States Agency for International Development (USAID)
Website: www.ehproject.org/

The Hygiene Improvement Project (HIP) was a 6-year USAID-funded program (2004-2010) that sought to reduce diarrheal diseases and improve child survival through the promotion of three key hygiene practices: hand washing with soap, safe feces disposal, and safe storage and treatment of household drinking water. The website remains available to share the resources developed by HIP, but will no longer be updated.

United States Agency for International Development (USAID)
Website: www.ehproject.org

USAID is the largest bi-lateral donor supporting HWTS. On their website, they have resources and materials developed by their implementers, as well as a comprehensive bibliography on point of use water disinfection at: www.ehproject.org/ehkm/pou_bib2.html. There is also a link to a Google group on household water treatment.

Water and Sanitation Program (WSP)
Website: www.wsp.org

WSP is a multi-donor partnership administered by the World Bank. The goal is to help the poor gain sustained access to improved water supply and sanitation services (WSS). WSP works directly with client governments at the local and national level in 25 countries through regional offices in Africa, East and South Asia, Latin America and the Caribbean, and in, Washington D.C. WSP focuses on five topics: Financing the Sector, Rural Water Supply and Sanitation, Strategic Communications, Sanitation and Hygiene, Urban Water Supply and Sanitation. WSP offers the Access Newsletter and news updates to subscribers.

World Health Organization (WHO)
Website: www.who.int/household_water/en/

WHO works on aspects of water, sanitation and hygiene where the health burden is high, where interventions could make a major difference and where the present state of knowledge is poor. WHO has produced several documents related to HWTS that are available online. As well, the WHO manages a water, sanitation and health listserve to subscribers.

5 References

Arnold B and Colford J (2007). Treating Water with Chlorine at Point-of-Use to Improve Water Quality and Reduce Child Diarrhea in Developing Countries: A Systematic Review and Meta-Analysis. American Journal of Tropical Medicine and Hygiene, 76(2):354–364.

Arnold B, Arana B, Mausezahl D, Hubbard A and Colford J (2009).Evaluation of a Pre-Existing, 3-year Household Water Treatment and Handwashing. Int'l J Epidemiology 2009;1–11.

Ashraf N, Berry J and Shapiro J (2006). Can Higher Prices Stimulate Product Use? Evidence from a Field Experiment on Clorin in Zambia.Presentation at the Berkeley Water Center Workshop on Water, Sanitation and Hygiene. Berkeley, California, November 6, 2006.

Blanton B, Ombeki S, Oluoch GO, Mwaki A, Wannemuehler K and Quick R (2010). Evaluation of the Role of School Children in the Promotion of Point-of-Use Water Treatment and Handwashing in Schools and Households—Nyanza Province, Western Kenya, 2007. Am J Trop Med Hyg, 2010; 82: 664 - 671.

Boisson S, Schmidt W.P, Berhanu T, Gezahegn H and Clasen T (2009).Randomized Controlled Trial in Rural Ethiopia to Assess a Portable Water Treatment Device.
Environ SciTechnol, 2009; 43(15):5934-9.

Brown J, Sobsey M and Proum S (2007).Improving Household Drinking Water Quality: Use of Ceramic Water Filters in Cambodia.Field Note, Water and Sanitation Program.Cambodia Country Office, Phnom Penh, Cambodia. Available at: www.wsp.org

Carty, W. (1991).Towards an Urban World.Earthwatch (43): 2-4. 1991. *Cited in*Solutions for a Water-Short World, Population Reports (1998). Population Information Program, Center for Communication Programs, the Johns Hopkins School of Public Health, USA. Volume XXVI, Number 1, September, 1998. Available at: www.infoforhealth.org/pr/m14edsum.shtml

Clasen T and Boisson S (2006).Household-Based Ceramic Water Filters for the Treatment of Drinking Water in Disaster Response: An Assessment of a Pilot Programme in the Dominican Republic. Water Practice & Tech. 1:2 doi:10.2166/WPT.200603.

Clasen T., Roberts I, Rabie T., Schmidt W and Cairncross S (2006). Interventions to Improve Water Quality for Preventing Diarrhoea.Cochrane Database of Systematic Reviews 2006, Issue 3. Art. No.: CD004794. DOI:10.1002/14651858.CD004794.pub2.

Clasen T, Haller L, Walker D, Bartram J, Cairncross S (2007). Cost-Effectiveness Analysis of Water Quality Interventions for Preventing Diarrhoeal Disease in Developing Countries. J. Water & Health 5(4):599-608.

Clasen T, Saeed T, Boisson S, Edmondson P, Shipin O (2007). Household-Based Chlorination of Drinking Water Using Sodium Dichloroisocyanurate (NaDCC) Tablets: A Randomized, Controlled Trial to Assess Microbiological Effectiveness in Bangladesh. Am J. Trop. Med. &Hyg. 76(1):187-92.

Clasen T, Do Hoang T, Boisson S, Shippin O (2008). Microbiological Effectiveness and Cost of Boiling to Disinfect Water in Rural Vietnam.Environmental Sci. & Tech. doi 10.1021/es7024802.

Clasen, T (2009). Scaling Up Household Water Treatment in Low-Income Countries.World Health Organization, Geneva, Switzerland. Available at: www.who.int/household_water/research/household_water_treatment/en/

Dow Baker C, Rolling L, Martinez R, Baryar A, Bulos G, Lipman M (2008).Power of Knowledge in Executing Household Water Treatment Programs Globally.WEDC International Conference, Accra, Ghana. Available at: http://wedc.lboro.ac.uk/knowledge/conference_papers.html?cid=33

Environmental Technology Verification Canada (2007).Frequently Asked Questions about the ETV Canada Environmental Performance Claim Verification Program. Available at: www.etvcanada.ca/faq.asp

Esrey SA, Feachem RG and Hughes, JM (1985). Interventions for the Control of Diarrhoeal Diseases Among Young Children: Improving Water Supplies and Excreta Disposal Facilities. Bull. WHO 64, 776-72.
Esrey SA, Potash JB, Roberts L and Shiff, C (1991).Effects of Improved Water Supply and Sanitation on Ascariasis, Diarrhoea, Dracunculiasis, Hookworm Infection, Schistosomiasis, and Tracoma. Bull. WHO 69, 609-21.

Fewtrell, L., Kaufmann, RB., Kay, D., Enanoria, W., Haller, L. and JM Jr. Colford (2005). Water, Sanitation, and Hygiene Interventions to Reduce Diarrhoea in Less Developed Countries: A Systematic Review and Meta-analysis. *Lancet Infect Dis 5*: 42-52.

Figueroa ME and Kincaid DL (2010). Social, Cultural and Behavioral Correlates of Household Water Treatment and Storage. Center Publication HCI 2010-1: Health Communication Insights, Baltimore: Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs. Available at: www.jhuccp.org/sites/all/files/Household%20Water%20Treatment%20and%20Storage%202010.pdf

Graf J, Meierhofer, R., Wegelin, M. and Mosler, HJ. (2008). Water Disinfection and Hygiene Behaviour in an Urban Slum in Kenya: Impact on Childhood Diarrhoea and Influence of Beliefs. International Journal of Environmental Health Research, 18(5), 335-355. Available at: www.sodis.ch/methode/forschung/publikationen/index_EN

Hagan JM, Harley N, Pointing D, Sampson M, Smith K and Soam V (2009). Ceramic Water Filter Handbook, Version 1.1. Resource Development International, Phnom Penh, Cambodia. Available at: www.rdic.org/waterceramicfiltration.htm

Hanson M and Powell K (2006). Procter & Gamble and Population Services International (PSI): Social Marketing for Safe Water. Paris, Institut Européen d'Administration des Affaires.

Heri S and Mosler HJ (2008).Factors Affecting the Diffusion of Solar Water Disinfection: A Field Study in Bolivia. Health EducBehav 2008; 35; 541. Available at: www.sodis.ch/methode/forschung/publikationen/index_EN

Hörman A, Rimhanen-Finne R, Maunula L, von Bonsdorff CH, Rapala J, Lahti K and Hänninen ML (2004). Evaluation of the Purification Capacity of Nine Portable, Small-Scale Water Purification Devices.Water Science and Technology. 02/2004; 50(1):179-83.

Hunter P (2009). Household Water Treatment in Developing Countries: Comparing Different Intervention Types Using Meta-Regression. Environ Sci Technol. 43(23):8991-7.

Hunter PR, Zmirou-Navier D and Hartemann P (2009).Estimating the Impact on Health of Poor Reliability of Drinking Water Interventions in Developing Countries.Sci Total Environ. 407(8):2621-4.

Hutton, G. and L. Haller (2004).Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level.Water, Sanitation and Health Protection of the Human Environment, World Health Organization, Geneva WHO/SDE/WSH/04.04.

Hutton G, Haller L, Bartram J (2007). Global Cost-Benefit Analysis of Water Supply and Sanitation Interventions. J Water Health 5(4):481-502.

Hutton G and J Bartram (2008).Regional and Global Costs of Attaining the Water Supply and Sanitation Target (Target 10) of the Millennium Development Goals. World Health Organization, Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/economic/cba_interventions/en/index.html

International Finance Corporation (2009). Safe Water for All: Harnessing the Private Sector to Reach the Underserved. International Finance Corporation, World Bank Group, Washington, DC, USA. Available at: www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/p_SafeWaterReport/$FILE/IFC_WaterReport.pdf

International HIV/AIDS Alliance (2006). All Together Now: Community Mobilization for HIV/AIDS. Available at: www.aidsalliance.org

Johns Hopkins University (2009).AmanTirta, Safe Water Systems.Johns Hopkins Bloomberg School of Public Health, the Centre for Communications Programs. Available at: www.jhuccp.org/node/755

Kremer M, Miguel E, Mullainathan S, Null C and Zwane A (2008). Trickle Down: Chlorine Dispensers and Household Water Treatment. Workshop on Scaling Up the Distribution of Water Treatment Technologies, Harvard University, Cambridge, MA December 12, 2008.

Kraemer S (2009). Insights from the SODIS Project in Zimbabwe: Assessment of Adoption Factors and Recommendations for Effective promotion Strategies. Eawag, Dübendorf. Available at: www.sodis.ch/methode/forschung/publikationen/index_EN

Luby SP, Mendoza C, Keswick BH, Chiller TM and Hoekstra RM (2008).Difficulties in Bringing Point-of-Use Water Treatment to Scale in Rural Guatemala. Am J Trop Med Hyg 78(3):382-387

Makutsa P, Nzaku K, Ogutu P, Barasa P, Ombeki S, Mwaki A and Quick R (2001). Challenges in Implementing a Point-of-Use Water Quality Intervention in Rural Kenya.Am J Pub. Health 91(10): 1571-1573.

Mausezahl D, Christen A, Duran Pacheco G, Tellez FA, Iriarte M, et al. (2009) Solar Drinking Water Disinfection (SODIS) to Reduce Childhood Diarrhoea in Rural Bolivia: A Cluster-Randomized, Controlled Trial. PLoS Med 6(8): e1000125. doi:10.1371/journal.pmed.1000125.

Ministry of Health and Social Welfare, Tanzania (2009). Report on The International Conference on Household Safe Water Management for Waterborne Disease Control, 4th - 6th February 2009, Bagamoyo Tanzania.

Mintz E, Bartram J, Lochery P and Wegelin M (2001). Not Just a Drop in the Bucket: Expanding Access to Point-of-Use Water Treatment Systems. Am. J. Pub. Health 91(10): 1565-70.

Moser S, Heri S, and Mosler HJ (2005).Determinants of the Diffusion of SODIS, A Quantitative Field Study in Bolivia, Summary Report.Duebendorf, Switzerland: Eawag Available at: www.sodis.ch/methode/forschung/publikationen/index_EN

Namsaat (2001).Promoting Options for Cleaner, Healthier Lives: Translating Sector Strategy into Better Hygiene Practices in Lao PDR.Water and Sanitation Program for East Asia and the Pacific. Lao PDR. Available at: www.sulabhenvis.in/admin/upload/pdf_upload/eap_lao_translating.pdf

Ngai T (2010). Characterizing the Dissemination Process of Household Water Treatment Systems in Developing Countries. Dissertation Submitted for the Degree of Doctor of Philosophy. Centre for Sustainable Development, Department of Engineering, University of Cambridge, UK.

Olembo L, Kaona FAD, Tuba M, Burnham G (2004). Safe Water Systems: An Evaluation of the Zambia Clorin Program. Johns Hopkins University, Baltimore, USA.

O'Reilly CE, Freeman MC, Ravani M, Migele J, Mwaki A, Ayalo M, Ombeki S, Hoekstra RM, Quick R (2006). Evaluation of the Role of School Children in the Adoption of a School-Based Safe Drinking Water and Hygiene Intervention in Their Households

O'Reilly, CE, Freeman MC, Ravani M, Migele J, Mwaki A, Ayalo M, Ombeki S, Hoekstra RM and Quick R. (2008). The Impact of a School-Based Safe Water and Hygiene program on Knowledge and Practices of Students and Their Parents — Nyanza Province, Western Kenya, 2006. Epidemiology and Infection (2008), 136:80-91. Available at: http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=1585664

Parker A (2009). How Can Water and Sanitation Services to the Urban Poor Be Scaled Up? Water & Sanitation for the Urban Poor, London, England. Available at: www.wsup.com/documents/Howtoscaleup23Dec09.pdf

Parker A, Stephenson R, Riley P, Ombeki S, Komolleh C, Sibley L and Quick R. (2006). Sustained High Levels of Stored Drinking Water Treatment and Retention of Hand Washing Knowledge in Rural Kenyan Households Following a Clinic-based Intervention.Epi Infect 2006; 134(5):1029-36.

Population Services International (2010).About PSI. Available at: www.psi.org

POUZN Project (2007). Best Practices in Social Marketing Safe Water Solution for Household Water Treatment: Lessons Learned from Population Services International Field Programs. The Social Marketing Plus for Diarrheal Disease Control: Point-of-Use Water Disinfection and Zinc Treatment (POUZN) Project, Abt Associates Inc., Bethesda, MD, USA.

Prüss-Üstün A and Corvalan C (2006).Preventing Disease Through Health Environment. Towards an Estimate of the Environmental Burden of Disease.World Health Organization, Geneva, Switzerland. Available at: www.who.int/quantifying_ehimpacts/publications/preventingdiseasebegin.pdf

Rheingans and Dreibelbis R (2007). Disparities in Sûr'Eau use and Awareness: Results from the 2006 PSI TraC Survey (Preliminary Results).

Roberts L, Chartier Y, Chartier O, Malenga G, Toole M and Rodka H. (2001).Keeping Clean Water Clean in a Malawi Refugee Camp: A Randomized Intervention Trial. Bulletin of the World Health Organization, 79:280–287

Rosa G and Clasen T (2010).Estimating the Scope of Household Water Treatment in Low- and Middle-Income Countries. Am. J. Trop. Med. Hyg. 82(2), 2010, pp. 289-300.

Ryan K, Ray C and Sherris J (2003).Sherris Medical Microbiology: An Introduction to Infectious Diseases. McGraw Hill Medical.

Schmidt WP and Cairncross S (2009). Household Water Treatment in Poor Populations: Is There Enough Evidence for Scaling Up Now? Environ Sci Technol. 43(4):986-92.

Sobsey, MD (2002). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply. Geneva, Switzerland. (WHO/SDE/WSH/02.07)

Sobsey MD, Stauber CE, Casanova LM, Brown JM and Elliott MA (2008). Point of Use Household Drinking Water Filtration: A Practical, Effective Solution for Providing Sustained Access to Safe Drinking Water in the Developing World. Environ Sci Technol. 42(12):4261-7.

SODIS (2010).Projects, Asia, Lao PDR. Swiss Federal Institute of Aquatic Science and Technology, Switzerland, Available at: www.sodis.ch/projekte/asien/laos/index_EN
United Nations Children's Fund (2008). Promotion of Household Water Treatment and Safe Storage in UNICEF WASH Programmes. Available at: www.unicef.org/wes/files/Scaling_up_HWTS_Jan_25th_with_comments.pdf

United Nations Children's Fund (2009).UNICEF Strategies on Scaling Up HWTS.Presentation.5th World Water Forum, Istanbul, Turkey. March, 2009.

United Nations Development Program (2006). Human Development Report 2006:Beyond Scarcity: Power, Poverty and the Global Water Crisis. New York, USA. Available at:http://hdr.undp.org/en/media/HDR06-complete.pdf

United Nations Environment Programme (2002).Vital Water Graphics. Available at:www.unep.org/dewa/assessments/ecosystems/water/vitalwater/21.htm

United States Agency for International Development (2010).Access and Behavioral Outcome Indicators for Water, Sanitation and Hygiene.USAID Hygiene Improvement Project, Washington, DC, USA. Available at:http://pdf.usaid.gov/pdf_docs/PNADW489.pdf

United States Environmental Protection Agency (2007). EPA's Environmental Technology Verification Program Fact Sheet.EPA/600/F-07/005. Available at: www.epa.gov/etv/index.html

Waddington H, Snilstveit, White H and Fewtrell L (2009).Water, Sanitation and Hygiene Interventions to Combat Childhood Diarrhoea in Developing Countries. Delhi: International Initiative for Impact Evaluation.

Water and Sanitation Program (2002). Learning What Works for Sanitation: Revisiting Sanitation Success in Cambodia. Water and Sanitation Program, East Asia and the Pacific Region. Jakarta, Indonesia. Available at: www.wsp.org

Water Quality Association (n.d.).Water Classifications. Available at: www.pacificro.com/watercla.htm

Wood, C. (2008) Dry Spring: The Coming Water Crisis of North America. Raincoast Books, Vancouver, Canada.

World Health Organization (2002). World Health Report 2002: Reducing Risks, Promoting Healthy Life. Geneva, Switzerland. Available at: www.who.int/whr/2002/en/

World Health Organization (2003).Domestic Water Quantity, Service, Level and Health. Geneva, Switzerland. Available at: www.emro.who.int/ceha/pdf/Doc-Domestic.pdf

World Health Organization (2004). The World Health Report 2004: Changing History. Geneva, Switzerland. Available at: www.who.int/whr/2004/en/

World Health Organization (2004). Inheriting the World: The Atlas of Children's Health and the Environment. Geneva, Switzerland. Available at: www.who.int/ceh/publications/atlas/en/

World Health Organization (2006).Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

World Health Organization (2007).Combating Waterborne Disease at the Household Level. International Network to Promote Household Water Treatment and Safe Storage, World Health Organization. Geneva, Switzerland. Available at: www.who.int/household_water/advocacy/combating_disease/en/index.html

World Health Organization (2008). Water Quality Interventions to Prevent Diarrhoea: Cost and Cost-Effectiveness. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/economic/prevent_diarrhoea.pdf

World Health Organization (2008).Essential Prevention and Care Interventions for Adults and Adolescents Living with HIV in Resource-Limited Settings. Geneva, Switzerland. Available at: www.who.int/hiv/pub/prev_care/OMS_EPP_AFF_en.pdf

World Health Organization (2011).Evaluating Household Water Treatment Options: Health-based Targets and Microbiological Performance Specifications. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/publications/2011/household_water/en/index.html

World Health Organization and United Nations Children's Fund (2000).Global Water Supply and Sanitation Assessment 2000 Report.
WHO/UNICEF, Geneva/New York.

World Health Organization and United Nations Children's Fund (2006).Core Questions on Drinking-Water and Sanitation for Household Surveys. Available at: www.wssinfo.org/pdf/WHO_2008_Core_Questions.pdf

World Health Organization and United Nations Children's Fund (2008). Progress on Drinking Water and Sanitation: Special Focus on Sanitation. UNICEF, New York, USA and WHO, Geneva, Switzerland. Available at:www.wssinfo.org/en/40_MDG2008.html

World Health Organization and United Nations Children's Fund (2010).Progress on Sanitation and Drinking-Water.WHO Press, Geneva, Switzerland. Available at: www.wssinfo.org

Wright, J., Gundry, S. and R. Conroy (2004). Household Drinking Water in Developing Countries: A Systematic Review of Microbiological Contamination Between Source and Point-of-Use. *Journal of Tropical Medicine and International Health*.Vol 9, No 1, pp 106–117, January 2004.

Appendix A – Chemical Fact Sheets

Centre for Affordable Water and Sanitation Technology

Chemical Contaminants in Drinking Water
Fact Sheet: Arsenic

Sources

Arsenic can naturally occur in ground water and some surface water. It is one of the greatest chemical problems in developing countries. The WHO considers arsenic to be a high priority for screening in drinking water sources (WHO, 2006).

High levels of arsenic can be found naturally in water from deep wells in over 30 countries, including India, Nepal, Bangladesh, Indonesia, Cambodia, Vietnam, Lao PDR, Mexico, Nicaragua, El Salvador and Brazil. In south Asia alone, it is estimated that 60 to 100 million people are affected by unsafe levels of arsenic in their drinking water. Bangladesh is the most severely affected, where 35 to 60 million of its 130 million people are exposed to arsenic-contaminated water. It is possible that arsenic may be found in other locations as more extensive testing is done.

Potential Health Effects

Arsenic is poisonous, so if people drink water or eat food contaminated with arsenic for several years, they develop chronic health problems called arsenicosis.

Melanosis is the first symptom of drinking arsenic contaminated water over a few years. Melanosis is light or dark spots on people's skin, often on the chest, back, or palms. The next step is that hardening skin bulges develop on people's palms and feet – called keratosis. Drinking high amounts of arsenic for a longer time may cause cancer in the lungs, bladder, kidney, skin, liver, and prostate. Arsenic may also cause vascular diseases, neurological effects, and infant developmental defects.

Arsenicosis can be partially reversed and treated in the early stages, by making sure people stop drinking arsenic contaminated water and by improving their nutrition. There is currently no effective cure for arsenic poisoning. The only prevention is to drink water that has safe levels of arsenic.

According to the UNDP (2006), the projected human costs over the next 50 years include 300,000 deaths from cancer and 2.5 million cases of arsenic poisoning.

WHO Guidelines

The World Health Organization (WHO) considers arsenic to be a high priority for testing in drinking water sources. The WHO suggests that drinking water should have less than 0.01 mg/L of arsenic. (0.01 mg/L is the same as 10 μg/L or 10 ppb.)

WHO Guideline for Arsenic in Drinking Water < 0.01 mg/L

Centre for Affordable Water and Sanitation Technology

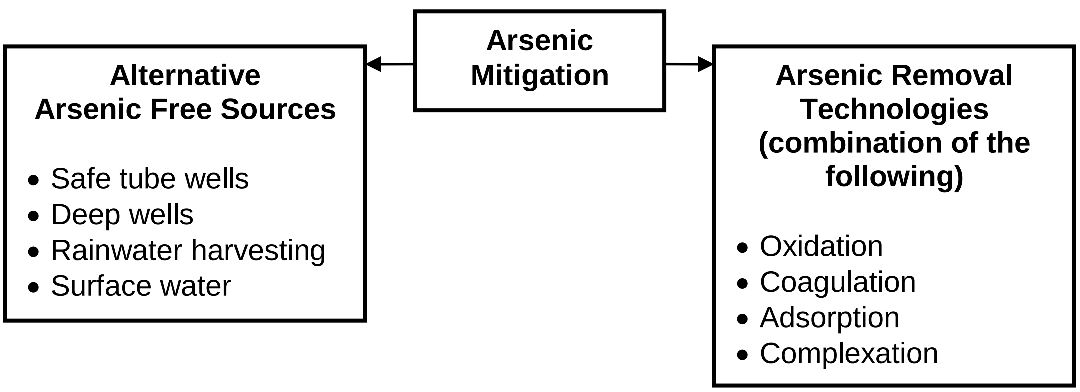
Chemical Contaminants in Drinking Water Fact Sheet: Arsenic

Many countries have their own standards which are less strict than the WHO Guidelines, ranging from 0.025 mg/L to 0.05 mg/L (25-50 ppb). Many Southeast Asian countries that have an arsenic problem have adopted a temporary standard of 0.05 mg/L because it is difficult to test accurately to 0.01 mg/L and to treat water to meet that standard.

Household Water Treatment Options

One way to deal with arsenic in groundwater is to use a different source of drinking water, such as rainwater or surface water. Some people collect and store their rainwater and use it for drinking and cooking instead of arsenic contaminated ground water. If people change their water source to surface water, they will probably need to treat the water to remove turbidity and pathogens.

If people are unable to change to a water source that doesn't have arsenic, there are several different technologies that have been developed to remove arsenic from water. Each technology has advantages and limitations. Many of these technologies are being used in Bangladesh where the arsenic problem is widespread. See the *Household Water Treatment for Arsenic Removal Fact Sheets* for more information on the different technologies.



References

United Nations Development Program (2006). Human Development Report 2006: Beyond Scarcity: Power, Poverty and the Global Water Crisis. New York, USA. Available at: http://hdr.undp.org/en/media/HDR06-complete.pdf

World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

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Chemical Contaminants in Drinking Water Fact Sheet: Fluoride

Sources

Fluoride can naturally occur in groundwater and some surface water. Drinking water is normally the major source of fluoride exposure, with exposure from diet and from burning high fluoride coal also major contributors in some regions.

High levels of fluoride can be found naturally in many areas of the world including, Africa, the Eastern Mediterranean and southern Asia. One of the best known high fluoride areas extends from Turkey through Iraq, Iran, Afghanistan, India, northern Thailand and China. However, there are many other areas with water sources that contain high fluoride levels and which pose a risk to those drinking the water, notably parts of the rift valley in Africa. It is possible that fluoride may be found in other locations as more extensive testing is done.

Potential Health Effects

A small amount of fluoride in water is generally good for strengthening people's teeth and preventing decay. Fluoride is added to some city water systems and certain consumer products to protect teeth such as toothpastes and mouthwashes.

Small amounts of fluoride are generally good for people's teeth. But at higher amounts over time, it can cause dental fluorosis and damage people's teeth by staining and pitting. Over many years, fluoride can build up in people's bones, leading to skeletal fluorosis characterized by stiffness and joint pain. In severe cases, it can cause changes to the bone structure and crippling effects. Infants and young children are most at risk from high amounts of fluoride since their bodies are still growing and developing.

There is currently no effective cure for fluorosis – the only prevention is to drink water that has safe levels of fluoride.

WHO Guidelines

The WHO suggests that drinking water should have 0.5 – 1.0 mg/L to protect teeth. Many cities around the world add fluoride to their drinking water to reach this level.

Higher amounts of fluoride between 1.5 – 4.0 mg/L can cause dental fluorosis. Very high amounts of fluoride greater than 10.0 mg/L can lead to skeletal fluorosis. This is why the WHO suggests that drinking water should not have more than 1.5 mg/L of fluoride.

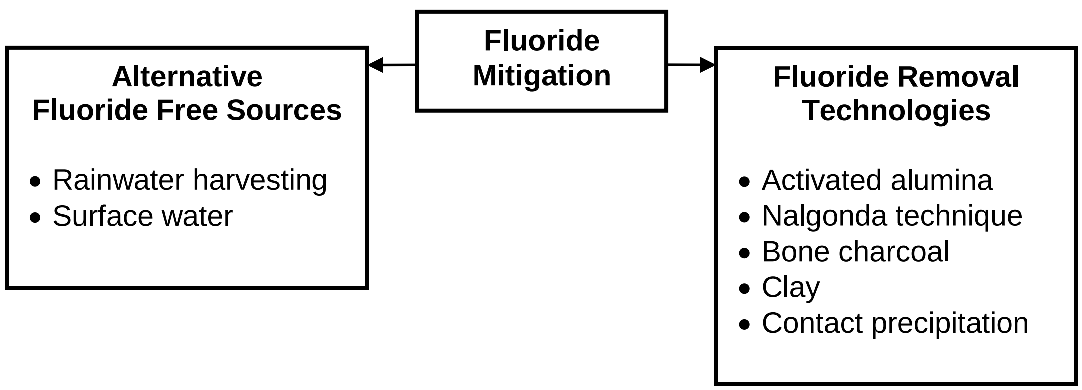
WHO Guideline for Fluoride in Drinking Water < 1.5 mg/L

Chemical Contaminants in Drinking Water
Fact Sheet: Fluoride

Household Water Treatment Options

The best way to deal with fluoride in groundwater is to find a different source of drinking water, such as rainwater or surface water. Some people collect and store their rainwater during the wet season and use it for drinking or to dilute their groundwater during the rest of the year. This helps to lower the amount of fluoride in their water and make it safer to drink. If people change their water source to surface water, they will probably need to treat the water to remove turbidity and pathogens.

Many of the areas that have fluoride contamination are arid and alternative sources of water are not available. There are emerging household water treatment technologies that are able to remove fluoride from drinking water. More research is needed to find a simple, affordable and locally available technology that can be easily used by households.



References

Fawell, J., Bailey, K., Chilton, J., Dahi, E., Fewtrell, L. and Y. Magara (2006). Fluoride in Drinking-water. World Health Organization. IWA Publishing, London, UK. Available at: www.who.int/water_sanitation_health/publications/fluoride_drinking_water/en/index.html

World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

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Chemical Contaminants in Drinking Water Fact Sheet: Iron

Sources

Iron can be naturally found in groundwater and some surface water (such as creeks, rivers and some shallow dug wells). There are areas of the world that have naturally high amounts of iron in their groundwater. Iron can also be found in drinking water that is passed through rusty steel or cast iron pipes.

Iron can come in two forms in water: dissolved and suspended. If groundwater comes from a deep tube well, the iron may be dissolved and not visible. However, once the iron is exposed to air, it usually turns the water black or orange colour. If surface water has iron in it, it will be a red-orange colour from the iron that is suspended in the water.

Iron is a nuisance – high levels can cause an objectionable colour and taste and can stain cooked food, water pipes and laundry. Some types of bacteria use dissolved iron as an energy source and leave slimy red deposits that can clog water pipes.

Potential Health Effects

Drinking water with high concentrations of iron will not make people sick. Iron, however, can change the colour and odour of water and it may cause people to not use it and choose another, possibly contaminated, water source instead.

WHO Guidelines

The WHO does not have a suggested guideline for iron in drinking water since it does not have any adverse health effects.

Usually, people do not like the taste and smell of drinking water that has more than 0.3 mg/L of iron. Concentrations between 1.0 – 3.0 mg/L can be acceptable to people used to drinking anaerobic well water.

Iron levels above 0.3 mg/L can stain water pipes and clothes during washing.

The presence of iron may also lead to bacterial growth that can clog water pipes.

No WHO Guideline for Iron in Drinking Water

Household Water Treatment Options

There are some different technology options that can be combined to help take iron out of drinking water, depending on the level of contamination. Practical household options include aeration to precipitate any dissolved iron, sedimentation, and then filtration to remove any iron particles that remain in suspension.

Chemical Contaminants in Drinking Water Fact Sheet: Iron

Removing suspended iron can be as simple as letting the water stand in a container for a period of time ranging from a few hours to a few days then decanting it, or by filtering the water through cloth. The iron residue will need to be disposed in a safe location.

Biosand or ceramic filters, which are designed primarily for pathogen removal, can also be used to take out some of the iron from drinking water. High levels of iron may cause these filters to clog more quickly, requiring more frequent maintenance which can reduce the efficiency of pathogen removal. In this case, it is recommended to sediment the water beforehand.

References

World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

Centre for Affordable
Water and Sanitation Technology

Chemical Contaminants in Drinking Water
Fact Sheet: Manganese

Sources

Manganese can be naturally found in groundwater and surface water, and it usually occurs with iron. However, human activities may also be responsible for manganese contamination in water in some areas.

Manganese can come in two forms in water: dissolved and suspended. If groundwater comes from a deep tube well, the manganese may be dissolved and not visible. In surface water, manganese can be dissolved or suspended. Water with high levels of suspended manganese usually has a black colour or black flakes in it.

Manganese causes similar nuisance issues as iron. High concentrations can turn water a black colour. It also causes an objectionable taste, stains water pipes and laundry, and forms coatings on water pipes. As well, some types of bacteria feed on manganese and leave black-brown deposits that can also clog pipes.

Potential Health Effects

People need small amounts of manganese to keep healthy and food is the major source for people. However, too much manganese may also cause adverse neurological effects.

High levels of manganese, moreover, can turn water a black colour and it may cause people to not use it and choose another, possibly contaminated, water source instead.

WHO Guidelines

The WHO suggests that drinking water should not have more than 0.4 mg/litre of manganese. The health-based guideline value for manganese is 4 times higher than the acceptability threshold of 0.1 mg/litre.

Usually, people do not like the taste of drinking water that has more than 0.1 mg/litre of manganese. Also, amounts above 0.1 mg/litre can stain water pipes, clothes during washing, and food during cooking. Even levels of manganese at 0.2 mg/litre may form black coatings on distribution pipes that come off into water as small black flakes.

The presence of manganese may also lead to bacterial growth that can clog water pipes.

WHO Guideline for Manganese in Drinking Water < 0.4 mg/L

Chemical Contaminants in Drinking Water
Fact Sheet: Manganese

Household Water Treatment Options

Manganese treatment options are similar to iron, however the removal rates are not as high. There are some different technology options that can be combined to help take manganese out of drinking water, depending on the level of contamination. Practical household options include aeration to precipitate any dissolved manganese, sedimentation, and then filtration to remove any manganese particles that remain in suspension.

Removing suspended manganese can be as simple as letting the water stand in a container for a period of time ranging from a few hours to a few days then decanting it, or by filtering the water through cloth. The manganese residue will need to be disposed in a safe location.

Biosand or ceramic filters, which are designed primarily for pathogen removal, can also be used to take out some of the manganese from drinking water. High levels of manganese may cause these filters to clog more quickly, requiring more frequent maintenance which can reduce the efficiency of pathogen removal. In this case, it is recommended to sediment the water beforehand.

References

World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at:
www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

Centre for Affordable Water and Sanitation Technology

Chemical Contaminants in Drinking Water Fact Sheet: Nitrate and Nitrite

Sources

Nitrate and nitrite are naturally occurring chemicals in the environment that are part of the nitrogen cycle. Nitrate is commonly used in fertilizers and for agriculture and nitrite is used as food preservatives, especially in processed meat.

Nitrate in ground water and surface water is normally low but can reach high levels if there is leaching or runoff from agricultural fertilizers or contamination from human and animal feces. Nitrite is formed as a consequence of microbial activity and may be intermittent.

Potential Health Effects

High nitrate and nitrite levels can cause serious illness by acute exposure. The main health concern is methaemoglobinaemia, or blue baby syndrome, which occurs in infants that are bottle fed with formula prepared with drinking water. It causes them to have difficulty breathing and their skin turns blue from a lack of oxygen. It is a serious illness that can sometimes lead to death.

WHO Guidelines

The WHO suggests that drinking water should have less than 50 mg/L of nitrate to protect against methaemoglobinaemia in bottle-fed infants (short term exposure). In most countries, nitrate levels in surface water are not more than 10 mg/L, although nitrate levels in well water often exceed 50 mg/L (WHO, 2006).

Nitrite levels should be less than 3 mg/litre to protect infants from methaemoglobinaemia (short-term exposure). There is a provisional guideline for long term nitrite exposure set at less than 0.3 mg/L. The guideline value is considered provisional because of the uncertainty of the chronic health effects and our susceptibility to it.

WHO Guideline for Nitrate in Drinking Water < 50 mg/L

WHO Guideline for Nitrite in Drinking Water < 3 mg/L (short-term exposure)

WHO Provisional Guidelines for Nitrite in Drinking Water < 0.2 mg/L (long-term exposure)

Chemical Contaminants in Drinking Water
Fact Sheet: Nitrate and Nitrite

Household Water Treatment Options

The best way to deal with nitrate and nitrite in ground or surface water is to use a different source of drinking water, such as rainwater. Some people collect and store their rainwater and use it for drinking, cooking and preparing baby formula. If people change their water source from ground to surface water, they will probably need to treat the surface water to remove turbidity and pathogens.

High nitrate levels are often associated with higher levels of microbiological contamination since the nitrates may have come from manure or sewage. If high levels of nitrate are detected, then people should treat their water to remove the potential microbiological contamination.

The WHO (2006) suggests that high levels of nitrite may be reduced to acceptable levels by using chlorination.

References

World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at:
www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

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Chemical Contaminants in Drinking Water
Fact Sheet: Total Dissolved Solids

Sources

Total dissolved solids (TDS) is the term used to describe the inorganic salts (mainly sodium chloride, calcium, magnesium, and potassium) and small amounts of organic matter that are dissolved in water. Technically, anything that dissolves in water contributes to the TDS level.

There are areas of the world that have naturally high amounts of TDS in their drinking water. TDS in drinking water comes from natural sources, and to a lesser extent sewage, urban runoff and industrial wastewater. Brackish or saline aquifers can exist naturally or develop overtime in coastal regions with sea water infiltration due to lowering of aquifer depths.

- Fresh: <1,000 mg/litre TDS
- Brackish: 1,000 - 5,000 mg/litre TDS
- Highly Brackish: 5,000 - 15,000 mg/litre TDS
- Saline: 15,000 - 30,000 mg/litre TDS
- Sea Water: 30,000 - 40,000 mg/litre TDS

(Water Quality Association, nd)

Fresh water with high or low levels of TDS is often called “hard” or “soft” water, respectively. Hard water received this name because it requires more soap to get a good lather and makes the water “hard” to work with. Soap is less effective with hard water due to its reaction to the magnesium and calcium; leading to high use of soap for laundry and bathing. As well, hard water (> 500 mg/litre) can leave a residue and cause scale to build up on cooking pots and water pipes.

Soft water is usually preferred for laundry, bathing and cooking.

Potential Health Effects

Drinking water with high concentrations of total dissolved solids will not make people sick.

Although there are no direct health concerns, the presence of dissolved solids in water may affect its taste. People generally prefer the taste of hard water due to the dissolved minerals, however high concentrations of TDS can cause a bitter or salty taste. According to the WHO (2003), the acceptability of drinking water has been rated by a panel of tasters in relation to its TDS concentrations as follows:

- excellent, less than 300 mg/litre
- good, between 300 and 600 mg/litre
- fair, between 600 and 900 mg/litre
- poor, between 900 and 1200 mg/litre (e.g. brackish water)
- unacceptable, greater than 1200 mg/litre (e.g. saline water)

Centre for Affordable Water and Sanitation Technology

Chemical Contaminants in Drinking Water Fact Sheet: Total Dissolved Solids

Some people can taste salt in drinking water at levels around 500 mg/L, and it may cause them to not use it and choose another, possibly contaminated, water source instead.

Water with extremely low TDS concentrations (e.g. rainwater) may also be unacceptable because of its flat taste.

WHO Guidelines

The WHO does not have a suggested guideline for total dissolved solids since it occurs in drinking water at concentrations well below those at which toxic effects may occur. Most people will reject drinking water due to odor, taste and colour at a level much lower than is required for harm. People usually do not like the taste of water that has more than 500 mg/L of TDS.

No WHO Guideline for Total Dissolved Solids in Drinking Water

Household Water Treatment Options

There are some limited household options to remove total dissolved solids from drinking water. Filtration does not work since the chemicals and organic matter are dissolved in the water. Distillation devices can help reduce TDS levels in drinking water; however they may not be practical or easy to use at the household level. Reverse osmosis systems are becoming popular in industrialized countries for removing TDS, however they are relatively expensive and require a power supply.

References

Water Quality Association (n.d.). Water Classifications. Available at: www.pacificro.com/watercla.htm

World Health Organization (2003). Total Dissolved Solids in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/chemicals/tds.pdf

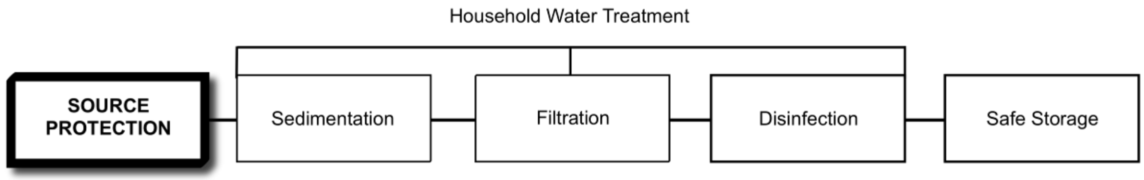
World Health Organization (2006). Guidelines for Drinking Water Quality, Third Edition. Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/gdwq3rev/en/index.html

Appendix B – Household Water Treatment and Safe Storage Fact Sheets

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Source Protection

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Local contamination of the water source		• Naturally occurring contamination • Contaminants introduced upstream of the water source

What is Source Protection?

There are many pollution problems which may threaten drinking water quality at the source, point of collection, or during transport. Source protection can reduce or eliminate the risk of contamination, resulting in improved water quality and reduced risk of disease. Source protection should always be practiced as the first step in the multi-barrier approach to safe drinking water.

What Causes Contamination?

The main risk factors for contamination at the water source, collection point and during transport are:

- Poor site selection of the water source
- Poor protection of the water source against pollution (e.g. agricultural runoff contaminated with manure and fertilizers)
- Poor structure design or construction (e.g. lack of a well lining and/or cover, tank sealing, poor pipe connections)
- Deterioration or damage to structures (e.g. cracks can be entry points for contaminants)
- Lack of hygiene and sanitation knowledge and practice in the community

Source Protection Practices

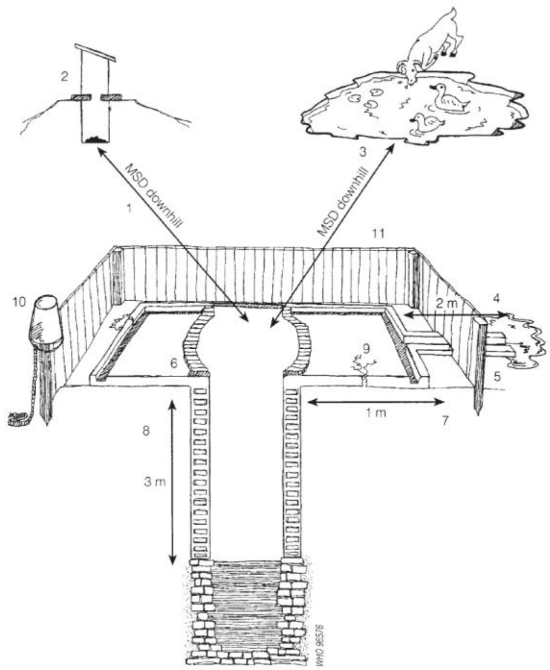
The following provides suggestions on several things that can be done to protect different water sources from contamination and improve the quality.

For all Water Sources and Points of Use (where the water is stored or used):

- Locate latrines down hill and at least 30 meters away from water sources.
- Keep animals away by using fences around the water source
- Maintain separate area for washing clothes and watering animals
- Keep the general environment around the water source and points of use clean and free from excreta and garbage
- Plant trees along creeks and rivers and maintain a well forested area above your water source, to trap contaminants and prevent erosion
- Provide adequate drainage to prevent wastewater from pooling and becoming stagnant, which provides an ideal breeding ground for insect vectors

Household Water Treatment and Safe Storage Fact Sheet: Source Protection

- Maintain and repair all constructed elements and ensure water source and structures are physically sealed from contaminant inflow (e.g. surface run-off)
- Ensure watershed use is non-polluting



Maintain separation distances between source/collection points and latrines, washing and animal watering points

Wells, Tubewells and Boreholes:

- Line wells and boreholes (provide a sanitary seal in the top 2 to 3 meters)
- Keep protected and covered, and construct a parapet wall around open wells
- Use a separately designated, clean rope and bucket, a windlass or a hand pump to pull water out of the well. Store the bucket in its own covered clean platform.
- Build a platform with adequate drainage at the collection point to prevent mud and wastewater from pooling

Springs and Gravity Fed Piped Systems:

- Stabilize springs by building retaining walls and collector boxes with screened intakes
- Dig a surface water diversion channel, ditch or bund above and around the spring development
- Seal the top of the source with a sanitary cap when possible to prevent infiltration of surface run-off
- Plant vegetation around the catchment area but ensure roots will not crack the any structures
- Fence off the spring and the catchment area directly above it to prevent contamination from livestock or people
- For gravity fed systems, protect and maintain collection and storage tanks, lay piping 50cm below ground or deeper were possible

Rivers and Lakes:

- Mark separate zones for washing and watering animals downstream and away from water collection areas

Rainwater Harvesting:

- Cut back any trees or vegetation overhanging the catchment surface
- Collect and store rainwater in covered tanks which are periodically cleaned
- Clean catchment surface, gutters and screens prior to first rain of the season
- Divert and do not consume water from the first rain
- Use a first-flush system to divert first few millimetres of each rainfall event as it contains dust accumulated on the roof or catchment area

Water Collection and Transport

It is vital that people collect water in clean containers and keep them covered while transporting water from the source to the point of use, to prevent contamination of the water after collection.

Household Water Treatment and Safe Storage Fact Sheet: Source Protection

Further Information

Davison et al. (2005) Water Safety Plans: Managing Drinking-water Quality from Catchment to Consumer. World Health Organization, Geneva, Switzerland. Available at: www.who.int/water_sanitation_health/dwq/wsp0506/en/index.html

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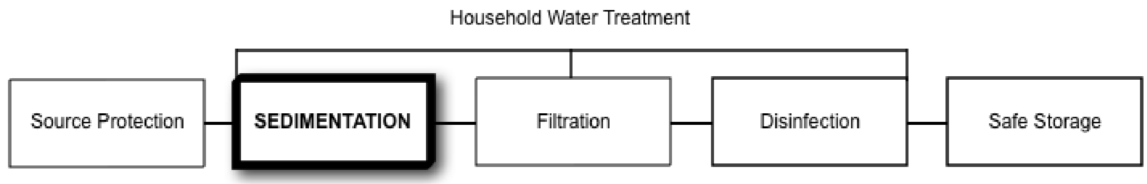
Last Update: June 2011

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Settling

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Turbidity • Protozoa • Helminths	• Bacteria • Suspended particles (e.g. iron) • Taste, odour, colour	• Viruses • Dissolved chemicals

What is Settling?

Settling has been a traditional practice throughout history using small vessels or larger basins, cisterns and storage tanks.

Water quality can sometimes be improved by allowing it to stand undisturbed long enough for larger suspended particles to settle out by gravity, including those that cause turbidity (e.g. sand and silt) and certain pathogens (e.g. protozoa and helminths) Fine clay particles and other pathogens like bacteria and viruses are generally too small to settle by gravity.

How Does It Remove Contamination?

Although viruses, bacteria and smaller protozoa are too small to settle by gravity, some of these pathogens can attach themselves to larger suspended particles that can settle.

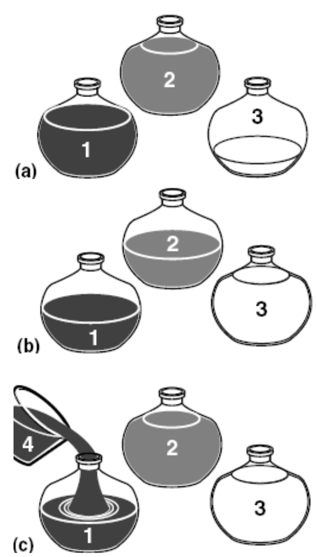
Storing water for at least one day will also promote the natural die-off of some bacteria.

Operation

At least two containers are needed: one to act as the settling container and another to put the clean water into after the settling period. Water can be settled for a few hours and up to days depending on its quality. The settled water is then carefully removed by decanting, ladling or other gentle methods that do not disturb the sedimented particles. It is important to clean the containers between each use.

The three pot settling method ensures water is settled for a minimum of 2 days to maximize settling and pathogen die-off. As shown in the following illustration:

(a) After 24 hours, slowly pour water from Pot 2 into a clean Pot 3. Clean Pot 2.
(b) Slowly pour water from Pot 1 into Pot 2.
(c) Pour source water (Bucket 4) into Pot 1.
Wait 24 hours before repeating step (a).



Household Water Treatment and Safe Storage Factsheet: Settling Key Data

Inlet Water Quality

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	Up to 90%[1]	Up to 90%[1]	> 90%[1]	> 90%[1]	Varies[2]
Field	Not available	Not available	Not available	Not available	Varies[2]

[1] Sobsey. M. (2002), effective removal of protozoa and helminths may require longer storage times of 1-2 days
[2] Depends on the size of the suspended particles in the water - the larger the suspended particles, the more efficient.

- Efficiency varies from one water source to another
- Longer storage times of 1-2 days can improve efficiency

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

Robustness

- Simple and easy to perform

Estimated Lifespan

- Containers may need to be replaced over time if they develop leaks

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- Containers

Fabrication Facilities:
- Not applicable

Labour:
- Traditional practice done in the household

Maintenance

- Need to wash container after decanting the clear water

Household Water Treatment and Safe Storage Factsheet: Settling Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$0	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

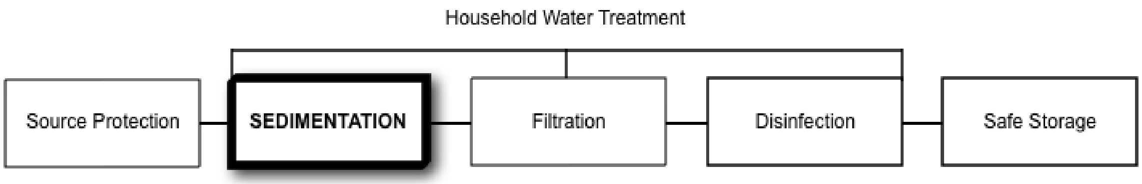
References

Sobsey, M. (2002). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply. Water, Sanitation and Health, Department of Protection of the Human Environment, World Health Organization, Geneva, Switzerland.

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Natural Coagulants

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Turbidity	• Bacteria • Viruses • Protozoa • Helminths • Taste, odour, colour	• Dissolved chemicals

What are Natural Coagulants?

The sedimentation process can be quickened by adding coagulants to the water.

Coagulation with extracts from natural and renewable vegetation has been widely practiced since recorded time. There is a variety of natural coagulants used around the world, depending on the availability.

Extracts from the seeds of *Moringa oleifera* can be used, the trees of which are widely present in Africa, the Middle East and the Indian subcontinent. *Strychnos potatorum,* also known as clearing nuts or the nirmali tree, is found in India to treat water. Prickly pear cactus is prevalent and traditionally used in Latin America. There are also reports of other natural coagulants being used, such as fava beans.

How Does it Remove Contamination?

Coagulants contain significant quantities of water-soluble proteins which carry an overall positive charge when in solution. The proteins bind to the predominantly negatively charged particles that cause turbidity (e.g. sand, silt, clay).

Coagulation happens when the positively and negatively charged particles are chemically attracted together. They can then accumulate (flocculation) to form larger and heavier particles (flocs). The flocs can be settled out or removed by filtration.

Bacteria and viruses can attach themselves to the suspended particles in water that cause turbidity. Therefore, reducing turbidity levels through coagulation may also improve the microbiological quality of water.

Moringa seed pods *(*Credit: www.moringanews.org*)*

Household Water Treatment and Safe Storage Fact Sheet: Natural Coagulants

Operation

Little research has been done to optimize and standardize the use of natural coagulants. Their use is usually passed through traditional knowledge in the community.

Generally, natural coagulants are not available in a usable form and need to be prepared. This is usually done just beforehand to keep the coagulant fresh. For example, prickly pear cactus needs to be peeled and cut and moringa seeds need to be dried and crushed into a powder.

Users add the prepared dose of coagulant to the water. The water is then stirred for a few minutes to help create flocs. The flocs can be settled out and the clear water is decanted, or removed by filtration.

Moringa seeds in a pod *(*Credit: www.hear.org*)*

Dried clearing nuts *(*Credit: www.farmwealthgroup.com*)*

Prickly pear cactus *(*Credit: Tennant, R., www.freelargephotos.com*)*

Household Water Treatment and Safe Storage Fact Sheet: Natural Coagulants Key Data

Inlet Water Quality

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	90-99.99%[1] >96.0%[3]	Not available	Not available	Not available	80-99.5%[1] 83.2-99.8%[3]
Field	50%[2]	Not available	Not available	Not available	95%[2]

[1] Madsen et al. (1987). Tests based on *Moringa oleifera.*

[2] Tripathi et al. (1976); Able et al. (1984) cited in Sobsey. M. (2002). Tests based on *Strychnos potatorum.*

[3] Nkurunziza et al. (2009). Tests based on *Moringa oleifera.*

- Little research has been done to evaluate the efficacy of natural coagulants
- Effectiveness of natural coagulants varies from one to another

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Little research has been done to optimize and standardize the use of natural coagulants
- Generally, natural coagulants need to undergo some processing before use
- Preparation, use and dose varies according to the natural coagulant and water source

Robustness

- Availability depends on local conditions

Estimated Lifespan

- Dried beans and seeds can be stored for a long time
- Prickly pear cactus needs to be used before the sap dries

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Harvested and prepared locally

Materials:
- Natural coagulants (e.g. moringa seeds, prickly pear cactus)
- Miscellaneous tools (e.g. knife)

Fabrication Facilities:
- Prepared in households

Labour:
- Traditional practice, anyone can be taught to prepare and use natural coagulants

Household Water Treatment and Safe Storage Fact Sheet: Natural Coagulants Key Data

Maintenance

- Dried beans and seeds should be stored in a dry location

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$0	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

Other

- Jar testing can be undertaken to optimize effectiveness of particular coagulants with water sources
- Natural coagulants leave organic matter in the water, which may make subsequent chlorine treatment less effective
- Some users complain about the taste that natural coagulants may cause in water

References

Madsen, M., Schlundt, J. and E.F. Omer (1987). Effect of water coagulation by seeds of *Moringa oleifera* on bacterial concentrations. Journal of Tropical Medicine and Hygiene; 90(3): 101-109

Sobsey, M. (2002). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply, Water, Sanitation and Health, Department of Protection of the Human Environment, World Health Organization, Geneva, Switzerland.

Nkurunziza, T., Nduwayezu, J. B., Banadda E. N. and I. Nhapi (2009). The effect of turbidity levels and *Moringa oleifera* concentration on the effectiveness of coagulation in water treatment. Water Science & Technology, Vol 59, No 8, pp 1551–1558.

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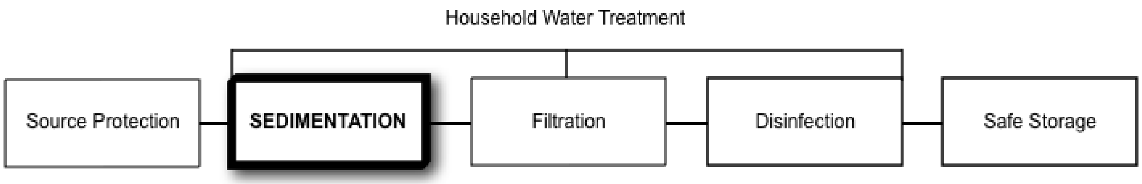
Household Water Treatment and Safe Storage Factsheet: Chemical Coagulants

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Turbidity	• Bacteria • Viruses • Protozoa • Helminths • Hardness • Taste, odour, colour	• Dissolved chemicals

What are Chemical Coagulants?

The sedimentation process can be quickened by adding coagulants to the water.

Chemical coagulants are commonly used in community drinking water treatment systems though some application in household water treatment occurs.

The main chemicals used for coagulation are aluminium sulphate (alum), polyaluminium chloride (also known as PAC or liquid alum), alum potash, and iron salts (ferric sulphate or ferric chloride).

Lime ($Ca(OH_2)$), lime soda ash (Na_2CO_3) and caustic soda (NaOH) are sometimes used to "soften" water, usually ground water, by precipitating calcium, magnesium, iron, manganese and other minerals that contribute to hardness.

How Does it Remove Contamination?

Particles that cause turbidity (e.g. silt, clay) are generally negatively charged, making it difficult for them to clump together because of electrostatic repulsion. But coagulant particles are positively charged, and they chemically attracted to the negative turbidity particles, neutralizing the latter's negative charge. With mixing the neutralized particles then accumulate (flocculation) to form larger particles (flocs) which settle faster. The flocs can then be settled out or removed by filtration.

Some bacteria and viruses can also attach themselves to the suspended particles in water that cause turbidity. Therefore, reducing turbidity levels through coagulation may also improve the microbiological quality of water.

Operation

Users follow the manufacturer's instructions and add the prepared dose of coagulant to the water. The water is then stirred for a few minutes to help create flocs. The flocs can be settled out or removed by filtration.

Alum block (Credit: www.cdc.org)

Household Water Treatment and Safe Storage Fact Sheet: Chemical Coagulants Key Data

Inlet Water Quality

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	>90 to >99%[1]	>90 to >99%[1]	>90 to >99%[1]	>90 to >99%[1]	Not available
Field	< 90%[2] 95%[3]	Not available	Not available	Not available	Not available

[1] Sproul (1974), Leong (1982), Payment and Armon (1989) cited in Sobsey (2002)
[2] Ongerth (1990) cited in Sobsey (2002)
[3] Wrigley (2007)

- Maximum effectiveness requires careful control of coagulant dose, pH and consideration of the quality of the water being treated, as well as mixing
- Effectiveness of chemical coagulants varies from one to another

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Need to follow manufacturer's instructions

Robustness

- Difficult to optimize without training and equipment
- Requires coagulant supply chain and regular purchase

Estimated Lifespan

- 6 months in liquid form and 1 year in solid form

Manufacturing Requirements

Worldwide Producers:

- Many producers around the world

Local Production:

- Most chemical products are difficult and complex to manufacture and local production is not feasible

Maintenance

- Chemicals should be stored in a dry location and away from children

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$9-91/year[1]	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Sobsey (2002). Assumed 25 litres/household/day.

Other

- Jar testing can be undertaken to optimize effectiveness of particular coagulants with water sources

References

Sobsey M. (2002). Managing Water in the Home: Accelerated Health Gains From Improved Water Supply, Water, Sanitation and Health, Department of Protection of the Human Environment, World Health Organization, Geneva, Switzerland.

Wrigley. T. (2007) Microbial Counts and Pesticide Concentrations in Drinking Water After Alum Flocculation of Channel Feed Water at the Household Level, in Vinh Long Province, Vietnam, Journal of Water and Health; 05:1.

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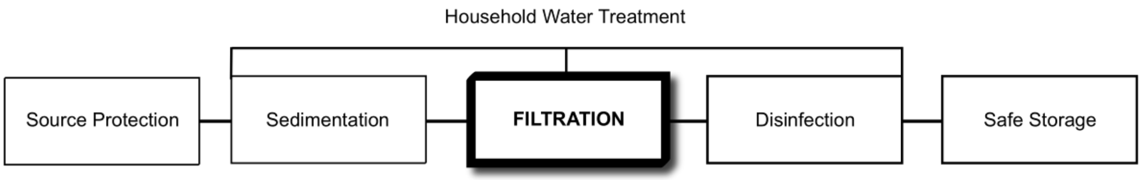
Last Update: June 2011

Household Water Treatment and Safe Storage Fact Sheet: Straining

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Helminths • Protozoa	• Turbidity • Bacteria • Taste, odour, colour	• Viruses • Chemicals

What is Straining?

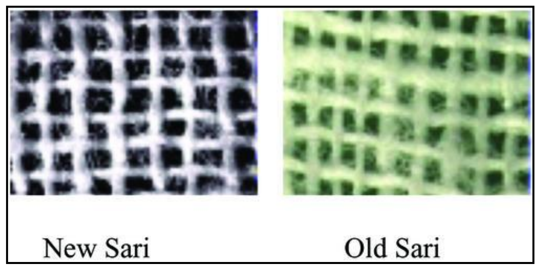
Straining water through a cloth has been widely used for household water treatment in many cultures for centuries. A common sari cloth is usually used for this in South Asia, for example.

How Does it Remove Contamination?

The pore size range in old (laundered) sari cloth is 100–150 μm, but about 20 μm if the cloth is folded four to eight times. The holes allow water to pass but retain particles and pathogens >20 μm.

Straining through sari cloth has been shown to be effective in filtering out the plankton to which cholera bacteria may attach themselves, therefore reducing the risk of cholera. This simple method can also filter out many helminths and their eggs and larvae.

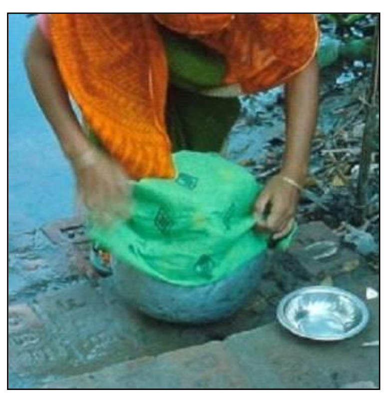
Old sari cloth made of cotton was found to be most effective in removing cholera based on laboratory experiments (Colwell et al., 2002). After several launderings, threads of an old sari become soft and loose, reducing the pore size, compared with new sari cloth.



Electron micrographs of a single layer of sari cloth filters (Credit: Colwell et al., 2002)

Operation

Fold a large, clean piece of cloth seven to eight times. Place the folded cloth over a clean water container, and secure in place. Pour water through the cloth into the container. Wash the cloth in clean water before using it again.



A woman uses a sari cloth to strain water

Household Water Treatment and Safe Storage Fact Sheet: Straining — Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	> 99%[1]	Not available	> 100%[2]	> 100%[2]	Varies[3]
Field	Not available	Not available	Not available	Not available	Not available

[1] Colwell et al. (2002), Huq et al. (1996), *Vibrio cholerae* attached to plankton and particles >20 μm
[2] Helminths and protozoa >20 μm do not pass through the cloth
[3] Suspended particles >20 μm do not pass through the cloth

- Efficiency depends on the weave of the cloth and the number of times folded

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

Robustness

- Simple and easy to perform
- Cloth is available around the world, discarded cloth may be used

Estimated Lifespan

- Cloth may need to be replaced if there are holes

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- Cloth
- Containers

Fabrication Facilities:
- Not applicable

Labour:
- Traditional practice done in the household

Maintenance

- Cloth needs to be washed in clean water after every use

Household Water Treatment and Safe Storage Fact Sheet: Straining — Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$0	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

References

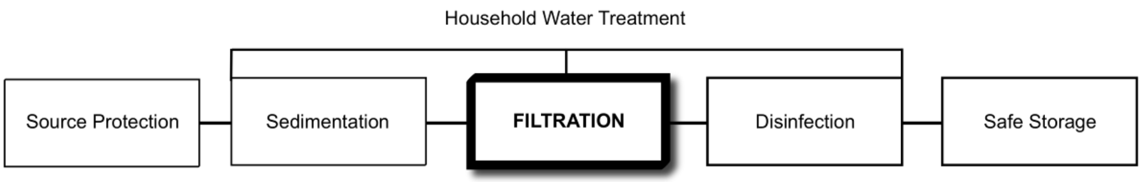
Colwell, R., Huq, A., Sirajul Islam, M.S., Aziz, K.M.A., Yunus, M., Huda Khan, N., Mahmud, A., Sack, R.B., Nair, G.B., Chakraborty, J., Sack, D.A., and Russek-Cohen, E. (2002), Reduction of Cholera in Bangladeshi Villages by Simple Filtration. Proc Natl Acad Sci USA. 100(3): 1051–1055. Available at: www.pubmedcentral.nih.gov/articlerender.fcgi?tool=pmcentrez&artid=298724#B11

Huq, A., Xu, B., Chowdhury, M.A.R., Islam, M.S., Montilla, R., and Colwell, R.R. (1996), A Simple Filtration Method to Remove Plankton-Associated V*ibrio cholerae* in Raw Water Supplies in Developing Countries. *Appl Environ Microbiol.* 1996;62:2508–2512. Available at: www.ncbi.nlm.nih.gov/pubmed/8779590

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Protozoa • Helminths • Turbidity • Taste, odour, colour	• Viruses • Iron	• Dissolved chemicals

What is a Biosand Filter?

The biosand filter (BSF) is an adaptation of the traditional slow sand filter, which has been used for community water treatment for hundreds of years. The BSF is smaller and adapted for intermittent use, making it suitable for households.

Water treatment is carried out by the sand inside the filter. The filter container can be made of concrete, plastic or any other water-proof, rust-proof and non-toxic material. The concrete filter box is cast from a steel mold or made with pre-fabricated pipe.

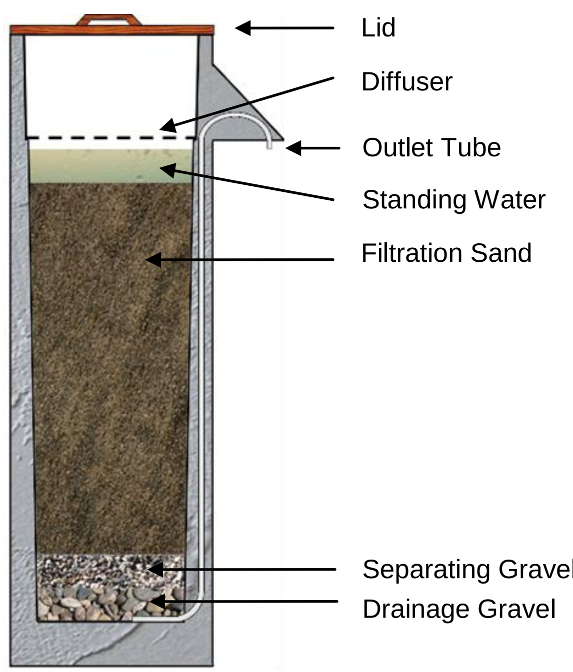
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

As in slow sand filters, a biological layer of microorganisms (also known as the biolayer or schmutzedecke) develops at the sand surface, which contributes to the water treatment.

A perforated diffuser plate or basin is used to protect the biolayer from disturbance when water is poured into the filter.

How Does It Remove Contamination?

Pathogens and suspended material are removed through a combination of biological and physical processes that take place in the biolayer and within the sand bed. These processes include: mechanical trapping, adsorption, predation and natural death.



Cross-Section of Concrete Biosand Filter

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter

Cross Section of Plastic Biosand Filter (Credit: TripleQuest)

Operation

Contaminated water is poured into the top of the filter on an intermittent basis. The water slowly passes through the diffuser, and percolates down through the biolayer, sand and gravel. Treated water naturally flows from the outlet pipe.

The biolayer is the key pathogen removing component of the filter. Without it, the filter is significantly less effective. It may take up to 30 days to establish the biolayer depending on inlet water quality and frequency of use.

The water from the filter can be used during the first few weeks while the biolayer is being established, but disinfection is recommended during this time, as during regular on-going use.

The biolayer requires oxygen to survive. When water is flowing through the filter, dissolved oxygen in the water is supplied to the biolayer. During pause times, when the water is not flowing, the oxygen is obtained by diffusion from the air.

Correct installation and operation of the biosand filter has a water level of approximately 5 cm above the sand during the pause period. A water depth of greater than 5 cm results in lower oxygen diffusion to the biolayer. A water depth less than 5 cm may evaporate quickly in hot climates and cause the biolayer to dry out.

A pause period is needed between uses to allow time for the microorganisms in the biolayer to consume pathogens in the water. Users should wait at least one hour after all the water has been filtered before filling the filter again. It is recommended to use the filter every day; however users can wait up to a maximum of 48 hours between batches.

The biosand filter has been designed to allow for a filter loading rate (flow rate per square metre of filter area) which has proven to be effective in laboratory and field tests. This filter loading rate has been determined to be not more than 600 litres/hour/square metre.

The recommended flow rate for the CAWST Version 10 concrete biosand filter is 0.4 litres/minute measured when the inlet reservoir is full of water. If the flow rate is much faster, the filter may become less efficient at removing pathogens. If the flow rate is much slower, the user may become impatient and not use the filter even though the filter is working well at removing pathogens. Since the flow rate is controlled by the size of the sand grains, it is very important to select, sieve and wash the sand properly.

The flow rate through the filter will slow down over time as the biolayer develops and sediment is trapped in the upper layer of the sand. For turbidity levels greater than 50 NTU, the water should first be strained through a cloth or sedimented before using the BSF.

The biosand filter requires maintenance when the flow rate drops to a level that is inadequate for the household use. This is done by a simple 'swirl and dump' procedure performed on the top of the sand, and only takes a few minutes.

The outlet should also be cleaned regularly using soap and water or a chlorine solution.

The treated water should be collected by the user in a safe storage container placed on a block or stand, so that the container opening is just under the outlet, minimizing the risk for recontamination.

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter Key Data

Inlet Water Criteria

- Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron
Laboratory	Up to 96.5%[1,2]	70 to >99%[3]	>99.9%[4]	Up to 100%[5]	95% to <1 NTU[1]	Not available
Field	87.9 to 98.5%[6,7]	Not available	Not available	Up to 100%[5]	85%[7]	90-95%[8]

1 Buzunis (1995)
2 Baumgartner (2006)
3 Elliott et al. (2008)
4 Palmateer et al. (1997)
5 Not researched. However, helminths are too large to pass between the sand, up to 100% removal efficiency is assumed
6 Earwaker (2006)
7 Duke & Baker (2005)
8 Ngai et al. (2004) *[Note: These tests were done on a plastic version of a biosand filter]*

- Filtration sand selection and preparation are critical to ensure flow rate and effective treatment. Refer to CAWST's Biosand Filter Manual for detailed instructions on how to select and prepare the filtration sand.
- Treatment efficiencies provided in the above table require an established biolayer; it takes up to 30 days to establish the biolayer depending on inlet water quality and usage
- Filter should be used every day to maintain the biological layer
- Best performance requires a consistent water source; switching sources may decrease treatment efficiency
- Swirl and dump maintenance will reduce treatment efficiency until the disturbed biolayer is re-established
- Taste, odour and colour of filtered water is generally improved
- Treated water temperature is generally cooler from concrete filters

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
< 0.4 litres/minute*	12-18 litres	24-72 litres**

Note: Operating criteria is for the concrete biosand filter, plastic biosand filter may have different parameters.

* 0.4 litres/minute is the maximum recommended flow rate for the CAWST Version 10 concrete biosand filter. The actual flow rate will fluctuate over the filter cleaning cycle and between filters.

** Based on 4 batches per day (i.e. morning, lunch, dinner, before bed).

- Pause period is needed between uses to allow time for the microorganisms in the biolayer to consume pathogens in the water
- Recommended pause period is 6 to 12 hours with a minimum of 1 hour and maximum of 48 hours

Robustness

- No moving or mechanical parts to break
- Concrete filters have the outlet pipe embedded in the concrete, protecting it against breaks and leaks

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter Key Data

- Plastic filters have an external outlet pipe which may be prone to damage and leakage; once broken repair is difficult or impossible
- Plastic filters are lighter (3.5 kg) than concrete filters (70-75 kg for thin wall version and 135 kg for heavy wall version)
- Poor transportation of concrete filters can lead to cracking and/or breakage; cracks can sometimes be repaired
- Plastic filters are made from medical grade plastic which is resistant to ultraviolet (UV) degradation and breakage
- Preferably, filters should not be moved after installation

Estimated Lifespan

- 30+ years for concrete filters; concrete filters are still performing satisfactorily after 10+ years
- 10+ years for plastic filters
- Lids and diffusers may need replacement over time

Manufacturing Requirements

Worldwide Producers:
- Concrete biosand filter designs are freely available from CAWST, Canada
- Plastic biosand filters are patented and licensed to International Aid, USA for manufacturing and sales

Local Production:
- Concrete biosand filters can be manufactured locally
- Molds can be borrowed, rented, bought or welded locally
- Filters can be constructed at a central production facility, or in the community
- Filter sand and gravel can be prepared (sieved and washed) on-site or nearby

Materials for Concrete Filters:
- Steel mold
- Sand, gravel, and cement
- Filter sand and gravel
- Copper or plastic outlet tubing
- Metal or plastic for the diffuser
- Metal or wood for the lid
- Water for concrete mix and to wash filter sand and gravel
- Miscellaneous tools (e.g. wrench, nuts, bolts)

Fabrication Facilities:
- Workshop space for filter construction

Labour:
- Skilled welder required to fabricate steel mold
- Anyone can be trained to construct and install the filter

Hazards:
- Working with cement and heavy molds is potentially hazardous and adequate safety precautions should be used
- Concrete filters are heavy and difficult to move and transport

Maintenance

- Required when the flow rate drops to a level that is insufficient for household use; frequency depends on turbidity of inlet water

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter Key Data

- Swirl and dump maintenance for the top layer of sand is simple, takes a few minutes and can be done by household users
- Outlet, lid and diffuser should be cleaned on a regular basis

Direct Cost

Filter Type	Capital Cost	Operating Cost	Replacement Cost
Concrete	US$12-50	US$0/year	US$0
Plastic	US$75[1]	US$0/year	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

[1] Prices do not include shipping container, shipping fees, or clearing/related costs.

References

Buzunis, B. (1995). Intermittently Operated Slow Sand Filtration: A New Water Treatment Process. Department of Civil Engineering, University of Calgary, Canada.

Baumgartner, J. (2006). The Effect of User Behavior on the Performance of Two Household Water Filtration Systems. Masters of Science thesis. Department of Population and International Health, Harvard School of Public Health. Boston, Massachusetts, USA.

Duke, W. and D. Baker (2005). The Use and Performance of the Biosand Filter in the Artibonite Valley of Haiti: A Field Study of 107 Households, University of Victoria, Canada.

Earwaker, P. (2006). Evaluation of Household BioSand Filters in Ethiopia. Master of Science thesis in Water Management (Community Water Supply). Institute of Water and Environment, Cranfield University, Silsoe, United Kingdom.

Elliott, M., Stauber, C., Koksal, F., DiGiano, F., and M. Sobsey (2008). Reductions of E. coli, echovirus type 12 and bacteriophages in an intermittently operated 2 household-scale slow sand filter.Water Research, Volume 42, Issues 10-11, May 2008, Pages 2662-2670.

Ngai, T., Murcott, S. and R. Shrestha (2004). Kanchan Arsenic Filter (KAF) – Research and Implementation of an Appropriate Drinking Water Solution for Rural Nepal. *[Note: These tests were done on a plastic biosand filter]*

Palmateer, G., Manz, D., Jurkovic, A., McInnis, R., Unger, S., Kwan, K. K. and B. Dudka (1997). Toxicant and Parasite Challenge of Manz Intermittent Slow Sand Filter. Environmental Toxicology, vol. 14, pp. 217- 225.

Stauber, C., Elliot, M., Koksal, F., Ortiz, G., Liang, K., DiGiano, F., and M. Sobsey (2006). Characterization of the Biosand Filter for Microbial Reductions Under Controlled Laboratory and Field Use Conditions. Water Science and Technology, Vol 54 No 3 pp 1-7.

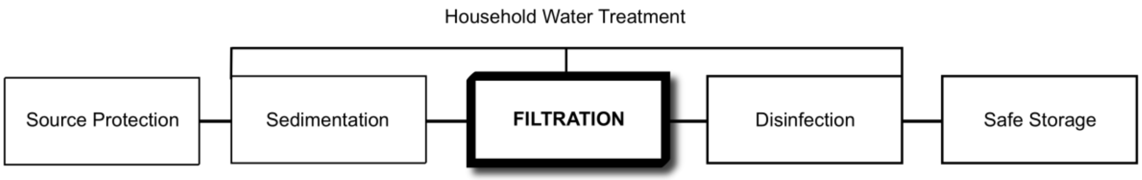
Further Information

CAWST (Centre for Affordable Water and Sanitation Technology): www.cawst.org

Triple Quest: www.hydraid.org

Household Water Treatment and Safe Storage Product Sheet: Concrete Biosand Filter

Treatment Type



Product Name: Concrete biosand filter

Product Manufacturer: Designs are freely available from CAWST, Calgary, Canada

Manufacturer Location(s): Constructed locally

Product Description: Square concrete filter with diffuser plate and lid. The filter box is cast from a steel mold. The filter box is filled with layers of sieved and washed sand and gravel.

Availability: As of June 2009, CAWST estimates that over 200,000 concrete biosand filters have been implemented in more than 70 countries.

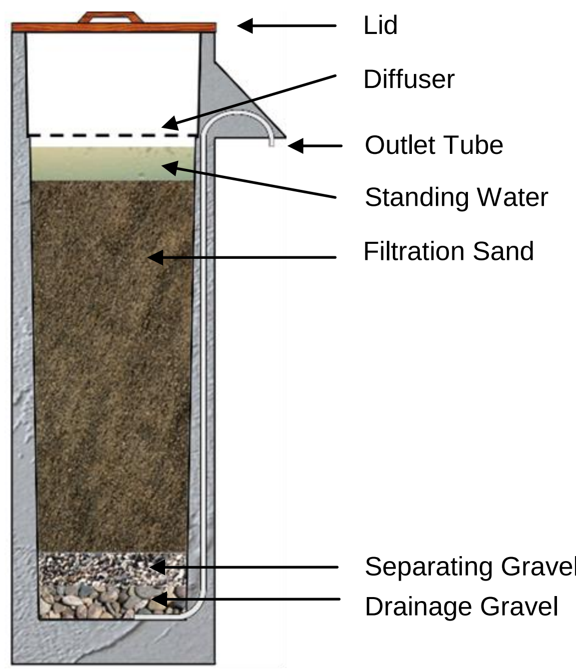
Robustness: There are no moving or mechanical parts to break. Outlet pipe is embedded in the concrete, protecting it against breaks and leaks. Poor transportation can lead to cracking and/or breakage; cracks can sometimes be repaired. Filters should not be moved after installation.

Lifespan: 30+ years, still performing satisfactorily after 10+ years

Dimensions: 0.9 m tall by 0.3 m

Weight: 70-75 kg for thin wall version and 135 kg for heavy wall version (empty with no sand)

Costs: US$12-60, costs will vary depending on location



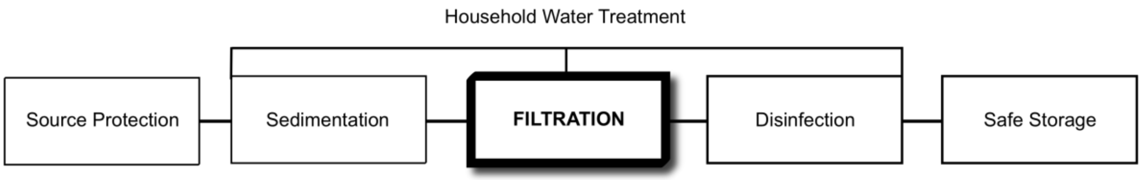
Further Information

CAWST (Centre for Affordable Water and Sanitation Technology): www.cawst.org

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: HydrAid™ BioSand Filter

Treatment Type



Product Name: HydrAid™ BioSand Water Filter

Product Manufacturer: Triple Quest (venture between Cascade Engineering and Windquest Group)

Manufacturer Location(s): Michigan, United States of America

Product Description: Plastic biosand filter with diffuser plate and lid. The filter is filled with layers of sieved and washed sand and gravel.

Availability: Available for bulk purchase to partner organizations.

Robustness: There are no moving or mechanical parts to break. Uses ultraviolet (UV) resistant plastic so it won't break down in sunlight. Made from US Food and Drug Administration (FDA) approved materials. The external outlet pipe may be prone to damage and leakage. Filters should not be moved after installation.

Lifespan: 10+ years

Approximate Dimensions: Height – 0.75 m, Diameter – 0.4 m

Approximate Weight: Empty – 3.5 kg, Filled – 55 kg

Costs: Display filter – US$58, Single filter with sand – US$75

International retail and wholesale purchase also available. Prices do not include shipping container, shipping fees, or clearing/related costs.

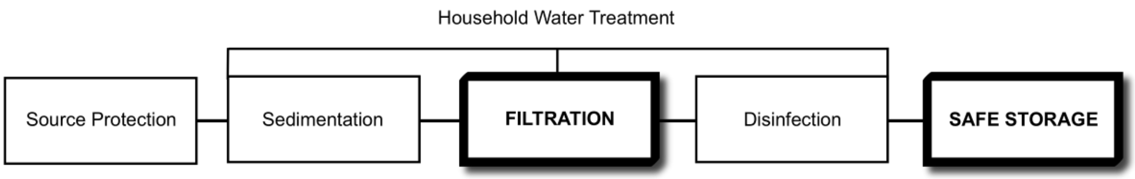
Further Information

www.hydraid.org

HydrAid BioSand Filter (Credit: International Aid)

Household Water Treatment and Safe Storage Fact Sheet: Ceramic Candle Filter

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Protozoa • Helminths • Turbidity • Taste, odour, colour	• Viruses	• Dissolved chemicals

What is a Ceramic Candle Filter?

Locally produced ceramics have been used to filter water for hundreds of years. Ceramic candles are hollow cylindrical forms fastened into the bottom of a container. Water seeps through the ceramic candle and falls into a lower container, which is fitted with a tap at the bottom. Units often use more than one candle because the flow rate through one candle can be slow. A lid is placed on top of the filter to prevent contamination. This system both treats the water and provides safe storage until it is used.

Ceramic candles are usually made from local clay mixed with a combustible material like sawdust, rice husks or coffee husks. When the candle is fired in a kiln, the combustible material burns out, leaving a network of fine pores through which the water can flow through.

Colloidal silver is sometimes added to the clay mixture before firing or applied to the fired ceramic candle. Colloidal silver is an antibacterial which helps in pathogen removal, as well as preventing growth of bacteria within the candle itself.

How Does It Remove Contamination?

Pathogens and suspended material are removed from water through physical processes such as mechanical trapping and adsorption.

Ceramic Candle Filter (Credit: USAID, Nepal)

Quality control on the size of the combustible materials used in the clay mix ensures that the filter pore size is small enough to prevent contaminants from passing through the filter. Colloidal silver aids treatment by breaking down pathogens' cell membranes, causing them to die.

Household Water Treatment and Safe Storage Fact Sheet: Ceramic Candle Filter

Operation

Contaminated water is poured into the top container where the candles are attached. The water slowly passes through the pores in the candles and is collected in the lower container. The treated water is stored in the container until needed, protecting it from recontamination. The user simply opens the tap at the bottom of the container to get water.

Filter with one ceramic candle

For turbidity levels greater than 50 NTU, the water should first be strained through a cloth or sedimented before using the ceramic candle filter.

The candles should be regularly cleaned using a cloth or soft brush to remove any accumulated material. It is recommended that the candles be replaced every 6 months to 3 years, depending on the manufacturer's instructions and quality of the candles. This is in part to protect against fine cracks which may have developed and are not be visible. Any cracks will reduce the effectiveness since water can short-circuit through the crack without being filtered through the ceramic pores.

Different types of ceramic candles

Household Water Treatment and Safe Storage Fact Sheet: Ceramic Candle Filter Key Data

Inlet Water Quality

- Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	>99%[1,3,4,5]	>90%[4,5]	>100%[5, 6]	>100%[6]	88-97%[3]
Field	>99.95% [2,3]	Not available	>100%[6]	>100%[6]	97-99%[3]

1 Mattelet (2006)
2 Clasen & Boisson (2006)
3 Franz (2004)
4 Chaudhuri et al. (1994)
5 Horman et al. (2004)
6 Not researched, however helminths and protazoa are too large to pass between the 0.6-3 μm pores. Therefore, up to 100% removal efficiency can be assumed.

- Efficiencies provided in the above table require colloidal silver
- Pore size and construction quality are critical to ensure flow rate and effective treatment
- Taste, odour and colour of filtered water is generally improved
- The system provides safe storage to prevent recontamination

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
0.1-1 litres/hour	Depends on size of upper container	About 10 litres

- Flow rate is highest when the upper container is full
- Flow rate declines with use and accumulation of contaminants within the filter pores
- Flow rate can be improved by using more than one candle in the filter

Robustness

- Lower container is a safe storage container
- There are no moving or mechanical parts to break
- Small cracks can occur which are not visible to the naked eye, but which allow pathogens to pass through the candle
- Seal between the candle and container is critical; water may pass through untreated if there is a gap; some locally manufactured candles have a poor seal resulting in lower treatment efficiencies
- Poor transportation of candles can lead to cracking and/or breakage
- Plastic taps in the lower container can break, metal taps last longer but increase cost
- Requires supply chain and market availability for replacement candles and taps
- Recontamination is possible during cleaning; care should be taken to use clean water, not to touch the ceramic with dirty hands, and not to place the filter on a dirty surface

Estimated Lifespan

- Up to 3 years, generally 6 months to 1 year
- Candle needs to be replaced if there are visible cracks
- Filters must be repaired, resealed or replaced if the seal between the candle and the container is damaged (e.g., if short-circuiting or dripping is observed)

Manufacturing Requirements

Worldwide Producers:

- Produced by different manufacturers around the world

Household Water Treatment and Safe Storage Fact Sheet: Ceramic Candle Filter Key Data

- Highest quality candles are generally produced by European and North American manufacturers

Local Production:
- Candles are generally imported, except in a few countries where candles are produced locally
- Filter units can be assembled locally using locally available plastic containers and taps

Materials:
- Ceramic candle
- Plastic container with lid
- Tap
- Sealant

Fabrication Facilities:
- A small factory with a kiln is required for local production
- A small workshop is required for local filter assembly
- Miscellaneous tools

Labour:
- Professional potter with experience in collecting clay, making ceramic articles, semi-industrial or mass production
- Assistants, preferably potters as well
- Skill and quality control in manufacturing is essential to ensure optimum pore size, flow rate and effectiveness

Hazards:
- Working with presses and kilns is potentially hazardous and adequate safety precautions should be used

Maintenance

- Filters are cleaned by lightly scrubbing the surface when the flow rate is reduced
- Some manufacturers recommend that soap and chlorine should not be used to clean the candle
- Lower container, tap and lid should be cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$15-30	US$0	~US$4.5/year[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

[1] Ceramic candles need to be replaced every 6-12 months

Other

- Safest design uses clear plastic containers so that candle seal leaks are visible

References

Chaudhuri, M., Verma, S. and A. Gupta (1994). Performance Evaluation of Ceramic Filter Candles. Journal of Environmental Engineering, Vol 120, No. 6, Nov/Dec 1994, Technical Note # 5432.

Clasen, T and S. Boisson. (2006). Household-based Ceramic Water Filters for the Treatment of Drinking Water in Disaster Response: An Assessment of a Pilot Programme in the Dominican Replublic, Water Practice & Technology. Vol 1 No 2. IWA Publishing.

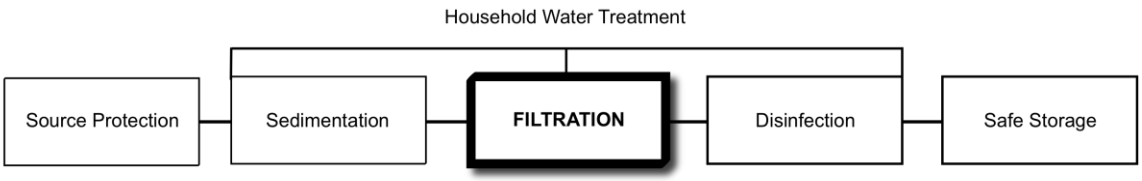
Franz, A. (2004). A Performance Study of Ceramic Candle Filters in Kenya Including Tests for Coliphage Removal. Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, Massachusetts, USA.

Horman, A., Rimhanen-Finne, R., Maunula, L., von Bonsdorff, C., Rapala, J. Lahti, K., and M. Hanninen (2004). Evaluation of the Purification Capacity of Nine Portable, Small-scale Water Purification Devices. Water Science and Technology, Vol 50, No. 1, pp 179-183.

Mattelet, C. (2006). Household Ceramic Water Filter Evaluation Using Three Simple Low-cost Methods: Membrane Filtration, 3M Petrifilm, and Hydrogen Sulfide Bacteria in Northern Region, Ghana. Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, Massachusetts, USA.

Household Water Treatment and Safe Storage Product Sheet: Siphon Filter

Treatment Type



Product Name: Siphon Filter

CrystalPur® (India, East Africa, Cambodia) and Tulip® (Africa, SouthEast Asia, India, Central & South America) are the brand names available in the market.

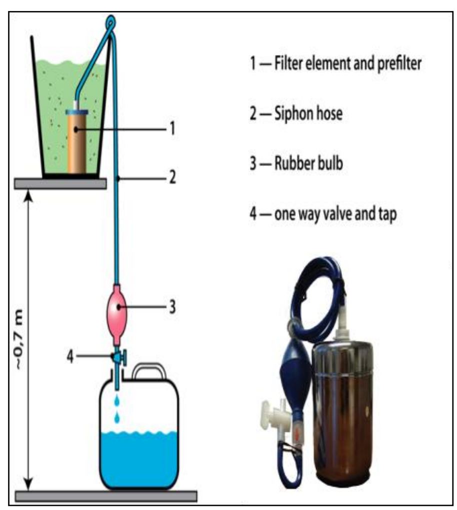
Manufacturer: Basic Water Needs India Pvt Ltd, Pondicherry, India

Product Description: The siphon filter is a ceramic candle-type water filter for household use. It uses gravity pressure to force water through a high-quality ceramic filter element impregnated with silver. The product is very compact, consisting of only a filter element, a plastic hose, and a valve. Some kits come with 2 water containers, or households can use existing containers. The siphon action (flow) is started by squeezing the bulb, and then the water flows by itself.

Availability: Produced and imported by Basic Water Needs India Pvt Ltd. Filter element cannot usually be produced locally. Currently implemented around the globe by EnterpriseWorks/VITA and Connect International.

Robustness: Ceremic element is quite fragile; plastic parts are robust. A washable fabric layer strains large particles to reduce clogging of the ceramic element, but the element may clog if inlet water contains fine silt. Ceramic filter element needs to be replaced if there are cracks or leaks. Use out of direct sunlight to avoid degradation of plastic parts.

Lifespan: Can treat up to 7,000 litres, depending on the turbidity of the water. At 20 L/household per day, this will last just under 1 year. Plastic parts will last 5 years.



Siphon Filter
(Credit: www.akvo.org)

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: Siphon Filter

Approximate Dimensions: (Tulip® filter) Diameter filter element: 60 mm
High filter element: 100 mm
Total volume (including package): 2.7 dm^3
During operation, the ceramic filter element inside the upper (source water) container needs to be elevated approximately 70 cm above the height of the lower (filtered water) container.

Tulip Filter
(Credit: www.300in6.org)

Approximate Weight: 0.45 kg (not including water containers)

Output: 4-6 L/hour

Costs: US $7-12
Shipping: US $5-6 per filter (depending on quantity)
Replacement ceramic filter element: US $3-4

Maintenance: Two options for filter cleaning: backwashing and scrubbing the filter element. Backwashing is done by closing the tap and squeezing the bulb, which forces the water back through the filter, pushing dirt particles out.

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	94-100%[1,2]	50-90%[2,3]	> 90%[2]	> 90%[2]	96-99.8%[1,2]	N/A
Field	96%[1]	N/A	N/A	N/A	81.2%[1]	N/A

N/A: Not available.

[1] Ziff, 2009

[2] Basic Water Needs BV/Pvt.

[3] The pore size in the ceramic element may not be small enough to remove all viruses, however some viruses will be removed due to filtration, adsoption and reaction with the silver in the element.

Further Information

Akvopedia: www.akvo.org/wiki/index.php/Siphon_filter and www.akvo.org/wiki/index.php/Solution_of_the_week_6

CrystalPur filter (World Health Works): www.enterpriseworks.org/pubs/WHW_onesheet.pdf

Tulip Water Filter: www.tulipwaterfilters.com/

Basic Water Needs: www.basicwaterneeds.com

References

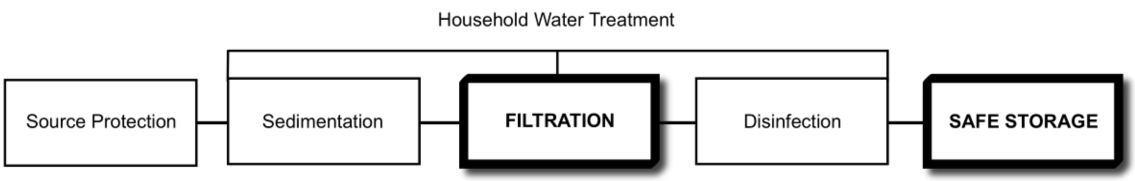
Basic Water Needs BV/Pty. Test results from independent laboratories (2010-2011) and product information published on filter manufacturer's website: www.basicwaterneeds.com

Ziff, S.E. (2009).Siphon filter assessment for Northern Ghana. Thesis (M.Eng.) Massachusetts Institute of Technology, Dept. of Civil and Environmental Engineering, USA.

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter

Treatment Type



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Protozoa • Helminths • Turbidity • Taste, odour, colour	• Viruses • Iron	• Dissolved chemicals

What is a Ceramic Pot Filter?

Locally produced ceramics have been used to filter water for hundreds of years. Water is poured into a porous ceramic filter pot, and is collected in another container after it passes through the ceramic pot.

Ceramic pot filters usually have a diameter of about 30 cm by 25 cm deep, with an 8 litre capacity. Two variations of ceramic filters, flat-bottom and round-bottom, are currently manufactured.

The ceramic pot typically sits or hangs in the top of a larger plastic or ceramic container (20-30 litres), which is fitted with a tap at the bottom. A lid is placed on top of the filter to prevent contamination. The system both treats the water and provides safe storage until it is used.

Ceramic pots are usually made from local clay mixed with a combustible material like sawdust, rice husks or coffee husks. The clay and combustible material are sieved through a fine mesh, and then mixed together with water until it forms a homogeneous mixture. The mixture is pressed into shape using a mold. When the pot is fired in a kiln, the combustible material burns out, leaving a network of fine pores through which the water can flow through.

Colloidal silver is sometimes added to the clay mixture before firing or applied to the fired ceramic pot. Colloidal silver is an antibacterial which helps in pathogen removal, as well as preventing growth of bacteria within the filter itself.

Some ceramic pot filters also include activated charcoal in the clay mixture to improve odour, taste, and colour.

How Does It Remove Contamination?

Pathogens and suspended material are removed from water through physical processes such as mechanical trapping and adsorption. Colloidal silver breaks down the pathogens' cell walls causing them to die.

Quality control on the size of the combustible materials used in the clay mix ensures that the filter pore size is small enough to prevent contaminants from passing through the filter. Colloidal silver aids treatment by breaking down pathogens' cell membranes, causing them to die.

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter

Operation

Contaminated water is poured into the ceramic pot. The water slowly passes through the pores and is collected in the lower container. The treated water is stored in the container until needed, protecting it from recontamination. The user simply opens the tap at the base of the container when they need water.

For turbidity levels greater than 50 NTU, the water should first be strained through a cloth or sedimented before using the ceramic pot filter.

The filter pot should be regularly cleaned using a cloth or soft brush to remove any accumulated material. It is recommended that the filter pot be replaced every 1-2 years. This is in part to protect against fine invisible cracks which may have developed over time. Any cracks will reduce the effectiveness since water can short-circuit without being filtered through the ceramic pores.

Cross Section of Ceramic Pot Filter (Credit: Filter Pure Inc)

Round Bottom Ceramic Pot Filter (Credit: Filter Pure Inc)

Flat Bottom Ceramic Pot Filter (Credit: Potters for Peace)

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter — Key Data

Inlet Water Quality

- Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron
Laboratory	>98%[1]-100%[4]	19%[1]->99%[6,7]	>100%[8]	>100%[8]	83%[1]–99%[5]	Not available
Field	88%[2] to >95.1%[3]	Not available	>100%[8]	>100%[8]	<5 NTU[2]	>90%[5]

1 Lantagne (2001)
2 Smith (2004)
3 Brown and Sobsey (2006)
4 Vinka (2007)
5 Low (2002)
6 Van Halem (2006)
7 Some additives to the clay may increase virus removal
8 Not researched, however helminths and protozoa are too large to pass between the 0.6-3 μm pores. Therefore, up to 100% removal efficiency can be assumed.

- Efficiencies provided in the above table require colloidal silver
- Pore size and construction quality are critical to ensure flow rate and effective treatment
- Taste, odour and colour of filtered water is generally improved
- The system provides safe storage to prevent recontamination

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
1-3 litres/hour	8 litres	20-30 litres

- Flow rate is highest when the pot is full
- Flow rate declines with use and accumulation of contaminants within the filter pores

Robustness

- Lower container can be used as a safe storage container
- There are no moving or mechanical parts to break
- Small cracks can occur which are not visible to the naked eye, but which allow pathogens to pass through the filter
- Poor transportation of filters can lead to cracking and/or breakage
- Plastic taps in the lower container can break, metal taps last longer but increase cost
- Requires supply chain and market availability for replacement filters and taps
- Requires construction quality control process to ensure effectiveness
- Recontamination is possible during cleaning; care should be taken to use clean water, not to touch the ceramic with dirty hands, and not to place the filter on a dirty surface

Estimated Lifespan

- Up to 5 years, generally 1-2 years
- Filter needs to be replaced if there are visible cracks

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter Key Data

Manufacturing Requirements

Worldwide Producers:
- Free press and kiln designs are available from Potters for Peace

Local Production:
- Local production of the filters is common and preferable
- Requires quality control process to ensure filter effectiveness
- The lower container, lid and tap can usually be purchased locally

Materials:
- Clay
- Combustible material (e.g. sawdust, rice husks, coffee husks)
- Colloidal silver (optional)
- Lid
- 20-30 litre ceramic or plastic container with tap

Fabrication Facilities:
- A ceramic factory requires at least 100 square metres of covered area
- 15 to 20 ton hydraulic press (can be fabricated locally)
- Filter molds (can be fabricated locally)
- Mixer for clay and combustible material (can be fabricated locally)
- Hammer mill (can be fabricated locally)
- Kiln with an internal area of at least 1 cubic metre (can be fabricated locally)
- Racks
- Work benches
- Miscellaneous tools (e.g. traditional pottery tools)

Labour:
- Professional potter with experience in collecting clay, making ceramic articles, semi-industrial or mass production
- Assistants, preferably potters as well
- Skill and quality control in manufacturing is essential to ensure optimum pore size, flow rate and effectiveness

Hazards:
- Working with presses and kilns is potentially hazardous and adequate safety precautions should be used

Maintenance

- Filters are cleaned by lightly scrubbing the surface when the flow rate is reduced
- Some manufacturers recommend to boil the filter every three months to ensure effectiveness
- Some manufacturers recommend that soap and chlorine should not be used to clean the filter
- Lower container, tap and lid should be cleaned on a regular basis

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$12-25	US$0	~US$4[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

[1] Filter pots generally need to be replaced every 1-2 years

References

Brown, J. and M. Sobsey (2006). Independent Appraisal of Ceramic Water Filtration Interventions in Cambodia: Final Report, Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, USA.

Lantagne, D. (2001). Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter Report 2: Field Investigations. Alethia Environmental for USAID, USA.

Low, J. (2002). Appropriate Microbial Indicator Tests for Drinking Water in Developing Countries and Assessment of Ceramic Water Filters', Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, Massachusetts, USA.

Napotnik, J., Mayer, A., Lantagne, D. and K. Jellison. Efficacy of Silver-Treated Ceramic Filters for Household Water Treatment. Department of Civil and Environmental Engineering, Lehigh University, USA. Available at: www.filterpurefilters.org/files/pdf/silver.pdf

Smith, L. (2004). Ceramic Water Filter Use in Takeo, Cambodia – Operational Issues and Health Promotion Recommendations. Submitted in partial fulfilment as a requirement for a Master of Science in Control of Infectious Diseases, London School of Hygiene and Tropical Medicine, London, England.

Van Halem, D. (2006). Ceramic silver impregnated pot filters for household drinking water treatment in developing countries. Masters of Science in Civil Engineering Thesis, Department of Water Resources, Delft University of Technology, Netherlands.

Vinka, A. et al. (2007). Sustainable Colloidal-Silver-Impregnated Ceramic Filter for Point-of-Use Water Treatment. Environmental Science & Technology, Vol. 42, No. 3, 927–933

Further Information

Centers for Disease Control and Prevention: www.cdc.gov/safewater/publications_pages/options-ceramic.pdf

Filter Pure, Inc: www.filterpurefilters.org

International Development Enterprises: www.ideorg.org/OurTechnologies/CeramicWaterPurifier.aspx

Potters for Peace: www.pottersforpeace.org

Resource Development International Cambodia: www.rdic.org/water-ceramic-filtration.html

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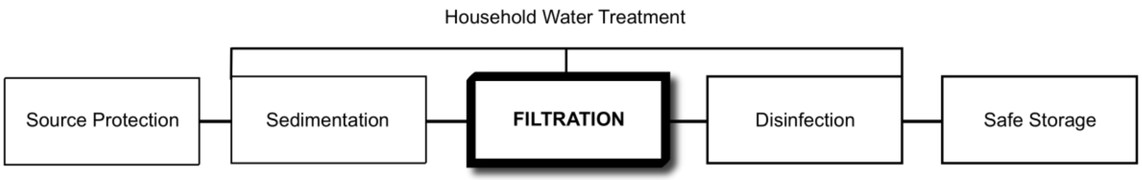
Last Update: June 2011

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Membrane Filters

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria (UF[1], NF[2], RO[3]) • Viruses (UF, RO, NF) • Protozoa (MF[4], UF, NF, RO) • Helminths (MF, UF, NF, RO) • Salt (RO, NF)	• Colour (UF, RO, NF) • Turbidity (UF, RO, NF) • Iron (UF, RO, NF) • Manganese (UF, RO, NF)	• Chemicals, pesticides (UF) • Heavy metals (UF)

[1] Ultrafiltration (see below)
[2] Nanofiltration (see below)
[3] Reverse Osmosis (see below)
[4] Microfiltration (see below)

What Is a Membrane Filter?

A membrane is a thin barrier with holes, or pores. Some particles, such as water, are small enough to pass through the membrane pores, while larger particles cannot pass through and are retained on the membrane. Membrane filtration is used as a step in the multi-barrier approach for water treatment, but it is also used in other areas such as desalination and water quality testing.

Membrane filtration can be classified according to the diameter of the pores in the membrane, or by the molecular weight of contaminants the membrane retains.

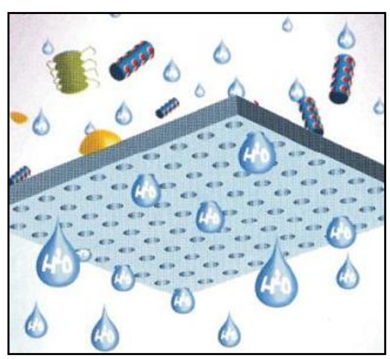
Filtration Type	Pore Size (µm / nm)	Molecular Weight (Daltons)
Microfiltration (MF)	0.1-10 µm (1-1000 nm)	
Ultrafiltration (UF)	0.01-0.1 µm (1-100 nm)	10,000-500,000
Nanofiltration (NF)	<0.001 µm (<1 nm)	200-1,000
Reverse osmosis (RO)	<0.001 µm (<1 nm)	<100

(Wagner, 2001 and US EPA, 2005)

Ultrafiltration is the most common membrane filtration in household drinking water treatment.

How Does It Remove Contamination?

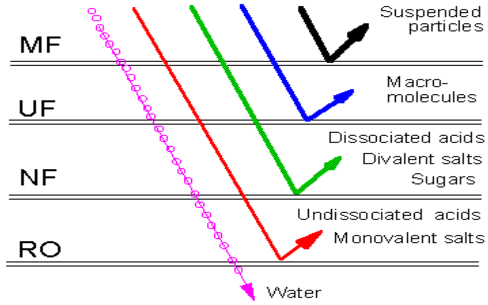
As water passes through the membrane, pathogens and other contaminants are removed because they are too big to fit through the membrane pores. Pressure is required to force the water through the membrane. For microfiltration and ultrafiltration, gravity alone may provide enough pressure to make the water flow through the filter.



Filter Membrane Illustration
(Credit: www.firstprinciples.com)

Household Water Treatment and Safe Storage Factsheet: Membrane Filters

Ultrafiltration membranes will remove large and heavy particles such as sand, bacteria, protozoa, helminths, and some viruses. They will not effectively remove most dissolved or small substances such as salt or smaller viruses.



Types of Membrane Filtration and Their Contaminant Removal Capabilities
(Credit: https://netfiles.uiuc.edu/mcheryan/www/mem-tech.htm)

Microfiltration alone is not as effective as ultrafiltration for treating drinking water because the membrane pores are bigger than most viruses and some bacteria. Microfiltration is sometimes used as a pre-treatment step in a multi-barrier treatment system.

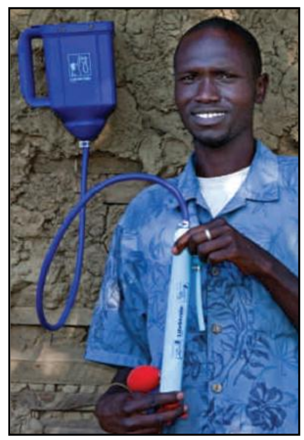
Nanofiltration and reverse osmosis are very effective at removing microbiological contamination, but these membranes are more commonly used in water desalination and industrial processes where the removal of dissolved contaminants is required.

Operation

There are several HWT products that use membrane technologies. Operation and maintenance procedures vary between products. A driving force is required to force the water through the membrane – this may be gravity (microfiltration and ultrafiltration), pressure or vacuum (nanofiltration and reverse osmosis). No electricity is required if manual pumping or gravity are used to force the water through the membrane. No chemicals are required, although some household membrane filter products also include a chemical disinfection step afterwards.

Some examples of such products are Sawyer® filters and Lifestraw®, which use ultrafiltration, and Nerox® filters, which use microfiltration. Please refer to the individual CAWST Membrane Filtration Product Sheets for further information on these technologies.

Sawyer Filter
(Credit: www.sawyerpointonefilters.com)



Lifestraw Family Filter
(Credit: www.vestergaard-frandsen.com/lifestraw)

Nerox-02 Filter
(Credit: www.scan-water.org)

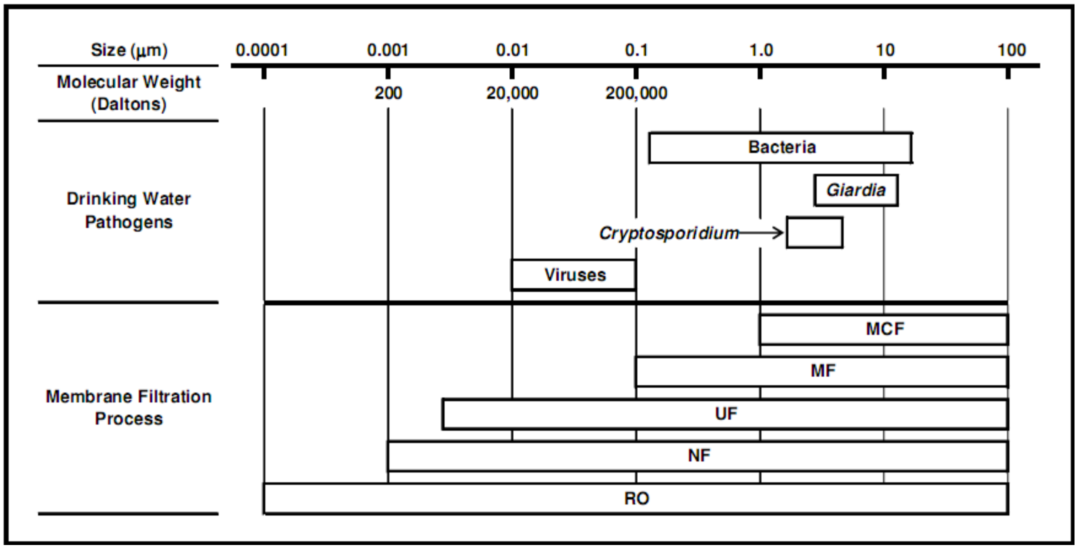
Household Water Treatment and Safe Storage Fact Sheet: Membrane Filters Key Data

Inlet Water Criteria

- Some products recommend or incorporate a pre-filtration step such as straining through a cloth, settling, or sand filtration to reduce inlet water turbidity
- Very turbid water will clog membranes, reducing flow rate and requiring more frequent cleaning

Treatment Efficiency

- Depends on membrane pore size and filter product; see Membrane Filtration Product Sheets
- The following illustration shows the different pore sizes of each filtration type in comparison to the size of various pathogens. It is important to research the pore size and treatment capability of any filter product before purchase.



Pore Size for Various Filtration Types and Relative Pathogen Sizes ("MCF" = Membrane Cartridge Filtration)
(US EPA, 2005)

Operating Criteria

- Operation depends on product

Membrane Filter Product	Flow Rate	Daily Water Supply	Lifespan Volume
Sawyer® 0.02 filter[1]	13.6-15 litres/hour	327 litres	3.78 million litres
Sawyer® 0.1 filter[2]	46.5-54 litres/hour	1117 litres	N/A
Lifestraw® Individual[3]	N/A	2 litres	700 litres
Lifestraw® Family[3]	6-8 litres/hour	144-192 litres	18,000 litres
Nerox® filter[4]	N/A	15-25 litres	2,500 litres

N/A – not available

[1] www.sawyerpointonefilters.com; based on a 3-foot hose attached to a 5-gallon bucket at sea level. Increasing the hose length, using a larger container or continuously keeping the bucket full will increase flow rate.

[2] www.sawyerpointonefilters.com; based on a 1-foot hose attached to a 5-gallon bucket at sea level. Increasing the hose length, using a larger container or continuously keeping the bucket full will increase flow rate.

[3] www.vestergaard-frandsen.com/lifestraw

[4] www.scan-water.com

Household Water Treatment and Safe Storage Fact Sheet: Membrane Filters Key Data

Robustness

- Many membrane filter products cannot be used or stored in temperatures below zero
- Some products are available for use in emergency contexts

Estimated Lifespan

- Depends on product

Manufacturing Requirements

Worldwide Producers:
- There is a wide variety of companies that manufacture membrane filter products worldwide
- Compact designs usually allow for easy handling and transport

Local Production:
- It could be difficult to find local producers of membranes or membrane filter products
- Some components for manufacturing or assembling membrane filter products can be found locally (e.g. tubing, containers)

Materials:
- Membranes are made from a variety of materials such as acrylonitrile, polysulfone, polypropylene, polyester or polytetrafluoroethylene

Labour:
- Anyone can be trained to construct and install the system

Hazards:
- No specific manufacturing or operational hazards

Maintenance

- Membranes and other parts of the product may need regular cleaning and/or backwashing

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
Depends on product	Not available[1]	Depends on product

[1] Operational cost will depend on product chosen, location, local infrastructure, pumping system (manual or electric)

References

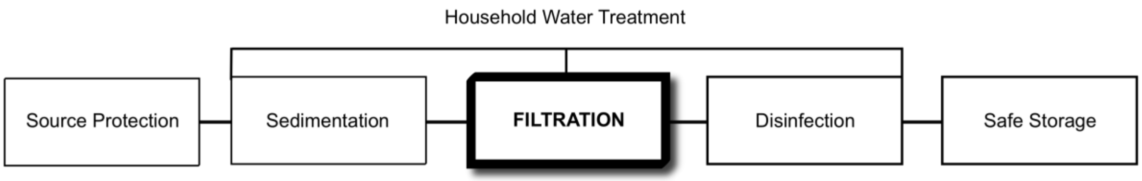
Wagner, J. (2001). Membrane Filtration Handbook. Second Edition, Revision 2. Osmonics, Inc. USA. Available online at: www.ionics.com/content/pdf/1229223-%20Lit-%20Membrane%20Filtration%20Handbook.pdf

United States Environmental Protection Agency (US EPA). (2005). Membrane Filtration Guidance Manual. USA, Nov 2005. Available online at: www.epa.gov/ogwdw/disinfection/lt2/pdfs/guide_lt2_membranefiltration_final.pdf

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: LifeStraw® Family

Treatment Type



Product Name: LifeStraw® Family

Manufacturers: Vestergaard-Frandsen

Product Description: LifeStraw® Family is a water filtration and disinfection system that uses gravity to move water through it. The untreated water is poured into a container at the top. Safe water comes out of the blue tap at the bottom.

The inlet water is treated first by a pre-filter with a pore size of 80 μm, located in the upper container. This pre-filter removes large particles and sediment. Water then flows down the hose due to gravity, and into the purification cartridge. Inside the purification cartridge, the water is filtered again through a membrane with a pore size of 0.02 μm (20 nm). This ultrafiltration step removes remaining pathogens and turbidity.

Each time the filter is used; the user must open the red valve at the bottom of the purification cartridge and let water flow out for 5 to 30 seconds. This empties the cartridge of air and allows maximum treatment. Water from the red outlet should not be drunk.

Using Lifestraw Family
(Credit: Vestergaard-Frandsen)

Availability: Must be purchased from Vestergaard Frandsen (regional offices located in parts of Africa and Asia) and imported. Not available on single unit basis, large quantities must be purchased.

Robustness: Requires no electricity or spare parts. There is a chlorine chamber at the bottom of the upper container which adds a small amount of active chlorine to the water for the purpose of protecting the ultrafiltration membrane from fouling, extending the life of the membrane. The pre-filter and purification cartridge require daily cleaning to prevent clogging

Lifespan: 18,000 litres (about 2.5 years at 20 litres/day)

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: LifeStraw® Family

Approximate Dimensions: Upper container capacity: 2 litres
Plastic hose length: 1 metre

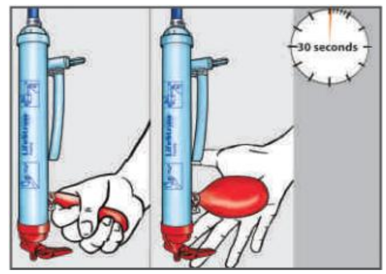
Approximate Weight: Not available

Output: Average 9 to 10 litres/hour

Cost: US$25-40; only available in large orders

Maintenance: Pre-filter should be cleaned daily. Remove pre-filter from container, wash and replace.

Purification cartridge should be cleaned daily. Follow instructions provided to clean the cartridge by squeezing the red bulb, waiting 30 seconds, and repeating twice. Open the red valve and allow water to flow out of the red outlet for 30 seconds.



Squeezing the bulb for backwash
(Credit: Vestergaard-Frandsen)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	>99.9999%[1,2]	99.99%[1,2]	>99.9%[1,2]	100%[3]	N/A[4]	0[2]
Field*	N/A	N/A	N/A	N/A	N/A	N/A

N/A : Not available

[1] Clasen et al., 2009

[2] www.vestergaard-frandsen.com/lifestraw/lifestraw/faq

[3] Due to the pore size (0.02 μm), it would be expected that helminths will be removed

[4] Due to the pore size (0.02 μm), turbidity removal is expected to be high. Extensive testing has shown it will make turbid water clear (www.vestergaard-frandsen.com/lifestraw/lifestraw-family/faq).

Lifestraw does not remove salt or chemicals such as arsenic, iron or fluoride.

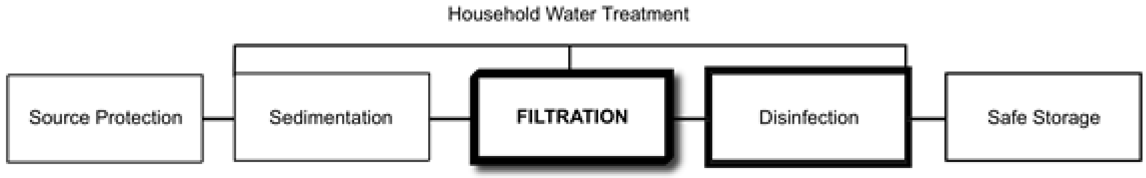
References

Clasen, T. et al. (2009). Laboratory assessment of a gravity-fed ultrafiltration water treatment device designed for household use in low-income settings. Am. J. Trop. Med. Hyg., 80(5), 2009, pp. 819–823.

Vestergaard-Frandsen. (no date). Lifestraw®. Safe drinking water interventions for home and outside use. Verstergaard Frandsen Group S.A., Switzerland. Available at: www.lifestraw.com

Household Water Treatment and Safe Storage Product Sheet: LifeStraw®

Treatment Type



Product Name: LifeStraw®

Manufacturers: Vestergaard-Frandsen

Product Description: LifeStraw® is a portable water filter that can be carried around with the user. Water is drunk directly out of the filter apparatus - the user dips LifeStraw® into a water source and sucks on it like a straw to draw the water up. The personal filter is recommended for adults and children over 3 years old. The filter is recommended for use when away from home.

Drinking with Lifestraw
(www.lifestraw.com)

LifeStraw® contains a chamber with a specially developed halogenated resin (containing iodine) that kills bacteria and viruses on contact. Micro-filters are also used to remove all particles larger than 0.2 microns (μm). Activated carbon adsorbs residual iodine, improving the taste of water. The filter will remove some turbidity. More frequent backwashing will be required if the source water is turbid.

Availability: Must be purchased from Vestergaard Frandsen (regional offices located in parts of Africa and Asia) and imported

Robustness: Requires no electricity or spare parts. The outer shell is composed of high impact polystyrene plastic. Can be carried around by the user on a string around their neck. Should be regularly backwashed by blowing through it to prevent clogging; will require more frequent backwashing if turbid water is used.

Lifespan: 1,000 litres (about 15 months at 2 litres/day)

Approximate Dimensions: Not available

Approximate Weight: Not available

Output: Maximum 0.6 litres/minute (the actual flow rate will change over the filter cleaning cycle and the lifespan of the filter)

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: LifeStraw®

Cost: US$3-$6.50; available retail and wholesale. Not currently available on a retail basis in North America.

Storage: Can be stored for three years at a maximum temperature of 30 degrees. Storage at higher temperatures will results in lower treatment rates for the first few millilitres of water consumed.

Maintenance: Regularly blow through it after drinking to keep the filters clean and to prevent clogging

Backwashing by blowing
(Credit: Vestergaard-Frandsen)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Metals
Laboratory	>99.999%[1,2,3]	99-99.8%[1]	>99.9%[2,3]	100%[4]	99.6%[3]	0[2]
Field*	N/A	N/A	N/A	N/A	N/A	N/A

N/A: Not available

[1] Sobsey, no date

[2] www.vestergaard-frandsen.com/lifestraw/lifestraw/faq

[3] Naranjo and Gerber, 2010; turbidity removal based on inlet water with turbidity of 104 NTU

[4] due to the pore size (0.2 μm), it would be expected that helminths will be removed

LifeStraw does not remove salt or chemicals such as arsenic, iron or fluoride.

Inlet water criteria not specified; very turbid water should be pre-filtered or settled first. If turbid water is to be consumed, only use LifeStraw to drink from the surface (top layer) of the water.

References

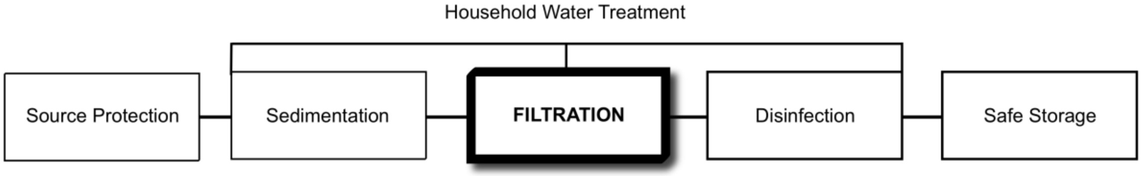
Naranjo, J and Gerber, C.P. (2010). Laboratory Test: Evaluation of Vestergaard Frandsen's hollow fiber LifeStraw® for the removal of Escherichia Coli and Cryptosporidium according to the US Environmental Protection Agency guide standard and protocol for evaluation of microbiological water purifiers. Department of Soil, Water and Environmental Science, University of Arizona, USA. Available at: www.vestergaard-frandsen.com/lifestraw/lifestraw/longevity-and-efficacy

Sobsey, M. (no date). LifeStraw® Personal: Summary of Test Data Received from the University of North Carolina, USA.

Vestergaard-Frandsen (no date). Lifestraw®. Safe drinking water interventions for home and outside use. Verstergaard Frandsen Group S.A., Switzerland. Available at: www.lifestraw.com

Household Water Treatment and Safe Storage Product Sheet: Nerox®- 02 Drinking Water Filter

Treatment Type



Product Name: Nerox®-02 Drinking Water Filter

Manufacturers: First Principals Inc., USA

Scan-Water, Norway/Finland

Simpex, Ukraine

Product Description: The Nerox®-02 filter is a patented technology. The filter system is comprised of a chamber containing the membrane, with an outlet hose and nozzle. The membrane is a thin polymeric film with pore size of 0.2[1], 0.28[2] or 0.4[3] microns. The filter operates mechanically using gravity.

[1] Simpex
[2] ScanWater
[3] First Principles

(Credit: www.filter-systems.com)

Availability: Must be shipped. May also be available as a kit including water containers or bags with spigot.

Robustness: There are no moving or mechanical parts to break.
Can only be used in above-zero climates.

Warnings: Do not store in sub-zero temperatures.
Do not clean the membrane with coarse material or brush.
Do not expose the filter to direct sunlight or excessive heat.
Do not use the filter if the membrane is in any way damaged.

Lifespan: Can treat up to 2,500 litres depending on source water turbidity. Typical use is 15-25 L/day. Lasts up to 10 years when kept in original packaging and in temperatures between –10 and +50º C.

Approximate Dimensions: 16 cm x 17.5 cm x 2.5 cm.
The height of the water surface in the inlet water container must be kept a minimum of 30 cm above the end of the outlet tube.

Approximate Weight: 300 grams (0.66 lb)

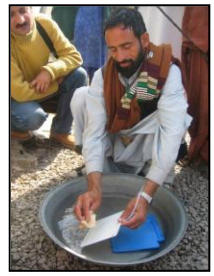
Output: Typically 15 to 25 L/day, turbid water gives lower output

Cost: US$12-15

Household Water Treatment and Safe Storage Product Sheet: Nerox®- 02 Drinking Water Filter

Storage: Dry environment, above 0 ºC.

Maintenance: The filter membrane must be cleaned with a sponge when membrane gets clogged.



(Credit: Scan Water)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	94-100 %[1,2]	N/A[3]	100%[1,2]	100%[2]	90 %[4]	60-100 %[5,6]
Field*	N/A[7]	N/A[3]	N/A[6]	N/A[6]	N/A[6]	N/A[6]

N/A - Not available

[1] First Principles Inc., nd

[2] www.scan-water.com / www.filter-systems.com / Tullilaboratorio Laboratories, Finland

[3] The membrane pore size is too large to retain most viruses

[4] www.filter-systems.com

[5] Removal of metals and chemicals depends on the quality of the water source. The filter is able to remove some to all iron, lead, copper, aluminum, manganese, zinc, arsenic and some pesticides. (www.firstprinciples.com, www.filter-systems.com)

[6] Arsenic removal efficiency: 90-100% (First Principles Inc., nd)

[7] The Nerox filter has been used by international organizations, such as UNICEF, in the field, especially for emergency situations (see websites below for more information)

References

First Principals Inc. (no date). Nerox Water Filter, No More Bacteria. First Principals Inc., Cleveland, USA. Available at: www.firstprincipals.com/3pager_Filter.pdf

Further Information

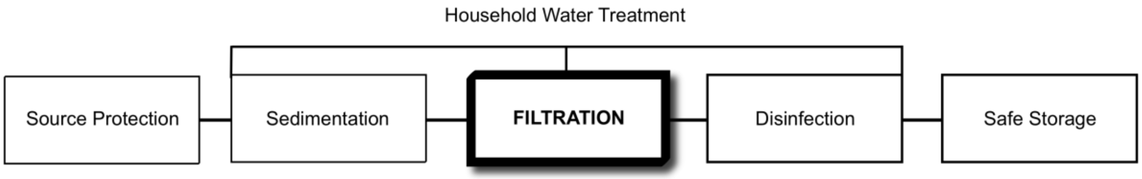
First Principals: www.firstprincipals.com/Nerox.htm
Information brochure: www.firstprincipals.com/3pager_Filter.pdf

Scan Water: www.scan-water.com
Information brochure: www.scan-water.com/products.php?vareid=103

Simpex/Filter-systems: www.filter-systems.com

Household Water Treatment and Safe Storage Product Sheet: Sawyer Point One^{TM} Filter

Treatment Type



Product Name: Sawyer Point One^{TM} filter

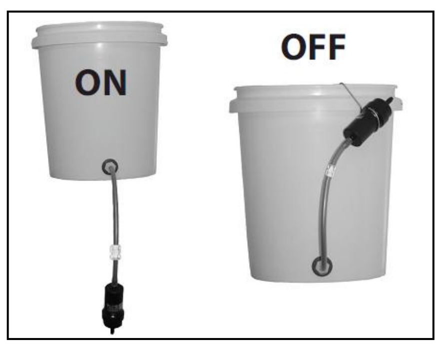
Manufacturer: Sawyer Products Inc., USA

Product Description:

The Sawyer Point One® filter is a gravity membrane filtration technology that uses hollow fibre membranes to remove pathogens. It has a pore size of 0.1 microns, making it effective for removing bacteria, protozoa and helminths. The Point One® filter does not remove viruses (see Sawyer Point Zero Two Product Sheet for virus removal).

Sawyer PointOne^{TM} Filter Kit
(Credit: www. www.sawyer.com)

The kit includes a filter, hose, compression fitting, backwash syringe, a hanger for storing the hose, and a hole cutter for attaching the hose to the inlet water container. The kit does not include a container to hold the inlet water or a container to collect the filtered water. The kit is designed to be used with a plastic container, but other types may also work; water storage containers should not be a container that has ever been used to transport chemicals or toxic materials.



Sawyer Filter Operation
(Credit: www.sawyer.com)

The filter membrane is located at the end of the outlet hose. To stop the flow, the hose and filter are raised up to the top of the inlet water bucket and hooked on a hanger (provided) until the next use.

Availability: Available online. Cannot be exported internationally through Sawyer Products Inc. They recommend contacting an international logistic company for shipping outside of North America.

Robustness: The membrane filter doesn't need to be replaced; backwashing using the syringe when the filter clogs is all that is required to restore the flow rate. Water pre-filtration using a cloth and/or settling is recommended for turbid inlet water.

Lifespan: No field data available yet to estimate how long the filter will remain useable.

Household Water Treatment and Safe Storage Product Sheet: Sawyer Point One™ Filter

Approximate Dimensions: Cylindrical filter: length 22 cm, diameter 7 cm.
Plastic tube length: 30 cm (1 foot); other lengths are available.

Approximate Weight: 0.3 kg (0.63 lb)

Output: 46.5-54 litres/hour; 1117 litres/day. Based on a 1-foot hose attached to a 5-gallon bucket at sea level. Increasing the hose length, using a larger container, continuously keeping the bucket full will increase flow rate. Flow rate will be lower at higher altitudes.

Costs: Retail US$60

Maintenance: Need to backwash filter using syringe provided in the kit when flow rate slows down. With relatively clear inlet water, backwashing is recommended every 3,800 litres. If inlet water is extremely turbid, backwashing is recommended every 40 litres or less.

Sawyer PointOne™ Bucket Filter
(Credit: www.sawyer.com/gallery.htm)

Treatment Efficiency

	Bacteria**	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	>99.99999%[1]	N/A[2]	> 99.999%[3]	100%[4]	N/A	N/A
Field	N/A[5]	N/A	N/A	N/A	N/A	N/A

N/A: Not available.

[1] Hydreion LLC, 2005. Test bacteria: Klebsiella.

[2] The Sawyer Point One™ filter does not claim to remove viruses.

[3] Hydreion LLC, 2005. Test organisms: Cryptosporidium parvium oocysts and Giardia Lamblia cysts.

[4] Helminth removal should be equal to or greater than bacteria and protozoa removal based on pathogen size.

[5] A field project implementation by Give Clean Water shows its applicability in the field. Available at: www.sawyerpointonefilters.com . The results from a field study in Bolivia are being analyzed.

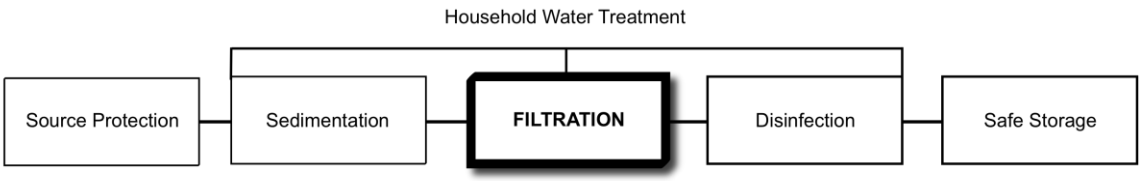
References

Hydreion LLC. (2005). Microbiological Testing of the Sawyer 7/6B Filter. USA. Available at: www.sawyerpointonefilters.com/downloads/MicrobiologicalTest_HydreionLabReport_12-01-2005_76BFilter.pdf

Sawyer Products Inc (2011). Available at: www.sawyerpointonefilters.com. Accessed May 16, 2011.

Household Water Treatment and Safe Storage Product Sheet: Sawyer Point Zero Two™ Purifier

Treatment Type



Product Name: Sawyer Point Zero Two™ Purifier filter

Manufacturer: Sawyer Products Inc., USA

Product Description:

The Sawyer Point Zero Two® filter is a gravity membrane filtration technology that uses hollow fibre membranes to remove pathogens from water. It has a pore size of 0.02 microns, making it effective for removing viruses, bacteria, protozoa and helminths.

The kit includes a filter, hose, compression fitting, backwash syringe and a hole cutter for attaching the hose to the inlet water container. The kit does not include a container to hold the inlet water or a container to collect the filtered water. The kit is designed to be used with a plastic container, but other types may also work; water storage containers should not be a container that has ever been used to transport chemicals or toxic materials.

The filter membrane is located at the end of the outlet hose. To stop the flow, the hose and filter are raised up to the top of the inlet water bucket and hooked on a hanger (provided) until the next use.

Sawyer Point Zero Two Filter (Bucket Not Included)
(Credit: www.sawyerdirect.net)

Availability: Available online. Cannot be exported internationally through Sawyer Products. They recommend contacting an international logistic company for shipping outside of North America.

Robustness: The membrane filter doesn't need to be replaced; backwashing using the syringe when the filter clogs is all that is required to restore the flow rate. Water pre-filtration using a cloth and/or settling is recommended for turbid inlet water.

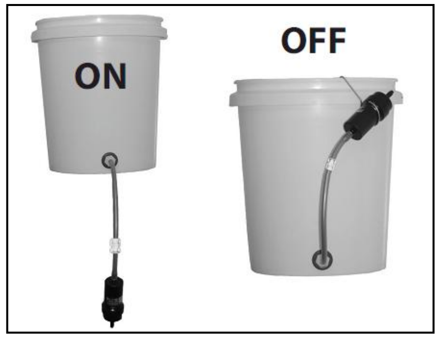
Lifespan: There is no field data available yet to estimate how long the filter will remain useable.

Household Water Treatment and Safe Storage Product Sheet: Sawyer Point Zero Two™ Purifier

Approximate Dimensions: Cylindrical filter: length 22 cm, diameter 7 cm. Plastic tube length: 90 cm (3 feet); other lengths are available.

Approximate Weight: 0.5 kg (1.13 lb)

Output: 13.6-15 litres/hour; 327 litres/day. Based on a 3-foot hose attached to a 5-gallon bucket at sea level. Increasing the hose length, using a taller container or continuously keeping the bucket full will increase flow rate. Flow rate will be lower at higher altitudes.



Sawyer Filter Operation
(Credit: www.sawyer.com)

Cost: Retail US$145

Maintenance: Need to backwash filter using syringe provided in the kit when flow rate slows down. With relatively clear inlet water, backwashing is recommended every 3,800 litres. If inlet water is extremely turbid, backwashing is recommended every 40 litres or less.

Treatment Efficiency

	Bacteria**	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	>99.9999%[1]	>99.999%[2]	> 99.999%[3]	100%[4]	N/A	N/A
Field	N/A[5]	N/A	N/A	N/A	N/A	N/A

N/A: Not available.

[1] Hydreion LLC, 2005. Test bacteria: Klebsiella. Results are for the Point One™ filter; the Point Zero Two™ filter should have as good or better removal based on pore size.

[2] Hydreion LLC, 2005. Test virus: MS2 coliphage

[3] Hydreion LLC, 2005. Test organisms: Cryptosporidium parvium oocysts and Giardia Lamblia cysts. Results are for the Point One™ filter; the Point Zero Two™ filter should have as good or better removal based on pore size.

[4] Helminth removal should be equal to or greater than bacteria and protozoa removal based on pathogen size.

[5] A field project implementation developed by Give Clean Water shows its applicability in the field. Available at: www.sawyerpointonefilters.com. The results from a field study in Bolivia are being analyzed.

References

Hydreion LLC. (2005). Microbiological Testing of the Sawyer 7/6B Filter. USA. Available at: www.sawyerpointonefilters.com/downloads/MicrobiologicalTest_HydreionLabReport_12-01-2005_76BFilter.pdf

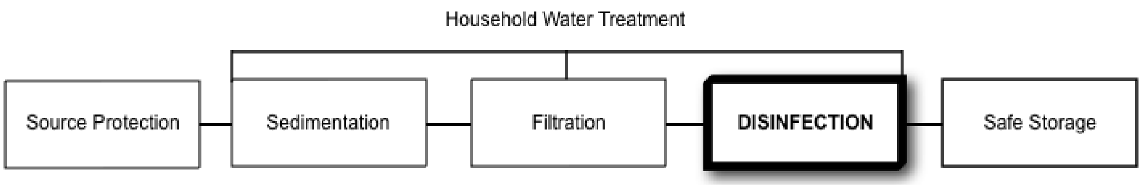
Hydreion LLC. (2005). Virus Removal Test of the Sawyer 7/6BV Filter. USA. Available at: www.sawyerpointonefilters.com/downloads/PurificationTest_HydreionLabReport_1-6-2006_76VPurifier.pdf

Sawyer Products Inc (2011). Available at: www.sawyerpointonefilters.com. Accessed May 16, 2011.

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Boiling

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa • Helminths		• Turbidity • Chemicals • Taste, odour, colour

What is Boiling?

Boiling is considered the world's oldest, most common, and one of the most effective methods for treating water. If done properly, boiling kills or deactivates all bacteria, viruses, protozoa (including cysts) and helminths that cause diarrheal disease.

How Does It Remove Contamination?

Pathogens are killed when the temperature reaches 100 degrees Celsius.

Operation

Water is heated over a fire or stove until it boils. Different fuel sources can be used depending on local availability and cost (e.g. wood, charcoal, biomass, biogas, kerosene, propane, solar panels, electricity).

Water bubbling as it boils provides a visual indicator does away with the need for a thermometer.

Recommended boiling times varies among organizations. The World Health Organization recommends that water be heated until it reaches the boiling point (WHO, nd). The Centers for Disease Control and Prevention, recommends a rolling boil of 1 minute, to ensure that users do not stop heating the water before the true boiling point is reached (CDC, 2009). CAWST recommends boiling water for 1 minute and adding 1 minute per 1000 metres of elevation.

Recontamination of boiled water is a major problem. Water is often transferred from the pot into dirty storage containers which then make it unsafe to drink. It is recommended to store boiled water in its pot with a lid to reduce the risk of recontamination.

Boiled tastes flat to some people. This is caused by dissolved oxygen escaping from the water as it boils. The flat taste can be reduced by vigorously stirring or shaking cooled water to increase its dissolved oxygen content.

Boiling water (Credit: Phitar, 2005)

Household Water Treatment and Safe Storage Fact Sheet: Boiling Key Data

Inlet Water Criteria

- Any water can be boiled

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	100%	100%	100%	100%	0%	0%[3]
Field	97-99%[1,2]	Not available	Not available	Not available	0%	0%

[1] Clasen, T. et al (2007)
[2] Clasen, T. (2007)
[3] May precipitate some dissolved chemicals

- Pathogens are killed when the temperature reaches 100 degrees Celsius

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Depends on container size	Depends on container size and availability of fuel

- Boil water for 1 minute and add 1 minute per 1000 metres of elevation
- Boiled water should be kept in the pot covered with a lid until it is consumed

Robustness

- Almost all households have the equipment required to boil water
- Requires fuel supply
- Users may not consistently boil water to save fuel and effort

Estimated Lifespan

- On-going requirement for fuel
- Pots used for boiling need may need to be replaced over time

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- Fuel (e.g. wood, charcoal, biomass, biogas, kerosene, propane, solar panels, electricity)
- Stove or heater
- Pot and lid

Fabrication Facilities:
- Not applicable

Labour:
- Regular collection of some fuels (e.g. wood, charcoal, other biomass)

Household Water Treatment and Safe Storage Fact Sheet: Boiling Key Data

Hazards:

- Potential for burn injuries; caution should be maintained around stoves and fires and when handling hot water
- Cause of respiratory infections associated with poor indoor air quality; improved stoves can be used to improve indoor air quality and reduce illness and death

Maintenance

- Pot and lid should be cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0[1]	US$0-0.06/10 litres[2]	US$0[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Households are assumed to already have a pot and fire/stove for cooking
[2] Clasen (2007)

Other

- Boiled water tastes flat to some people. This is caused by dissolved oxygen escaping from the water as it boils. The flat taste can be reduced by vigorously stirring or shaking cooled water to increase its dissolved oxygen content.

References

Centers for Disease Control and Prevention (2009). Household Water Treatment Options in Developing Countries: Boiling. Atlanta, USA.

Clasen, T. (2007). Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water: Case Studies from Vietnam and India. (Presentation) London School of Hygiene and Tropical Medicine.

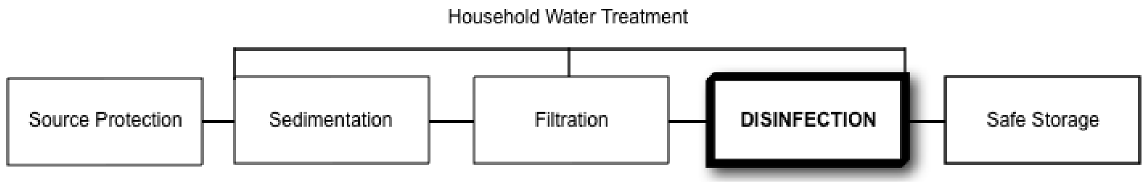
Clasen, T., Thao, D., Boisson, S., and O. Shipin (2008). Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water in Rural Vietnam. Environmental Science and Technology; 42(12): 42:55.

World Health Organization (nd). Household Water Treatment and Safe Storage Following Emergencies and Disasters: South Asia Earthquake and Tsunami. Available at: www.who.int/household_water/en/

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets)

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses	• Some protozoa • Helminths	• *Cryptosporidium parvum* • Toxoplasma oocysts • Turbidity • Chemicals • Taste, odour, colour

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What is NADCC?

Chlorine began to be widely used as a disinfectant in the early 1900's. It revolutionized drinking water treatment and dramatically reduced the incidence of waterborne diseases. Chlorine remains the most widely used chemical for water disinfection in the United States.

NaDCC also known as sodium dichloroisocyanurate or sodium troclosene, is one form of chlorine used for disinfection. It is often used to treat water in emergencies, and is now widely available for household water treatment.

Tablets are available from Medentech Ltd. with different NaDCC contents (e.g. 2 mg to 5 g) to treat different volumes of water (e.g. 1 to 2,500 litres) at a time. They are usually effervescent, allowing the smaller tablets to dissolve in less than 1 minute.

How Does It Remove Contamination?

When added to water, NaDCC releases hydrochlorous acid which reacts through oxidization with microorganisms and kills them.

Three things can happen when chlorine is added to water:

1. Some chlorine reacts through oxidization with organic matter and the pathogens in the water and kills them. This portion is called consumed chlorine.
2. Some chlorine reacts with other organic matter, ammonia and iron and forms new chlorine compounds. This is called combined chlorine.
3. Excess chlorine that is not consumed or combined remains in the water. This portion is called free residual chlorine (FRC). The FRC is the most effective form of chlorine for disinfection (particularly for viruses) and helps prevent recontamination of the treated water.

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets)

Operation

Each product should have its own instructions for correct dosing. In general, the user adds the correct sized tablet for the amount of water to be treated, following the product instructions. Then the water is agitated, and left for the time instructed, normally 30 minutes (contact time). The water is then disinfected and ready to be used.

The effectiveness of chlorine is affected by turbidity, organic matter, ammonia, temperature and pH.

Turbid water should sedimented or filtered before adding chlorine. These processes will remove some of the suspended particles and improve the reaction between the chlorine and pathogens.

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets) Key Data

Inlet Water Criteria

- Low turbidity
- pH between 5.5 and 7.5; disinfection is unreliable above a pH of 9

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	High[4]	High[4]	Low[4]	Ineffective[5] – Moderate[6]	0%
Field	Not available	Not available	Not available	Not available	0%

[1] Bacteria include *Burkholderia pseudomallei, Campylobacter jejuni, Escherichia coli, Salmonella typhi, Shigella dysenteriae, Shigella sonnei, Vibrio cholerae, Yersinia enterocolitica.*
[2] Viruses include enteroviruses, adenoviruses, noroviruses, rotavirus.
[3] Protozoa include *Entamoeba histolytica, Giardia lamblia, Toxoplasma gondii, Cryptosporidium parvum.*
[4] CDC (2007)
[5] AWWA (2006) shows that chlorine is ineffective for *Ascariasis lumbricoides* ova.
[6] Mercado-Burgos et al.(1975) show moderate effectiveness for *Schistosoma* species. Assume moderate effectiveness for *Dracunculus medinensis.*

- *Toxoplasma* oocysts and C*ryptosporidium parvum* oocysts are highly resistant to chlorine disinfection (CDC, 2007). Chlorine alone should not be expected to inactivate these pathogens.

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Need to follow manufacturer's instructions for specific NaDCC products
- Required dose and contact time varies with turbidity, pH and temperature (Lantagne, 2009)
- Very turbid water should be sedimented or filtered prior to chlorination
- Use a 30-minute minimum contact time

Robustness

- Free residual chlorine protects against recontamination
- Most users cannot determine the dosing themselves; need to follow manufacturer instructions
- Users may use less than the recommended dose to save money
- Requires supply chain, market availability and regular purchase

Estimated Lifespan

- Five year shelf-life in strip packs and a three year shelf-life in tubs (Medentech, 2009)

Manufacturing Requirements

Worldwide Producers:

- Medentech Ltd. manufactures Aquatabs for water disinfection, hospital surface infection control and general environmental disinfection

Local Production:

- NaDCC tablets cannot be produced locally, but they can be bought in bulk and packaged locally

Materials:

- Tablets and packaging materials

Fabrication Facilities:

- Workshop space for packaging the tablets

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets) Key Data

Labour:

- Anyone can be trained for light packaging work

Hazards:

- NaDCC tablets are safe to handle and store

Maintenance

- Products should be protected from exposure to temperature extremes or high humidity
- Should be stored away from children

Direct Cost

Capital Cost(s)	Operating Cost(s)	Replacement Cost
US$0	US$0.03/20 litre tablet[1] US$10.95/year[2]	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Medentech (2009)
[2] Assumed 20 litres/household/day

Other

- Some users complain about the taste and odour that chlorine may cause in water, some NaDCC products claim that at there is no bad odour or taste using the recommended doses
- Chlorine reacts with organic matter naturally present in water to form by-products such as trihalomethanes (THMs), which are potentially cancer-causing
- Study results indicate THM levels produced during household chlorination may fall below WHO guideline values (Lantagne et al., 2008)

References

Clasen, T. and P. Edmondson (2006). Sodium dichloroisocyanurate (NaDCC) tablets as an alternative to sodium hypochlorite for the routine treatment of drinking water at the household level. International Journal of Hygiene and Environmental Health Volume 209, Issue 2, pp. 173-181.

Clasen, T., Saed, T., Boisson, S., Edmondson, P., and O. Shipin. (2007). Household Water Treatment Using Sodium Dichloroisocyanurate (NaDCC) Tablets: A Randomized, Controlled Trial to Assess Microbiological Effectiveness in Bangladesh. Am. J. Trop. Med. Hyg., 76(1), 2007, pp. 187–192.

Lantagne, D.S., Blount, B. C., Cardinali, F., and R. Quick, R (2008). Disinfection by-product formation and mitigation strategies in point-of-use chlorination of turbid and non-turbid waters in western Kenya. Journal of Water and Health, 06.1, 2008.

Lantagne, D. (2009). Summary of Information on Chlorination and pH. Prepared for UNICEF.

Medentech (2009). Personal communication, March 2009.

Molla, N., (2007). Practical Household Use of the Aquatabs Disinfectant for Drinking Water Treatment in the Low-Income Urban Communities of Dhaka, Bangladesh. Thesis, Asia Institute of Technology, School of Environment, Resources and Development.

Further Information

Medentech Ltd: www.aquatabs.com or www.medentech.com

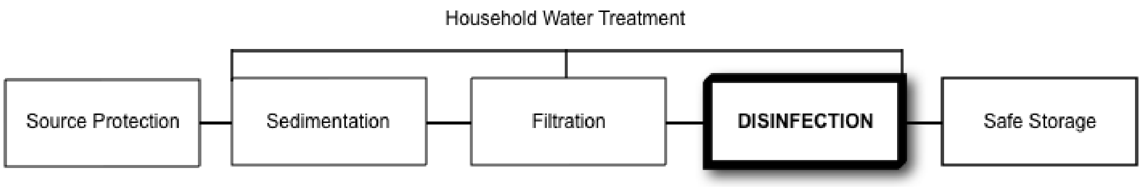
CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: June 2011

Centre for Affordable Water and Sanitation Technology

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite)

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses	• Some protozoa • Helminths	• *Cryptosporidium parvum* • Toxoplasma oocysts • Turbidity • Chemicals • Taste, odour, colour

What is Sodium Hypochlorite?

Chlorine began to be widely used as a disinfectant in the early 1900's. It revolutionized drinking water treatment and dramatically reduced the incidence of waterborne diseases. Chlorine remains the most widely used chemical for water disinfection in the United States.

Sodium hypochlorite is one form of chlorine used for water disinfection. It can be manufactured in most locations since it can be obtained through the electrolysis of salt water.

Bottles can be purchased for household water treatment from many manufacturers in various sizes. Chlorine concentrations range from 0.5 to 10% and each product should have its own instructions for correct dosing of contaminated water. Liquid household bleach also contains sodium hypochlorite, and is widely available.

How Does it Remove Contamination?

Chlorine forms hydrochlorous acid when added to water which reacts through oxidization with microorganisms and kills them.

Three things can happen when chlorine is added to water:

1. Some chlorine reacts through oxidization with organic matter and the pathogens in the water to kill them. This portion is called consumed chlorine.
2. Some chlorine reacts with other organic matter, ammonia and iron and forms new chlorine compounds. This is called combined chlorine.
3. Excess chlorine that is not consumed or combined remains in the water. This portion is called free residual chlorine (FRC). The FRC is the most effective form of chlorine for disinfection (particularly for viruses) and helps prevent recontamination of the treated water.

Air Rahmat, Indonesia (Credit: Tirta/JHUCCP)

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite)

Operation

There are several different brands of chlorine products that have been manufactured specifically for household water treatment. Each product should have its own instructions for correct dosing and contact time.

Clorin sold in grocery stores, Zambia

Liquid household bleach products are also commonly used to disinfect drinking water. The strength of the product must be known to calculate how much bleach is needed to disinfect a given volume of water. See CAWST's *Technical Brief on Chlorine Disinfection of Drinking Water* for information on how to determine the chlorine dose and contact time using household bleach.

The effectiveness of chlorine is affected by turbidity, organic matter, ammonia, temperature and pH.

Turbid water should sedimented or filtered before adding chlorine. These processes will remove some of the suspended particles and improve the reaction between the chlorine and pathogens.

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite) Key Data

Inlet Water Criteria

- Low turbidity
- pH between 5.5 and 7.5; disinfection is unreliable above a pH of 9

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	High[4]	High[4]	Low[4]	Ineffective[5] – Moderate[6]	0%
Field	Not available	Not available	Not available	Not available	0%

[1] Bacteria include *Burkholderia pseudomallei, Campylobacter jejuni, Escherichia coli, Salmonella typhi, Shigella dysenteriae, Shigella sonnei, Vibrio cholerae, Yersinia enterocolitica.*
[2] Viruses include enteroviruses, adenoviruses, noroviruses, rotavirus.
[3] Protozoa include *Entamoeba histolytica, Giardia lamblia, Toxoplasma gondii, Cryptosporidium parvum.*
[4] CDC (2007)
[5] AWWA (2006) shows that chlorine is ineffective for *Ascariasis lumbricoides* ova.
[6] Mercado-Burgos et al.(1975) show moderate effectiveness for *Schistosoma* species. Assume moderate effectiveness for *Dracunculus medinensis.*

- *Toxoplasma* oocysts and C*ryptosporidium parvum* oocysts are highly resistant to chlorine disinfection (CDC, 2007). Chlorine alone should not be expected to inactivate these pathogens.

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Need to follow manufacturer's instructions for specific sodium hypochlorite products
- Required dose and contact time varies with water quality (e.g. turbidity, pH, temperature)
- Very turbid water should be sedimented or filtered prior to chlorination
- Use a 30-minute minimum contact time
- For high pH water (>9), the contact time should be increased (Lantagne, 2009)
- The contact time should be increased to 1 hour when the temperature is between 10˚ and 18˚C. It should be increased to two or more hours when the temperature falls below 10˚C.

Robustness

- Free residual chlorine protects against recontamination
- Most users cannot determine the dosing quantity themselves; proper use requires following instructions from the manufacturer
- Users may use less than the recommended dose to save money
- Requires supply chain, market availability and regular purchase
- Requires quality control process to ensure product reliability
- Sourcing suitable plastic containers to manufacture chlorine solutions can sometimes be a challenge

Estimated Lifespan

- Chlorine deteriorates over time, especially in liquid form
- Liquid chlorine expiry is 6 weeks without pH stabilization and 1 year if the pH of the solution is above 11.9 (Lantagne et al., 2010)

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite) Key Data

Manufacturing Requirements

Worldwide Producers:
- There are many producers of chlorine solutions all around the world.

Local Production:
- Can be made locally using salt water solution and electrolysis equipment

Materials (in manufacturing chlorine products):
- Generator with electrolysis equipment
- Plastic bottles and labelling equipment
- Salt
- Water

Fabrication Facilities:
- Workshop space required for chlorine production and bottling
- Good ventilation required in the workshop space

Labour:
- Trained workers needed to produce and test the sodium hypochlorite

Hazards (in manufacturing chlorine products):
- Chlorine fumes and contact with skin are hazardous
- Skin and eye protection should be used when handling chlorine solutions
- Work should be conducted in a well ventilated area or in the open air

Maintenance

- Chlorine should be stored in a cool, dark place in a closed container
- Should be stored away from children

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$0.45/1,000 litres[1] US$3.29/year[2]	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Clasen (2007) based on WaterGuard™
[2] Assumed 20 litres/household/day

Other

- Some users complain about the taste and odour that chlorine may cause in water
- Chlorine reacts with organic matter naturally present in water to form by-products such as trihalomethanes (THMs), which are potentially cancer-causing
- Lantagne et al. (2008) indicate that THM levels produced during household chlorination may fall below World Health Organization (WHO) guideline values

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite) Key Data

References

American Water Works Association (2006). Waterborne Pathogens. American Water Works Association, USA.

Centers for Disease Control and Prevention (2007). Effect of Chlorination on Inactivating Selected Pathogens. Available at:www.cdc.gov/safewater/about_pages/chlorinationtable.htm

Clasen, T. (2007). Presentation. London School of Hygiene and Tropical Medicine.

Lantagne, D.S., Blount, B. C., Cardinali, F., and R. Quick (2008). Disinfection by-product formation and mitigation strategies in point-of-use chlorination of turbid and non-turbid waters in western Kenya. Journal of Water and Health, 06.1, 2008.

Lantagne, D. (2009). Summary of Information on Chlorination and pH. Prepared for UNICEF.

Lantagne, D., Preston, K., Blanton, E., Kotlarz, N., Gezagehn, H., van Dusen, E., Berens, J. and K. Jellison (2010). Hypochlorite Solution Expiry and Stability in Household Water Treatment in Developing Countries. Submitted to Journal of Environmental Engineering.

Luby, S., Agboatwalla, M., Razz, A. and J. Sobel (2001). A Low-Cost Intervention for Cleaner Drinking Water in Karachi, Pakistan. International Journal of Infectious Diseases; 5(3): 144-150.

Mercado-Burgos, N., Hoehn, R.C. and R.B. Holliman (1975). Effect of Halogens and Ozone on Schistosoma Ova. Journal Water Pollution Control Federation, Vol. 47, No. 10 (Oct., 1975), pp. 2411-2419.

Further Information

Centers for Disease Control and Prevention:
www.cdc.gov/safewater/publications_pages/pubs_chlorine.htm

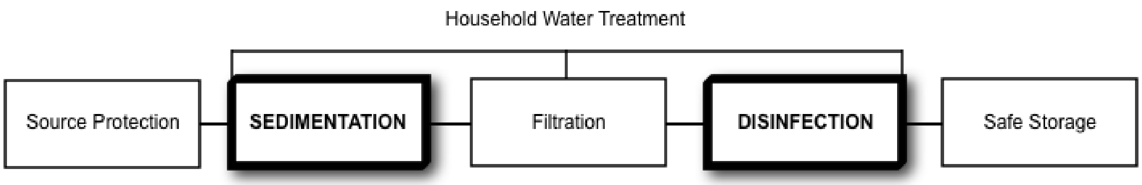
Environment and Public Health Organization (ENPHO):
www.enpho.org/product_treatment_piyush.htm

Population Services International (PSI): www.psi.org/child-survival/

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: P&G Purifier of Water (formerly known as PUR)

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa (including Cryptosporidium and Giardia) • Helminths • Arsenic • Turbidity and some organic matter	• Some heavy metals (e.g. chromium, lead) • Some chemicals and pesticides • Taste, odour, colour	• Salt • Fluoride • Nitrate

What is P&G Purifier of Water?

The P&G Purifier of Water (formerly known as PUR) is a combined flocculent-disinfectant. The Purifier of Water packet was developed by Procter & Gamble (P&G) in collaboration with the U.S. Centers for Disease Control and Prevention (CDC) to replicate the community water treatment process at the household level.

Purifier of Water is a powder which contains both coagulants and a timed release form of chlorine. Purifier of Water is sold in single packets designed to treat 10 litres of water.

The product uses coagulation and disinfection to remove turbidity and pathogens from water at the same time. When added to water, the coagulant first helps the suspended particles join together and form larger clumps, making it easier for them to settle to the bottom of the container. Then chlorine is released over time to kill the remaining pathogens. The treated water contains residual free chlorine to protect against recontamination.

How Does it Remove Contamination?

Particles that cause turbidity (e.g. silt, clay) are generally negatively charged, making it difficult for them to clump together because of electrostatic repulsion. However, coagulant particles are positively charged, and they are chemically attracted to the negative turbidity particles, neutralizing the latter's negative charge. With mixing the neutralized particles then accumulate (flocculation) to form larger particles (flocs) which settle faster. The flocs can then be settled out or removed by filtration.

P&G Purifier of Water Packet
(Credit: Procter & Gamble, 2012)

Household Water Treatment and Safe Storage Fact Sheet: P&G Purifier of Water

Some bacteria and viruses can also attach themselves to the suspended particles in water that cause turbidity. Therefore, reducing turbidity levels through coagulation may also improve the microbiological quality of water. The flocculent process effectively removes larger organisms such as parasites and has been shown to be very effective even for smaller parasites such as Cryptosporidium and Giardia.

As well, chlorine forms hydrochloric acid when added to water which reacts through oxidization with microorganisms and kills them.

Operation

The contents of a Purifier of Water packet is added to 10 litres of water and stirred vigorously for five minutes. The water is then left to settle for 5 minutes.

Once the water becomes clear and the flocs have all settled to the bottom, the water is decanted and filtered through a cotton cloth. The water should then be left for 20 additional minutes before it is consumed. The total of 30 minutes from start of the process is sufficient for the chlorine to disinfect pathogens.

Contaminated source water | Formation of flocculant after introduction of Purifier of Water | Formation of flocculent after 5 minutes of stirring | Decanting the water through a clean cotton cloth | Clean water ready for storage and use

How to Use Purifier of Water (Credit: Population Services International)

Household Water Treatment and Safe Storage Fact Sheet: P&G Purifier of Water Key Data

Inlet Water Criteria

- pH between 5.5 and 7.5; disinfection is unreliable above a pH of 9

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Arsenic
Lab	> 100%[1,2]	> 99%[1,2]	> 99%[1,2]	> 99%[1]	> 100%[1]	> 98%[1,2,3]
Field	> 100% [2]	Not available	Not available	Not available	87%[5]	85-99%[2,4]

[1] Allgood (2004)
[2] Souter et al (2003)
[3] Shaw Environmental Inc (2006)
[4] Norton et al (2003)
[5] Norton et al (2003)

- Can remove small organisms such as Cryptosporidium oocysts and Giardia cysts through the flocculent process (Souter et al., 2003)
- Can remove some organics and some pesticides (Allgood, 2004)
- Can remove significant quantities of heavy metals including arsenic (Shaw Environmental Inc., 2006, Souter et al., 2003), lead and chromium (Allgood, 2004)

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	10 L per packet	Unlimited

- Need to follow manufacturer's instructions

Robustness

- Free residual chlorine protects against recontamination
- Dosing is predetermined according to a typical water source; proper use requires following instructions from the manufacturer
- Requires supply chain, market availability and regular purchase of the product

Estimated Lifespan

- Packet needs to be used within 3 years of manufacture

Manufacturing Requirements

Worldwide Producers:
- Procter & Gamble

Local Production:
- Cannot be made locally; must be shipped, distributed and sold locally. No special handling required; can be shipped as non-hazardous material.

Maintenance

- Products should be protected from exposure to temperature extremes or high humidity

Household Water Treatment and Safe Storage Fact Sheet: P&G Purifier of Water Key Data

Direct Cost

Capital Cost(s)	Operating Cost(s)	Replacement Cost
US$0	US$0.05[1]-0.10[2]/10 L US$36.50-$73/year[3]	US$0

Note: Program, transportation and education costs are not included. Costs may vary depending on location.
[1] Allgood, G., personal communication, 2011, [2] Clasen (2007), [3] Assumed 20 litres/household/day

Other

- Approved by the United States Environmental Protection Agency (US EPA) as a microbiological purifier of water indicating that independent studies have demonstrated >99.9999% removal of pathogenic bacteria, >99.99% kill of viruses, and >99.9% removal of parasites including Giardia and Cryptosporidium.
- Some users complain about the taste and odour that chlorine may cause in water. However, the level of chlorine in Purifier of Water is lower than chlorine only products.
- Lantagne et al. (2008) indicate that possibly produced carcinogenic trihalomethane (THM) levels during typical household chlorination processes (including sodium chloride and Purifier of Water) may fall below World Health Organization (WHO) guideline values. THM levels after using Purifier of Water were shown to be lower than after using chlorine only.

References

Allgood, G. (2004). Evidence from the Field for the Effectiveness of Integrated Coagulation-Flocculation-Disinfection. IWA World Water Congress 2004. Marrakech, Morocco. Workshop 33.

Clasen, T. (2007). Presentation. London School of Hygiene and Tropical Medicine.

Lantagne, D.S. et al. (2008). Disinfection by-product formation and mitigation strategies in point-of-use chlorination of turbid and non-turbid waters in western Kenya. Journal of Water and Health, 06.1, 67-82.

Norton, D.M et al. (2003). A Combined Flocculent-Disinfectant Point-of-Use Water Treatment Strategy for Reducing Arsenic Exposure in Rural Bangladesh. 10th Asian Conference on Diarrhoeal Diseases and Nutrition , Dhaka, Bangladesh.

Norton, D. M. et al. (2003). Field Trial of a Flocculent-Disinfectant Point-of-Use Water Treatment for Improving the Quality and Microbial Safety of Surface Pond Water in Bangladesh. 10th Asian Conference on Diarrhoeal Diseases and Nutrition Dhaka, Bangladesh.

Shaw Environmental Inc (2006). Evaluation of Grainger Challenge Arsenic Treatment Systems, PuR System #1. Prepared for the US Environmental Protection Agency and the National Academy of Engineering. Cincinnati, USA.

Souter et al. (2003). Evaluation of a New Water Treatment for Point-of-Use Household Applications to Remove Microorganisms and Arsenic from Drinking Water. Journal of Water and Health, 01.2, 73-84.

Further Information

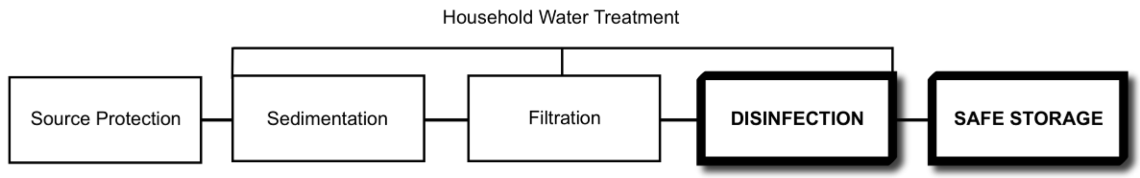
Proctor & Gamble: www.csdw.org/csdw/pur_packet.shtml

http://news.pg.com/press-release/pg-corporate-announcements/pg-underlines-commitment-its-childrens-safe-drinking-water-

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: January 2012

Household Water Treatment and Safe Storage Fact Sheet: Solar Disinfection (SODIS)

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Some Protozoa • Helminths	• *Cryptosporidium parvum*	• Turbidity • Chemicals • Taste, odour, colour

What is SODIS?

The idea of solar water disinfection (SODIS) was presented by Professor Aftim Acra for the first time in a booklet published by UNICEF in 1984.

SODIS has been promoted worldwide since 1991 when an interdisciplinary research team at EAWAG/SANDEC began laboratory and field tests to assess the potential of SODIS and to develop an effective, sustainable and low cost water treatment method.

SODIS uses sunlight to destroy pathogens. It can be used to disinfect small quantities of water with low turbidity. Most commonly, contaminated water is put into transparent plastic bottles and exposed to full sunlight. The pathogens are destroyed after a period during the exposure to the sun. Users determine the length of exposure based on the weather conditions.

How Does It Remove Contamination?

EAWAG/SANDEC (2002) describes how pathogens are vulnerable to two effects of sunlight:

- Ultraviolet-A (UV-A) radiation which damages DNA and kills living cells
- Infrared radiation which heats the water and is known as pasteurization when the temperature is raised to 70-75 degrees Celsius

Many pathogens are not able to resist increased temperatures, nor do they have any protection mechanisms against UV radiation (EAWAG/SANDEC, 2002).

More pathogens are destroyed when they are exposed to both temperature and UV-A light at the same time. A synergy of these two effects occurs at a water temperature of 50 degrees Celsius (Wegelin et al, 1994).

As well, SODIS is more efficient in water with high levels of oxygen. Sunlight produces highly reactive forms of oxygen in the water. These reactive molecules also react with cell structures and kill pathogens (Kehoe et al, 2001).

Operation

Use a transparent, non-coloured plastic bottle made from polyethylene terephthalate (PET). Do not use plastic bottles made from polyvinyl chloride (PVC) since it contains additives that may leach into the water. Some types of glass bottles (i.e. those with a higher content of iron oxide, like window glass) should also not be used since they do not transmit as much UV-A light.

Household Water Treatment and Safe Storage Factsheet: Solar Disinfection (SODIS)

UV radiation is reduced at increasing water depth. Bottles used for SODIS should not exceed 10 cm in water depth, such as 1-2 litre volume PET bottles placed on their sides in the sunlight (EAWAG/SANDEC, 2002).

Heavily scratched and old bottles should be replaced since they reduce the amount of UV light that can pass through (Wegelin et al. 2000).

The source water should first be sedimented and/or filtered if turbidity levels are greater than 30 NTU, (Sommer et al, 1997).

Fill the plastic bottle ¾ full of low turbidity water. Shake the bottle for about 20 seconds and then fill the bottle completely. Place the bottles horizontally on a roof or rack in the sun for the following times:

- 6 hours if the sky is cloudless or up to 50% cloudy
- 2 consecutive days if the sky is more than 50% cloudy
- Do not use SODIS during days of continuous rainfall.

The efficiency of SODIS is dependent on the amount of sunlight available. The bottles must NOT be placed so that they are in shade for part of the day. The most favourable geographical regions for SODIS are located between latitudes 15°N and 35°N (as well as 15°S and 35°S). The majority of developing countries are located between latitudes 35°N and 35°S (EAWAG/SANDEC, 2002).

The treatment efficiency can be improved if the plastic bottles are placed on sunlight reflecting surfaces, such as corrugated aluminum or zinc roofs. This can increase the water temperature by about 5°C. This has been found to be especially beneficial in low sunlight conditions when the disinfection process is the slowest (Mani et al., 2006).

The treated water should preferably be used directly from the bottle to minimize the possibility of recontamination. Non-pathogenic organisms, such as algae, may grow in the conditions created in a SODIS bottle (EAWAG/SANDEC, 2002).

(Credit: EAWAG/SANDEC)

Household Water Treatment and Safe Storage Fact Sheet: Solar Disinfection (SODIS) Key Data

Inlet Water Criteria

- Turbidity < 30 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	99.9-99.99%[0]	90-99.9%[0]	90-99.99%[3]	> 100%[3]	0%	0%
Field	91.3-99.4%[0]	Not available	Not available	Not available	0%	0%

[1] Wegelin et al (1994)
[2] Saladin (2002)
[3] Dependent on reaching a water temperature of 50°C

- SODIS can reduce the potential viability of *Cryptosporidium parvum* oocysts, although longer exposure periods appear to be required than those established for bacteria (Méndez-Hermida et al., 2007; Gómez-Couso et al., 2009). SODIS alone should not be expected to inactivate all *Cryptosporidium parvum* oocysts.

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
1-2 litres/bottle per 6-48 hours	1-2 litres/bottle	Dependent on the number of bottles and weather

- Use a transparent, non-coloured plastic bottle made from polyethylene terephthalate (PET)
- Do not use plastic bottles made from polyvinyl chloride (PVC) since it contains additives that may leach into the water
- Some types of glass bottles (i.e. those with a higher content of iron oxide, like window glass) should not be used since they do not transmit as much UV-A light
- Bottles should be filled to ¾ of their capacity, capped and shaken for 20 seconds, and then filled to the top
- Requires 6 hours in full sun or up to 50% cloudy sky; or 2 consecutive days for more than 50% cloudy sky
- Placing bottles on surfaces that reflect sunlight increases the treatment efficiency
- Treated water should be kept in the same bottle until it is consumed

Robustness

- Bottle can be used as a safe storage container
- Requires suitable climate and weather conditions; most favourable location: between latitudes 15° and 35° north/south; next most favourable location: between latitudes 15° north/south and the equator
- PET bottles are abundant in urban areas, but may be less so in rural areas
- Not useful for treating large volumes of water, several bottles needed for a large family
- Bottles will soften and deform if the temperature reaches 65°C
- Users are unable to determine by their senses when sufficient disinfection has taken place, and so need to keep track of them to know which bottles have been treated and ensure that they always have treated water

Estimated Lifespan

- Bottles become scratched or aged by sunlight and must be replaced periodically

Household Water Treatment and Safe Storage Fact Sheet: Solar Disinfection (SODIS) Key Data

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- 1 or 2 L clear plastic bottles (2 sets of 2 bottles per person, one set of bottles must be filled and placed on the roof each day, while the water in the other set is consumed)
- Accessible surface that receives full sunlight (e.g. roof, rack)

Maintenance

- Bottles and caps should be cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0-5[1]	US$0	US$0-5[2]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] PET bottles may be free or cost less than US$0.50/bottle. Assumed 10 bottles required per household.
[2] Bottles become scratched or aged by sunlight and must be replaced periodically

Other

- Studies have shown that PET plastic does not leach chemical additives into water

References

EAWAG/SANDEC (2002). Solar Water Disinfection: A Guide for the Application of SODIS. SANDEC Report No 06/02.

Gómez-Couso, H., Fontán-Saínz, M., Sichel, C., Fernández-Ibáñez, P. and E. Ares-Mazás (2009). Efficacy of the solar water disinfection method in turbid waters experimentally contaminated with *Cryptosporidium parvum* oocysts under real field conditions. Tropical Medicine & International Health, Volume 14, Number 6, June 2009, pp. 620-627(8)

Mani, S., Kanjur, R., Singh, I. and R. Reed (2006). Comparative effectiveness of solar disinfection using small-scale batch reactors with reflective, absorptive and transmissive rear surfaces. Water Research, Volume 40, Issue 4, February 2006, pp 721-727.

Méndez-Hermida, F., Ares-Mazás, E., McGuigan, K., Boyle, M., Sichel, C. and P. Fernández-Ibáñez (2007). Disinfection of drinking water contaminated with *Cryptosporidium parvum* oocysts under natural sunlight and using the photocatalyst TiO_2. Journal of Photochemistry and Photobiology B: Biology. Volume 88, Issues 2-3, 25 September 2007, pp 105-111.

Saladin, M. (2002). SODIS in Nepal – Technical Aspects. EAWAG/SANDEC and ENPHO.

Sommer, B., Marino, A., Solarte, Y., Salas, M.L., Dierolf, C., Valiente, C., Mora, D. Rechsteiner, R., Setter, P., Wirojanagud, W., Ajarmeh, H., Al-Hassan, A. And M. Wegelin. (1997). SODIS – An Emerging Water Treatment Process. *J. Wat. Sci. Res. Technol*. AQUA 46, pp 127-137.

Wegelin, M., Canonica, S., Mechsner, K., Fleischmann, T., Pesaro, F. and A. Metzler (1994). Solar Water Disinfection: Scope of the Process and Analysis of Radiation Experiments, J Water SRT, Aqua Vol. 43, No. 4, pp 154-169.

Wegelin, M., Canonica, S., Alder, A., Marazuela, D, Suter, M., Bucheli, T., Haefliger, O., Zenobi, R., McGuigan, K., Kelly, M., Ibrahim, P. and M. Larroque. (2000) Does sunlight change the material and content of polyethylene terephthalate (PET) bottles? IWA Publishing, Journal of Water Supply: Research and Technology, Aqua No. 1.

Further Information

Centers for Disease Control and Prevention:
www.cdc.gov/safewater/publications_pages/options-sodis.pdf

EAWAG (The Swiss Federal Institute of Aquatic Science and Technology) and SANDEC (EAWAG's Department of Water and Sanitation in Developing Countries): www.sodis.ch

Household Water Treatment and Safe Storage Factsheet: Solar Distillation

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa • Helminths • Turbidity • Chemicals • Salt and hardness • Taste, odour, colour		

What Is Solar Distillation?

Solar distillation is an ancient method of using the sun's energy to treat drinking water. Distillation is the process of evaporating water into vapour, and then capturing and cooling the vapour so it condenses back into a liquid. Any contaminants in the water are left behind when the water is evaporated.

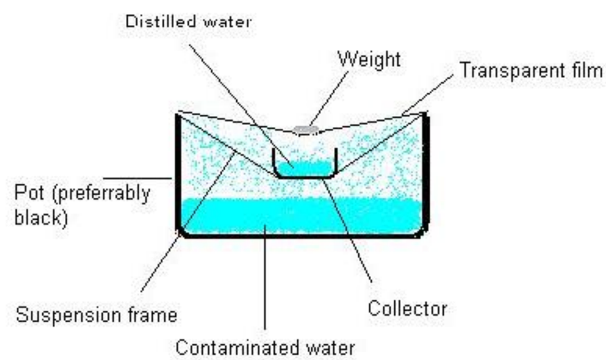
There are many different designs for solar distillation units (also known as stills). The simplest are a piece of plastic stretched over a container with the source water in the bottom. The plastic is weighted down in the middle so that the condensate can drip into a smaller collection container inside the bucket.

A simple design requiring some basic construction, but yielding more water, is that of a flat bed, basin or box solar still. It consists of a shallow reservoir containing water covered with an angled piece of clear glass or transparent plastic sheet. The sunlight heats the water through the glass or plastic, and the water vapour collects and condenses on it, drips down, and flows into the collection channel.

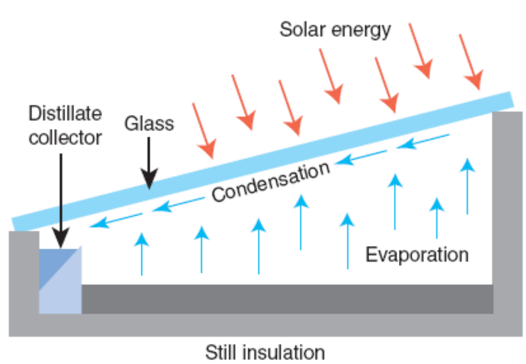
Another simple still uses a removable plastic cone rimmed on the inside edge with a collection channel. The condensed water flows down the sides of the cone into the channel. Water is removed by opening a cap at the apex of the cone, and turning the still upside down into a container.

How Does it Remove Contamination?

As the radiation from the sun heats the water, it evaporates leaving behind any contaminants, including pathogens, chemicals and minerals. The contaminants collect in the bottom of the still and are periodically flushed or cleaned out.



Container Still (Credit: www.ehow.com)



Box Still (Credit: Smith, 2005)

Household Water Treatment and Safe Storage Factsheet: Solar Distillation

Operation

Flat Bed/Box Still:

The still is filled daily with two to three times as much water as will be produced. This is so that the excess, using the built-in overflow outlets, will flush the unit clean each day (to remove accumulated salts and other contaminants). Treated water is collected in a safe storage container placed under the outlet.

If systems are not designed to be self cleaning and flush out accumulated contaminants, the reservoirs should be regularly cleaned using soap and clean water.

Flat Bed Still
(Credit: www.planetkerala.org)

Cone Still:

1.
Pour salty / brackish Water into pan. Then float the Watercone® on top. The black pan absorbs the sunlight and heats up the water to support evaporation..

2.
The evaporated Water condensates in the form of droplets on the inner wall of the cone. These droplets trickle down the inner wall into a circular trough at the inner base of the cone.

3.
By unscrewing the cap at the tip of the cone and turning the cone upside down, one can empty the potable Water gathered in the trough directly into a drinking device.

How to Use the WaterCone® (Credit: www.watercone.com)

Household Water Treatment and Safe Storage Fact Sheet: Solar Distillation Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	> 99.9%[1]	Not available	> 100%[1]	> 100%[2]	> 100%[2]	> 99.9%[1]
Field	Not available	Not available	Not available	Not available	Not available	Not available

[1] Smith (2005). The pilot project showed the stills to be effective in removing salts and minerals (Na, Ca, As, Fl, Fe, Mn); bacteria (*E coli, cholera, botulinus*); protozoa (*giardia, cryptosporidium*) and heavy metals (Pb, Cd, Hg). Theoretically should remove arsenic, although no data available at this time.

[2] Not tested, but theoretically distillation should remove helminths and turbidity.

Operating Criteria

Flow Rate	Batch Volume[1]	Daily Water Supply
Not applicable	4–8 litres per m^2 (box)[2,3] 1-1.7 L for cone[4]	Variable[5]

[1] Solar still sizes can vary from 0.5 m^2 for household use up to around 600 m^2 for community use
[2] Foster (2005)
[3] Planet Kerala (2006)
[4] Watercone®
[5] Daily water supply depends on number sunshine hours and temperature, as well as still size

Robustness

- No moving or mechanical parts to break
- Requires suitable climate and weather conditions
- Requires airtight seals and smoothly stretched plastic during construction and operation; poor handling can break seals

Estimated Lifespan

- Box still: 10+ years, depending on materials and construction quality
- Watercone®: ~5 years

Manufacturing Requirements

Worldwide Producers:
- There are many worldwide producers (e.g. Solaqua, Solar Water Distillation Products, Watercone®, Waterpyramid®)
- Simple designs are available at no cost on the internet

Local Production:
- Can be built with locally available materials

Materials:
- See design details (on internet)

Fabrication Facilities:
- Workshop space for filter construction

Labour:
- Anyone can be trained to construct solar distillation units

Household Water Treatment and Safe Storage Fact Sheet: Solar Distillation Key Data

Hazards:

- No specific manufacturing hazards.

Maintenance

- Some systems are designed to be self cleaning to flush out accumulated contaminants
- Systems without a flushing function should be regularly cleaned using soap and clean water
- Very turbid water can be sedimented or filtered prior to distillation to reduce cleaning the reservoir

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$10-400/$m^2$ (box still)[1] ~US$32 (cone still)[2]	US$0/year	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] A square meter for a single basin solar still costs about $400 in Mexico (Foster et al., 2005)
[2] Watercone®

Other

- About 0.5 m^2 of solar box still is needed per person to meet potable water needs consistently throughout the year (Foster et al., 2005)

References

Foster, R., Amos, W. and S. Eby (2005). Ten Years of Solar Distillation Application Along the U.S.-Mexico Border. Solar World Congress, International Solar Energy Society, Orlando, Florida, August 11, 2005. Available at: http://solar.nmsu.edu/publications/1437ISESpaper05.pdf

Planet Kerala (2006). Solar Distillation: A Natural Solution for Drinking Water, Now Practical. Available at: www.planetkerala.org/downloads/SolarDistillation.pdf

Smith, K. (2005). Still Distilled! Water Conditioning & Purification Magazine. Available at: www.wcponline.com/pdf/0705%20distilled.pdf

Further Information

Planet Kerala, Participatory Learning and Action Network, India: www.planetkerala.org/downloads/SolarDistillation.pdf

Solaqua, Solar Water Distillation Products, USA: www.solaqua.com/solstilbas.html

AquaCone™: www.solarsolutions.info/main.html

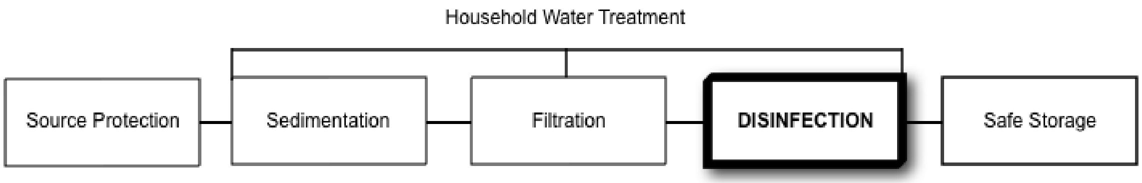
Watercone®, Germany: www.watercone.com

Waterpyramid®, The Netherlands: www.waterpyramid.nl

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Solar Pasteurization

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa • Helminths		• Turbidity • Chemicals • Taste/odour/colour

What is Solar Pasteurization?

Pasteurization is the process of disinfecting water by heat or radiation, short of boiling. Typical water pasteurization achieves the same effect as boiling, but at a lower temperature (usually 65-75°C), over a longer period of time.

A simple method of pasteurizing water is to put blackened containers of water in a solar cooker. The cooker may be an insulated box made of wood, cardboard, plastic, or woven straw, with reflective panels to concentrate sunlight onto the water container. It may also be an arrangement of reflective panels, or a reflective "satellite dish", on which the water pot sits.

A thermometer or indicator is needed to tell when sufficient temperature is reached for pasteurization. Common devices for monitoring the water temperature use either beeswax, which melts at 62°C, or soya bean fat, which melts at 69°C. A simple device known as the Water Pasteurization Indicator (WAPI) has been developed at the University of California.

How Does It Remove Contamination?

As the water heats due to radiation from the sun, the increased temperature will kill or inactivate pathogens at 65°C.

Operation

Water is put into a black container, which is placed in a solar cooker that reflects sunlight onto the container. The box cooker should be frequently repositioned to ensure it is catching all available sunlight (and never in shade) until the indicator device shows the water has reached the required temperature. Water may take 1 to 4 hours or more to heat to temperature.

Box Cooker and Water Pasteurization Indicator (WAPI) (Credit: Solar Cooker International)

Household Water Treatment and Safe Storage Fact Sheet: Solar Pasteurization Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	> 100% [1,2]	> 100%[3]	> 100%[4]	> 100%[4]	0%	0%
Field	Not available	Not available	Not available	Not available	0%	0%

[1] 100% *E. coli* in 1.5 hours at 60°C (Ciochetti & Metcalf 1984, Safapour & Metcalf 1998)
[2] 100% *E. coli, Salmonella, S. dysenteriae,* and *V. cholerae* at 70°C (Iijima et al., 2001)
[3] 100% in 1.5 hours at 70°C (Safapour & Metcalf 1998)
[4] Not tested, but other research suggests that many helminths and protozoa will be killed at a temperature of 70°C if maintained for 45 seconds

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Depends on container size	Depends on container size

Robustness

- Does not work during continuous rainfall or in very cloudy days
- Users require a thermometer or pasteurization indicator device
- Users need to keep track of containers to know which ones have been treated and ensure that they always have treated water
- Users may need to wait for water to cool prior to use
- Cookers are made from lightweight and easily breakable materials
- Recontamination is possible after the water has cooled; safe storage is essential
- The system requires no additional inputs after installation

Estimated Lifespan

- 5+ years

Manufacturing Requirements

Worldwide Producers:

- There are many worldwide producers
- Simple designs are available at no cost on the internet

Local Production:

- This device may be built with parts available throughout most countries.

Materials:

- Cardboard
- Straw
- Aluminium foil
- Glass or plastic sheet
- Silver/metallic reflective spray paint
- Dark paint or mud
- Glass or plastic water containers to be painted; or dark/black metal pots
- Water Pasteurization Indicators (WAPI) or thermometers

Household Water Treatment and Safe Storage Fact Sheet: Solar Pasteurization Key Data

Fabrication Facilities:

- Workshop space to manufacture solar cookers

Labour:

- Anyone can be trained to construct a solar cooker

Hazards:

- No specific manufacturing hazards

Maintenance

- Cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$20-25	US$0/year	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location

Other

- Solar pasteurization boxes can also be used as solar cookers for cooking meals
- Boiling is sometime preferred because it provides a visual measure of when the water has reached sufficient temperature without requiring a thermometer

References

Andreatta, D. (1994). A Summary of Water Pasteurization Techniques. S.E.A. Inc http://solarcooking.org/pasteurization/solarwat.htm

Ciochetti, D. A., and R. H. Metcalf (1984). Pasteurization of Naturally Contaminated Water with Solar Energy. California State University, USA.

Iijima Y., Karama M., Oundo, J. O., and T. Honda (2001). Prevention of Bacterial Diarrhea by Pasteurization of Drinking Water in Kenya. Microbiological Immunology, 45(6), 413-416.

Safapour, N. and R. H. Metcalf (1999). Enhancement of Solar Water Pasteurization with Reflectors. Applied and Environmental Microbiology, Feb. 1999, p. 859–861.

Further Information

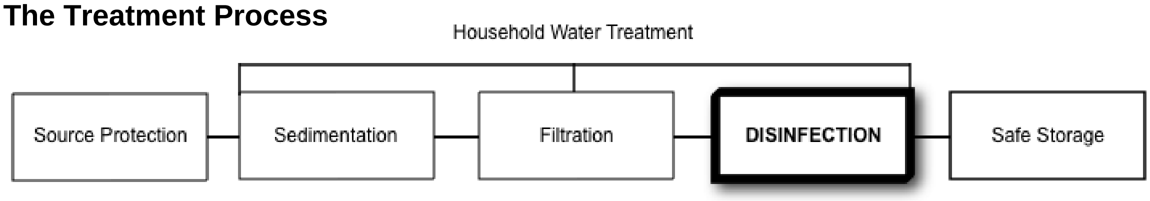
Solar Cookers International: http://solarcookers.org

Safe Water Systems: www.safewatersystems.com

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Ultraviolet (UV) Disinfection

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa • Helminths		• Turbidity • Chemicals • Taste, odour, colour

What is UV Disinfection?

Ultraviolet (UV) disinfection has been used for more that 100 years in commercial and community water treatment systems. With the recent development of the UV tube using local components, UV is now a viable household water treatment method.

The household design uses a UV bulb suspended inside a larger tube or covered trough. The water enters the tube at one end, flows through the tube under the UV bulb, and through the outlet at the other end of the tube. The height of the outlet point determines the depth of water in the tube. This height also helps regulate the hydraulic retention time within the tube which is part of determining the UV dose for the water.

It is common for a UV treatment system to incorporate a pre-filter to remove turbidity since it can interfere with UV light penetration through the water.

The UV tube does not require water pressure to operate. As such, it may be adapted to fit a variety of water supply schemes, including piped water, rainwater catchment systems, wells, or springs.

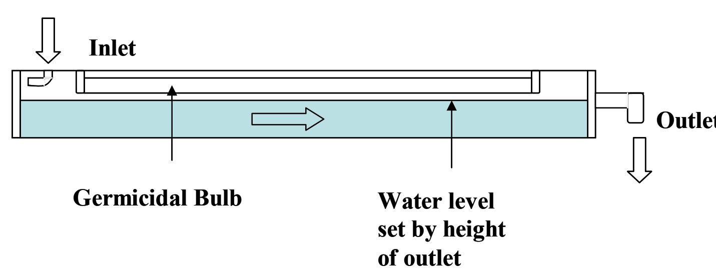
How Does It Remove Contamination?

The UV bulb emits UV-C light, which inactivates microorganisms by damaging their genetic material (DNA), rendering them unable to replicate. UV is effective in inactivating most pathogens, including bacteria, viruses, and cyst forming protozoa, such as cryptosporidium.

Operation

Once the user has installed the equipment they only need to plug it in and make sure the water flows though the system at the prescribed rate. Water should be collected in a safe storage container and protected from recontamination.

Users may need to regularly clean the bulb if it becomes dirty. The UV bulbs should be replaced every 12 months.



UV Tube Design Concept
(Credit: Fundacion Cantaro Azul)

Household Water Treatment and Safe Storage Factsheet: Ultraviolet (UV) Disinfection Key Data

Inlet Water Criteria

- Turbidity < 5 NTU (Nephelometric Turbidity Units)
- Iron < 1 ppm (parts per million)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	> 99.99%[0]	> 99.99%[0]	> 99.99%[0]	> 99.9%[0]	0%	0%
Field	97% to 100%[0,3]	Not available	Not available	Not available	0%	0%

[1] Cohn (2002)
[2] Lang et al. (2006)
[3] Gadgil et al. (1998)

- Effectiveness depends on UV dose; these numbers are for NSF Standard 40 mW-s/cm^2
- Required UV dose varies with water quality (e.g. turbidity, organic matter, pH)

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
5 litres/minute[1]	Not applicable	2,000 litres[1]

[1] Depends on the UV tube/apparatus design

- Flow and volume depend on system design
- Very turbid water should be sedimented or filtered prior to UV treatment

Robustness

- Requires regular source of electricity, either through a grid or solar panels
- Requires supply chain, market availability and regular purchase of UV bulbs
- The design flow rate must be maintained by the user to ensure adequate UV dosing
- If electricity is intermittent, water can be treated when electricity is available and stored

Estimated Lifespan

- 10+ years
- UV bulbs should be replaced every 12 months (dirty or scratched bulbs reduce performance)

Manufacturing Requirements

Worldwide Producers:

- Some companies make UV tubes for household water treatment (e.g. UV Waterworks, USA)
- UV bulbs are available in various sizes from most major lamp manufacturers (e.g. General Electric, Sylvania, Phillips)

Local Production:

- Household UV treatment units can be manufactured from local materials provided adequate knowledge and UV bulbs are available
- Design will vary depending on local materials available

Materials:

- Feed container
- PVC tubing, or metal, pottery or cement channel
- Stainless steel sheet metal

- Various tubing connectors, valves and taps
- Electrical wires and connectors
- Miscellaneous tools for construction and installation

Fabrication Facilities:
- Workshop space for construction of UV units

Labour:
- Skilled workers with basic construction and electrical expertise can be taught to manufacture UV units

Hazards:
- Water and electricity in combination are potentially dangerous
- Necessary safety precautions should be taken both during manufacture and in the home
- Precautions should be taken to prevent the UV bulb and electrical components from getting wet if it is not enclosed with a protective quartz sleeve

Maintenance

- Clean the bulb if it gets dirty (frequency depends on source water quality)
- Replace the bulb every 12 months

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$60-150	Depends on cost of electricity	US$10-25/year[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] UV bulbs need to be replaced every 12 months, bulb price varies

References

Cohn, A. (2002). The UV Tube as an Appropriate Water Disinfection Technology: An Assessment of Technical Performance and Potential for Dissemination. Masters Project for Energy and Resource Group, University of California, Berkeley.

Lang, M., Kaser, F., Reygadas, F., Nelson, K., and D. Kammen (2006). Meeting the Need for Safe Drinking Water in Rural Mexico through Point-of-Use Treatment. Center for Latin American Studies. University of California, Berkeley.

Gadgil, A., Greene, D., Drescher, A., Miller, P. and N. Kibata (1998). Low Cost UV Disinfection System For Developing Countries: Field Tests In South Africa. Water Health International, Napa, CA, USA.

Further Information

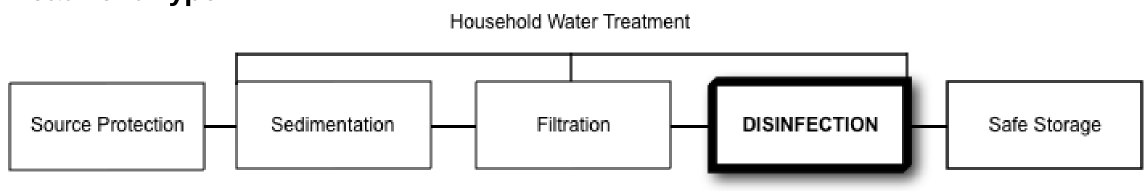
University of California Berkeley: http://uvtube.berkeley.edu/home

WaterHealth International: http://waterhealth.com

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: Guardian Solid Form Biocide (SFB) Rope

Treatment Type



Product Name: Guardian Solid Form Biocide (SFB) Rope

Manufacturer: H2O, Inc.

Product Description: The Guardian SFB Rope uses silver to kill pathogens on contact. SFB strands are covered with water permeable synthetic fabric with a string attached to one end and used to pull the rope from the container. Users put the Guardian SFB Rope into a 20 litre collection container at the water source point, allowing it to be treated on the way to the household. This technology was especially designed for transporting source water. Virus and bacteria removal is accelerated by the motion caused by carrying the water. The Guardian SFB Rope also prevents water from recontamination.

Availability: Can be purchased from the manufacturer upon request.

Robustness: There are no moving or mechanical parts to break. Inlet water needs to have low turbidity, total dissolved solids and hardness. The Guardian SFB Rope has been laboratory tested by the manufacturer and tested in the field.

Warnings: If turbidity is higher than 30 NTU, filter the water and shake it vigorously for 1 minute before using the Guardian Rope. If water hardness is over 500 ppm, allow 50% more time for treatment.

The treatment effectiveness will be significantly reduced if the Guardian SFB Rope comes into contact with chlorine products (such as bleach).

The Guardian SFB Rope may corrode if placed in a metal container with saline water. The Guardian SFB Rope should be cleaned if this occurs.

Lifespan: Up to 2 years, or after processing 12,500 litres of water

Approximate Dimensions: 1.5 metres (5 feet) in length

Approximate Weight: 70 grams when dry

Output: 20 litres/day

Cost: US$12-15 plus shipping (minimum order of 100)

Household Water Treatment and Safe Storage Product Sheet: Guardian Solid Form Biocide (SFB) Rope

Storage:

Cleaning is recommended if the Guardian SFB Rope is stored for more than a year without use.

Maintenance:

Clean every 4 months if the water source has low turbidity, total dissolved solids (TDS) and hardness. However, when hardness is higher than 400 ppm and TDS is higher than 600 ppm, it is recommended to clean every 3 months. If turbidity is higher than 30 NTU, the Guardian SFB Rope needs to be cleaned every 2 months.

To clean, soak the Guardian SFB Rope in cleaning solution for 1 hour. To make the cleaning solution, use the juice of 1 lemon or 3 grams vitamin C powder or 4 tablespoons vinegar per 1 litre of water. Then rinse the Guardian SFB Rope with non-turbid water, and return to use.

Treatment Efficiency*

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	99.9999%[1]	99.9999%[3]	0%	0%	0%	0%
Field	99.9999%[2]	N/A	0%	0%	0%	0%

* Efficiency depends on contact time and water conditions. These results are after 90 minutes and the initial water conditions were: pH= 6.3, Turbidity= 0.4 NTU, hardness= 284mg/L TDS= 360 mg/L and fluoride= 0.35 mg/L. Data provided by H2O, Inc.

1 *E.coli* removal. Tested by EMS Lab in India, reported by H2O, Inc.

2 Tested in the field by Oxfam, reported by H20 Inc. These results are after 120-360 minutes contact time for three different water sources and stirring every 30 minutes.

3 Colipaghe-MS2 removal. Tested by EMS Lab in India, reported by H2O, Inc.

N/A: Not available

Further Information

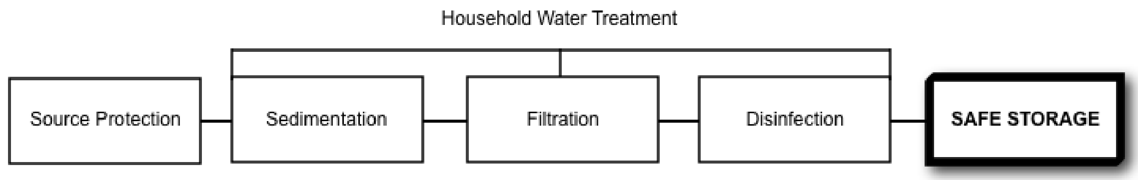
H2O Water Solutions Inc.
760 Hobart Street
Menlo Park, CA 94025 USA
Tel: 1.650.325.5321
Website: www.htwentyinc.com

(Credit: www.htwentyinc.com)

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Safe Storage and Handling

Treatment Type



Potential Protection Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Preventing recontamination of safe water	• Keeping water cool • Preventing algae growth	• Removing existing contaminants

What is Safe Storage and Handling?

Households do a lot of work to collect, transport and treat their drinking water. Safe water must be handled and stored properly to protect it from becoming recontaminated. Promoting safe storage and handling of water in the home is a critical component for safe drinking water. Recontamination of safe drinking water is a common issue around the world and has been documented in several cases.

What Causes Recontamination?

Water can become recontaminated through several different mechanisms, such as:

- Using the same container for water collection and storage
- Dipping a dirty cup or hand into the container
- Drinking directly from the container
- Children, animals or insects accessing the container
- Poor cleaning and hygiene practices

Recontamination is more likely to occur in uncovered containers that have wide openings (e.g. buckets, pots). Using chlorine can provide residual protection against recontamination, however, proper storage and handling are still essential for keeping water safe to drink.

Safe Storage and Handling Practices

Safe storage means keeping treated water away from sources of contamination. There are many designs for water containers around the world. A safe water storage container should be:

- With a strong and tightly-sealing lid or cover
- With a tap or narrow opening at the outlet
- With a stable base so it does not tip over
- Durable and strong
- Not transparent or see-through
- Easy to clean

Safe storage containers should also have pictorial and/or written instructions describing how to properly use and clean the container. Ideally the instructions are permanently affixed to the container, or they can be provided as a separate document to the household.

Sometimes it is difficult for rural and poor households to find or buy good storage containers. **The most important things are to make sure that they are covered and only used to store treated water.**

Safe water handling practices include:

- Using a separate container to collect source water

Household Water Treatment and Safe Storage Fact Sheet: Safe Storage and Handling

- Using a proper safe storage container for treated water, and never use this container for untreated water
- Cleaning the safe storage container frequently with safe water and soap or chlorine
- Storing treated water off the ground in a shady place in the home
- Storing treated water away from small children, animals and insects
- Pouring water from the safe storage container of using the tap when needed instead of dipping or scooping water from it
- Using the treated water as soon as possible, preferably on the same day

Examples of Safe Storage Containers

A number of internationally manufactured containers, locally produced containers, and locally adapted traditional containers can be used to store water safely.

Safe storage containers should always be evaluated in-country for their cost, availability, robustness and user acceptability.

Oxfam Bucket Used Mainly in Emergencies *(*Credit: Oxfam*)*

CDC Safe Water System *(*Credit: Centers for Disease Control*)*

Ceramic Filter Container *(*Credit: Potters for Peace*)*

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: June 2011

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Kanchan™ Arsenic Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Bacteria • Protozoa • Helminths • Turbidity • Taste/odour/colour	• Viruses • Iron	• Chemicals

What is a Kanchan™ Arsenic Filter?

The Kanchan™ Arsenic Filter (KAF) is an adaptation of the biosand filter. The KAF has been designed to remove arsenic from drinking water, in addition to providing microbiological water treatment. Arsenic removal is achieved by incorporating a layer of rusty nails in the diffuser basin of the filter.

The filter container can be constructed out of concrete or plastic. The container is about 0.9 m tall and either 0.3 m square or 0.3 m in diameter.

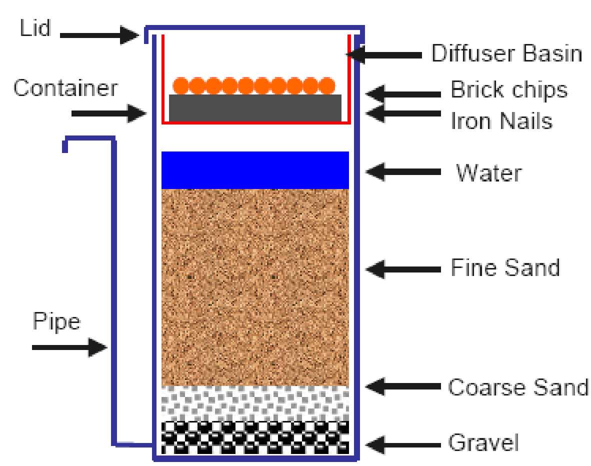
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

Similar to slow sand filters, a biological layer of microorganisms (also known as the biolayer or schmutzedecke) develops at the sand surface, which contributes to the microbiological water treatment.

The diffuser basin is filled with 5 to 6 kg of non-galvanized iron nails (that will rust) for arsenic removal. A layer of bricks on top of the nails prevents displacement of the nails when water is poured into the filter.

How Does it Remove Contamination?

Arsenic from the water is rapidly adsorbed onto the rust on the iron nails. The rust and arsenic flake off the nails, and are caught in the sand filter and retained. This is a very tight bond; re-suspension of arsenic into the water, or re-mobilization of the arsenic from the waste produced from cleaning the filter has shown to be negligible.



Cross-Section of Kanchan™ Arsenic Filter

In addition, pathogens, iron and suspended material are removed from water through a combination of biological and physical processes. These occur both in both the biolayer and within the sand bed. These processes include: mechanical trapping, adsorption/attraction, predation and natural death.

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Operation

Contaminated water is poured into the top of the filter on an intermittent basis. The water slowly passes through the diffuser, and percolates down through the biolayer, sand and gravel. Treated water flows by gravity out of the outlet tube.

The rusted iron nails are essential for removing arsenic. The nails need to be evenly distributed to avoid the water from short-circuiting. A layer of bricks on top of the nails prevents displacement of the nails when water is poured into the filter. As well, users should pour the water slowly and carefully into the filter to prevent the nails from moving around.

The biolayer is the key pathogen removing component of the filter. Without it, the filter is significantly less effective. It may take up to 30 days to establish the biolayer depending on inlet water quality and frequency of use.

The water from the filter can be used during the first few weeks while the biolayer is being established, but disinfection is recommended during this time, as during regular on-going use.

The biolayer requires oxygen to survive. When water is flowing through the filter, dissolved oxygen in the water is supplied to the biolayer. During pause times, when the water is not flowing, the oxygen is obtained by diffusion from the air.

Correct installation and operation of the biosand filter has a water level of approximately 5 cm above the sand during the pause period. A water depth of greater than 5 cm results in lower oxygen diffusion to the biolayer. A water depth less than 5 cm may evaporate quickly in hot climates and cause the biolayer to dry out.

A pause period is needed between uses to allow time for the microorganisms in the biolayer to consume pathogens in the water. Users should wait at least one hour after all the water has been filtered before filling the filter again. It is recommended to use the filter every day; however users can wait up to a maximum of 48 hours between batches.

The KAF has been designed to allow for a filter loading rate (flow rate per square metre of filter area) which has proven to be effective in laboratory and field tests. This filter loading rate has been determined to be not more than 600 litres/hour/square metre.

The recommended flow rate for the CAWST Version 10 concrete KAF is 0.4 L/minute measured when the inlet reservoir is full of water. If the flow rate is much faster, the filter may become less efficient at removing pathogens. If the flow rate is much slower, the user may become impatient and not use the filter even though the filter is working well at removing pathogens. Since the flow rate is controlled by the size of the sand grains, it is very important to select, sieve and wash the sand properly.

The KAF requires maintenance when the flow rate drops to a level that is inadequate for the household use. This is done by a simple ‘swirl and dump’ procedure performed on the top of the sand, and only takes a few minutes.

The outlet should also be cleaned regularly using soap and water or a chlorine solution.

The treated water should be collected by the user in a safe storage container placed on a block or stand, so that the container opening is just under the outlet, minimizing the risk for recontamination.

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Inlet Water Criteria

- Turbidity < 50 NTU

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron	Arsenic
Lab	Up to 96.5%[1,2]	70 to >99%[3]	>99.9%[4]	Up to 100%[5]	95% to <1 NTU[1]		
Field	87.9 to 98.5%[6,7,8]			Up to 100%[5]	80 to 95%[7,9,10,11]	90 to 99%[9,10,11]	85 to 95%[9,10,11]

1 Buzunis (1995)
2 Baumgartner (2006)
3 Stauber et al. (2006)
4 Palmateer et al. (1997)
5 Not esearched. However, helminths are too large to pass between the sand, up to 100% removal efficiency is assumed
6 Earwaker (2006)
7 Duke & Baker (2005)
8 Sharma (2005)
9 Ngai et al. (2004)
10 Ngai et al., (2007)
11 Uy et al., (2008)

- Treatment efficiencies provided in the above table require an established biolayer; it takes up to 30 days to establish the biolayer and 2 weeks to establish rust on the nails depending on inlet water quality and usage
- Filter must be used almost every day to maintain the biological layer (maximum pause period is 48 hours)
- Best performance requires a consistent water source; switching sources may decrease treatment efficiency
- Normal cleaning will reduce filter efficiency until the disturbed biolayer re-establishes itself
- Appearance and odour of treated water is generally improved
- Cannot remove pesticides or fertilizers (organic chemicals)
- Cannot remove salt, hardness, and scale (dissolved compounds)
- Does not provide residual protection to minimize recontamination

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
< 0.4 litres/minute*	12-18 litres	24-36 litres**

Note: Operating criteria is for the concrete biosand filter, plastic biosand filter may have different parameters.

* 0.4 litres/minute is the maximum recommended flow rate for the CAWST Version 10 concrete biosand filter. The actual flow rate will fluctuate over the filter cleaning cycle and between filters.
** Based on 2 batches per day to ensure effective arsenic removal

- Pause period is needed between uses to allow time for the microorganisms in the biolayer to consume pathogens in the water, and to allow time for the nails to rust properly
- The recommended pause period is 6 to 12 hours with a minimum of 1 hour and maximum of 48 hours

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Robustness

- There are no moving or mechanical parts to break
- In concrete models, piping is embedded in concrete, protecting it against breaks and leaks
- Concrete has been shown to last in excess of 30 years
- Concrete filters are heavy (70 – 75 kg for thin wall version and 135 kg for heavy wall version)
- Poor transportation of concrete filters can lead to cracking and/or breakage
- Filters should not be moved after installation
- Cracks can be sometimes be repaired

Estimated Lifespan

- Unlimited; biosand filters are still performing satisfactorily after 10+ years
- Lids and diffusers may need replacement
- Nails need to be replaced every 2-3 years to ensure effective arsenic removal

Manufacturing Requirements

Worldwide Producers:

- Free mold designs are available from CAWST

Local Production (for concrete KAF):

- Local production of concrete filters is common
- Molds for concrete filters can be borrowed, rented, bought or constructed locally
- Concrete filters can be cast at a central production facility, or in the community
- Filter sand and gravel can be prepared (sieved and washed) on-site or nearby

Materials (for concrete KAF):

- Steel mold
- Sand, gravel, and cement
- Filter sand and gravel
- Copper or plastic outlet tubing
- Metal or plastic for the diffuser basin
- 5 to 6 kg of non-galvanized iron nails
- Metal or wood for the lid
- Water is needed during for cement mix and to wash filter sand and gravel
- Miscellaneous tools for construction and installation (e.g. wrench, nuts, bolts)

Fabrication Facilities (for concrete KAF):

- Workshop space required for filter construction

Labour (for concrete KAF):

- Skilled welder required to fabricate molds
- Anyone can be trained to construct and install the filter
- Individual householders can assist in constructing their own filters

Hazards (for concrete KAF):

- Working with cement and heavy molds is potentially hazardous and adequate safety precautions should be used
- Concrete filters are heavy and difficult to move and transport

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Maintenance Requirements

- Required when the flow rate drops to a level that is inadequate for the household use
- Swirl and dump maintenance for the top layer of sand is simple, takes a few minutes and can be done by household users
- Frequency of swirl and dump depends on turbidity of inlet water
- Outlet, lid and diffuser should be cleaned on a regular basis

Direct Cost

Filter Type	Capital Cost	Operating Cost	Replacement Cost
Concrete	US$12-40	US$0/year	US$0
Plastic	US$75[1]	US$0/year	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

[1] Prices do not include shipping container, shipping fees, or clearing/related costs.

Other

- Sand and iron nail selection and preparation are critical to ensure flow rate and treatment
- Filters should not be moved after installation

References

Buzunis, B. (1995). Intermittently Operated Slow Sand Filtration: A New Water Treatment Process', Department of Civil Engineering, University of Calgary, Canada.

Baumgartner, J. (2006). The Effect of User Behavior on the Performance of Two Household Water Filtration Systems. Masters of Science thesis. Department of Population and International Health, Harvard School of Public Health. Boston, Massachusetts, USA.

Duke, W. and D. Baker (2005). The Use and Performance of the Biosand Filter in the Artibonite Valley of Haiti: A Field Study of 107 Households, University of Victoria, Canada.

Earwaker, P. (2006). Evaluation of Household BioSand Filters in Ethiopia. Master of Science thesis in Water Management (Community Water Supply). Institute of Water and Environment, Cranfield University, Silsoe, United Kingdom.

Elliott, M., Stauber, C., Koksal, F., DiGiano, F., and M. Sobsey (2008). Reductions of E. coli, echovirus type 12 and bacteriophages in an intermittently operated 2 household-scale slow sand filter.Water Research, Volume 42, Issues 10-11, May 2008, Pages 2662-2670.

Ngai, T., Murcott, S. and R. Shrestha (2004). Kanchan Arsenic Filter (KAF) – Research and Implementation of an Appropriate Drinking Water Solution for Rural Nepal. *[Note: These tests were done on a plastic biosand filter]*

Ngai, T., Shrestha, R., Dangol, B., Maharjan, M. and S. Murcott (2007). Design for Sustainable Development – Household Drinking Water Filter for Arsenic and Pathogen Treatment in Nepal. Journal of Environmental Science and Health, Part A. Vol A42 No 12 pp 1879-1888

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Palmateer, G., Manz, D., Jurkovic, A., McInnis, R., Unger, S., Kwan, K. K. and B. Dudka (1997). Toxicant and Parasite Challenge of Manz Intermittent Slow Sand Filter. Environmental Toxicology, vol. 14, pp. 217- 225

Sharma, D. (nd) Kanchan Arsenic Filter: Removal of Total Coliform of Gem505 model, 4 weeks daily study. Bachelor of Science Thesis, Environmental Science, Kathmandu University, Nepal.

Stauber, C., Elliot, M., Koksal, F., Ortiz, G., Liang, K., DiGiano, F., and M. Sobsey (2006). Characterization of the Biosand Filter for Microbial Reductions Under Controlled Laboratory and Field Use Conditions. Water Science and Technology, Vol 54 No 3 pp 1-7.

Uy, D., Chea, S., Mao, S., Ngai, T. and T. Mahin (2008). Kanchan Arsenic Filter - Evaluation of Applicability to Cambodia - Phase I Technical Report. Cambodian Ministry of Rural Development and the Institute of Technology of Cambodia.

Further Information

CAWST (Centre for Affordable Water and Sanitation Technology): www.cawst.org

AKVOpedia: www.akvo.org/wiki/index.php/Kanchan_Arsenic_Filter

Massachusetts Institute of Technology (MIT):
http://web.mit.edu/watsan/tech_hwts_chemical_kanchanarsenicfilter.html

Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Sono Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Turbidity • Taste/odour/colour	• Chemicals	

What is a Sono Filter?

The Sono Filter is a three bucket system developed in Bangladesh. It uses a composite iron matrix (CIM) from zero valent iron filings (cast iron turnings) to remove arsenic.

The filter is manufactured from indigenous materials and it works without chemical treatment, without regeneration, and without producing toxic waste. It removes arsenic, 22 other heavy metals, and bacteria.

How Does It Remove Arsenic?

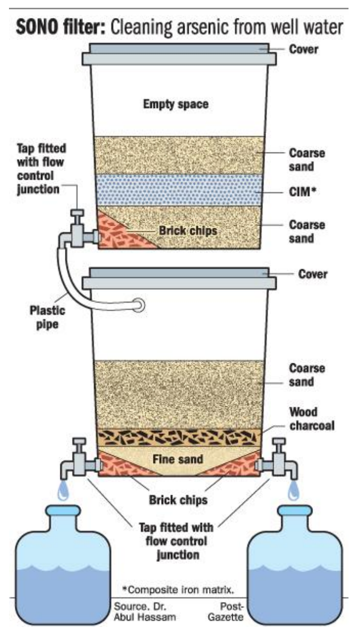
The primary active material is the composite iron matrix (CIM), made of cast iron. Manganese in the CIM catalyzes oxidation of As(III) to As(V). Arsenic (V) is removed by a surface-complexation reaction (strong adsoption) between the hydrated iron (FeOH) molecules in the CIM and Arsenic (V). FeOH is also known to remove many other toxic species.

Each of the three buckets contains different media:

- Top bucket: 3 kg cast iron filings from a local machine shop, 2 kg coarse sand
- Middle bucket: 2 kg sand, 1 kg of wood charcoal and 2 kg of brick chips
- Bottom bucket: water collection container

Operation

The inlet water is poured into the first bucket containing coarse river sand and the composite iron matrix (CIM). Then it flows into a second bucket where it is filtered through another layer of coarse sand, wood charcoal to remove organics, fine sand and brick chips to remove fine particles and stabilize water flow. The unit should be replaced every 3-5 years.



Sono Filter
(Credit: www.robrasa.com)

Key Information

Treatment Efficiency	Output	Cost
90-95% arsenic removal	20-30 litres per hour	$40-50 capital cost

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

References

Munir, A.K., S.B. Rasul, M. Habibuddowla, M. Alauddin, A. Hussam and A.H. Khan. (2001.) Evaluation of performance of Sono 3-Kolshi Filter for arsenic removal from groundwater using zero valent iron through laboratory and field studies. Bangladesh University of Engineering and Technology, Dhaka and The United Nations University, Tokyo. Pages 171-189.

Ngai, T., Shrestha, R., Dangol, B., Maharjan, M. and S. Murcott (2007). Design for Sustainable Development – Household Drinking Water Filter for Arsenic and Pathogen Treatment in Nepal. Journal of Environmental Science and Health, Part A. Vol A42 No 12 pp 1879-1888

Ontario Centre for Environmental Technology Advancement. (no date.) Assessment of five technologies for mitigating arsenic in Bangladesh well water. Environmental Technology Verification-Arsenic Mitigation, Arsenic Mitigation Based on an Agreement between the Governments of Canada and Bangladesh. Available at: www.physics.harvard.edu/~wilson/arsenic/remediation/ETVAM%20Poster.ppt

Sutherland, D., M. Woolgar, Dr. Nuruzzaman, T. Claydon. (2001). Rapid assessment of household level arsenic removal technologies: Phase II Executive Summary. WS Atkins International Ltd., Bangladesh Arsenic Mitigation Water Supply Project and Water Aid Bangladesh. Bangladesh and United Kingdom. Available at: www.wateraid.org/documents/phs2execsum.pdf
Full Phase I Report available at: www.wateraid.org/documents/phs1report.pdf
Full Phase II Report available at: www.wateraid.org/documents/phs2fullrpt.pdf

Further Information

Summary poster of several arsenic mitigation technologies (MIT):
http://web.mit.edu/watsan/Docs/Posters/Ghana%20HWTS%20meeting%20-%20arsenic%20tech%20poster%20May08%20FINAL2.ppt

Narrative on the innovation of the Sono Filter by Abul Hussam (2005):
www.physics.harvard.edu/~wilson/arsenic/remediation/SONO/Narrative_Grainger_AH.pdf

World Bank (2005). Towards a More Effective Operational Response – Arsenic Contamination of Groundwater in South and East Asian Countries. Vol. II. Technical Report. Washington, USA:
http://siteresources.worldbank.org/INTSAREGTOPWATRES/Resources/ArsenicVolII_WholeReport.pdf

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Magc-Alcan Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Turbidity • Taste, odour, colour		

What Is a Magc-Alcan Filter?

The Magc-Alcan is a two bucket arsenic filter. The buckets are in series (water flows from one bucket into the other). Both buckets are filled with an activated alumina media made in the United States. The media was developed by MAGC Technologies and Alcan of the USA; it is produced by thermal dehydration of an aluminium hydroxide at 250-1150˚C.

How Does It Remove Arsenic?

The Magc-Alcan filter removes arsenic by adsorption (adhesion or sticking together) of the arsenic to the media, which is porous and has a large surface area.

The arsenic removal rate can be sensitive to pH level, so additional equipment may be required to control pH levels.

Operation

- Place two buckets in a stand so that one empties into the other. Each bucket should have a tap at the bottom and be filled with activated alumina media
- Place a clean container at the outlet of the second bucket for collecting treated water
- Pour arsenic contaminated water into the top bucket with all of the taps open, and collect arsenic-free water in the container at the bottom

Similar Technology: Nirmal Filter

A similar filter called the "Nirmal Filter" exists in India. Arsenic is adsorbed using an Indian-made activated alumina media. Water is then filtered through a ceramic candle. The filter needs to be regenerated every 6 months.

Magc-Alcan Filter

Nirmal Filter

(Credit: Ngai)

Key Information:

Treatment Efficiency	Output	Cost	Lifespan
MAGC-ALCAN FILTER			
80-85% arsenic removal	100 litres/hour	$35-50 capital cost	6 months to 1 year
NIRMAL FILTER			
80-90% arsenic removal	Not Available	$10-15 capital cost	Not Available

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Shapla Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Turbidity		

What Is a Shapla Filter?

The Shapla filter is an earthen household arsenic removal technology developed by International Development Enterprises (IDE), Bangladesh. It is based on adsorption of the arsenic to the iron on brick chips inside the filter. The brick chips are coated using a ferrous sulphate solution. The filter can hold up to 30 litres of inlet water.

How Does It Remove Arsenic?

As water passes through the filter, arsenic from the water is rapidly adsorbed by the iron on the brick chips. The filter will reduce arsenic concentrations to undetectable levels.

Operation

Pour the water into the filter and allow it to pass through the filter and out the outlet. Collect treated water in a clean container for drinking.

Each filter has 20 kg of media (brick chips), which will treat 4,000 litres of arsenic-contaminated water. The filter can supply 25-32 litres of treated drinking water per day. The brick chips must be replaced every 3 to 6 months.

The used brick chips are non-toxic and can be disposed of safely without danger to the environment or human health as the arsenic is attached strongly to the iron. The earthen filter container is re-useable and easily maintained.

Shapla Filter
(Credit: T. Ngai)

Key Information

Treatment Efficiency	Output	Cost	Lifespan
80-90% arsenic removal	25-32 litres/day	$10 capital cost $10-15 media replacement cost/year	Short media lifespan (3-6 months)

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

References

Ontario Centre for Environmental Technology Advancement (OCETA). (no date.) Assessment of five technologies for mitigating arsenic in Bangladesh well water. Environmental Technology Verification-Arsenic Mitigation, Arsenic Mitigation Based on an Agreement between the Governments of Canada and Bangladesh. Available at:
www.physics.harvard.edu/~wilson/arsenic/remediation/ETVAM%20Poster.ppt

Sutherland, D., M. Woolgar, Dr. Nuruzzaman, T. Claydon. (2001). Rapid assessment of household level arsenic removal technologies: Phase II Executive Summary. WS Atkins International Ltd., Bangladesh Arsenic Mitigation Water Supply Project and Water Aid Bangladesh. Bangladesh and United Kingdom. Available at: www.wateraid.org/documents/phs2execsum.pdf
Full Phase I Report available at: www.wateraid.org/documents/phs1report.pdf
Full Phase II Report available at: www.wateraid.org/documents/phs2fullrpt.pdf

World Bank Water and Sanitation Program (2005). Towards a more effective operational response: Arsenic contamination of groundwater in South and East Asia countries, Volumes I & II. Available at:
http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:22392781~pagePK:146736~piPK:146830~theSitePK:223547,00.html

Further Information

Summary poster of several arsenic mitigation technologies (MIT):
http://web.mit.edu/watsan/Docs/Posters/Ghana%20HWTS%20meeting%20-%20arsenic%20tech%20poster%20May08%20FINAL2.ppt

Magc-Alcan Filter:

Water Safety Plan for MAGC-ALCAN arsenic removal technology (2007):
www.buet.ac.bd/itn/pages/outcomes/ALCAN%20WSP%20Jul%2001_2007%20v1.pdf

An Overview of Arsenic Issues and Mitigation Initiatives in Bangladesh (2003), by NGOs Arsenic Information & Support Unit (NAISU), NGO Forum for Drinking Water Supply & Sanitation and WaterAid:
www.wateraid.org/documents/plugin_documents/arsenicweb.pdf

Shapla Filter:

Website for Shapla and Surokka Aresnic Filters:
https://sites.google.com/site/shaplasurokkaarsenicfilter/

Arsenic Crisis Newsletter and Discussion Group:
http://tech.groups.yahoo.com/group/arsenic-crisis/
(Search for “Shapla” to view messages related to the Shapla filter)

Household Water Treatment for Arsenic Removal Fact Sheet: Oxidation

Passive Oxidation

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
	• Arsenic • Turbidity • Pathogens • Taste, odour, colour	• Chemicals

What Is Passive Oxidation?

Passive oxidation uses iron compounds that naturally reduce the arsenic content of groundwater. When groundwater that naturally contains dissolved $Fe(OH)_2$ is left to stand in containers, the iron undergoes a natural chemical process called oxidation (when an element loses electrons). It changes form into $Fe(OH)_3$ and precipitates out (or becomes solid). Arsenic adsorbs or sticks to the iron precipitate. The combined iron and arsenic particles then settle to the bottom of the container, thereby removing the arsenic from the water. This technology does not require chemicals; it relies only on natural oxidation, adsorption and sedimentation that take place when both iron and arsenic are present in the water. Generally, the higher the level of iron in the groundwater, the better the arsenic removal.

Passive oxidation is seen as an easy technology for users in some areas to adopt because of the natural habits of some rural people to store their water in containers before they drink it. However, its performance at removing arsenic to safe levels has not been proven.

How Does It Remove Arsenic?

Naturally occurring iron precipitates of $Fe(OH)_3$, produced from the oxidation of dissolved iron $Fe(OH)_2$ present in groundwater, is a good adsorbent for arsenic. The method is based on co-precipitation with iron and sedimentation. It does not require the use of chemicals, but requires aeration (oxygen), settling and iron rich water.

The amount of arsenic removal depends on the concentration of iron in water.

Operation

- Stir the water for 2 minutes
- Leave water overnight in an open container

Passive Oxidation in locally available water jars
(Credit: T. Ngai)

Key Information

Treatment Efficiency	Output	Cost
Typically 30 - 50% arsenic removal	No limit	Minimal cost

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Arsenic Removal Fact Sheet: Oxidation

Solar Oxidation

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Pathogens		• Turbidity • Chemicals • Taste, odour, colour

What Is SORAS?

The SORAS (Solar Oxidation and Removal of Arsenic) method is similar to the SODIS method of water treatment, but also requires the addition of lemon juice. Ultraviolet (UV) rays from the sun cause the oxidation (loss of electrons) of As(III), changing it into As(V). The As(V) is strongly attracted to iron hydroxide particles naturally present in the water, and adsorbs (sticks) to these particles. The As(V)/$Fe(OH)_3$ co-precipitate (become solid particles) which settle to the bottom of the container.

How Does It Remove Arsenic?

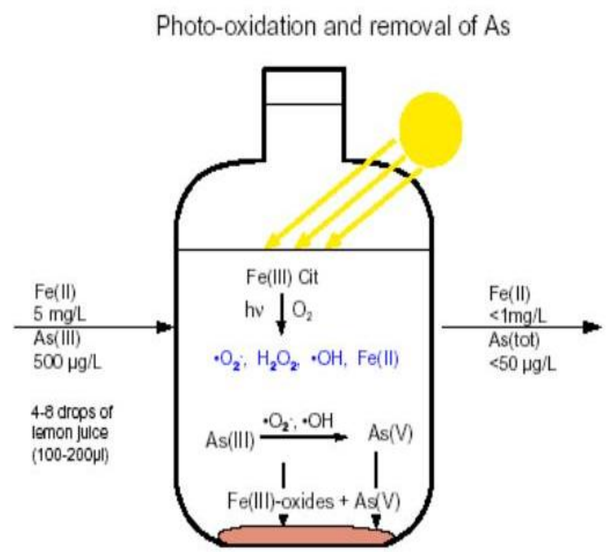
SORAS removes arsenic using a two-step procedure:

- First step: As(III), which only weakly adsorbs to iron hydroxide, is oxidized by the sun to the As(V), which strongly adsorbs to iron hydroxide
- Second step: the iron hydroxide precipitates with the adsorbed arsenic settle to the bottom of the container

Instead of adding chemical oxidants such as chlorine or permanganate, reactive oxidants are produced photo chemically using sunlight.

Operation

- Fill PET (or other UV–A) transparent bottles with water
- Add lemon juice to bottles
- Place the bottled in the sunlight for 1-2 days
- During the night, place the bottles in vertical position so particles can settle
- Decant clear water into a clean container, it may be filtered through a cloth or a ceramic filter



SORAS process
(Credit: T. Ngai)

Key Information

Treatment Efficiency	Output	Cost
If iron > 8 ppm, 75-90% arsenic removal If iron < 5 ppm, <50 % arsenic removal Excellent microbial removal (99+%)	No limit	Minimal

Household Water Treatment for Arsenic Removal Fact Sheet: Oxidation

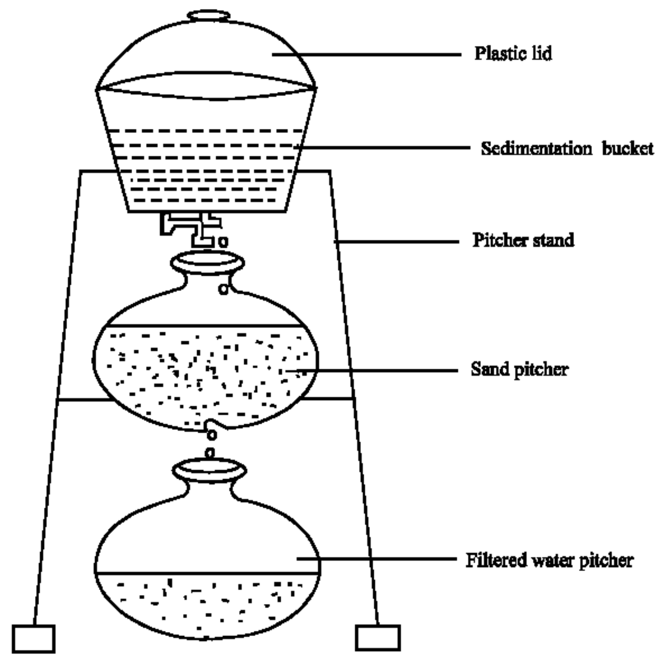
Asia Arsenic Network Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Most pathogens • Turbidity • Taste, odour, colour		• Viruses • Chemicals

What Is Asia Arsenic Network Filter?

The Asia Arsenic Network Filter consists of an upper plastic bucket with a lid and tap, and two clay pitchers (or plastic buckets) that are positioned so water flows from one container to the next. The process consists of manual aeration, oxidation of iron naturally present in the water, and the co-precipitation of the arsenic and the iron. Arsenic removal depends on iron concentrations in water. The process is completed by filtering the water through sand in the second bucket. Treated water is collected from the bottom bucket.



Asia Arsenic Network Filter
(Credit: Asia Arsenic Network, 2001)

How Does It Remove Arsenic?

Water added to the upper bucket is stirred and then allowed to stand. The dissolved iron compound $Fe(OH)_2$ naturally present in the groundwater undergoes a natural chemical process called oxidation (when an element loses electrons). It becomes $Fe(OH)_3$, which precipitates out or becomes solid. Arsenic strongly adsorbs (sticks to) $Fe(OH)_3$. The combined iron and arsenic particles settle to the bottom of the container, thereby removing the arsenic from the water. The water is then filtered through sand, which retains any particles of iron and arsenic.

Operation

- Pour raw water into the top bucket and manually stir for 2 minutes
- Let water settle for 6 hours
- Open the tap in the top bucket and let the water flow through the middle bucket, which contains 2 kg of coarse sand
- Collect treated water from the bottom bucket

Key Information

Treatment Efficiency	Production	Cost
Typically 70-80% arsenic removal	20 litres/6 hours	$15-20 capital cost

Household Water Treatment for Arsenic Removal Fact Sheet: Oxidation

References

Roberts, L.C., S.J. Hug, T. Ruettimann, MD.M. Billah, A.W. Khan, and M.T. Rahman, (2003). Arsenic removal with iron(II) and iron(III) in waters with high silicate and phosphate concentrations (2003). Environmental Science & Technology, Web Published November 18, 2003, VOL 38 NO.1, 2004
Available at: http://pubs.acs.org/doi/abs/10.1021/es0343205

Sutherland, D., M. Woolgar, Dr. Nuruzzaman, T. Claydon. (2001). Rapid assessment of household level arsenic removal technologies: Phase II Executive Summary. WS Atkins International Ltd., Bangladesh Arsenic Mitigation Water Supply Project and Water Aid Bangladesh. Bangladesh and United Kingdom.
Available at: www.wateraid.org/documents/phs2execsum.pdf
Full Phase I Report available at: www.wateraid.org/documents/phs1report.pdf
Full Phase II Report available at: www.wateraid.org/documents/phs2fullrpt.pdf

World Bank Water and Sanitation Program (2005). Towards a more effective operational response: Arsenic contamination of groundwater in South and East Asia countries, Volumes I & II. Available at:
http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/0,,contentMDK:22392781~pagePK:146736~piPK:146830~theSitePK:223547,00.html

Further Information

Solar Oxidation and Removal of Arsenic (SORAS):

SORAS Paper. By: Martin Wegelin, Daniel Gechter, Stephan Hug, Abdullah Mahmud, Abdul Motaleb. No Date. Available at:
http://phys4.harvard.edu/~wilson/arsenic/remediation/sodis/SORAS_Paper.html

Presentation: Arsenic Removal by Solar Oxidation in Groundwater of Los Pereyra Tucumán Province, Argentina. By: J. d´Hiriart, M.V. Hidalgo, National University of Tucumán, M.G. García, National University of Córdoba, and M.I. Litter, M.A. Blesa National Atomic Commission Argentina. No Date. Available at:
www.cnea.gov.ar/xxi/ambiental/iberoarsen/docs/presentationAs2006litter.pdf

Presentation: Innovative and Sustainable Technologies to Address the Global Arsenic Crisis. By: Susan Murcott and Tommy Ngai, Civil and Environmental Engineering Department, Massachusetts Institute of Technology. (2005.) Available at:
www.sandia.gov/water/Arsenic2005/2005tech_session/Murcott_pres.pdf

Asia Arsenic Network Filter:

Delawar, H.K.M. et al. (2006). A Comparative Study of Household Groundwater Arsenic Removal Technologies and Their Water Quality Parameters. Journal of Applied Sciences 6(10):2193-2200. Available at:
www.scialert.net/pdfs/jas/2006/2193-2200.pdf?sess=jJghHkjfd76K8JKHgh76JG7FHGDredhgJgh7GkjH7Gkjg57KJhT&userid=jhfgJKH78Jgh7GkjH7Gkjg57KJhT68JKHgh76JG7Ff

Household Water Treatment for Fluoride Removal Factsheet: Activated Alumina Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Fluoride • Arsenic • Turbidity • Taste, odour, colour		• Bacteria • Viruses • Protozoa • Helminths • Hardness

What Is Activated Alumina Filter?

Activated alumina, also called aluminium oxide (Al_2O_3) granular, is one of the most widely used materials for the removal of chemicals from water. This highly porous material is prepared by low temperature (300-600°C) dehydration of aluminium hydroxides.

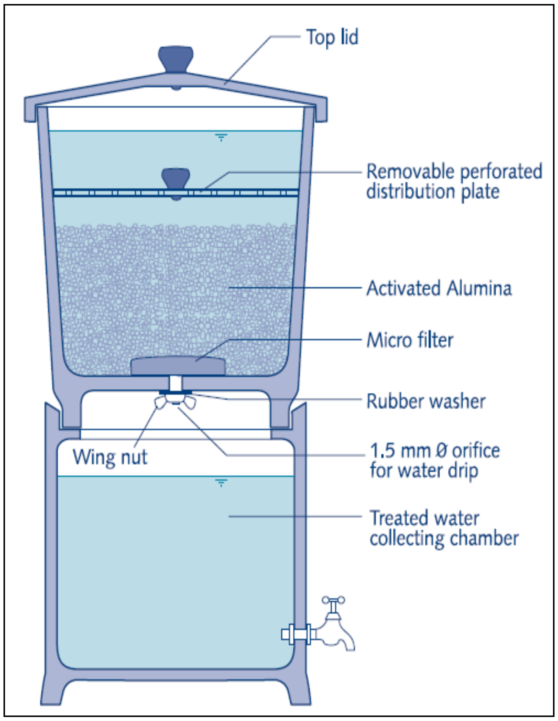
Activated alumina grains are packed in a filter like sand. When water passes through it, certain contaminants in the water adsorb (stick) to the activated alumina. Activated alumina removes fluoride from water, and can also be used for arsenic removal (see the corresponding Arsenic Removal by Adsorption factsheet).

How Does It Remove Contamination?

Fluoride is removed from water through an exchange reaction at the surface of the activated alumina. Fluoride adsorbs to the alumina more easily than other molecules in water. This results in high defluoridation capacity.

According to laboratory tests, the fluoride removal capacity of alumina is between 4 and 15mg of fluoride per gram alumina (Hao and Huang, 1986). However, field experience shows that the removal capacity is often about 1mg/g (COWI, 1998). The treatment capacity also depends on the specific grade (quality) of activated alumina, the particle size and the water chemistry (pH, alkalinity and fluoride concentrations).

The optimum dosage of activated alumina for a particular source water needs to be determined by conducting a jar test experiment.



Activated Alumina-based Household Defluoridation (Credit: Lyengar, 2002)

Operation

There are different kinds of activated alumina filters. One of them consists of two containers (see above diagram). The upper container holds the activated alumina (3 kg, depth of 17 cm, Lyengar 2002). The top of this container can be covered with a perforated stainless steel disc to avoid disturbing the media when water is poured in. It should also be covered by a lid. The lower container can be any kind of bucket or pot with tap, used for storing the treated water.

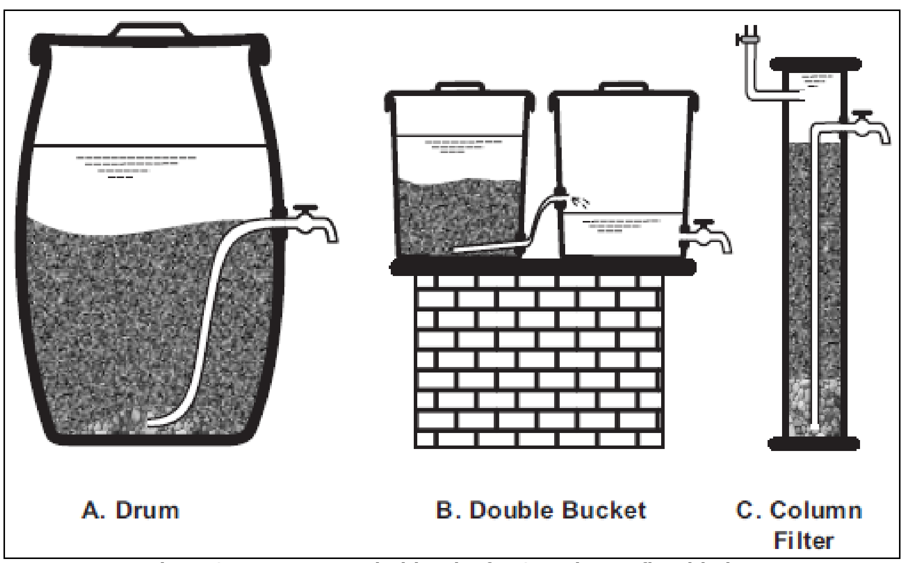
Household Water Treatment for Fluoride Removal Factsheet: Activated Alumina Filter

Activated alumina filters can also consist of a domestic candle water filter with an additional middle chamber holding a bag of activated alumina. The filter could also simply be an bucket, drum or column with a tap and drainage pipe that is filled with activated alumina (see illustration below).

The contact time of the filter is the amount of time the fluoride contaminated water is in contact with the activated alumina. Bulusu and Nawlakhe (1988) conducted jar test experiments to determine the effect of contact time on fluoride removal. It was observed that the optimum contact time to reduce the fluoride level from 4.8 mg/L to 1 mg/L is 30 minutes. This can be used as a recommendation, but as of yet there is no formal recommendation for contact time.

When the activated alumina media becomes saturated, meaning there are no more places for fluoride to adsorb to the media, the media can be regenerated using HCl, H_2SO_4, alum or NaOH. The wastewater created from this process should be disposed of in an appropriate manner away from water sources and human contact.

Note: When 4% caustic soda (NaOH) is used for regeneration it needs to be followed by a neutralization step to remove residual NaOH from the filter.



Three Common Household Units for Sorption Defluoridation (Credit: WHO, 2006)

Household Water Treatment for Fluoride Removal Fact Sheet: Activated Alumina Key Data

Inlet Water Criteria

- The pH of the water should preferably be between 5 and 6; at a pH > 7 silicate and hydroxyl ions become stronger competitors against fluoride ions for adsorption preference (Renu, Singh and Maheswari, 2001)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Fluoride
Laboratory	Not available	Not available	Not available	Not available	Not available	90% in batch[1] up to 98% in column[2]
Field	Not available	Not available	Not available	Not available	Not available	Not available

[1] An initial fluoride concentration of 5 mg/L reduced to down to 1.4 mg/L before regeneration and to 0.5 mg/L on regeneration with 2N HCl (Savinelli, 1958).

[2] (Nakkeeran and Sitaramamurthy, 2007)

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not available[1]	Not available[1]	Not available[1]

[1] Depending on filter type (WHO, 2006)

- The flow rate, batch volume and daily water supply depend on the kind of filter used

Robustness

- Taps can be broken and may need replacement
- Activated alumina needs to be replaced or regenerated once saturated
- It is necessary to measure the fluoride concentration in the outlet water to know when to replace or regenerate media

Estimated Lifespan

- Media regeneration every 6 months to 1 year
- Estimation of the filter lifespan can be made based on the fluoride concentration of the raw water, the daily volume through the filter and the adsorption capacity of the activated alumina

Manufacturing Requirements

Worldwide Producers:

- Many producers around the world

Local Production:

- Difficult and complex to manufacture, local production is not feasible

Maintenance

- The regeneration cannot be left to the users: skilled labour is required to test the filtered water and recharge activated alumina
- The effluent from regeneration is high in fluoride and must be disposed of carefully to avoid recontamination of nearby groundwater

Household Water Treatment for Fluoride Removal Fact Sheet: Activated Alumina Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$35-50[1]	US$0/year	US$1.3-2/kg media[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location and filter type.
[1] India, WHO 2006

- Activated alumina has become less costly and more easily available, especially in locations near to where it is manufactured.

References

Banuchandra, C. and P. Selvapathy (2005). A household defluorodation technique. TWAD Technical Newsletter.

Cavill, S. (2007). Appropriate treatment options for high levels of fluoride in groundwater, Naiva sha, Kenya. Dew Point.

World Health Organization (2006). Fluoride in drinking-water: Chapter 5, Removal of excessive fluoride. World Health Organization.

Lyengar L. (2002). Technologies for fluoride removal. Small Community Water Supplies: Technology, people and partnership, TP 40, Chapter 22.

Miller, K. (2007). Defluoridation of drinking water using appropriate sorption technologies. Proceedings of the Water Environment Federation, no. 8: 9245–9254.

Nagendra, R. (2003). Fluoride and environment – A review. Proceedings of the Third International Conference on Environment and Health, Chennai, India: Pages 386 – 399.

Nakkeeran, E. and D. V. Sitaramamurthy (2007). Removal of fluoride from groundwater. Canadian Journal of Pure and Applied Sciences: 79.

Household Water Treatment for Fluoride Removal Factsheet: Bone Char Filter

Potential Treatment Capacity

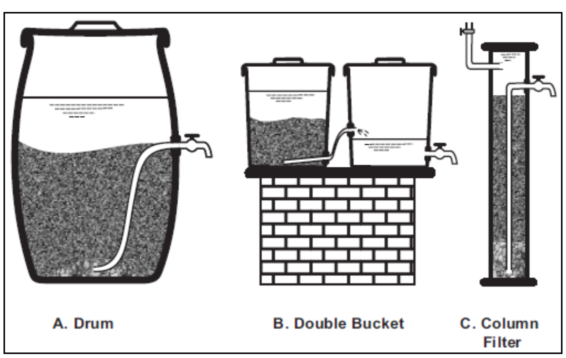
Very Effective For:	Somewhat Effective For:	Not Effective For:
• Fluoride • Taste, odour, colour	• Turbidity • Other Chemicals	• Bacteria • Viruses • Protozoa • Helminths • Hardness

What Is a Bone Char Filter?

Bone was one of the earliest media suggested for fluoride removal from water. It was not widely implemented due to the bad taste of treated water, the high cost and unavailability. But in 1988, the WHO claimed it to be an applicable technology for developing countries.

Bone char is a blackish porous granular media capable of absorbing a range of contaminants. The bone char grains are packed in a filter (bucket, drum or column) and water flows through.

Bone char is made from animal bones that are charred (burnt) and crushed. Correct preparation of the bone char is essential to ensure good fluoride removal and to avoid unattractive taste, colour and odour in the treated water. Decades ago, bone char was industrially produced and widely available, but now the supply is limited. However, bone char grains can be produced locally by communities.



Three Common Households Units for Sorption Defluoridation (Credit: WHO, 2006)

How Does It Remove Contamination?

Major components of bone char are calcium phosphate, activated carbon and calcium carbonate. Fluoride is removed from water through a process based on ion exchange. When raw water containing fluoride comes into contact with bone char, the fluoride ion changes places with the carbonate ion in the bone char, and the fluoride becomes “stuck” to the bone char.

Bone char has high fluoride removal efficiency, and can also absorb a wide range of other contaminants. The fluoride adsorption capacity is 2mg fluoride per gram of bone char (Albertus, 2000).

Operation

Bone Char Production

The steps for preparing bone char are: charring, crushing, sieving and washing/drying.

The colour of the charred bone is a simple way to determine its quality (Jacobsen and Dahi, 1997):

- Grey-brownish: Highest fluoride removal
- Black: Still contains organic impurities causing odour and colour
- White: Reduced fluoride removal capacity

Bone char from any animal needs to be carbonized at a temperature of 400 to 500 ºC with a controlled air supply. Then the charred bones can be crushed manually or by using a crushing machine. Particles between 0.5 mm and 4 mm can be used as media.

Household Water Treatment for Fluoride Removal Factsheet: Bone Char Filter

If bone char is not prepared properly, it may result in low defluoridation capacity and/or lower water quality.

Filter Examples

Bone char media can be use in different kinds of filters. One example is a 20 litre bucket with a tap fixed at the bottom connected to an outlet pipe. A perforated plate can be placed on the surface of the media to avoid disturbance during addition of raw water. The use of bone char alone is efficient with a flowing system, but is not effective in a batch method (Larsen, 1993).

The water level in the filter should never drop below the top of the bone char. If the bone char is left dry, its adsorption capacity will decrease. The water should be in contact with the bone char for a minimum of 20 minutes. The filter can be combined with a ceramic candle to remove microbiological contamination as well (see picture). For new filters or after changing the media, the first few containers of treated water should be discarded due to high turbidity and colour (CDN, 2006).

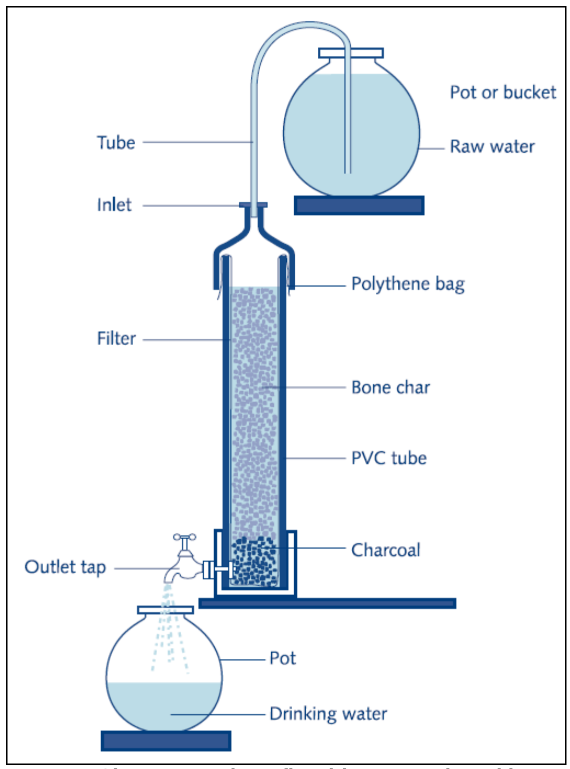
Single and Combined Bone Char Filter (Credit: Eawag, 2006)

Media Regeneration

Bone char media needs to be renewed or regenerated periodically. Regeneration can be done using caustic soda (NaOH). The fluoride concentration in the treated water needs to be measured periodically to know when to replace or regenerate the media. However, an estimation of the lifespan of the media can be made based on the fluoride concentration of the source water, the volume of water filtered each day and the adsorption capacity of the bone char.

Acceptance

The use of bones in water treatment might not be consistent with local customs and beliefs. Depending on the community, it may be important to consider the implications of religious beliefs, etc. on acceptance of using bone char for water treatment.



Bone Char Domestic Defluoridator Developed by ICOH-Thailand (Credit: Lyengar, 2002)

Household Water Treatment for Fluoride Removal Factsheet: Bone Char Filter Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Fluoride
Laboratory	Not available	N/A	N/A	N/A	N/A	65% in batch[1] 99% in flowing system[2]
Field	N/A	N/A	N/A	N/A	N/A	90%[3]

[1] Watanesk and Watanesk, 2000
[2] Mavura et al., 2002
[3] CDN, 2006

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not available	1.6 to 6.5 litres[1]	Not available

[1] Depending on filter type (WHO, 2006)

- The flow rate, batch volume and daily water supply depend on the kind of filter used

Robustness

- Taps can be broken and may need replacement
- Bone char needs to be replaced or regenerated when saturated
- It is necessary to measure the fluoride concentration in the outlet water to know when to replace or regenerate media

Estimated Lifespan

- Estimating the lifespan can be made based on the fluoride concentration of the source water, the water volume filtered each day, and the adsorption capacity of the bone char
- According to Catholic Diocese of Nakuru Water Quality's laboratory research, the filter can be filled 200 times with water (using an inlet concentration of 6 mg fluoride/litre) before the fluoride concentration in the outlet water exceeds 1.5 mg fluoride/litre

Manufacturing Requirements

Worldwide Producers:
- Bone char is still produced in several countries as it is used in food industries such as sugar production

Local Production:
- Bone char can be produced locally in any country

Materials:
- Bones from animals
- Furnace or kiln
- Crushing machine or tools for manual crushing
- Sieves to obtain correct grain size for bone char media

Fabrication Facilities:
- Storage place with roof to keep bones dry

Household Water Treatment for Fluoride Removal Factsheet: Bone Char Filter Key Data

Labour:

- Anyone can be trained to produce bone char

Hazards:

- Safety precautions are needed when charring the bones

Maintenance

- Replacement or regeneration of bone char (skilled labour required)
- Cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$17-23[1]	US$1.8/1000 litres[2]	US$1.8/1000 litres[2]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

[1] CDN, 2006 for the whole defluoridation unit and depending on tap type, Kenya

[2] For bone char media replacement (CDN, 2006)

References

Albertus, J. (2000). Bone char quality and defluoridation capacity in contact precipitation. 3rd International Workshop on Fluorosis Prevention and Defluoridation of Water Session 1 Epidemiology: 57.

Cavill, S. (2007). Appropriate treatment options for high levels of fluoride in groundwater, Naiva sha, Kenya. Dew Point.

Catholic Diocese of Nakuru, Water Quality (CDN) and K. Müller (2007). CDN's experiences in producing bone char. Kenya.

Catholic Diocese of Nakuru, Water Quality (CDN) and K. Müller (2006). CDN's defluoridation experiences on a household scale. Kenya. Available at: www.eawag.ch/forschung/qp/wrq/publications/pdfs/household_filters

Fawell, J. Kirtley, K. Bailey, and World Health Organization (2006). Fluoride in drinking-water: Chapter 5, Removal of excessive fluoride. World Health Organization

Korir H., K. Mueller, L. Korir, J. Kubai, E. Wanja, N. Wanjiku, J. Waweru, M.J. Mattle, L. Osterwatder and C.A. Johnson (2009). The Development of Bone Char-Based Filters For the Removal of Fluoride From Drinking Water. 34th WEDC International Conference, Addis Ababa, Ethiopia.

Lyengar L. (2002). Technologies for fluoride removal. Small Community Water Supplies: Technology, people and partnership, TP 40, Chapter 22.

Miller, K. (2007). Defluoridation of drinking water using appropriate sorption technologies. Proceedings of the Water Environment Federation, No. 8: 9245–9254.

Nagendra, R. (2003). Fluoride and environment – A review. Proceedings of the Third International Conference on Environment and Health, Chennai, India: Pages 386 – 399.

Watanesk, S. and R. Watanesk (2000). Sorption study for defluoridation by bone Char. Session 1 Epidemiology: 80.

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CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Fluoride Removal Factsheet: Clay

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Fluoride • Turbidity	• Bacteria • Protozoa • Helminths • Viruses	• Chemicals

What Is Clay?

Clay is a very fine textured earthy material. It is composed mainly of very small particles of hydrous aluminium silicates, other minerals and may include other materials. It is used for making pottery (ceramics), brick and tile. Both clay powder and fired (baked) clay are capable of removing fluoride and other contaminants from water. The ability of clay to clarify turbid water is well known and it is believed to have been used in households in ancient Egypt (WHO, 2006).

Clay can be used in powder form in a bucket system, or freshly fired clay/brick chips can be used in column filters. The use of clay powder in column filters is possible, but it is troublesome because of difficulties in packing the columns and controlling the flow.

How Does It Remove Contamination?

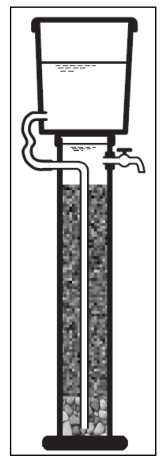
Clay is a good flocculent and absorbent for removing fluoride, because of its relatively high density (the particles are heavy).So once the fluoride attaches to the clay particles, it settles out well.

The best clay for fluoride removal has high levels of iron oxide and aluminium (e.g. bauxites, goethite/ hematite). The removal process is an ion exchange between fluoride and iron or aluminium.

Operation

Domestic clay column filters are normally packed using fired (burnt) clay chips. The fired clay chips can be found as waste from the manufacturing of brick, pottery or tile.

The Clay Column Defluoridator (pictured) is an example of a burnt clay filter used in Sri Lanka. It is a layered column of freshly fired brick chips, pebbles and crushed coconut shells. Water is passed through the unit upwards (from the bottom to the top). The filters can be made out PVC pipe or cement. In the columns, brick chip sizes are generally between 15 and 20 mm.



Column filter used in Sri Lanka (Credit: WHO, 2006)

The firing/burning of the clay is important because it activates the aluminium oxide which reacts with the fluoride. Once the clay is fired it is also easier to break into clay chips.

In the bucket system, clay powder is added at large dosages to water, stirred and left to settle for several hours. The clean water is scooped or decanted off the top. The sludge in the bottom of the bucket must be disposed of appropriately away from water sources. This method cannot be used for source water with high concentrations of fluoride (above 3 mg/L, WHO 2006).

Clay pottery can also be used if the water is allowed to drip through the clay. Since water is often stored in clay pots in many cultures this method may be quite feasible in communities where the aluminum oxide concentration in the soil (and therefore in the clay pots) is high. The storage time in the pots varies depending on the aluminum oxide level in the clay.

Household Water Treatment and Safe Storage Fact Sheet: Clay — Key Data

Inlet Water Criteria

- The treatment capacity of clay is optimum when water pH is about 5.6 (Jinadasa et al. 1988)
- Bucket system is only good for low fluoride concentration (<3 mg/L, WHO 2006)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Fluoride
Laboratory	Not available	Not available	Not available	Not available	Not available	>93.8%[1]
Field	Not available	Not available	Not available	Not available	Not available	Not available

[1] Using bauxite from Malawi (Sajidu et al. 2008)

- Treatment efficiency depends on the quality of the clay and kind of filter used

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not available	Not available	Not available

- The flow rate, batch volume and daily water supply depend on the technique and kind of filter used

Robustness

- The clay used in filters needs to be replaced or regenerated (very costly) when saturated
- It is necessary to measure the fluoride concentration in the outlet water to know when to replace or regenerate media

Estimated Lifespan

- Clay media needs to be replaced every 25-40 days typically

Manufacturing Requirements

Worldwide Producers:
- Bricks are produced everywhere

Local Production:
- Clay can be burnt in a kiln locally

Materials:
- Clay
- Kiln

Labour:
- Anyone can be trained to produce burnt clay chips

Maintenance

- Frequent replacement or regeneration of clay
- Clean filter on a regular basis

Household Water Treatment and Safe Storage Fact Sheet: Clay Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
Not available	Not available	Not available

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

- Clay treatment for fluoride may only be cost effective if good quality, freshly burnt broken bricks are available on site or near to the users, and if the filter is prepared using low cost, locally available materials (WHO 2006)

References

Bjorvatn K. and A. Bardsen (1995). Use of activated clay for defluoridation of water. Ngurdoto, Tanzania.

Bjorvatn K. and A. Bardsen (1995). Fluoride sorption isotherm on fired clay.Workshop on fluorosis and defluoridation of water. Publ. Int. Soc. Fluoride Res, 46–49.

Cavill, S. (2007). Appropriate treatment options for high levels of fluoride in groundwater, Naiva sha, Kenya. Dew Point.

Chidambaram S., A. L. Ramanathan, and S. Vasudevan (2004). Fluoride removal studies in water using natural materials: technical note. Water SA 29, no. 3: 339.

Fawell, J.Kirtley, K. Bailey, and World Health Organization (2006). Fluoride in drinking-water: Chapter 5, Removal of excessive fluoride. World Health Organization.

Lyengar L. (2002). Technologies for fluoride removal. Small Community Water Supplies: Technology, people and partnership, TP 40, Chapter 22.

Miller, K. (2007). Defluoridation of drinking water using appropriate sorption technologies. Proceedings of the Water Environment Federation, no. 8: 9245–9254.

Nagendra, R. (2003). Fluoride and environement – A review. Proceedings of the Third International Conference on Environment and Health, Chennai, India: Pages 386 – 399.

Sajidu et al. (2008). Groundwater fluoride levels in villages of Southern Malawi and removal studies using bauxite, International Journal of Physical Sciences 3, no. 1: 001–011

Wijesundara T. (2004). Low-cost defluoridation of water using broken bricks. in 30th WEDC International Conference.

Household Water Treatment for Fluoride Removal Factsheet: Contact Precipitation

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Fluoride • Taste, odour, colour	• Other chemicals • Turbidity	• Bacteria • Viruses • Protozoa • Helminths • Hardness

What Is Contact Precipitation?

Contact precipitation is a technique in which fluoride is removed from water through the addition of calcium and phosphate compounds, which leads to precipitation of fluoride. The water is then filtered through bone char that has been pre-saturated with fluoride.

The process uses buckets, column filters or a combination. Different kinds of contact precipitation filters exist.

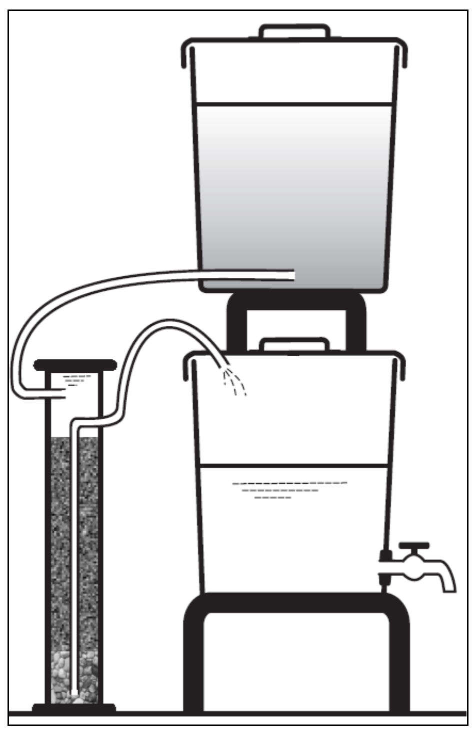
How Does It Remove Contamination?

The precipitation of fluoride from water containing calcium and phosphate is theoretically possible, but in reality it is not feasible because the reactions are so slow. The addition of a compound like bone char is necessary to allow the precipitation of fluoride within a reasonable time. The saturated bone char helps with the removal of fluoride, and filters out the precipitate. The contact time of the water in the filter with the compounds needs to be long enough to allow sufficient fluoride removal; however, if the contact time is too long, calcium ions may precipitate in the filter and fluoride removal efficiency will decrease. A 20 to 30 minute contact time is recommended.

Operation

Water is first treated with calcium and phosphate compounds. Any calcium and phosphate compounds can be used, but it is important to dissolve the chemicals prior to mixing them with the water. The chemicals are preferably prepared as two separate stock solutions and can be prepared once every month, but should not be mixed together before treatment to avoid the precipitation of calcium phosphate. It is advisable to check the bulk density as it may vary for different brands.

The most common calcium compounds used to react with the fluoride are either lime or calcium chloride (CC). This reacts with fluoride to form a precipitate (solid form) of calcium fluoride. A common phosphate compound used is sodium dihydrogenphosphate, also called monosodium phosphate or MSP.



Contact Precipitation Filter for Household Use (Credit: WHO, 2006)

Long term operation of the contact precipitation technique in Tanzania has shown that the process functions effectively when the dosage ratios are 30 and 15 for CC and MSP respectively, with a raw water fluoride concentration of about 10 mg/L. This dosage ensures at least 65% precipitation of fluorapatite (fluoride compound) and a surplus of calcium for precipitation of the residual fluoride as calcium fluoride (WHO 2006).

Water is then passed through a column filter filled with gravel or coarse grained bone char. It is important to take into account that the use of bone char may not be culturally acceptable. The steps for preparing bone char include: charring, crushing, sieving and washing/drying.

The colour of the charred bone char is a simple way to determine its quality (Jacobsen and Dahi, 1997):

- Grey-brownish: highest fluoride removal
- Black: still contains organic impurities causing odour and colour
- White: reduced fluoride removal capacity

Bone char from any animal needs to be carbonized (burnt) at a temperature of 400 to 500ºC with a controlled air supply. Then the charred bones can be crushed manually or by machine. Particles between 0.5 mm and 4 mm can be used as media.

The bone char used in contact precipitation needs to be pre-saturated with fluoride through contact with water containing a high concentration of fluoride (up to 100 mg/L).

Household Water Treatment and Safe Storage Fact Sheet: Contact Precipitation Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Fluoride
Laboratory	Not available	Not available	Not available	Not available	Not available	>90%[1]
Field	Not available	Not available	Not available	Not available	Not available	>95 %[2]

[1] Depending on dose (Albertus et al., 2000)

[2] WHO, 2006

- High fluoride removal efficiency, even the fluoride concentration in inlet water is high

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not available	20 litres (typical)	Not available

- The flow rate, batch volume and daily water supply depend on the kind of filter used

Robustness

- Taps can be broken and may need replacement
- Difficult to optimize without training and equipment
- Requires supply chain, market availability and regular purchase of chemical compounds

Estimated Lifespan

- Chemical solutions must be prepared every month

Manufacturing Requirements

Worldwide Producers:

- Bone char is still produced in several countries as it is used in food industries such as sugar production
- Calcium and phosphate compounds: many producers around the world

Local Production:

- The chemical products involved are difficult and complex to manufacture and local production is not always feasible
- Bone char can be produced locally in any country

Materials:

- For saturated bone char: bones from animals, furnace or kiln, sieves, crushing machine (facultative), fluoride solution for saturation

Fabrication Facilities:

- For bone char: Storage place with roof to keep bones dry

Household Water Treatment and Safe Storage Fact Sheet: Contact Precipitation Key Data

Labour:

- Anyone can be trained to produce bone char

Hazards:

- Safety precautions are needed when charring the bones

Maintenance

- Daily operation is easy; experience from Tanzania has shown that a young student can easily operate the system
- No health risk in the case of misuse or over-dosage of chemicals
- The two stock solutions can be prepared once every month
- Clean filter on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
Not available	Not available	Not available

Note: Program, transportation and education costs are not included. Costs will vary depending on location.

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References

Albertus, J. (2000). Bone char quality and defluoridation capacity in contact precipitation. 3rd International Workshop on Fluorosis Prevention and Defluoridation of Water Session 1 Epidemiology: 57.

Cavill, S. (2007). Appropriate treatment options for high levels of fluoride in groundwater, Naiva sha, Kenya. Dew Point.

Fawell, J.Kirtley, K. Bailey, and World Health Organization (2006). Fluoride in drinking-water: Chapter 5, Removal of excessive fluoride. World Health Organization.

Lyengar L. (2002). Technologies for fluoride removal. Small Community Water Supplies: Technology, people and partnership, TP 40, Chapter 22.

Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Fluoride Removal Factsheet: Nalgonda Technique

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Turbidity	• Fluoride • Bacteria • Viruses • Protozoa • Helminths • Hardness • Taste, odour, colour	• Other chemicals

What Is the Nalgonda Technique?

The Nalgonda technique was first developed by the National Environmental Engineering Research Institute (NEERI) in Nalgonda, India. It involves adding alum (aluminum sulphate, ($Al_2(SO_4)_3 \cdot 16H_2O$)) and lime (calcium carbonate) to the raw water to precipitate the fluoride.

Compared with normal drinking-water flocculation processes, a much larger dose of alum is required in the defluoridation process. Because the alum solution is acidic, addition of lime is needed at the same time to maintain a neutral pH in the treated water and to complete precipitation of aluminum.

Calcium hydroxide may be added instead of lime. Chlorine or bleaching powder can also be added to the raw water to disinfect it against microbiological contamination.

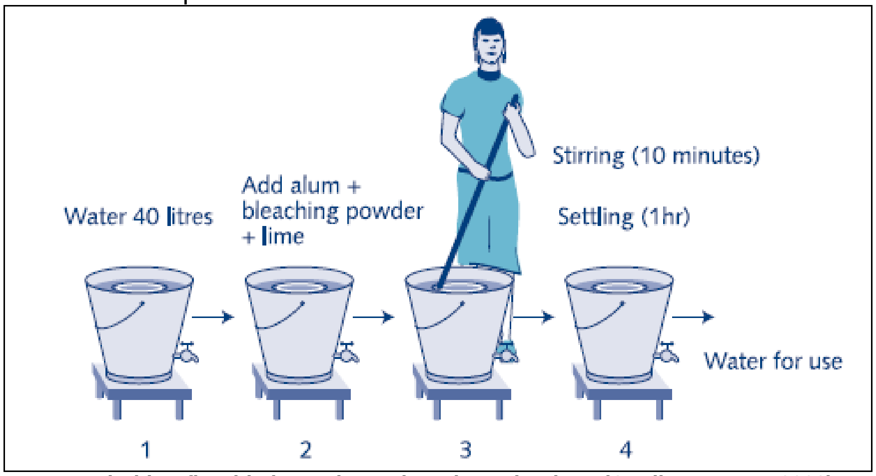
After treatment with the chemicals, the treated water can be decanted or poured into another container. The water may be passed through a filter or cloth while decanting to ensure that no sludge particles escape with the treated water.

How Does It Remove Contamination?

Aluminum salt is responsible for removal of the fluoride from the water. During the flocculation process (creation of large particles in the water which stick together) many kinds of micro-particles and negatively charged ions (including fluoride) are partially removed by electrostatic attachment to the flocs.

In this technique, up to a third of the fluoride is precipitated, while up to 82% reacts with the alum to make a soluble and toxic aluminum fluoride complex (Miller, 2007) which will settle to the bottom as sludge. This should be disposed of away from water sources.

The process can produce treated water with fluoride concentrations of 1 to 1.5 mg/L.



Household Defluoridation Using Nalgonda Technology (Credit: Lyengar, 2002)

Household Water Treatment and Safe Storage Factsheet: Nalgonda Technique

Operation

The Nalgonda Technique is a bucket system designed to be used on a household scale. It consists of a 40 litre plastic bucket with a tap located 5 cm above the bottom of the bucket.

The process involves adding aluminum sulfate, lime and bleaching powder (optional) to the water in the bucket, followed by rapid mixing for 10 minutes. The water is then left to stand for 1 hour. After coagulation/flocculation and settling are complete, the treated water is poured out through the tap, and stored for the day's drinking in a clean bucket or safe storage container.

The dose of alum to be added depends on the fluoride concentration and the alkalinity of the raw water (see table below from Lyengar, 2002). The dose of lime to be added is 5% of the amount of alum (Lyengar, 2002).

Lime is added to maintain the neutral pH in the treated water. Excess lime is used to help sludge settling as it helps form denser (heavier) flocs, which speeds up settling.

This technique produces large quantities of sludge. The environmental impact of the hazardous sludge disposal should be considered.

Moreover, care has to be taken to avoid the presence of aluminum in the treated water, as this may have adverse health effects. With this technique, the free residual aluminum content in the treated water can be as high as 2.01 to 6.86 mg/L (Kailash et al., 1999). The maximum limit is 0.2 mg/L aluminum.

Approximate volume of 10% alum solution (ml) to be added in 40 litres of test water to obtain the acceptable limit (1.0 mg F/l) of fluoride at various alkalinity and fluoride levels. The lime to be added is 5% of the alum amount (mg/l)

Test water fluorides (mg/l)	Test water alkalinity as mg $CaCO_3$/l							
	125	200	300	400	500	600	800	1000
2	60	90	110	125	140	160	190	210
3	90	120	140	160	205	210	235	310
4		60	165	190	225	240	275	375
5			205	240	275	290	355	405
6			245	285	315	375	425	485
8					395	450	520	570
10							605	675

Alum and Lime Dosage for the Nalgonda Technique
(Credit: Lyengar, 2002)

Household Water Treatment and Safe Storage Fact Sheet: Nalgonda Technique   Key Data

Inlet Water Criteria

- Total dissolved solids (TDS) must be less than 1500 mg/L
- The process cannot be used in cases of fluoride concentration above 20 mg/L

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Fluoride
Laboratory	>90 to >99%[1]	>90 to >99%[1]	>90 to >99%[1]	>90 to >99%[1]	Not available	Up to 70%[4]
Field	< 90%[2] 95%[3]	Not available	Not available	Not available	Not available	Not available

[1] Sproul (1974), Leong (1982), Payment and Armon (1989) as cited in Sobsey, 2002
[2] Ongerth (1990) as cited in Sobsey, 2002
[3] Wrigley, 2007
[4] Fawell et al., 2006

- Maximum effectiveness requires careful control of coagulant dose, pH and consideration of the quality of the water being treated, as well as mixing

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	40 litres	Unlimited

- Need to follow instructions
- Discarding the sludge from the Nalgonda process is considered to be an environmental health issue. The sludge is quite toxic because it contains the removed fluoride in a concentrated form. The sludge should be properly disposed (e.g. buried and covered in a pit).

Robustness

- Difficult to optimize without training and equipment
- Requires supply chain, market availability and regular purchase

Estimated Lifespan

- 6 months in liquid form and 1 year in solid form

Manufacturing Requirements

Worldwide Producers:
- Many producers around the world

Local Production:
- The chemical products involved are difficult and complex to manufacture and local production is not always feasible

Maintenance

- Chemicals should be stored in a dry location and away from children

Household Water Treatment and Safe Storage Fact Sheet: Nalgonda Technique Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0	US$12/year [1]	US$0

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Cavill, 2007. Assumed 20 litres/household/day.

References

Agarwal, K.C., S. K. Gupta, and A. B. Gupta (1999). Development of new low cost defluoridation technology (Krass). Water science and technology: 167–173.

Banuchandra, C. and P. Selvapathy (2205). A household defluorodation technique. TWAD Technical Newsletter.

Cavill, S. (2007). Appropriate treatment options for high levels of fluoride in groundwater, Naiva sha, Kenya. Dew Point.

Fawell, J.Kirtley, K. Bailey, and World Health Organization (2006). Fluoride in drinking-water: Chapter 5, Removal of excessive fluoride. World Health Organization.

Miller, K. (2007). Defluoridation of drinking water using appropriate sorption technologies. Proceedings of the Water Environment Federation, no. 8: 9245–9254.

Lyengar L. (2002). Technologies for fluoride removal. Small Community Water Supplies: Technology, people and partnership, TP 40, Chapter 22.

Appendix C – Decision Making Tools

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Tool: Matrix Scoring

What Is It?
This tool places the different HWTS options side by side on a table or matrix to compare them. Participants rate them against various agreed-upon selection criteria, usually with a simple scoring system, and then total their respective ratings. The totals indicate which HWTS options appear to be best choices.

Why Use It?
Matrix scoring provides a way to score and compare different things against the same criteria. It enables intuitive preferences to be quantified in a logical manner.

The matrix can be put on a board visible to all and completed in a participatory manner. The visual nature of the tool facilitates comparative scoring of the choices, even by participants who would not otherwise be conversant with spreadsheets.

How To Use It
1. Agree on what subject and options to discuss. For example, 'What household water treatment technology are we going to promote in our community?' Draw or write each option on a separate card. This is called an options card.
2. Agree on criteria for scoring the options. This will depend on what is important to the participants. For example, criteria for prioritising ways of selecting a HWTS technology may be: ‘Less expensive’, ‘Easier to use’, ‘Highest’ level of contaminant removal, ‘Easily accessible’ and ‘Less maintenance’.
3. Draw a matrix – a big rectangle with rows and columns. The number of columns is the same as the number of options cards plus one more, the leftmost one, for the criteria.
4. Put one option card at the top of each column, except the leftmost one.
5. Put the criteria in the leftmost column, each to its own row, starting with the second row from the top.
6. Agree to a scoring method. For example, numbers 1–10, where 1 is very low and 10 is very high.
7. Give each option a score for each of the criteria. Participants can use beans or stones, or write in their scores for each criterion and this is totalled. Write the total score under each option, on the row of the criteria concerned. It is OK to give the same score to different options.
8. Add up the scores for each option.
9. When the matrix is finished, encourage the participants to discuss what the matrix shows. Talk about whether the matrix makes sense or whether there should be further discussion or the weighing-in of expert opinion. Sometimes results will not be acceptable to the group but will provide insights to aid further refinement and iteration of the decision-making process.

Trainer Notes

- The selection of criteria for scoring is a very important part of this process. Help the participants to discuss and agree to the criteria and allow enough time for this part of the process.
- Using beans or stones to 'vote' allows participants to make changes easily during discussion and provides a visual of what the scores are.
- Different HWTS options can be combined to provide the most effective treatment through a multi-barrier approach. The matrix can include a combination of technologies. For example, the bio-sand filter followed by SODIS, or sedimentation and a ceramic filter.

(Adapted from International HIV/AIDS Alliance, 2006)

Tool: Weighted Matrix Scoring

What Is It?
This tool is a version of the matrix scoring tool where agreed-upon weights or multipliers are assigned to each criterion to take into account their relative importance to each other. This helps prioritize options according to the criteria that participants think are most important.

Why Use It?
Weighted matrix ranking is most useful if there are many criteria and some are much more important than others. If there are only three or four criteria of roughly equal importance, then the matrix scoring tool will be more useful.

How To Use It
There are at least two ways to do this, after following the previously mentioned steps outlined in the Matrix Scoring Tool.

1. Where the 'voting' system is by beans or stones, discuss before 'voting' the relative importance of each criteria so the group can get a sense of such. Participants will then be given a uniform amount of beans and will be free to budget them in as many or as few of the choices and criteria they deem important.

2. If 'voting' is by conventional scoring, the groups will agree first on the relative weights of the criteria. For example, one criterion will have a weight of 0.2, another 0.3, and a last one 0.5 for a total of 1.0. These weights are written beside their respective criterion.

   'Voting' then proceeds as usual. But the scores for each criterion are multiplied by its weight before the scores are totalled under each option. A computer spreadsheet connected to a projector can facilitate the computation.

(Adapted from International HIV/AIDS Alliance, 2006)

Tool: Ranking Line

What Is It?
This tool involves drawing a line and placing things on it in order of their preference.

Why Use It?
Using a ranking line helps to:

- Put things visually and spatially in order of preference and show the reasons for the order
- Resolve the sometimes varied or conflicting concerns and priorities of different people
- Decide which problems are most serious or most common, and why
- Illustrate how information gained during an assessment relates to each other
- Select technologies according to agreed criteria – for example, the technology that is most cost effective for a community

How To Use It
1. Agree what HWTS technologies to rank.
2. Draw or write each of the items to be ranked on separate cards (‘ranking cards’).
3. Agree on the first reason for ranking these items. For example, the first reason for ranking the technology options could be how effective participants think each option is.
4. Draw a long line. Use drawing or writing to show what the line represents – for example, effectiveness of different technologies. One end of the line should represent ‘most effective’ and the other end ‘least effective’.
5. Discuss each ranking card and decide where to place it on the line. For example, if participants are ranking the effectiveness of different technologies, the most effective treatment option will be placed at one end of the line. The least effective treatment option will be placed at the other end of the line. Cards of equal ranking can be put beside each other.
6. Repeat the process for other criteria. Draw a new ranking line for each criterion.
7. When the activity is complete, discuss what the ranking lines show. For example, compare where items have been placed on different lines. Are there items that always appear high or low on the ranking lines? Relate such insights to how selection of the preferred decisions will be made,

(Adapted from International HIV/AIDS Alliance, 2006)

Appendix D – Implementation Case Studies

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

AQUA CLARA INTERNATIONAL

Introduction

Aqua Clara International (ACI) is a non-profit NGO headquartered in the USA and operating in Kenya. They are focused on empowering communities to meet their own needs by using a partnership-based, entrepreneurial model. The goal of ACI is a completely locally-driven and sustainable program that involves partnership between schools, their surrounding communities and ACI. All partners work together to sensitize the area in the use and adoption of different types of beneficial technologies, including biosand filters, rainwater harvesting, sanitation, and household high-yield gardens.

ACI developed a biosand filter using a plastic container for the filter body in 2007 and have received training and follow-up support from CAWST. As of August 2011, ACI has implemented more than 1,800 biosand filters in Kenya. Currently, their project consists of two main areas in rural communities around the towns of Kisii and Eldoret.

Creating Demand

ACI raises awareness and creates demand for the biosand filter and other products, through schools, Community Development Entrepreneurs (CDEs), and Community Health Promoters (CHPs). These 2 key roles have different functions. The CDE operates a small ACI business and is responsible for social marketing, constructing and selling water, hygiene and sanitation (WASH) products to end users; whereas the CHP is mainly responsible for education, oversight and follow-up with the end users.

Each small business, run by a CDE, is based at a rural school. Primary schools are selected through an application process after initial meetings called by the local district education officer. Interested schools submit application forms to ACI and go

Demonstration ACI Filter in Kisii, Kenya (2011)

through a selection process. ACI selects 1 school per sub-location so that the CDEs have different markets for the various ACI products. The first level of ACI products consists of 3 WASH products: biosand filters, two types of safe water storage containers, and hand washing containers.

CDEs are identified through the school and ACI interviews each candidate to select the best individual for the position. These individuals are not paid a salary, but receive a small profit from each of the items sold. They drive the success of their business.

School launches are held to kick-off the local business. Local chiefs, neighbors, clubs, parents of the students, and other stakeholders are all invited by the school. The launch is participatory to engage the public and help them understand the filter and why it’s important. It also serves as a public endorsement of the CDE and their work by ACI. CDEs can take orders for filters starting at the launch. CDEs receive a financial incentive from ACI for monthly sales that exceed 5 filters.

During the launch, local ACI staff explain how the program works, introduce the CDE, CHP and school representative, and discuss how the biosand filter works. All the participants then work together to prepare sand and gravel for a demonstration filter installation.

CHPs are women recruited from the local community to help promote good WASH practice alongside the products for sale. One of the main roles of the CHPs is to make household visits 30-60 days after purchase of the biosand filters to check on construction standards, end user knowledge of filter use and safe water storage. They also use this opportunity to train on simple hygiene and sanitation improvements.

Some of their awareness and education materials were prepared by ACI themselves, while others were provided by CAWST and UNICEF.

Supplying Products and Services

ACI staff manage the supply chain of the materials for biosand filter production and arrange transportation of the materials to the schools.

The school acts as a "neutral zone" and local partner for the business in the community. Schools provide the following:

- Safe place for the materials – away from animals and secure from theft
- A demonstration site for the ACI products that is open to the local community
- A timetable for care and maintenance of all of the ACI products used in the school
- School representative and students in the Water & Hygiene Club to care for and maintain all the ACI products
- Support for the Water & Hygiene Clubs e.g. a room to meet and the School Representative for oversight

The plastic filter body is a locally available, 75 liter container commonly used in Kenya for rainwater harvesting and water storage. ACI's management of the supply chain enables them to negotiate with Kenyan suppliers so that the cost of the filter is as low as possible for the end user. This is also true for the safe water storage and hand washing containers.

Most raw materials for the filters are found in the project areas; however, filtration sand is sieved at a centralized source in Nakuru and transported by truck to the project areas. ACI is considering washing the sand in Nakuru, to further improve quality control.

Biosand filters are priced at 1070 Kenyan Shillings [KES] (US$12). 820 KES (US$9) is the material cost of the filter and the CDE receives a profit of 250 KES (US$3). Safe water storage containers are also for sale from the CDE for 350 KES, for which they receive 20 KES profit. 80% of households that purchase a filter also purchase a safe water storage container.

Filters are constructed and installed by the CDE. CDEs are given the tools and materials necessary for their first 20-25 filters. As they sell each filter, they repay 820KES back into a material resupply account. Once they have sold their first batch of filters, the money collected is used to order the next batch of filters.

The CDE is also responsible for training the end user on how to use the filter, how to store treated water safely, and how to identify when the swirl and dump (maintenance) needs to take place. The CDE will also return to teach the user how to do the swirl and dump for the first time. The sales contract between ACI and the CDE clearly stipulates that 50KES of their 250KES profit is for this purpose. The user will contact the CDE when they think the maintenance needs to be done.

Households are expected to pay for their filter, participate in sand washing for their filter with the CDE, and transport all the materials to their homes from the school.

The community health promoters (CHPs) that have been recruited by ACI help to educate the filter users, deliver training to the school students, and monitor filter use in the homes. ACI selects women to be CHPs because they have better access to the women in the households and collect more honest responses.

CHPs are chosen based on the following criteria:

- Must be a resident of the local community
- Enthusiasm and interest in WASH education in the community
- Mobility – ability and willingness to visit different homes
- Good command of spoken and written English

CHPs are not ACI staff, but receive stipends for conducting specific program activities, such as follow-up visits and school education sessions with the Water & Hygiene Clubs. Each CHP supports the work of 1-2 CDEs. The number of visits that they make each month is determined by the productivity of the CDE, thus they have a financial incentive to promote the CDEs work in their area.

CHPs receive field kits that have the following materials: ruler, notebook, binder, 1 liter container, ACI brochure, 3 PHAST games, CAWST WASH posters, CAWST HWTS posters, Prescription for Health DVD, and ACI's biosand filter manual. They are also provided with bags, t-shirts and lanyards to increase their credibility in the community. Items are added to this kit on a regular basis. CHPs are also provided with a biosand filter for their own home so they understand how to use and maintain the filters and be a good role model for their community.

Monitoring and Improvement

ACI uses the CHPs as their primary method of monitoring the biosand filters. They have established a follow-up visit schedule:

- 1st visit – 1-2 months after installation
- 2nd visit – 12 months after installation
- 3rd visit – 24 months after installation

At a monthly meeting, CHPs receive the sales orders from the CDEs for the previous month. These are the households they must visit in the next month, provide follow-up support to and complete a questionnaire which is then submitted to ACI staff. The promoter receives a stipend of 100KES for each follow-up visit conducted.

The monitoring information is used later by the program staff to help determine what should be implemented next.

ACI's model is reaching the poorest of the poor who earn less than $2/day. In a monitoring survey completed in 2010, the survey estimated reported household income of biosand filter users to be less than $1/person/day. They have learned that if a product is marketed well with a good distribution mechanism, people are willing to pay the full hard cost of a filter.

Building Human Capacity

ACI is committed to capacity building within their staff and at the community level. They see this as one of the best ways to ensure the long-term sustainability of the project.

ACI project managers have received training from CAWST on Community Health Promotion for WASH and Low Cost Sanitation to further build their skills and knowledge to implement their program.

Initially, CHPs and CDEs participate in a 5-day training workshop. The training content includes the basics of water, hygiene and sanitation, how the filter works, filter construction, filter operation and maintenance, and basic filter troubleshooting. There is a strong emphasis on safe water storage as well as how to train the end user on all of the above. CHPs are trained on how to conduct basic filter tests and household surveys while CDEs are trained on basic social marketing techniques and record keeping. This forms the basis for CHPs and CDEs to begin working as part of the project. Additional training is provided at each of the monthly meetings.

ACI project managers deliver refresher training to CDEs as needed. They use the information from their monitoring program to help them identify common problems and areas that need additional training.

CHPs have monthly meetings where training is an integral part of the agenda. They review lesson plans with the project manager for the sessions to be delivered at the schools in the next month. Project managers also provide refresher training based on monitoring data during the monthly meetings.

End user training is done by the CDE at installation and during each of the follow-up visits by the CHP. The CDE provides the training on filter maintenance once it has been requested by the household.

Currently, CHPs are teaching end users filter use, maintenance, safe water storage, and hand washing at critical times. ACI plans to expand this content. They recognize this is also a good way to introduce sanitation improvements and options for low cost sanitation.

CHPs are also working to build the capacity of students at the schools where the CDE businesses are based. CHPs deliver twice monthly education sessions with the Water & Hygiene Clubs and school representatives. This strengthens their local partnership with the school and community.

Program Financing

ACI subsidizes their staff costs as well as education and follow-up to the users and schools. The end users pay the complete hard cost of the filter and safe storage container.

ACI receives funding for education and project management through a variety of sources, including individuals, foundations and corporations.

References

Rumpsa, C. Personal communication, August 2011.

Rumpsa, S. Personal communication, August 2011.

Further Information

Aqua Clara International: http://aquaclara.org/

CAWST, Centre for Affordable Water and Sanitation Technology
Calgary, Alberta, Canada
Website: www.cawst.org Email: cawst@cawst.org
Wellness through Water.... Empowering People Globally
Last Update: August 2011

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

CLEAR CAMBODIA

Introduction

Clear Cambodia is a local faith-based non-governmental organization (NGO). Their mission is to transform water quality, sanitation and health in target communities by making appropriate technology and education accessible to all. Clear separated its operations from Hagar Cambodia in 2010 to focus on its own mission and vision.

They were originally trained by Samaritan's Purse in 1999 and have received follow-up support from CAWST. As of November 2010, Clear has implemented 67,000 biosand filters in the country. Currently, their project consists of five teams and works in five provinces (Kampong Thom, Prey Veng, Svay Rieng, Kampong Chhnang and Pursat). Their target for 2010 was to install another 15,600 biosand filters.

Creating Demand

In general, people in Cambodia already have a high awareness about household water treatment. This was achieved through mass media communications (e.g. television and radio broadcasting), implementation by NGOs, and cooperation with government in their community plans for water, health and sanitation.

Clear raises their own awareness and creates demand for the biosand filter by conducting promotion meetings in the target villages. The meetings are usually held with schools and general community groups. They meet with each group twice in the first stage (promotion and health education) and then follow-up meetings are conducted after the filters have been installed.

Their community outreach and health education teams use a variety of tools and communication methods to reach their audiences, including posters, leaflets, booklets, videos and presentations.

Some of their awareness and education materials were prepared by Clear themselves, while others were provided by Samaritan's Purse, CAWST and UNICEF.

Community health promoters, who are volunteers selected by village leaders, are trained to support the Clear staff in promoting the biosand filters and providing education to recipients. They receive at least one day of training and then apprentice with Clear staff for a period of time, such as one week or longer depending on need and situation of the community. Competent community health promoters may be contracted later by the program to conduct monitoring work or follow up visits.

Seeing others experiencing the benefits has also been powerful in creating demand within villages. Clear reports that others who have seen the benefits of the filters want the same thing for themselves, and have sent written requests for filters to be installed in their villages as well.

Clear is incredibly successful at demand creation and has learned that collaboration with local community leadership and community meetings are the crucial entry points. People usually request a filter when they understand, accept and value the technology, and know why they get sick from contaminated water. The demand is actually beyond the program's capacity. To date, Clear still has 150,000 filter requests outstanding.

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

Supplying Products and Services

Clear employs Cambodian staff to manufacture and distribute biosand filters. They use travelling teams that transport the molds and tools required to build the filters at temporary work sites in each village. The team includes staff to supervise construction and conduct the community outreach and health education. They will spend several weeks in the village until the demand has been satisfied before moving onto the next.

Most construction materials are found locally, however filtration sand is transported by truck from a centralized source in one province to ensure quality control.

The full cost of a biosand filter and safe storage container is about US$60 (including transport, labour and education). Clear subsidizes the filters to make it affordable for those that cannot pay the full cost. The Village Development Committee identifies the poorest households in the village, and they have first priority to receive filters. Clear requires the following from a family before they can get a filter:

1. Contribute US$4 to partially pay for the cost of the filter
2. Contribute labour (e.g. mixing concrete and washing sand)
3. Transport the filter from construction site in the village to their house
4. Attend the BSF promotion meeting, the health and hygiene promotion meeting, and be present at follow-up visits

Households are also required to sign a contract committing them to properly using and maintaining their filters. If the filter is observed to not be in use after two follow up visits, it is taken away and the US$4 is given back to the household.

Clear also sells biosand filters to wealthier households who are able to pay the full cost.

Monitoring and Improvement

Clear has established a follow up visit schedule to monitor the biosand filters:

- 1st visit – 1 month after installation
- 2nd visit – 3 months after installation
- 3rd visit – 6 months after installation
- 4th visit – 12 months after installation

Monitoring is usually done by community health promoters who complete questionnaire forms that are submitted to Clear staff. As of 2011, monitoring will be changed to from paper forms to digital, and will be done by staff. Monitoring of older filters will still involve community health promoters.

The monitoring information is used later by the program to consider what should be implemented next.

The program has had some challenges in monitoring the filters that were purchased at full cost. They cannot monitor the filter when there is an individual household located far from the project area. Clear suggests that when a household wants to purchase a filter, they should cluster themselves with at least five households in the same area to buy filters. This makes it more cost effective for Clear to do follow up and check their filters.

Program Financing

Samaritan's Purse has fully funded all of Clear's work, and in addition, actively provide programmatic support.

References

Chee, S. Personal communication, December 2010.

Heng, K. Personal communication, July 2010.

Further Information

Clear Cambodia: http://clearcambodia.org

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

TEARFUND AFGHANISTAN

Introduction

Tearfund is an international relief and development agency based in the United Kingdom. They are working globally to end poverty and injustice, and to restore dignity and hope in some of the world's poorest communities. Tearfund has been operating in Afghanistan since 2001.

Tearfund believes strongly in supporting the development of sustainable livelihoods through their water, hygiene, and sanitation (WASH) programs. They are seeing success with a demand-led approach to implementing WASH interventions in post-conflict settings.

As of June 2011, Tearfund Afghanistan has implemented more than 15,000 biosand filters in 15 districts in 4 provinces. 7,000 of these filters were produced and sold by local artisans who are trained and supported by Tearfund.

Creating Demand

To create demand, Tearfund uses 2 participatory approaches in sequence – Community Led Total Sanitation (CLTS) followed by Participatory Hygiene and Sanitation Transformation (PHAST). CLTS is a mobilization approach to "ignite" the community to desire change. CLTS confronts a community about their dirty environment and provokes a decision by the community members to stop open defecation and build latrines.

After the community recognizes the role of sanitation for good health, Tearfund will facilitate PHAST methods, to educate the communities about the need for good hygiene, in particular hand washing with soap or ash.

These two promotion and education approaches set the foundation for community members to demand safe water. Biosand filters are promoted in areas where people are using open canals and streams

Biosand Filter Shop Opening Ceremony, Kapisa

that pass by their homes as their source of water. Tearfund works with artisans who market and sell the biosand filters in their communities. Together, they work closely with local Mullahs to receive their endorsement and promotion at religious gatherings. The support of religious leaders is critical in most communities to gain acceptance of new technologies and ideas.

Artisans initiate community demonstrations at schools, clinics and mosques. Successful artisans have also opened biosand filter shops to create and meet demand. As part of the initial promotion, Tearfund invited government officials, as well as religious and community leaders to endorse the shop at a grand opening ceremony. In some cases, television, radio and newspaper media are also invited to give the shop additional publicity and credibility.

While artisans promote the products locally, Tearfund has invested in a large-scale marketing campaign for biosand filters, advertising them on billboards, TV, radio and leaflets. Prior to implementing biosand filters, Tearfund had already used radio broadcasting for raising awareness about good hygiene practices and community development issues. They used this as a basis for developing the campaign for biosand filters. The social marketing approach has been successful at raising awareness about the technology and creating demand.

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

Government support of biosand filters has been integral to implementation and expansion of projects. Tearfund has lobbied the Ministry of Rural Rehabilitation and Development (MRRD) to amend the National WASH Policy to include the biosand filter as an appropriate WASH option in Afghanistan.

Supplying Products and Services

Tearfund staff are responsible for the marketing campaign, tools and education initiatives that accompany the biosand filter project.

Local artisans are selected in conjunction with the local government and community development committees to operate biosand filter businesses. Tearfund provides the artisans with:

- Training in filter production, installation and monitoring
- Materials for promotion and marketing
- Steel molds
- Ongoing support through joint monitoring visits with Tearfund staff
- Refresher training, as needed.

Artisans will manage between 1 and 2 molds as part of their filter business. Initially, in areas where the biosand filter was unknown to the community, Tearfund donated filters to selected households to help create demand. After a period of time, the retail cost of a filter was charged to other households.

A memorandum of understanding was signed with the artisans setting the retail cost of the filter at US$6 with US$2 in profit to the artisan. Over the last three years the price has risen to US$22 with US$9 in profit. The price adjustment reflects the willingness and ability to pay by community members. The full cost of a biosand filter is about US$30 (including materials, labor, education and marketing).

The artisans source and prepare the filtration sand and gravel as well as produce the concrete filter box. To assure and maintain the quality of the filters, Tearfund staff work closely with the artisans to train them in all stages of production through to training of the end users.

Monitoring and Improvement

During the implementation phase, Tearfund staff conduct household visits to monitor the project. They also provide artisans with monitoring and follow-up forms so that they have the tools to monitor their business. Artisans are not required to report back to Tearfund with the results of their day-to-day monitoring of the business. Side-by-side monitoring visits with Tearfund staff help the artisans to identify problems and take immediate action to correct any issues.

Community Water Groups are also engaged to help monitor the biosand filter projects. The groups are trained by Tearfund to manage different aspects of WASH in the community, including knowledge of the biosand filter and basic troubleshooting. Participation in the group is voluntary.

While the promotion and direct implementation phase by Tearfund has completed in some districts, they still have a presence in those districts for other projects. This presence enables them to do periodic monitoring of previous projects and receive feedback from various stakeholders; however, monitoring after the project has closed remains a challenge. There is no one responsible for regular monitoring and follow-up activities.

Tearfund is seeing significant improvements in the health and well-being of communities in Kapisa Province. Livelihoods have been improved for filter artisans and their families. District health clinics in targeted communities have also reported a 61% reduction in water-related diseases since the projects began.

Building Human Capacity

A key component of Tearfund's program is to build the capacity of the people involved in the project. They were originally trained in biosand filter implementation by BushProof. Since then, CAWST and the Danish Committee for Aid to Afghan Refugees (DACCAR) continue to provide additional training and follow-up support to Tearfund staff.

Household Water Treatment and Safe Storage Implementation Case Study: Biosand Filters

Artisans, initially, receive 5 days training on biosand filter construction, installation, operation, maintenance and troubleshooting. Tearfund also trains the Community Water Groups and does side-by-side monitoring visits with artisans and Water Group members. Refresher training is also provided as Tearfund identifies different needs.

Artisans do the initial training of the end users and are a resource for larger problems the users may encounter. Community Water Group members will also provide ongoing support to users in the community.

Tearfund remains active in the target districts. They are called on for support, periodically, by artisans.

Tearfund reports that, "*the high demand for filters in Kapisa Province has resulted in interest from other technicians to receive training on their manufacture*." To meet the demand, Tearfund has collaborated with UNICEF, DACAAR, and CAWST, to deliver biosand filter technician training to additional artisans.

Program Financing

Tearfund Afghanistan's WASH activities are funded through a variety of sources including UK Department for International Development (DFID), Bureau for Population, Refugees and Migration (BPRM), UNICEF, Canadian International Development Agency (CIDA), and trust funds.

Funding from the international community for relief and development activities in Afghanistan is being reduced as it withdraws from the country. Tearfund is hopeful the demand-led basis of the program will enable ongoing gradual expansion of the biosand filter. In the meantime, they are seeking other institutional funds to continue their efforts in Afghanistan.

References

Alemu, D. Personal communication. August 2011.

Burt, M.J. Personal communication. August 2011.

Burt, M.J. *Effective Emergency WASH Response Using Demand-Led Methods: Case Study from Afghanistan*. 35th WEDC International Conference, Loughborough, UK, 2011.

Greaves, F. Personal communication. August 2011.

Tearfund (2009) DFID *WASH Interim Report 2: Capacity building to improve humanitarian action in the water sanitation and hygiene (WASH) sector.* Unpublished paper. Teddington, UK: Tearfund.

Further Information

Tearfund: www.tearfund.org

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Implementation Case Study: Ceramic Pot Filters

RESOURCE DEVELOPMENT INTERNATIONAL (RDI), CAMBODIA

Introduction

Resource Development International (RDI) – Cambodia is an international NGO based in the USA. They have implemented various projects to provide safe water to rural villagers of Cambodia, including household water treatment, arsenic research and testing, rainwater harvesting, water supply and sanitation.

RDI has been manufacturing and distributing ceramic pot filters, called Ceramic Water Purifiers, in Cambodia since 2003. Their program originally started on a small scale as they developed their manufacturing techniques. They have scaled up over the years and in 2007 distributed 24,000 filters to households. In total they have distributed approximately 60,000 filters throughout Cambodia and internationally.

Creating Demand

RDI believes that user education is one of the most important aspects of a ceramic filter implementation program. Research conducted on their program confirms that filters are more likely to be used by households that already have some knowledge of safe water, sanitation, and hygiene practices.

RDI developed an extensive education program that links with the distribution of filters and their other programs (such as such as school rainwater tanks and hand washing). RDI creates their own education materials, including instruction brochure provided with filters, posters, flip charts and video.

They have developed key messages which are reinforced consistently with villagers, community members, and distributors to ensure correct filter use and maintenance practices are retained and implemented.

RDI has also found that it is very important for uptake to have the support of the village Group Leaders. They engage the Group Leaders by meeting to discuss the importance of safe drinking water and ceramic filters. The Group Leaders are normally given a filter which gives them an opportunity to try it out, understand how it works, and ask questions. RDI has found that this increases their support for the filter and provides an opportunity for demonstration within the community. If the Group Leader is convinced, they are given about 10 ceramic filters to sell to community members at a personal profit.

RDI also targets schools for education and promotion of ceramic water filters. Similar to the Group Leaders, teachers are often respected members of the community with recognized education and knowledge that give the filters credibility.

Two water filters are provided for each classroom in the school at no cost. RDI establishes letters of agreement with the schools to ensure there is clear understanding of the roles of the school in maintaining the ceramic water filters, along with other water, hygiene and sanitation facilities installed at the same time.

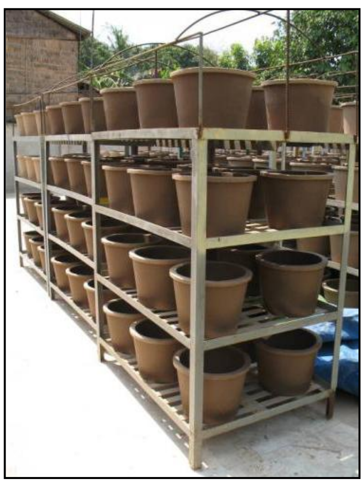
Household Water Treatment and Safe Storage Implementation Case Study: Ceramic Pot Filters

Teachers are responsible for maintaining the classroom filters. They are given training about safe drinking water, and filter manufacturing, use and maintenance. RDI also provides each teacher with a filter for use in their home, and conducts a follow up home visit. Teachers are also given the opportunity to become filter distributers.

Using a puppet show, RDI's educational team teaches up to 50 students at a time about health, hygiene and safe drinking water. Students are also given free water bottles to encourage the use of safe water.

Supplying Products and Services

RDI developed its initial product requirements, manufacturing process, and maintenance instructions over a 12 month period prior to the release of its first filter.



RDI manages a factory themselves in the Kien Svay district of Kandal province where they employ local skilled staff who are paid on an hourly basis. The cost to produce a ceramic filter is US$7.

RDI uses a number of different methods to ensure the filters are accessible to community members following manufacture. They have factory-based sales direct to users in Kandal province and to NGOs and government agencies in Cambodia.

In addition, 26 retailers and one distributor are operating in Kandal and Siem Riep provinces on a full cost recovery plus profit basis, accounting for one-third of total sales. The retail cost to users is US$8 and US$2.50 to replace the filter element. Other sales are direct to communities using mobile marketing and education teams. Using these different distribution strategies, RDI is able to sell about 23,000 filters a year at full cost.

A comparatively small number of filters are also distributed at subsidized cost to villages in NGO-led programs in Kandal province. The subsidized filters are targeted to the poorest households and costs vary from US$1 - $7.

A study of the RDI filters conducted by Brown et al. (2007) shows that investment, at any level, by the household was associated with continued filter use versus receiving the filter for free. Other NGOs and government agencies purchasing filters from RDI who distribute the filters free of charge which could negatively impact the overall commercial market that RDI has created.

RDI also believes that their filters are not a passive product; they require ongoing management and maintenance by users. Therefore, supplying support services to households is essential for the ongoing and appropriate use of ceramic filters. Key issues that are considered in RDI's distribution strategies are:

- Ensure appropriate training and education material is provided to the distributor in the short and long term so that they are capable of explaining the operation and maintenance requirements and providing on-going service to consumers (e.g. and answering questions about the filter)
- The distributor needs access to educational and instructional material to provide to the end user to ensure correct maintenance is conducted in the long term
- An ongoing connection between the distributor and the community is important to provide a contact point for filter replacements, purchases and service support

Household Water Treatment and Safe Storage Implementation Case Study: Ceramic Pot Filters

Monitoring and Improvement

RDI has a monitoring program to ensure that they manufacture high quality filters. Flow rate tests are carried out on every filter to ensure it is within the tolerance range. The filter elements are also examined for cracks and other defects at every production step, and removed from the process if they do not meet requirements. Each filter is stamped with a with a date, serial number and manufacture's name.

RDI also tracks the filters sold, and periodically goes back to the community and runs tests on the filters to verify that they are still functioning properly.

Their manufacturing and education method has been developed over 3 years and is continually reviewed and improved. Currently RDI is reviewing its fuel source for the kilns and piloting the use of compressed rice husks as a more sustainable fuel.

RDI is also the largest water quality tester in Cambodia. It provides water quality testing services for many NGOs and companies, and provides laboratory facilities and trained staff for partnership research with international universities. This experience and background increases RDI's ability to test, research and continue to develop ceramic water filter technologies.

RDI is open to sharing their knowledge and best practices with other implementers. With support from Engineers Without Borders Australia (EWB Australia) they released the RDI Ceramic Water Filter Factory Manual. This document provides information on the manufacture, education and distribution of ceramic filters to support other implementers who are interested in introducing factories to new communities.

They have also actively participated in external evaluations conducted and published by the Water and Sanitation Program in Cambodia.

Program Financing

Funding for RDI's program activities are provided by individuals and donors. Costs are also partially recovered through direct sales to users and to NGOs and government agencies in Cambodia.

RDI also actively encourages international volunteers to visit and support their Cambodian staff.

References

Brown J, Sobsey M and Proum S (2007). Improving Household Drinking Water Quality: Use of Ceramic Water Filters in Cambodia. Field Note, Water and Sanitation Program. Cambodia Country Office, Phnom Penh, Cambodia. Available at: www.wsp.org

Hagan JM, Harley N, Pointing D, Sampson M, Smith K and Soam V (2009). Ceramic Water Filter Handbook, Version 1.1. Resource Development International, Phnom Penh, Cambodia. Available at: www.rdic.org/waterceramicfiltration.htm

Further Information

RDI-Cambodia: www.rdic.org

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Implementation Case Study: Ceramic Pot Filters

THRIST-AID INTERNATIONAL, MYANMAR

Introduction

Thirst-Aid International is an NGO headquartered in the USA. Their primary focus is the prevention of waterborne illnesses that result in diarrheal morbidity and death, particularly among children under five. Thirst-Aid promotes education and knowledge as the principal tools for safe water intervention, inspiring the drive for improved water quality to come from within communities prior to the introduction of household water treatment technologies.

Thirst-Aid has been implementing ceramic filters in Myanmar since 2004. Their current project started in February 2006 and they have distributed approximately 200,000 filters in the country, providing about one million people with safe drinking water. They have also responded to emergency situations, such as providing filters after the 2005 tsunami that affected Southern Thailand and the 2008 cyclone in Myanmar. Thirst-Aid's plans to scale up to reach an additional 14 million people in Myanmar.

In addition to implementing ceramic filters themselves, Thirst-Aid is also working with the private sector to create a market. They have set up ceramic filter factories in the country, who ultimately become independent commercial manufacturers. Their work is supporting the development of the private sector by helping to build capacity and empowering local people.

Creating Demand

Thirst-Aid creates demand for safe drinking water by promoting education and knowledge as investment capital. They base their approach on the assumption that educated people do not willingly drink contaminated water – much less give it to their children.

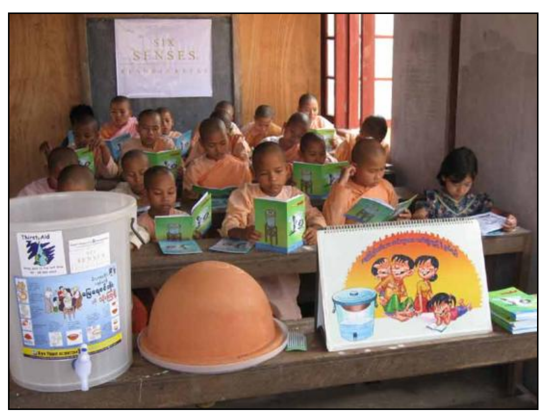
They use a marketing campaign that targets the population that can afford ceramic filters. There are two filter models, one for the middle class and one for the working poor.

Thirst-Aid staff conducts awareness raising and education with a variety of target audiences, including women's groups, schools, monasteries, orphanages, community based organizations, NGOs and international NGOs. They meet and follow up with the different groups as often as necessary.

Their staff use a variety of education tools and communication methods, including billboards, posters, games, flip charts, hands on practice and videos. Thirst-Aid created most of their education materials, with contributions from UNICEF. The government supports the program by approving their education materials before use.

Thirst-Aid provides the currency for community buy-in by issuing *Certificates of Knowledge* upon successful completion of their educational program. These certificates serve as legal tender that can be later used for the purchase of household water treatment technologies.

Thirst-Aid emphasizes that in order to create demand, the filters should not be viewed as a give-away product for the poor. They should be marketed as a desirable, easy to use and effective product for everyone who needs improved water.



Household Water Treatment and Safe Storage Implementation Case Study: Ceramic Pot Filters

Supplying Products and Services

Thirst-Aid first started with their own ceramic filter factory that employed local staff to manufacture filters for distribution through larger and international NGOs.

Thirst-Aid has since established eight ceramic filter factories in Myanmar. Once fully operational, the facilities are turned over to local people as income generation projects.

It has taken Thirst-Aid at least two years of training and support to make sure that the manufacturers truly understand the entire process; and that quality, production, and the market can be sustained. Based on their experience, Thirst-Aid recommends that new implementers do not start ceramic filter production unless they are willing to maintain a long-term presence and are certain of a sustainable market.

The units sell for between US$8 to $19 depending on the receptacle, distance from source, and manufacturer. Currently, filters are typically sold to international NGOs who have their own objectives and distribution methods, they have not agreed on a common standard.

While some NGOs distribute fully subsidized filters to households, Thirst-Aid advocates for them to be a commercial product and not something that people view as something that should or will be given to them. Thirst-Aid anticipates the biggest obstacle will be NGO's giving filters away without requiring recipients to invest at some level. It is difficult for Thirst-Aid to promote and market filters through the private sector if households believe it is a product for the poor and that if they wait long enough they might receive one for free.

Monitoring and Improvement

Thirst-Aid has a monitoring program to ensure quality control of their filter production process.

Most of the filters currently in use were distributed by NGOs in response to Cyclone Nargis, and as funding for this disaster has been used, there is currently little follow-up or monitoring being done by any organization besides Thirst-Aid.

Thirst-Aid also supports continuous improvement of implementation programs in the region. With support from UNICEF, they organized the "Myanmar Ceramic Water Filter Summit; Post Nargis Evaluation – Lessons Learned" that was attended by 13 international organizations, including several from Cambodia and Thailand.

Program Financing

Thirst-Aid's education component takes up about 75% of their project implementation resources, in terms of both money and time. Thirst-Aid recommends that other implementers should be willing to invest as much in education and training as they do in the technology. Funding for Thirst-Aid's awareness raising and education activities are provided by donors and partners, including UNICEF.

Most of the private sector manufacturers have already recovered their costs (including promotion, production, distribution and follow-up) and have a price system that will make it possible for them to earn an adequate profit.

References

Bradner, C. Personal communication, July 2010.

Further Information

Thirst-Aid: www.thirst-aid.org

Household Water Treatment and Safe Storage Implementation Case Study: Air RahMat Chlorine

AMAN TITRA, INDONESIA

Introduction

Aman Tirta is a public-private partnership that was created to manufacture, promote and distribute a liquid chlorine solution (called Air RahMat) and safe water storage in Indonesia. In an effort to promote safe water, Aman Tirta has also been working with the government of Indonesia to improve the policy and enabling political environment for household water treatment and storage (HWTS) in the country.

Program partners include:

- John Hopkins Bloomberg School of Public Health/Centre for Communication Programs – overall program management, communication and behaviour change interventions
- CARE International (NGO) – community participation component
- Lowe Worldwide – product promotion and marketing
- PT Tanshia Consumer Products – manufacturing, distribution, marketing and product development
- PT Ultra Salur – exclusive distributor
- Local retail outlets – product sales across the country

Air Rahmat, Indonesia
(Credit: Tirta/JHUCCP)

The program follows two approaches to increase access to safe water:

1. **Stimulating the commercial sector** to manufacture, distribute and market a product that makes water safe to drink through disinfection and appropriate safe storage at the point of use at affordable prices on a national scale; and
2. **Creating demand** through a strategic behaviour change program that effectively promotes and positions the product in the market place and maximizes linkages with Indonesian NGOs to increase its adoption.

Aman Tirta has been working closely with the private company PT Tanshia to prepare for the ultimate transfer of the program to the company after the end of the project.

Creating Demand

Air RahMat is targeted to middle-low income mothers with children under five. Its promotion and sales were rolled out using a phased approach in various locations across Indonesia over a period of several years – starting with the product launch in Jakarta in 2005.

The aim of the communication and marketing strategy is to raise awareness and get people to try Air RahMat. It promotes Air RahMat as an easy-to-use and affordable option for safe drinking water, endorsed by the Ministry of Health. Education materials and communication methods included posters, leaflets, radio and television spots, and mobile demonstration trucks giving away free water samples.

At the same time, a strong community mobilization effort, led by local NGOs, plays a significant and active role in increasing knowledge and education on safe drinking water. This is done through person-to-person communication, community dialogue and action. Mobile sampling 'road shows' were used throughout the country. These road shows provided information, games, quizzes, water samples, interpersonal communication, and dialogue with community members.

Aman Tirta also worked with government institutions in the areas of health and education to expand coverage.

Research and monitoring of advertising and sales trends initially showed that the program was effective at raising awareness of the product, but that people weren't necessarily buying it. This resulted in a change in advertising strategy, to better target mothers (e.g. through advertising in women's tabloid magazines), focusing on the believability of the ads and the product claims, and increasing the mobile sampling teams so people could try the water. Sales increased in the fourth year of the program following these changes and other initiatives.

Supplying Products and Services

The chlorine product was originally developed as part of the Centre for Disease Control and Prevention (CDC) Safe Water System (SWS) program which includes both disinfection and safe storage.

Air RahMat is manufactured and bottled in Indonesia by PT Tanshia. It is distributed extensively through both traditional retails outlets (e.g. stores and kiosks) and non-traditional outlets (e.g. community-based organizations (CBOs), NGOs, micro-credit organizations and community health volunteers). Distribution is managed by PT Ultra Salur, a private company.

Due to Aman Tirta's efforts to expand the market, the number of retail outlets selling Air RahMat went from 8,500 to over 15,000 in the fourth year of the project.

Air Rahmat is sold in 100 mL bottles – enough to treat 660 litres of water, or the average amount used in a household in one month. The bottle is sold for Rp 5,000 (about US$0.50). In 2008, $597,511 was invested in the program. In the same year, 71,000 bottles and 548,000 sachets of Air RahMat were sold. PT Tanshia also developed a 3 mL one-use sachet, which entered the market in 2008.

Monitoring and Improvement

The product manufacturer, PT Tanshia, established a laboratory on-site to assist with product quality control and research and development.

A Health and Economic Impact study was completed mid-way through the project. It showed that people's attitudes towards chlorination and their decisions to use Air RahMat were positively impacted through the project activities. It also showed a health impact, observable through a 50% decrease in diarrhea incidence, and safer stored water in the homes of those using Air RahMat and the purchased safe water storage container.

The slower pace of sales than targeted indicated that behaviour change for household water treatment may be slower than anticipated.

Program Financing

US Agency for International Development (USAID) funded the 6-year program that ran from 2004 to 2010.

References

Aman Tirta Program:
www.airrahmat-indonesia.com

John Hopkins University:
www.jhuccp.org/node/755

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Implementation Case Study: Aquatabs

PATH, VIETNAM

Introduction

Over the past several years in Vietnam, great strides have been made in raising awareness of households to the benefits of treating water through boiling. While most Vietnamese households now boil their water before consumption, there is still a sizable segment of the population that does not choose to boil. This creates a need for some other means of household water treatment and safe storage (HWTS).

Since 2008, PATH, an international non-profit organization committed to improving global health, has been working to better understand the environmnent for HWTS in Vietnam and how both awareness and treatment of household water can be improved. A component of this work is to better understand how commercial enterprises can produce, distribute, and support correct use of HWTS for low-income populations.

PATH's work in this area has included both research and targeted interventions through partnership with both public and private organizations. Research studies from 2008 to 2010 identified an opportunity for a public/private collaboration with Medentech, Zuellig Pharmaceuticals, and local district medical centers (DMC) in the the Mekong Delta region of Vietnam.

The Project

To complement boiling practices and to fill gaps in water treatment, the partners designed a pilot study to introduce the chlorine-based water treatment product, Aquatabs, to 4,200 households in two disctricts of Can Tho province. The pilot sought to create a new distribution channel for Aquatabs by making the product available through the health station collaborators (HSC) working with local DMC.

Product sales were supported by demand generation activities such as social marketing events, while correct water storage was encouraged through the distribution of free safe water storage containers to many households in each district.

Creating Demand

Historically, retailers, wholesalers, and even distributors have not carried new HWTS products in Vietnam for which the public has not yet expressed a desire, nor will they shoulder the burden of educating the public about them. As such, HWTS manufacturers need to create "pull" in channels that do not have much "push" (PATH, 2010).

To help create the pull, or demand, PATH used a combination of social marketing events and mass media exposure to promote Aquatabs to poor households and those with children under five years of age.

Social marketing events were held at least once in every commune and were led by government HSC and overseen by the DMC. The government is a common partner for outreach and education campaigns in Vietnam because it has excellent networks and reach, including clinic-based health education. Also, the government is trusted by consumers, especially by rural Vietnamese who place more trust in local leaders and institutions than outsiders (PATH, 2010).

Billboard created to encourage water treatment with Aquatabs Vietnam (Credit: PATH)

Household Water Treatment and Safe Storage Implementation Case Study: Aquatabs

Supplying Products and Services

Aquatabs is manufactured and packaged by Medentech in Ireland. The product is imported into Vietnam through the regional distributor Zuellig Pharma. Once in the country, it is transported and warehoused by DMC and the HSC sales staff based in the communes.

The product is then made available for 1,000 Vietnamese Dong per tablet to households by HSC as they visit communities as part of their normal daily responsibilities. In conjunction with making Aquatabs available, the HSC also instruct consumers on the health importance of treating water and the correct use of Aquatabs.

It was also recognized that not all households have appropriate storage containers. As such, select communes received free storage containers to test whether this will have an impact on uptake and correct and consistent use.

Building Human Capacity

In order to maximize impact of the pilot, the partners recognized the need to build the capacity of the HSC who play a critical role in the project implementation. As such, PATH, Zuellig, and the DMC trained 63 HSC through a two-day workshop focusing on water and sanitation, the benefits of water treatment with Aquatabs, and interpersonal communication skills. HSC also met regularly with oversight from the partners to discuss challenges faced and best practices in household education and to receive additional training.

Monitoring and Evaluation

Throughout the pilot, HSC captured information about the number of Aquatabs sold and household response to the pilot. These monthly reports have been compiled and will be combined with an endline survey of households performed by Abt Associates at the completion of the pilot. Results will be analyzed and made available later in 2011.

Challenges Faced

There were several challenges that needed to be overcome throughout the pilot implementation.

The first challenge was the historically low awareness of and demand for products such as Aquatabs in Vietnam. This product and others like it were not well-known before the project started and, therefore, made the demand generation activities sponsored by the pilot critical to successful acceptance by households.

In addition, chlorine-based products are not common to Vietnam and the residual taste and smell they leave in treated water is often not desired by households. Medentech has worked hard to develop a lighter chlorine taste/smell version of the product, but it still remains to be seen whether this will be acceptable to Vietnamese consumers. People often equate Aquatabs in tablet form with medication and have expressed concerns about its long-term side effects. All of these issues will need to continue to be addressed through proper education and marketing activities if the product is to succeed commercially in the country.

Finally, working through HSC presented unique challenges as well. While they were very dedicated to the project, many HSC found it difficult to spend enough time distributing Aquatabs since their other job responsibilities were also quite time consuming. Developing ways to incorporate this into their daily routine and providing proper incentives for HSC to prioritize the distribution of Aquatabs proved to be critical. Also, while sales and marketing materials were developed to assist HSC in creating demand for Aquatabs and to educate households on the benefits of treating water, they were not ready at the beginning of the pilot. Once these tools were made available, HSC feedback was that they were valuable assets to their work in the program.

About the Partners

PATH is an international nonprofit organization that creates sustainable, culturally relevant solutions, enabling communities worldwide to break longstanding cycles of poor health. By collaborating with diverse public- and private-sector partners, PATH helps provide appropriate health technologies and vital strategies that change the way people think and act. PATH's work improves global health and well-being.

Headquartered in Seattle, Washington, PATH has offices in 31 cities in 23 countries. PATH currently works in more than 70 countries in the areas of health technologies, maternal and child health, reproductive health, vaccines and immunization, and emerging and epidemic diseases. PATH's Safe Water Project is working to enable commercial enterprises to produce, distribute, sell, and maintain good-quality HWTS products for low-income populations.

Medentech, the manufacturer of Aquatabs, is committed to driving a significant positive health impact globally by improving access to safe drinking water and reducing surface and environmental contaminations by developing, manufacturing and marketing cost-effective disinfection solutions. Medentech is headquartered in Wexford, Ireland, with distribution agents in over 60 countries worldwide.

Zuellig Pharma Vietnam Ltd. is the largest multinational service provider for pharmaceutical and health care products in Vietnam. They distribute approximately 20 percent, by value, of the total pharmaceutical market in the country and partner with over 30 global principals.

The District Preventive Medicine Centers (DPMC) at Vinh Thanh and Co Do are governmental organizations working for preventive medicine and environmental health in the Can Tho province.

Program Financial Support

The Bill & Melinda Gates Foundation provides financial support to the PATH Safe Water Project. The private-sector partner, Zuellig Pharma, absorbed distribution and some marketing costs. The Vietnamese government paid the salaries for some of the HSC. Consumers pay the full cost of the product itself.

References

Vo Xuan, Hoa. Personal Communication. December 2010.

PATH (2010). Consumer and Market Research on Household Water Treatment Products in Vietnam. Available at: www.path.org/publications/detail.php?i=1796

Further Information

PATH Safe Water Project:
www.path.org/projects/safe_water.php

Household Water Treatment and Safe Storage Implementation Case Study: Piyush Chlorine

ENVIRONMENT AND PUBLIC HEALTH ORGANIZATION (ENPHO), NEPAL

Introduction

Established in 1990, ENPHO is a leading indigenous NGO in Nepal. They contribute to sustainable community development through the development, demonstration, and dissemination of appropriate technologies such as various HWTS options (e.g. chlorine, SODIS, ceramic filters, biosand filters, and arsenic mitigation), and sanitation technologies.

In 1994, ENPHO responded to a cholera epidemic among the Bhutanese refugees living in rural Eastern Nepal. After an initial site assessment, they concluded that chlorine was the most appropriate option and provided it to the refugees.

Realizing that the chlorine solution has enormous potential for wider use in the general population, ENPHO began to sell it as a commercial product from its office and in some pharmacy shops in Kathmandu. The product is registered with a brand name "Piyush", which is a Sanskrit word meaning "drinks of the gods".

Creating Demand

From 1994 until 2000, due to lack of donor and government support, ENPHO sustained Piyush promotion activities from its own internal budget, estimated at 8000-10,000 NRs per year (US$120/year). ENPHO could only afford to print some leaflets, and told others about Piyush by incorporating it as part of other training workshops of hygiene and sanitation programs. Piyush had a low profile in the market.

Starting from 2000, ENPHO started to attract increasing donor funding for HWTS promotion. This allowed them to:

- Develop additional information, education, and communication materials on Piyush
- Conduct awareness training to various schools, community associations, health clinics, and local governments
- Promote Piyush through mass media, exhibitions, and conferences

The intensity of HWTS promotion activities gained traction after 2006, when the government of Nepal, together with a number of international and national development agencies, collaborated to generically promote various HWTS options throughout the country, including boiling, SODIS, filtration, and chlorination.

Supplying Products and Services

Piyush is currently produced at ENPHO. Commercially available liquid bleach is purchased from the market, tested at ENPHO laboratory for its chlorine concentration, and diluted to achieve 0.5% chlorine concentration. ENPHO packages the solution in 60 mL bottles which are labelled, sealed, and dated. Each bottle can treat 400 litres of water, sufficient to meet the drinking water demand of an average family of 4 to 5 person for 1 to 2 months.

Previously, ENPHO tried to produce Piyush by an electric-powered chlorine generator, using salt (sodium chloride) as an ingredient. However, electricity is highly unreliable and expensive in Kathmandu, and the resulting chlorine solution degraded quickly. Therefore ENPHO prefers the current process of diluting liquid bleach.

The normal production capacity is about 2,000 bottles per day, but can reach to over 5,000 bottles by operating an extended schedule and using extra human resources. ENPHO manufactures Piyush on demand, and can fill an order within a few days.

Household Water Treatment and Safe Storage Implementation Case Study: Piyush Chlorine

Piyush is sold by ENPHO through two distinct channels. First, about 40% of the product is sold in bulk directly to institutional buyers such as UNICEF, other NGOs, or community groups, for mostly emergency response. The 12 NRs (US$0.15) wholesale price barely covers the cost of raw material and labour, with no profit margin.

The second channel is through pharmacies and retail shops. Prior to 2000, ENPHO sold Piyush directly to a few pharmacies. In 2001, ENPHO signed an agreement with New Loyal Medicine Distributor, one of the largest medical suppliers in Kathmandu, to exclusively sell Piyush through their network of regional distributors, and 800+ pharmacies and some retail shops within the Kathmandu Valley. The wholesale price from 2001 to 2009 was 12 NRs per bottle. The retail price during the same period had been 17 NRs per bottle. The 5 NRs profit margin is shared among the supply chain actors.

From 2009, ENPHO started to use Nepal CRS Company as a super-distributor because of its wider networks that can reach the entire country. To pay the extra transportation cost, Nepal CRS requires an 8 NRs margin to be shared among the supply chain, resulting in a standard 20 NRs cost to consumers across the country.

Monitoring and Improvement

ENPHO has an on-site accredited laboratory to test the chlorine solution to ensure product quality control, and to conduct research and product development.

Program Financing

ENPHO is dependent on external funding to support their promotion and education activities, and is vulnerable to funding fluctuation. They do not earn a profit margin from Piyush, and ENPHO is reluctant to raise the price due to intense competition from other chlorine products.

Competition

In 2005, Centres for Diseases Control (CDC) and Population Services International (PSI) of USA, introduced a rival chlorine solution, branded as WaterGuard in Nepal. WaterGuard is manufactured in Nepal by a bottled water company, and is sold in 250 mL bottle at a retail price of 35 NRs.

During the first two years, PSI implemented a large-scale social marketing campaign. They used mass media communications (e.g. advertisements on TV and radio), put up billboards throughout the city, and gave away free samples of WaterGuard to both households and institutional buyers.

On the one hand, WaterGuard expanded the market and achieved remarkable sales of more than 500,000 bottles (including free distribution) during this time. On the other hand, WaterGuard took away some customers who previously purchased Piyush. In particular, during 2005-2006, institutional buyers did not purchase Piyush as they could obtain WaterGuard for free or at nominal costs. WaterGuard took 80-90% of the market share of chlorine solution sales in Nepal by the end of 2006.

Yet, ENPHO, as a local NGO, lacked the capacity and resources to compete with CDC/PSI. They responded by negotiating a short-lived strategic alliance with PSI to promote Piyush and WaterGuard in parallel. In 2007, funding to PSI was terminated, and the sales of WaterGuard decreased.

In 2008 and 2009, ENPHO obtained some funding from Academy for Educational Development (AED) to promote Piyush and to build up ENPHO's social marketing capacity. Together with the government's initiatives to promote HWTS in general, sales of Piyush surged to over 300,000 bottles by 2009. Their market share of chlorine solution improved to over 40%.

Challenges to Scale Up

1. Chlorine as medicine. Because Piyush is sold mostly through pharmacies, the product is often seen as a medicine to be used temporarily, during the rainy season when the water is visibly more dirty, or when episodes of cholera or other water-borne diseases are becoming prominent in the daily news.

2. Competition. Many types of water treatment options, such as WaterGuard, ceramic filters, SODIS, boiling, are readily available in the market.

Household Water Treatment and Safe Storage Implementation Case Study: Piyush Chlorine

3. Funding support. ENPHO is vulnerable to fluctuations in donor funding.
4. Low interest among shopkeepers to sell Piyush. Because the margins given to Piyush distributors and retailers are very thin and the sales volume are low (e.g. a few bottles per month per shop), some shops are not interested to carry Piyush, and many are reluctant to display Piyush at more prominent positions within the shops.
5. Lack of product certification. Despite asking for years, ENPHO has never been able to obtain government certification of the effectiveness of Piyush for water treatment (neither did WaterGuard). Some medical doctors and local professors in Nepal claim that chlorine causes cancer, so some people are scared of using the product. It is believed that certification can improve the image of Piyush among potential buyers (both households and institutional), and can assist ENPHO in attracting donor funding.

Piyush promotion billboards in Kathmandu city

ENPHO's Piyush bottle labelling

References

Ngai, T (2010). Characterizing the Dissemination Process of Household Water Treatment Systems in Developing Countries. Dissertation Submitted for the Degree of Doctor of Philosophy. Centre for Sustainable Development, Department of Engineering, University of Cambridge, UK.

Further Information

ENPHO: www.enpho.org

CAWST, Centre for Affordable Water and Sanitation Technology
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Wellness through Water.... Empowering People Globally
Last Update: September 2010

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Implementation Case Study: *WaterGuard* Chlorine

Household Water Treatment and Safe Storage Implementation Case Study: *WaterGuard* Chlorine

POPULATION SERVICES INTERNATIONAL (PSI), MYANMAR

Introduction

PSI is a global health organization that targets reproductive health, malaria, child survival, HIV and safe water. Working in partnership with the public and private sectors, and using the power of commercial markets, PSI provides products, clinical services and behaviour change communications to empower the world's most vulnerable populations to lead healthier lives.

PSI/Myanmar was founded in 1995 with an early focus on HIV prevention that expanded into reproductive health and STI treatment. In 2001, PSI/M added malaria prevention products to its portfolio, which now also includes household water treatment.

PSI/M promotes *WaterGuard* chlorine solution with hygiene practices, such as hand washing and safe water storage.

Creating Demand

PSI/M's target population is children under the age of five and their caregivers.

They use social marketing, mass-media and mid-media communication campaigns, brand attachment, and health education to raise awareness at the village, small group and household levels.

Their Interpersonal Communicators (IPC), paid PSI/M staff, raise awareness in villages using communication sessions and *edu*tainment with mobile video units. Health education is targeted to small groups of 5-10 people in places of general community gatherings. Small group meetings are held at least once per year per township. Household visits are conducted once a month by PSI/M's community health promoters, known as Sun Primary Health Providers (SPH) who are selected members from the community.

They use a variety of education tools including flip charts, pamphlets, poster boards, vinyl posters, and promotional items related to diarrhea prevention (e.g. soap).

Because the media exposure of the target population is low, peer-to-peer recommendations and word-of-mouth have proved more effective in creating demand.

Supplying Products and Services

WaterGuard chlorine solution is locally manufactured and packaged in 250 mL plastic bottles by an outsourced supplier. PSI/M distributes it through the country using non-traditional and traditional markets.

The IPCs do direct sales to end-users and SPH sell *WaterGuard* to village level target groups. The SPHs earn 50 kyats (US$0.05) per bottle of *WaterGuard* they sell.

PSI/M also acts as the national distributor for traditional outlets. Their sales team covers 640 retail outlets, such as betel nut shops and grocery stores. The franchising team covers 87 franchised clinics and SPH cover 130 outlets. The appointed national distributor covers approximately 357 outlets. Potential retailers learn about *WaterGuard* through mass media communication, sales calls, and merchandising materials.

To ensure that the products are consistently available for people to buy, PSI/M provides regular sales calls to the outlets. The shelf-life of the product is only one year, so PSI/M staff also monitors the expiry date during market visits and sales calls.

Problems sometimes occur during product delivery since it is heavy and the bottles are breakable. They have also found that distributors are reluctant to stock large quantities of *WaterGuard* because of its limited shelf life.

Users pay variable prices for *WaterGuard* depending on whether they receive it through the IPC, SPH or a retail outlet. The end-user price through an IPC or SPH is 100 kyats (equivalent to 0.1 USD), which is 70% subsidized. The end-user price through retail channels is 350 kyats (equivalent to 0.35 USD), which covers the full cost.

Product prices are determined by the affordability of the product for specific groups. Direct sales channels, served by IPC and SPH, cater to users in rural communities that require greater subsidies to access the product. Retail channels target urban and peri-urban communities that can afford to pay slightly more. PSI/M does not mark-up on the product sales but they do offer a margin for retailers.

PSI/M has learned that when the price is subsidized in the direct sales channel, there is a slight increase in consumer demand, thereby linking lower price to higher demand. Nevertheless, they can not reduce the price too significantly in traditional sales channels, since the interest of wholesalers and retailers will decrease if they do not earn a profit from selling the product.

PSI/M also realized that free distribution of chlorine by other organizations reduces the willingness of consumers to pay.

The IPC and SPH use demonstrations to educate people on how to practice chlorination. The instructions are also clearly marked on the packaging, including illustrations for less literate populations.

Monitoring and Improvement

PSI/M provides the practices, guidelines, and necessary equipment to ensure quality control during product manufacturing. The finished product is kept in a quarantine room and inspected by PSI/M staff. Only products that have passed inspection are accepted for distribution into the market.

During monthly follow-up visits, PSI/M monitors the availability of the product, and whether caregivers are using the correct dose. PSI/M also conducts quantitative and qualitative research to better understand the demographics, psychology and product awareness of their target group.

Through their monitoring, PSI/Myanmar has determined that although IPCs and SPHs explain and demonstrate the mixing instruction of *WaterGuard* thoroughly, there is still some confusion amongst the target group with respect to correct dosage and mixing instructions. Some users also fail to read the instructions on the product.

Program Financing

International donor funding subsidizes manufacturing, distribution, retailing, promotion and education of *WaterGuard*, since the product price does not fully cover these associated costs.

The Myanmar government provides departmental (lower cost) rates for *WaterGuard* TV commercials.

References

Aye Myat Myat Thu. Personal Communication. July 2010.

Population Services International. PSI. Available at: www.psi.org/myanmar

Further Information

Population Services International: www.psi.org/

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Implementation Case Study: SODIS

EAWAG & INTERNATIONAL RELIEF AND DEVELOPMENT (IRD), LAO PDR

Introduction

SODIS is a HWTS method that was first developed and tested by Swiss Federal Institute of Aquatic Science and Technology (Eawag). They conduct projects in 24 countries in Africa, Asia and Latin America. Eawag's role is to provide technical assistance, on the ground support, and in some cases funding to its partners.

Since January 2009, Eawag has been supporting International Relief and Development (IRD), an international NGO based in the USA, in the implementation of a pilot project for the promotion of SODIS in rural areas of Laos. The project is in its second phase, starting from May 2010.

Phase I was focused on 20 communities in Khammouane Province, and Phase II is working with three pilot districts in three provinces (exact number of communities to be defined). The overall target is 1,200 households and 30 schools.

From the close collaboration with the National Centre for Environmental Health and Water Supply (Namsaat), Eawag expects indirect impact through progress towards the institutionalization of the SODIS method in the framework of integrated HWTS policies and programs of health and water supply authorities.

Creating Demand

The focus of the project is on raising awareness through promotional activities with households and schools. Namsaat trains provincial and district health staff who do most of the initial community/school training, capacity building among community promoters, and monthly follow up with the groups (with on-going support from IRD).

The health staff and community promoters use a variety of education tools and communication methods to reach the different target audiences. At health centres and schools, they set up tool demonstration units (e.g. table for bottle exposure, banners, laminated sheets with information and instructions). Banners, posters and stickers are used to raise awareness in the communities. Community promoters also use role plays in schools to engage the students in learning about HWTS/SODIS and hygiene.

Community promoters (Village Health Volunteers or village representatives from the Lao Women's Union) are trained to support the district health staff by doing reminders and follow up visits with households/school groups. They attend a 2-3 day training session at the District Health Office to learn about drinking water quality, transmission pathways of pathogens, hygiene and the SODIS methodology. The community promoters volunteer their time and only receive compensation (e.g. per diem, travel, accommodation) for attending the training session. They report back to the health staff and IRD during field visits.

The pilot project has been effective in creating demand. A survey indicated that 44% of the people used SODIS, though not all of them may use the method regularly or exclusively (boiling is still practiced, and untreated water consumption is also likely). Actual SODIS use may only partly reflect the overall demand for HWTS since in some remote villages bottle availability limits SODIS use.

Household Water Treatment and Safe Storage Implementation Case Study: SODIS

Supplying Products and Services

The limited availability of plastic (PET) bottles needed for SODIS is still a major constraint for the majority of people in remote villages. However, community promoters believe if a household is really motivated to use SODIS, they can find bottles in markets they go to regularly. Bottle supply systems (e.g. a person collecting/buying bottles and transporting them to the village) have been discussed but has not been embraced by any entreprenuers. Villagers dismissed most ideas for such supply systems as unlikely to be successful because no profit can be made unless bottles were sold at a price that users are not willing to pay.

In other villages that are closer to main roads, bottles seem to be more readily available. In one village, people managed to find around 200 PET bottles within a few days for SODIS treatment at the school.

A key lesson learned was that the initial free distribution of PET bottles created expectations for regular bottle supply through the project, which is not conducive to sustainable application of the method.

Monitoring and Improvement

Monitoring of the following indicators is done during household visits by community promoters and IRD staff:

- Number of SODIS users
- Number of bottles used
- Reasons for using / not using SODIS

Surveys are also conducted by IRD staff to collect information on water sources, treatment methods, hygiene behaviour, and diarrhea incidence.

The data analysis and final reporting is managed by IRD, and the results are shared with other organizations who participate in the training, and government staff (district, province, national level) who are involved in the promotion activities.

The monitoring results show that more emphasis needs to be placed on discussing the issue of bottle sourcing in the communities when people in remote areas mentioned this as a major constraint.

Program Financing

Funding for awareness raising and education activities are provided by a private foundation based in Switzerland. Nam Saat contributes their staff time to do the community training and follow up in the framework of their regular activities.

The only cost to the household is the effort or money spent to collect PET bottles.

No income is generated in the pilot project through the sales of bottles that could allow cost recovery for the staff training, awareness raising, and education activities. Promotion through the private sector is not very likely since there is little opportunity for them to earn a profit.

Per family costs for SODIS/HWTS promotion are expected to significantly lower for scaled up implementation, i.e. when SODIS promotion is integrated into national government HWTS campaign, compared to the pilot project (Phase I: 20,000 USD for training of Nam Saat staff at district and province level, production of IEC materials, monitoring through IRD, dissemination workshop; Phase II: 30,000 USD).

References

Luzi, S. Personal communication, July 2010.

Further Information

IRD: www.ird-dc.org/

SODIS/EAWAG: www.sodis.ch