HOUSEHOLD WATER TREATMENT AND STORAGE

Historically, interventions to provide people with safe water have focussed on improving water sources. However there is now a consensus among the WatSan community that even if the drinking water source is safe it can easily be re-contaminated during its transportation and storage in the household (Clasen and Bastable, 2003). A safe water intervention should therefore begin with an improved water supply and be followed by safe water collection, handling and storage. In circumstances where the source is not deemed safe, point of use water treatment should be performed. All of these should be coupled with hygiene promotion activities to ensure correct understanding, use and maintenance of the hardware.

This technical brief presents the current options for safe storage and point of use water treatment. It is intended to help field staff working in a variety of locations to decide upon the most appropriate course of action for providing safe water for the communities in which they work. The effectiveness of household water treatment options now and in the future rely to a huge extent on user compliance; it is critical that users are involved in the decision making process, and are aware of the PUR®pose, how to use, maintain and manage their household water options. The brief therefore details relevant hygiene promotion steps for the different treatment options.

Introduction

The main objective of an intervention to improve household water quality is to ensure that the water consumed will not produce disease - this is especially important for the under 5 age group who experience a large proportion of the morbidity and mortality associated with diarrhoeal disease, and for people with suppressed immune systems such as those suffering from HIV and AIDS. Also critical is that the appearance, taste and colour of the water are acceptable to the consumer.

Water and sanitation programmes working to achieve high drinking quality water are starting to focus on reducing contamination throughout the whole water chain, from the source to the point of consumption. This is based on years of comprehensive research which has shown that interventions to improve water quality at the household level, through safer household water handling, storage and treatment, are about twice as effective as those at the source, due to the ease at which water can be contaminated during these stages (Cochrane Review Clasen, Roberts et al 2006).

It is not always necessary to include household water treatment in the safe water chain – it is only appropriate when the water source is of a dubious quality. Otherwise, if the source is safe, what is required is to keep the water free from subsequent contamination. This is most simply and cost effectively done by promoting safe water handling and storage and if necessary providing appropriate containers to enable people to do so.

However if the quality of water at the source cannot be guaranteed, a treatment process is needed to PUR®ify the water before the drinking. This is referred to as **Point – of – use or household water treatment**. There are 7 main options for point of use water treatment in emergencies that are recommended by WHO and will be discussed herein (WHO, 2002). These are:

1. (Sedimentation)
2. PUR®® / waterMaker type sachets (coagulants and disinfectants)
3. Ceramic candle style water filters
4. Ceramic pot style filters
5. Biosand filters
6. Boiling
7. Solar disinfection (SODIS)
8. Chlorination (with tablets or liquid)

Table 1 presents a summary of point of use water treatment options. It is intended as a guide for field staff to help them decide which option (s) might be relevant in different settings. For turbid water sedimentation can be used as a pre-treatment method. Boiling is not included in the table as a recommended option - although it is widely practiced and much work has gone into promoting boiling which in the absence of a better treatment works well, it is an expensive and often environmentally damaging option, leaves the water immediately liable to recontamination and contributes to acute respiratory infections and burns.

After treatment, again preventing the PUR®ified water from being re-contaminated is key; the water should be either taken directly from the treatment unit (e.g. a ceramic water filter which has a storage bucket built in) or it should be stored in a safe water container (e.g. after boiling).

Box 1 lists the requirements for a good household treatment and storage unit

Box 1: Ideal requirements for good household water treatment and storage include:

1. Effective – removes or keeps drinking water free from all pathogens– bacteria, virus', ova, cysts
2. Simple system, easy to use and understand
3. Keeps water stored safely without risks of contamination – containers should be covered and able to dispense water in a sanitary manner (e.g. with tap)
4. The lid of the water container can be removed so that the container can be cleaned periodically, but also tight fitting to discourage users from using the lid as the main method of extracting water.
5. They must be acceptable to the user and consumer, and the resulting water must appear and taste good
6. Hardware systems should be accompanied by adequate training on their use, operation and maintenance
7. Regular monitoring of point of use water quality and maintenance of the system
8. In the longer term, the system should be affordable and replacement parts locally available

This technical brief summarises the three stages of the safe water chain – from source to consumption – these are:

- Collection and handling
- Storage
- Treatment

COLLECTION & HANDLING

Safe water collection and handling means preventing contamination of water when it is collected from the source, transferred from one receptacle to another and when it is extracted before drinking, and preventing further or re-contamination of treated water. Much can be done to prevent contamination through the use of safe containers and treatment processes, but without proper hygiene practices in place the benefits of the hardware are negated. This reinforces the need to address water quality as part of a holistic intervention that focuses on creating an enabling environment to practice safe hygiene.

Key principles include:

- Ensuring hands are clean before collecting or handling water and that they not come into direct contact with the water – this is facilitated through pouring rather than scooping, and having a tap structure on the container
- Use of clean cups and mugs for drinking
- Training on the safe water chain
- Regular cleaning of containers
- Children's activities on the safe water chain

Table 1: Point of use treatment and health promotion options in different settings

Scenario	Diarrhoea outbreak or high risk?	Household Water Hardware Intervention	Public Health Promotion Intervention
Centralised water distribution system with chlorine residual (Camp setting)	No	Safe water collection and storage containers Check chlorine levels	Safe collection and storage
	Yes	Check chlorine levels AND / OR Mass super chlorination of jerry can / storage containers	Safe collection and storage Sensitisation on use of chlorine
<5NTU water from taps or protected source but no chlorine residual (Multiple sources)	No	Safe water collection and storage containers	Safe collection and storage
	Yes	**Short term:** Household water chlorination (with tablets or liquid) If camp setting: Mass super chlorination of jerry can / storage containers	Sensitisation and training on use of chlorine
		Longer term (select one of): Sodis (if in village or camp with corrugated iron roofs and sun) OR Ceramic pot filters (if existing in-country experience) OR Ceramic Candle filters (preferably if spare parts available locally) OR Biosand filters + safe collection and storage containers AND If camp situation, Periodic super chlorination of jerry can / storage containers	O&M training + Safe collection and storage (especially Biosand) Sensitisation on use of chlorine
>5NTU water from taps or protected source but no chlorine residual (Multiple sources)	No	**Short term:** Safe water collection and storage containers AND/OR Explore locally available flocculants and coagulants e.g. alum, natural coagulants	Safe water collection and storage Correct use and safe disposal of coagulant
		Longer term (select one of): Ceramic pots filters (if existing in-country experience) OR Ceramic Candle filters (preferably if spare parts available locally) OR Biosand filters + Safe water collection and storage containers	O&M training + Safe collection and storage (especially Biosand)
	Yes	**Short term:** If available: PUR® / WaterMaker type sachets If not: Sedimentation (with provision of water storage containers if necessary) + household water chlorination (with tablets or liquid)	Correct use and safe disposal of coagulant + sensitisation on taste Sensitisation and training on sedimentation practices + use of chlorine
		Longer term (select one of): Ceramic Pots (if existing in-country experience) OR Ceramic Candle filters (preferably if spare parts available locally) OR Biosand filters + Safe water collection and storage containers AND If camp situation, Periodic super chlorination of jerry can / storage containers	O&M training + Safe collection and storage (especially Biosand) Sensitisation on use of chlorine

STORAGE

There are many styles of vessel used to transport and store water in different parts of the world. These range from traditional pots or urns made from naturally available materials such as gourds or clay, to metal containers made of steel, copper or aluminium, and increasingly plastic.

The different stages of water collection, transportation and storage require often necessitate different properties from the vessel – for example those used for carrying water need to be light, while ceramic jars which keep the water cool might be preferred for storing water. In terms of preventing contamination of water at the household level there are various design criteria that a storage container should include:

1. Durability – long life span
2. Water can be withdrawn in a sanitary manner (e.g. via a tap)
3. Cover which can be taken off for cleaning, but which users do not use as the main way of extracting drinking water
4. Easy to carry if being used for water collection as well
5. Presence or accessibility of documentation describing how to properly use the container for water treatment and sanitary storage

Ideally people should have separate containers for collection and storage of drinking water and for clothes washing, washing pots and personal hygiene, to reduce cross contamination with drinking water sources.

Emergency storage containers

In emergencies, water containers for collecting and storing water are required from the start. As per Sphere (2004) Oxfam promotes that 'each household has at least two clean water collecting containers of 10-20 litres, plus enough clean water storage containers to ensure there is always water in the household'.

Wherever possible Oxfam would advocate using locally appropriate storage vessels, however it is recognised that not all of these have properties and characteristics that are preferred or desirable as water storage vessels. Some, such as cooking pots might be better used as transport vessels especially if they are lightweight, have protective lids and are composed of easily cleaned materials (e.g. plastic).

Over the years Oxfam has designed and field-tested the Oxfam bucket to meet the criteria of a practical and safe storage unit (see Box 2). The design is now being used by other agencies in their emergency responses.

Box 2: OXFAM buckets

The OXFAM buckets have been designed for use in emergency situations. There are two models:

1. Bucket without a tap for collecting and storing water.
2. Bucket with a tap which is meant for safely dispensing water and can also be used as a handwashing device.

Both have been designed with the following features:

a) The lid is tight fitting with a capped spout to discourage users to remove the whole lid and prevent contamination of the water by their hands. The cap is attached to the lid to prevent it getting lost. The lid can be removed so the bucket can be periodically cleaned.

b) Where the walls meet the base, it is curved to prevent dirt and bacteria lodging in the corners and enables better cleaning.

c) They are stackable, with a pallet containing 200 buckets (compared to an equivalent 40 20litre jerry cans)

d) The bucket is made of tough durable UV treated plastic and should last many years.

e) When full, it is a safe weight to be carried on someone's head

e) The bucket with a tap has a push tap for a hygienic seal

Specifications can be viewed in the logistics catalogue:

Code TWCT/1 = 14 litre water container with tap (pallet of 200 units)

Code TWCT/2 = 14 litre water container without tap (pallet of 200 units)

OXFAM buckets – one with the tap shown on raised stand and one without tap on the ground, being used in an IDP camp in Pakistan

Keeping water storage containers clean

It is recommended to clean water storage containers on a regular basis (once a week or whenever they appear dirty). Steps for cleaning are:

a) Drain containers dry

b) Where possible scrub the inside using a clean soft bristle broom or cleaning rag and a solution of chlorinated water or water and soap (preferably liquid soap). Clean the exterior of the container with particular attention to the area around filling and discharge openings.

c) Rinse clean with clean drinking water to remove any residue of the cleaning agent.

In camp settings, Oxfam recommends doing periodic super chlorination of all receptacles. The Darfur case study in Box 3 illustrates this.

Box 3: Chlorine disinfection campaign in Darfur

In June 2004, an outbreak of shigellosis was confirmed in Abou Shouk camp in the Northern Darfur province of Sudan. As water testing at the source showed no contamination, it was assumed that post-collection contamination was happening. The decision was taken to launch a programme of mass disinfection of all water containers in order to break the contamination cycle.

Five percent chlorine solution was used to clean containers. Approximately 100–150 millilitres were added to every container, along with some small stones. The container was shaken vigorously if it was closed or scrubbed with a local straw broom if open. The idea behind the stones was that their abrasive movement would remove the dirt oxidised by the chlorine. Each container took approximately 15–20 minutes before being refilled with clean water with 1% chlorine solution.

Diarrhoea figures from the clinics showed a fall in cases following the disinfection campaign; although it is difficult to collect statistically rigorous data it does appear that the campaign had an impact on the prevalence of watery and bloody diarrhea.

Taken from Walden et al, 2005.

Rainwater harvesting tanks:

Rainwater is often a very valuable source of water for drinking and cooking, but frequently does not meet bacteriological water quality standards. This does not mean that the water is unsafe to drink; rather that contamination is occurring during collection and storage. In order to prevent this:

- Rainwater tanks and the surrounding water catchment areas should be designed to protect the water from contamination by faeces, leaves, dust, insects, vermin and other industrial or agricultural pollutants.
- Tanks should be dark and sited in a shady spot to prevent algal growth and keep the water cool
- Mechanisms to divert the dirty ‘first flush’ water away form the storage tank.

(Practical Action rainwater harvesting technical brief)

TREATMENT

There are different methods of water treatment that can be applied according to the turbidity of the water. With turbid water (>5NTUs), **Sedimentation** is a necessary first step to remove large particles (sand, grit, dirt) and attached bacteria.

Once the water is <5NTUs but still of a questionable quality, either **Filtration** or **Disinfection** can be used. If water is being supplied centrally or through a tankering system, chlorination is the often the easiest method.

If there are chemicals in the water such as Arsenic, specific **chemical treatment** processes are needed. PUR®® and Iron oxide coated sand, as well as Biosand filters are possible treatment options for arsenic.

At all stages safe handling and storage of water is vital to prevent recontamination of water.

The remainder of the technical brief discusses the different interventions at each stage.

Sedimentation, Coagulation and Flocculation

Where there is no option but to use water with turbidity, such as in a flooding situation, or where the only source of water is river water, the following methods can be used to remove the turbidity prior to treatment.

- Sedimentation
- PUR®® / waterMaker® type sachets

1. Sedimentation

How does it work?
Sedimentation through storing water and allowing it to settle is an effective and low cost natural sedimentation method to reduce water turbidity but it is not consistently effective in reducing microbial contamination; point of use treatment is also needed.

Effectiveness
The effectiveness varies depending on the type of turbidity; most viruses, bacteria and fine clay particles are too small to settle out by simple gravity sedimentation. For this reason it is usually recommended as a pre-treatment method, as treatments such a chlorination or UV radiation are known to work better on less turbid water.

Operation and Maintenance
Material and skills requirements are minimal. Two storage vessels are usually enough, one to store the sedimenting water and another in which to decant the clear supernatant into. Care should be taken not to disturb the sediment when decanting the water. It is essential that the solids are removed and the vessel cleaned on a regular basis

Advantages and Limitations

Advantages	Limitations
• Low cost and simple method • Reduces turbidity for subsequent treatment • Clear water is aesthetically more acceptable to the consumer • Possible reduction in arsenic	• Does not produce microbiologically safe water on its own • For long retention times several containers would be required

2. PUR®® / waterMaker® type sachets

Combined time–released flocculent and disinfection sachets such as PUR®® and waterMaker are available typically for use in first phase flooding type scenarios where people are still in their houses and it is impossible to have a centralized water point. PUR®® is produced by Proctor and Gamble and has been distributed free of charge in a number of emergency settings.

Fig 1: PUR®® Sachet

Oxfam stocks combined sachets in the equipment catalogue (**code FCF/1**)

How does it work?
PUR®® sachets contain both a coagulant (iron sulphate) to remove turbidity and a chlorine salt disinfectant to PUR®ify the water. The chlorine leaves some residual effect protecting the treated water from recontamination.

Effectiveness
Research has shown that PUR®® / waterMaker type sachets are highly effective against most pathogens, heavy metals (including arsenic) and pesticides, even in turbid water. Multiple trials of PUR®® in emergency settings have shown reductions in diarrhoeal disease, although there is still ongoing debate as to PUR®'s® impact on health.

Operation and Maintenance
The number of sachets required is calculated according to the size of the container (each sachet treats 10L water), and the contents are added to a container and stirred. After 30 minutes the water is poured into another container with a cloth or metal filter to prevent to residual passing through to the drinking water container. The water is then ready for drinking. The residue should be disposed of safely (ideally buried) but this is problematic in flooded areas.

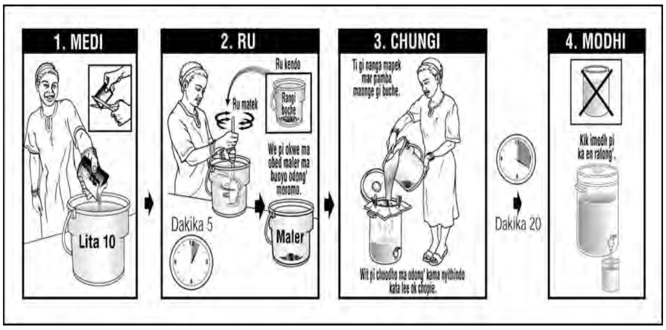

Fig 2 Instructions on how to use PUR®®/waterMaker type sachets

Cost
Each PUR®® sachet costs approximately $0.10 (assuming no further cost for mixing and storing vessels). Each sachet treats 10L, making treatment approximately $100.00 per 10,000L of water treated (Clasen, 2007)

Advantages and Limitations

Advantages	Limitations
• Highly effective against most microbial pathogens, heavy metals (arsenic) and pesticides even in turbid water • Residual protection • Visual improvements in clarity of water improve consumer acceptability • Portable, long shelf life • Relatively low up-front cost • Ease of scalability or use in an emergency because the sachets are centrally produced, and easily transported due to their small size, long shelf life, and classification as a non-hazardous material for air shipment) • Reduced concern about carcinogenic effects of chlorination because organic material is removed in the treatment process. (Clasen, 2007 and Lantagne *et al* 2007)	• High overall cost • Multi-step process requiring demonstrations for new users and a time commitment for water treatment from the users; • Some resistance to colour/taste • Requires 2 containers, cloth and a stirring rod to use • Little evidence of sustainability without subsidies • Difficult to dispose of pathogenic residue safely especially in flood affected areas.

Filtration

There are two principal methods of filtration that show the most promise as household water treatment technologies. These are ceramic water filters (candle and pot style) and Biosand filters.

Household Ceramic filters

There are different models of ceramic filters in use; in this technical brief two are discussed in detail – the ceramic candle filter and the ceramic pot style filter. Both models filter the water, remove turbidity and where they are coated or impregnated with silver, also provide a system of disinfecting the contaminated water. Filters are generally seen an acceptable technology and communities appreciate the physical asset of the filter as well as their improved water.

General advantages and limitations of ceramic filters

Advantages	Limitations
• Water is filtered as needed • Removes most pathogens and suspended solids • The filter is relatively light and can be placed anywhere in the home at the user's convenience (although lack of space can be an issue in emergency contexts) • The silver coating ensures disinfection so separate post filtration disinfection is not required • Safe and easy to use after training • Often seen as a valuable asset by the household	• Fragile, easy to crack allowing dirty water to pass through undetected cracks • Turbid water plugs filter • Cleaning results in removal of ceramic layer, which over time will need replacing • Dissolved compounds are not removed (same as other filters) • No residual disinfectant but the container provides safe storage

The following checklist provides some of the things to think about if you are considering doing a ceramic water filter intervention:

Box 4 Checklist for distributing filters:

- If there is a centralised water supply system what is the added value of distributing filters?
- If it's a rapid emergency, is there a more simple water treatment alternative available?
- Are ceramic filters a familiar technology in the area and are replacement supplies locally available - if not consider the appropriateness, additional training and supply chain implications.
- Are community members displaced? They will need space to put the filter which might not be available in temporary dwellings
- Do project staff have time to train users and follow up? (NB if filters (especially the lower bucket) are not properly cleaned they can be a focus of contamination)
- If ceramic candles are available locally have they been microbiologically tested and passed quality control checks?

3. Ceramic Candle filters

How does it work?
A Ceramic candle water filter comprise of an upper and a lower bucket, with one or more clay cylindrical, hollow 'candles' screwed into the upper bucket which function as the filter. As the dirty water from the upper bucket passes through the candle, microbes and other suspended solids are removed, and clean water drips through into the lower bucket where it can be tapped off (as is shown in Figure 3 below).

Fig 3: Ceramic candle filter designs - Photos courtesy of Tom Clasen LSHTM

Microbiological effectiveness

The ceramic candle may be impregnated or coated with silver, which acts as a germicide and prevent microbial growth. The evidence suggests that filters can be microbiologically very effective if they are correctly used and maintained, however their protective impact on reduction of diarrhoea is not yet conclusive. There are different models of ceramic candle of varying quality on the market, see Table 2 for details.

FW Grade	LRV Bacteria	Bacterio-stasis	Quality control	Candle cost ($US)	Examples
A	5,6	Impregnated silver	Total	6-9	Katadyn, Doulton, JP, Marathon
B	3,4	Coated silver	Some	2-4	**Stefani**, Pozanni, Butterfly
C	2 or less	None	None	1	Hong Fuc

Table 2, Taken from Clasen 2007

Oxfam currently stocks the Stefani model in its equipment catalogue – staff can order either the whole system (bucket + 2 candles + tap + pictorial leaflet - **Code FHF/1**) or filter sets (3 candles + 1 tap for areas where there are no locally available candles and taps but flat topped containers are available – **Code FHFCT/1**).

There have been various trials of ceramic candle water filters in emergency responses including Oxfam trials in Cambodia, Dominican Republic and Colombia.

In Sri Lanka there were a number of follow up studies conducted following the large post-tsunami distribution, that looked at both the microbiological effectiveness of filters and also the community acceptance and sustainability. The main findings of this latter report are summarised below. The reference section contains further details of Oxfam trials and relevant filter publications as well as further an Oxfam technical brief on household filters (also included on the accompanying CD)

Box 5: Community Acceptability of Ceramic Filters distribution in Sri Lanka

Jennifer Palmer in her review of the Oxfam ceramic candle filter distribution and the American Red Cross pot style distribution in the Sri Lanka tsunami response came up with the following recommendations:

- Household water filters should not be given out in the acute stages of an emergency response when internally displaced persons are living in emergency shelters, but were well received among settled recipients living in transitional and permanent shelters
- The Oxfam GB-distributed candle-style filter is not self-explanatory, as significant problems with first time assembly were observed - every effort should be made to give sufficient training on their use with distribution of the filters and clear pictures explaining washer order needs to accompany filters.
- Ensure that all filter materials contain very clear diagrams of how to assemble washers on candles and taps to prevent the recognizable leaks from taps and less recognizable leaks from candles
- Materials should include guidance on knowing when washers are assembled correctly (e.g. candles are tight and some water is left that cannot drain from the top vessel)
- The requirement for recipients to make a stand before receiving filters is useful for rapid uptake in transitional shelters where space is limited but not permanent housing
- Do not give filters out in unopened boxes and keep first time use, assembly and maintenance instructions with filters (e.g. on a sticker)
- Communities preferred the pot style filters as they were easier to assemble and manage

Jennifer Palmer, 2005

Operation and Maintenance

Operating a filter is generally a simple procedure. Users remove the lid, fill the upper bucket with water and decant water from the lower bucket using the tap. Filters are light and can be placed anywhere in the house at the users convenience.

Over time the filter can become clogged with debris, which blocks the pores in the ceramic and causes the flow rate to decrease. The ceramic candles can be cleaned by gently scrubbing the surface using a soft brush, and then rinsing with water (see Fig 4). The lower bucket should be cleaned using filtered or disinfected water.

Comparative research from Sri Lanka showed that good training and subsequent monitoring can greatly enhance the uptake of a filter programme. The household water filter programme in Sri Lanka recommended a series of training sessions for Oxfam staff, community members and government health staff on the benefits of using a filter as well as how to assemble, clean and maintain filters and discussions on accessing replacement parts. Detailed work plans and promotional materials are provided on the Water Filter CD rom that accompanies this brief.

Fig 4: Filling the filter and cleaning the ceramic candle

In summary, Ceramic Water Filter training should include practical and participatory sessions with users (including children) covering the following areas:

Ceramic Filter Training:
• PUR®pose of the filter • Preparing candles for first time use and 3-monthly sterilisation • How to correctly assemble and use a water filter, including building a stand • How to check the filter is working properly and determine when it needs to be cleaned • Correct methods of cleaning the candles and the buckets • Problem troubleshooting and establishing systems for replacement parts

Costs

A candle filter unit costs between $15. Each unit treats 20,000L, making treatment approximately $7.50 per 10,000L of water treated. It is estimated that a further $15 needs to be spent on replacement parts over a three year period (Clasen, 2007)

Advantages and Limitations

Advantages	Limitations
• Proven reduction of bacteria and protozoa • Inexpensive and cost effective (after chlorination shown to be most cost effective household intervention) • Seen as a valuable asset • Offer water storage capacity as well as filtration	• Fragile, easy to crack allowing dirty water to pass through undetected cracks • Turbid water plugs filter • Cleaning results in removal of ceramic layer, which over time will need replacing • Unknown effectiveness against viruses • Dissolved compounds are not removed (same as other filters) • Limited studies on the impacts on health • A low flow rate of 1-2L / hour • Unlikely to be appropriate in first phase emergency response (need space, training, supply of replacement parts, regular follow up) • Requires users to be educated on the O & M

4. Ceramic pot-style filters

Pot style filters (also known as the Potters for Peace, or IDE style filters after the organisations that have promoted them) have proved a successful water treatment technology in many parts of the world. In most cases local potters are trained to produce the filters and then they are either sold directly, or subsidised. They can be made at very low cost as they use local materials with no need for electricity or advanced technology, and with designs that suit the prevailing cultural methods of water storage (Potters for Peace, 2007).

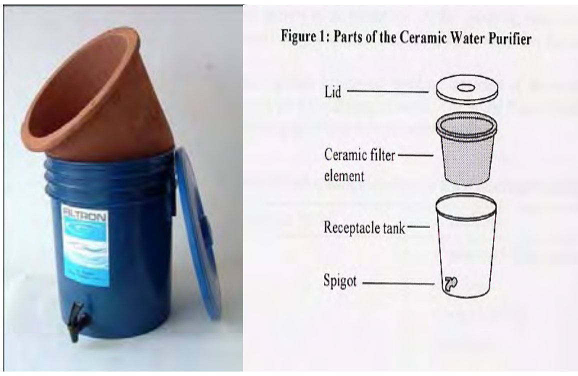

Fig 5: A Potters for Peace 'Filtron' ceramic pot filter

<u>How do they work?</u>

Pot filters work in a similar way to ceramic candle filters. The filter comes in two separate parts, a ceramic pot and a plastic or clay container that the pot rests inside. Water is poured into the pot and filters through the lower container where it can be tapped off. Like candle filters, the contaminants are mechanically trapped in the pores in the ceramic.

<u>Effectiveness</u>

They are similarly effective at removing pathogens as impregnated or coated silver candle filters

<u>Cost</u>

Unit costs range from $3-7 USD depending on the country in which it is being manufactured and local availability of the ceramic. As the silver in the ceramic disinfects the water there is no need for consumables making the running costs negligible.

<u>Operation and Maintenance</u>

Procedures for the operation and maintenance are generally similar to candle filters and it is recommended that the same training processes be followed. To use, the filter is filled with water and covered with a lid. Standard filtration rate is between 1-3 litres per hour and if a greater amount of water collects in less time, it is sign that there is something wrong with the filtering process.

<u>Advantages and Limitations</u>

Advantages	Limitations
As for candle filters plus: • Can be produced locally in many places and supports local craftsmen • Long life, if the pots remain unbroken • Easy to clean • Fewer parts to replacement than candles filters	• Difficult to stack for transportation • Quite a low flow rate (1-3 litres/hour) • Quality control difficult to ensure
When compared to candle filters: • Less liable to breakage (the candle has plastic washers to attach it to the bucket which when under pressure can crack the ceramic) • Usually locally made so easier to access replacement parts	• Because often locally produced bulk stock rarely available so generally not suitable for first phase emergency • Requires suitable raw materials and the appropriate technology to manufacture them

<u>Are ceramic filters an appropriate response in emergencies?</u>

Field staff often raise the question as to whether it is appropriate to distribute ceramic filters in emergency settings where we cannot guarantee a supply of spare parts. Unlike pot-style filters, which are usually made locally, candles are generally not and have to be procured and transported from outside the area (although the containers are sometimes available locally). It should be noted that whilst the ideal is to distribute treatment technologies that are sustainable in the long term and wherever possible to enhance the likelihood of their sustainability, e.g. by setting up access to markets for replacement candles and taps, even without this water filters can provide safe water for recipients for up to 2 years, which in most cases is enough to cover the risky post emergency period.

That said the immediate emergency environment is not always favourable for filter distribution (as Clasen and Smith (2006) comment in their review of programmes that distributed filters post tsunami). Instead they are more likely to be a more appropriate post emergency or longer-term response when the time can be dedicated to operation and maintenance training and monitoring, and to improving the likelihood of sustainability.

5. (Bio-sand filters (modified Slow Sand filters)

The BioSand Filter (BSF) is a slow-sand filter adapted for use in the home. Biosand filters provide a potentially permanent solution to household water treatment, combining mechanical filtration with biological inactivation of pathogens, however they do require considerable maintenance on the part of the user and the unit costs are still relatively high. Biosand filters can be small units and can easily supply enough clean water for a family.

Commercial distributions have largely been unsuccessful and so Biosand filters are now PUR®sued almost exclusively by NGOs. Promoters include The Centre for Affordable Water Supply (CAWST), Samaritan's PUR®se and Bushproof among others. CAWST offer trainings and have developed quality promotional materials. Their website offers plenty of information on the bio-sand filter (CAWST 2007)

How does it work?

The most widely used version of the BSF is a concrete container approximately 0.9 meters tall and 0.3 meters square, filled with sand. The BSF has been designed to overcome the problem faced with the conventional sand filter, which is that it must be used regularly to keep the biological layer functioning. The water level is maintained at 5–6 centimeters above the sand layer by setting the height of the outlet pipe. This shallow water layer allows a bioactive layer to grow on top of the sand, which helps reduce disease-causing organisms. plate with holes in it is placed on the top of the sand to prevent disruption of the bioactive layer when water is added to the system.

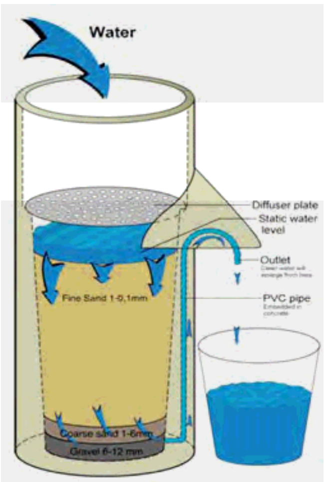

Fig 6: A Biosand filter Ref: CAWST

Box 7: Features of the Biosand filter

1. Can supply a household of 6-15 users
2. It runs at 1 litre / min and specific loading rate of 10 litres / min / m2. The rate of flow is controlled by the size of the sand media in the filter.
3. A biological layer forms on the surface of the sand media and pathogens are also strained out through the filtration process.
4. The sand layer has been designed to be of appropriate depth to ensure the biological layer does not dry out and that it gets enough oxygen.
5. Correct operation requires a constant water level of approximately 5cm above the sand level during the pause periods.
6. It is most efficient when operated intermittently (although the pause periods should not be too long).
7. It requires only intermittent cleaning which consists of washing the top few cm of sand by agitating it and then removing the dirty water using a small container. This can be repeated as many times as necessary.
8. Produces > 90% removal efficiency.
9. A start up period of 1 to 3 weeks is needed for the biological layer to develop.
10. It can treat water of < 50 NTU and water above this turbidity should be pre-treated.
11. The sand material can be obtained from clean, crushed rock screened through metal mosquito net screen and with a Uniformity Coefficient of 1.5 to 3.0.
12. It has a metal grid with holes in called a diffuser on top of the sand layer to prevent disturbance of the sand when pouring in the water.
13. Usually made out of concrete rather than plastic as concrete is easily acquired, strong and can be built locally.

Effectiveness

While coverage of Biosand filters is still limited, in laboratory and field-testing, the BSF has an average of 95% removal of coliforms and a 99% removal of *Cryptosporidium* and *Giardia* cysts (WEDC). Initial research has shown that the BSF removes less than 90 percent of indicator viruses. It has also been shown that Biosand filters are capable of continuing to deliver 1-2 log reductions in microbial pathogens more than five years after they were first used (Clasen, 2007).

Cost

Each Biosand filter unit costs between $12.00 – $40.00 and can treat an unlimited volume of water. There are no recurrent costs and the lifetime of a unit can be many years (Clasen, 2007).

Operation and Maintenance

To use the system, users simply pour water into the BSF, and collect finished water from the outlet pipe in a safe storage container.

Biosand filters ideally produce 1 litre per minute. When the flow rate becomes unacceptably low it is restored by scraping and removing the top layer of sand, which is where most clogging occurs. Various methods are possible, but all disturb the biological layer, which results in less effective filtration for some time. Some methods however are less disruptive than others and 'wet harrowing' is the process recommended. This is done by filling the filter with a bucket of water after blocking the spout. Following removal of the diffuser plate, water is slowly swirled around by hand inside the filter. Try not to touch the sand while doing so. The movement of the water loosens accumulated dirt, which comes into suspension. This muddy water can then be carefully decanted, using a cup. The process is repeated until most dirt has been removed. Remove the cork and the flow rate should have increased dramatically.

It is important to remember that a 'dirty' filter can actually produce water of better quality. Due to a reduced flow rate better filtration takes place, while there is an increased contact time with a mature biological layer. Cleaning should therefore only take place when the outflow of water has become inconveniently slow (Taken from CAWST 2007).

Biosand filter Cambodia
(Photos: Hazel Jones & Sarah House)

Fig 7 – Operation and Maintenance BSF : CAWST, Asia)

Advantages and Limitations

Advantages	**Limitations**
• Proven removal of protozoa and approximately 90 percent of bacteria; • Simple and cheap to operate and maintain • Operates under a range of temperature, pH and turbidity • Removes turbidity, some iron, manganese and arsenic • Suitable for local production and opportunities for local business • One time installation with few maintenance costs • High flow rate (up to 36 litres/ hour) • Long lasting • Evidence of long term use and performance (Clasen 2007)	• Sub-optimal removal of viruses • Lack of residual protection or built in safe storage leaves water susceptible to recontamination • Current lack of studies proving health impact • Does not remove colour, organic chemicals or dissolved compounds from the water • Limited portability (of concrete version) and high up front cost

Disinfection

There are three main methods of disinfection discussed herein:

- Boiling (not recommended for reasons discussed below)
- Solar disinfection (SODIS)
- Chlorination

6. Boiling

Boiling is an ancient method of treating water and common practice in many parts of the world. Over the years much work has gone into promoting boiling of drinking water. However, it is an expensive and fuel intensive procedure and boiling water at home has been associated with higher levels of burn accidents, especially among young children, and the resulting air pollution can contribute to respiratory infections. Oxfam's position is that boiling is not recommended as the optimum point–of use treatment for these reasons, but in areas where it is common place and other options are limited, efforts should focus on safe storage and making the practice of boiling as safe as possible.

Effectiveness

Boiling is effective in destroying all classes of waterborne pathogens (viruses, bacteria and bacterial spores, fungi, protozoa and helminth ova) and can be effectively applied to all waters, including those high in turbidity or dissolved constituents. Whilst boiling itself is an effective process, once boiled water begins to cool it is immediately vulnerable to recontamination from hands, utensils and added water since it contains no residual disinfectant and is often stored in open vessels without a tap.

Cost

The unit costs for boiling with wood are approximately \$0.012 for the treatment of 10L water. This results in a cost of \$12-\$24 per 10,000 L water treated. If gas is used, the price almost doubles: the unit cost is \$0.04 per 10 L, and the resulting cost for 10,000 L of water treated is $40-44. (These figures are based on Indian rates, Clasen 2007)

Boiling is fuel intensive with 1kg wood estimated to boil 1 litre of water. In areas of the world where fuel is in short supply boiling can be an expensive and environmentally damaging practice, as well as time consuming taking the collector (often women) away from other productive work.

Operation and Maintenance

Boiling itself is simple to do if the necessary fuel and boiling pans are there. There has been much debate on the minimum boiling time needed to PUR®ify water; WHO recommends bringing the water to a rolling boil for 10 minutes, largely as an indication that the water has reached sufficient temperatures; in fact heating to temperatures of 60^{o}C for 1 minute will kill or deactivate most pathogens (Clasen, 2007).

Operation and maintenance activities should focus on the safe handling and storage of the water. It is recommended that water be kept in the same container in which it was boiled, preferably a closed container with a lid and that safe boiling practices and fire safety should be emphasised.

Advantages and Limitations

Advantages	Limitations
• Common knowledge and practice in many places (and therefore something to be maintained in the absence of other alternatives) • Heating to a rolling boil for 1 minute will kill almost all pathogens (at altitude this should be increased to 2 minutes) • Generally uses locally available materials • Effectiveness is not affected by turbidity or dissolved constituents	• Once boiled water cools it is immediately vulnerable to recontamination from hands, utensils and added water since it contains no residual disinfectant and is often stored in open vessels without a lid. • Does not remove suspended or dissolved compounds • Inefficient and costly on fuel consumption (gas, bio fuels, gas, wood) • Concerns for environmental sustainability if wood or charcoal used • Time taken to collect wood for fuel can compromise livelihood activities and pose a protection threat in some places • Water needs cooling before use unless for hot drinks • Boiling is a leading cause of burns • Effects of indoor air pollution from cooking with biomass associated with reduced birth weight, respiratory infections, anaemia, stunting

7. 'SODIS' – solar disinfection

The Swiss Federal Institute developed the 'Sodis' system for Environmental Science and Technology (EAWAG) as a low cost water treatment technology for areas of high sunlight. The system is suitable for treating small volumes of water (<10L) of low turbidity (<30 NTU). It is only suitable for areas of high sunlight exposure.

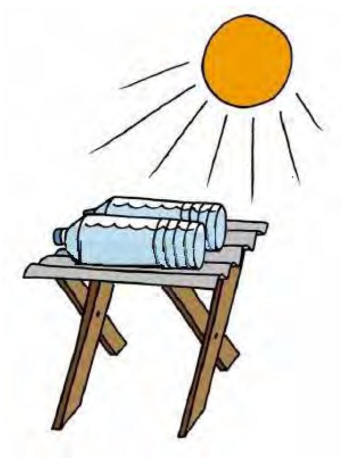

Fig 8: SODIS water treatment

How does it work?

Water is put in clear plastic bottles and left on a corrugated iron roof in the sun. Water is exposed to UV radiation in sunlight, primarily UV-A and it becomes heated; both effects contribute to the inactivation of waterborne microbes. If drops of citric acid (lemon juice) are added this has been shown to reduce levels of arsenic (process known as SORAS)

Effectiveness

SODIS is known to deactivate 99.9% of bacteria, and slightly less for viruses

Cost
A Sodis Solar Disinfection Unit costs $0.4, which comprises of 4, 2L bottles each costing $0.1 (based on alternating 2 bottles in the sun and 2 in the household each day). Each bottle treats approximately 730L water resulting in a cost of $5.48 per 10,000L water treated (Clasen, 2007).

Operation and Maintenance

The 'Sodis' system (heat + UV) consists of the following steps:

1. Placing low turbidity (<30 NTU) untreated water in clear plastic bottles.
2. Aerate it by vigorously shaking the bottle.
3. Expose the bottles to the sun, usually by placing them on corrugated metal roofs. Exposure times vary from 6 to 48 hours depending on the intensity of sunlight. If the day is more than 50% cloudy, then it is necessary to expose the bottles for 2 days. If the temperature of the water is more than 50 degrees C, only 1 hour of exposure is required
4. Usually households have 4 bottles in process, 2 on the roof and 2 for drinking (CAWST)

Advantages and Limitations

Provided the right conditions are present (Sunlight and a corrugated iron roof), the SODIS system is simple and cheap to operate. But care must be taken over it's apparent simplicity – if the turbidity is too high or the bottles are not left out in the sun for long enough the water might not be sufficiently disinfected. This is the main drawback for users as it's difficult to accurately judge turbidity and sunlight exposure.

Advantages	Limitations
• Highly effective against bacteria, viruses and protozoa • Low capital costs (just clear bottles) which are abundant in many places around the world and no consumables • Acceptable to users as simple and easy to handle and little change to taste of water • Convenient for storage and transportation • Little risk of recontamination as users drink from bottle Taken from CAWST, 2007	• Water should be of low turbidity (<30 NTUs) meaning that often pre-treatment is needed • Does not remove suspended particles or dissolved compounds • Requires bright sunlight • Waiting period 6-12 hours • Difficult for the user to judge the range of factors which are required for adequate disinfection • Watsan staff can over simplify the method and hence the process will not be effective • Can only treat limited volume of water at a time and requires lots of clean, large plastic bottles • Water needs to be cooled before consumption

8. Disinfection with chemicals (Chlorination)

Chemical disinfection is recognised as an effective and safe way to treat water at the point of use. There are a variety of different chemicals used but by far the most common in developing countries is chlorine and its compounds, usually bleach or sodium hypochlorite. Chlorine can be added either in liquid or in powdered form (such as Medentech Aquatabs®).

Chlorine, if not handled properly or if the dose is too high can be potentially harmful to health and so it is important that it is managed carefully and staff who are required to handle chlorine are well trained.

Chlorine can either be administered through a central supply system managed by trained government staff, the private sector or NGOs – examples would be either a piped water supply or tankered water, or it can be managed at the household level, preferably with fixed dose measures such as aquatabs or sodium hypochorite solution

<u>How does it work?</u>

Given sufficient contact time, chlorine causes chemical reactions, which inactivate or kill microbiological contaminants in the water. It also oxidizes organic matter, manganese, iron and hydrogen sulphide.

Treatment with chlorine not only disinfects water at the point of use but the chlorine residual can protect water from recontamination for several hours afterwards.

<u>Effectiveness</u>

Treatment with chlorine kills almost all bacteria and viruses but is not guaranteed to inactivate pathogenic parasites (e.g. *Giardia*, *Cryptosporidium* and helminth eggs).

<u>Operation and maintenance</u>

Chlorine works best in clear water. In turbid water it reacts with organic compounds, metals and other dissolved compounds, and the higher the turbidity the more quickly the chlorine is quickly used up, often before all pathogens have been killed. Turbidity makes it difficult to judge the concentration of chlorine that a quantity of water requires and so ideally turbidity of water should be tested and the concentration of chlorine calculated accordingly.

Chlorine disintegrates with time and exposure to sunlight. It is important to strike a balance when chlorinating water to ensure enough chlorine is added to kill pathogens and leave some residual, and adding too much chlorine, which will make the water undrinkable or disagreeable to the user.

Aquatabs come in strips of 10 tablets each tablet treating 20L water. One tab is added to a container and users should wait 30 minutes before drinking the water to ensure sufficient mixing of the chlorine in the water. Care should be taken to ensure the right amount of tablets for the size of the collection container and keep tablets out of the reach of children.

Sodium hypochlorite solution is packaged in a bottle with directions instructing users to add one full bottle cap of the solution to clear water (or two caps to turbid water) in a standard-sized storage container, agitate, and wait 30 minutes.

<u>Cost</u>

Powdered chlorine costs between $1-4 for every 10,000L treated. Medentech Aquatabs® are priced at $0.046 for a strip of 10 x 20L tablets. Each strip will treat 200L resulting in a cost of $2.30 for every 10,000L water treated.

<u>Advantages and Limitations</u>

Advantages	Limitations
• Inexpensive • Readily available in most places • Kills almost all pathogens bacteria and viruses • Leaves some residual chlorine which protects water for period of time • Ease of use and thus acceptability to users • Proven health impact in multiple randomised control trials • Opportunities for scale up in an epidemic of e.g. cholera	• Water should be clear • Relatively low protection against some viruses and parasites • Taste and colour can be potentially disagreeable • Users have to buy chlorine regularly • Chemical dosage required varies with water quality – dosage depends on users judgement of turbidity • Lower effectiveness of water contaminated with organic and some inorganic compounds • After time water could be subject to post contamination • Concern over the potential long term carcinogenic effects of chlorine by-products • Waiting period before consumption

Box 8: Kitgum cholera outbreak

During the 2006 cholera outbreak in Northern Uganda, Oxfam was responding in Kitgum District. The cholera task force stipulated that all water collected should be chlorinated, and that people who collected water from elsewhere in the camp (namely the river) during this time would be fined.

Community health volunteers (CHVs) were initially trained and paid to administer aquatabs to each jerry can at the hand pumps in the camp. Later, due to a shortage of aquatabs, the CHVs were trained on how to safely make up stock chlorine solution and administer doses of chlorine solution to each jerry can.

The campaign was largely successful but challenges involved:

- Compliance issues with mass chlorination – people continued to collect water from river complaining of the unfavourable taste of chlorinated water, especially for brewing
- It was decided that only CHVs should administer aquatabs to ensure correct use – there were concerns over people misinterpreting the use as medicines (it was a common perception that eating aquatabs would protect people from cholera) and a lack of storage space in the house out of the reach of children
- Using Stock chlorine solution made it easier to ensure the correct dose of chlorine– one aquatab treats 20L and for smaller quantities, tablets need to be divided which is very difficult given their small size. Stock chlorine solution is also more accurate, as it takes into account differing turbidities of water.

Bucket chlorination training in Kitgum

Treatment for Chemical Contamination

Chemically contaminated water is water that is contaminated by natural sources; that is, chemicals from rocks and soils.

Treatment for arsenic removal

Arsenic pollution of groundwater is a major problem in Bangladesh, West Bengal (India) and now in Nepal and Bihar (India). Household treatment can be an effective short-term solution until effective safe water supplies are found. Only water for drinking and cooking needs to be free from Arsenic and the challenge is to provide arsenic safe water that is also free form other microbiological contaminants.

Treatments known to reduce arsenic include iron oxide-coated sand (IOCS) and PUR® as well as SORAS, a similar solar disinfection process to SODIS but with a few drops of lemon juice added to the water.

Treatment for Flouride removal

Flourosis is endemic in 25 countries. Is very difficult to remove fluoride from the water and so the first option is to find an alternative source with a lower fluoride content. If there is no other possible or cost-effective source, deflouridation should be attempted to reduce the toxic effects. Several options exist including:

- Bone charcoal - in 1998, WHO introduced the ICOH enriched charcoal domestic filter in Thailand another countries
- Contact precipitation - based on the addition of calcium and phosphate compounds - so far this has only been implemented at domestic level in Kenya and Tanzania
- Nalgonda an aluminium sulphate based coagulation-flocculation sedimentation, used in India and Tanzania
- Activated alumina

(Taken from WHO, Arsenic brief)

Summary

- **Point of use treatment should only be used when the water from the source is contaminated.** Otherwise it is likely that contamination is occurring during the collection and storage of water, in which case efforts should focus on safe water handling and storage rather than point of use water treatment.

- **Ensure community specific needs and preferences are incorporated e.g. if users prefer a** current practice, such as storing water in ceramic pots, incorporate that practice into the project;

- **Ensure there is a mechanism to prevent recontamination of the treated water**: A number of HWTS options incorporate some form of residual protection (chlorine, SODIS, PUR®); safe storage or other mechanisms to prevent post-treatment contamination should be a part of every HWTS project;

- **The ability to obtain quality HWTS option components (and any replacement parts) locally;** wherever possible this should be looked into but a lack of replacement parts should not be the deciding factor in an emergency - if a treatment is available and fits the requirements of ensuring safe water to the people as quickly as possible then it should be considered

- **Behaviour change communications including person-to-person communications and/or social marketing;** community involvement in the programme as well as locally appropriate health promotion interventions will greatly enhance the uptake and long term sustainability of the HWTS intervention

- **Availability of implementation materials and technical assistance to support on-the-ground implementers.** There is a wealth of health promotion materials that have been developed for HTWS. A CD rom that accompanies this technical brief has links to many of these.

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Oxfam Household Water filter guide

Biosand Filters

1. The Centre for Affordable Water and Sanitation Technology http://www.cawst.org/

2. Biosandfilter.org http://www.biosandfilter.org

Health promotion materials

A variety of posters, stickers, user guides, implementation plans and monitoring forms for ceramic and Biosand filters are given in English and Spanish

Natural coagulants

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