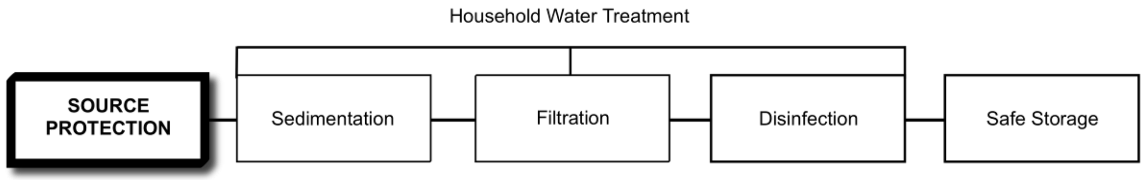
Appendix B – Household Water Treatment and Safe Storage Fact Sheets

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

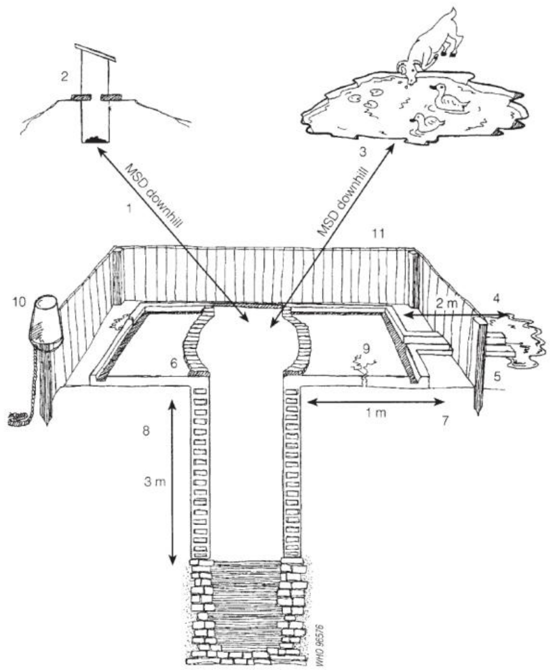
The following provides suggestions on several things that can be done to protect different water sources from contamination and improve the quality.

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

CAWST (Centre for Affordable Water and Sanitation Technology)
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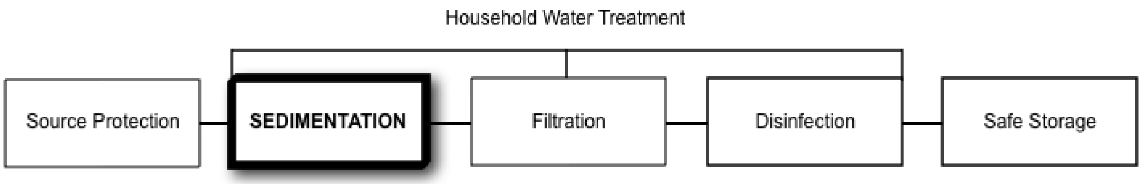
Last Update: June 2011

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.

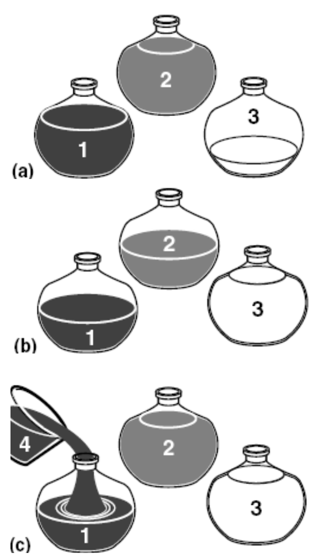
Storing water for at least one day will also promote the natural die-off of some bacteria.

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.

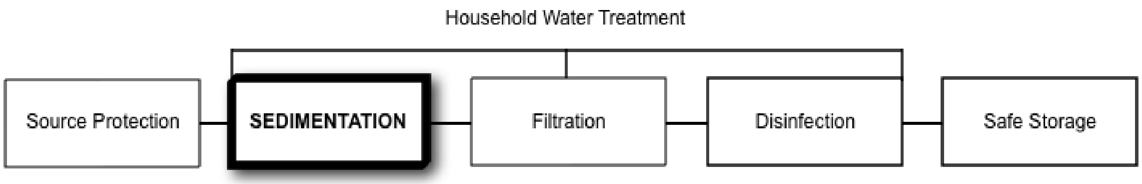
References

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

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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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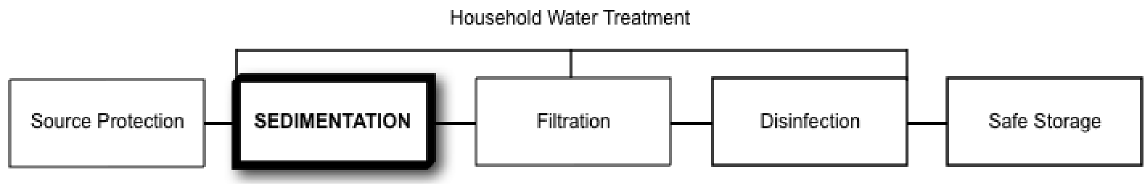
Household Water Treatment and Safe Storage Factsheet: Chemical Coagulants

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

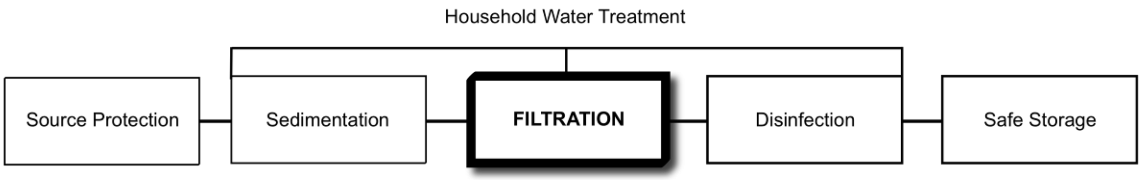
References

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.

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?

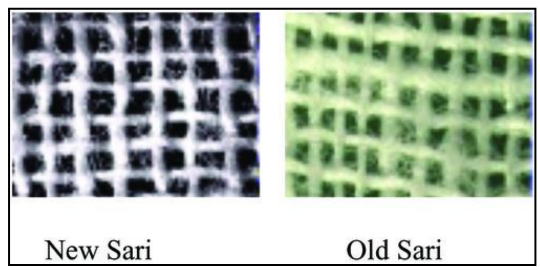
Straining water through a cloth has been widely used for household water treatment in many cultures for centuries. A common sari cloth is usually used for this in South Asia, for example.

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.

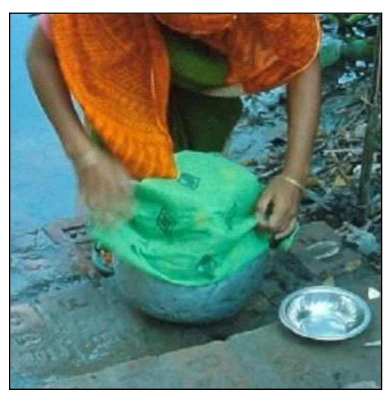
Old sari cloth made of cotton was found to be most effective in removing cholera based on laboratory experiments (Colwell et al., 2002). After several launderings, threads of an old sari become soft and loose, reducing the pore size, compared with new sari cloth.



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.

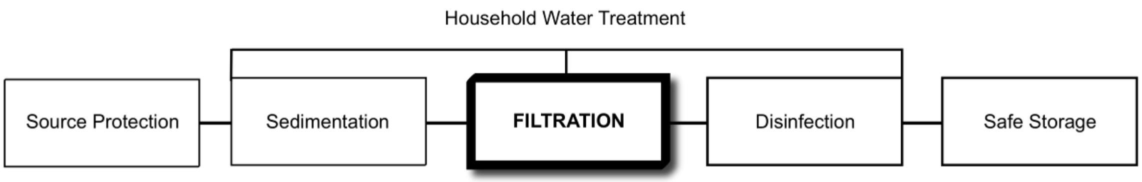
References

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

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.

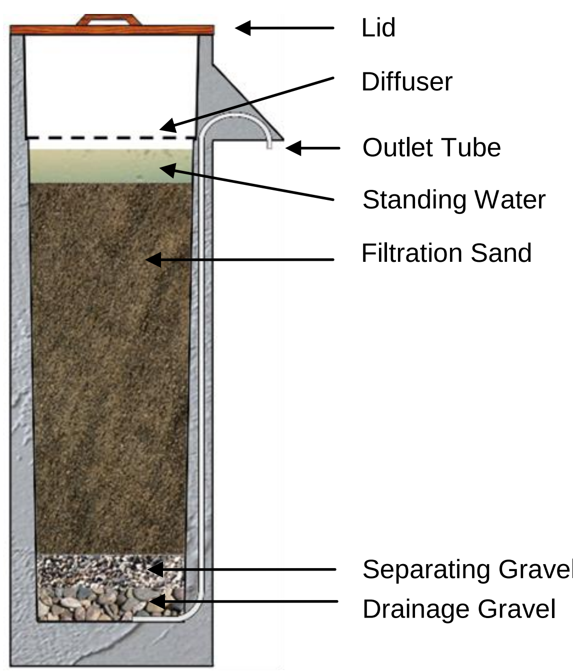
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

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.

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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.

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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.

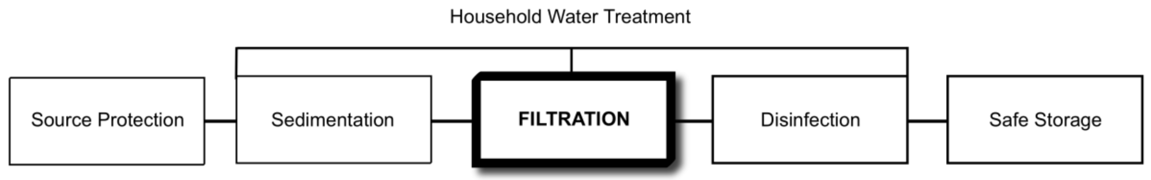
Further Information

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.

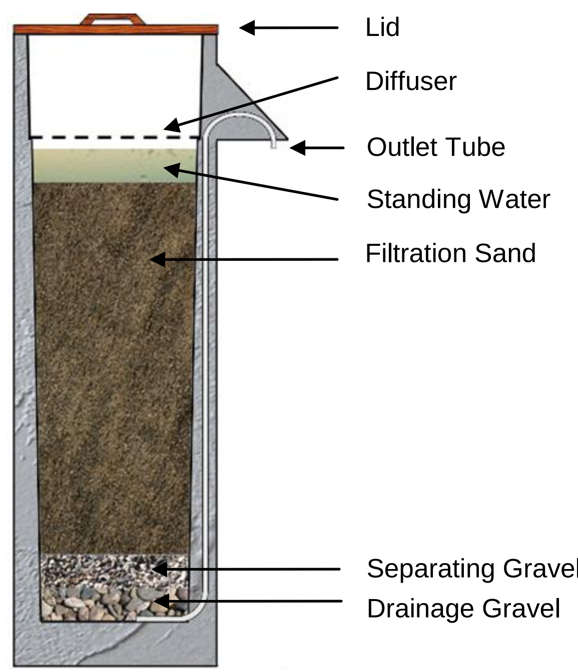
Robustness: There are no moving or mechanical parts to break. Outlet pipe is embedded in the concrete, protecting it against breaks and leaks. Poor transportation can lead to cracking and/or breakage; cracks can sometimes be repaired. Filters should not be moved after installation.

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



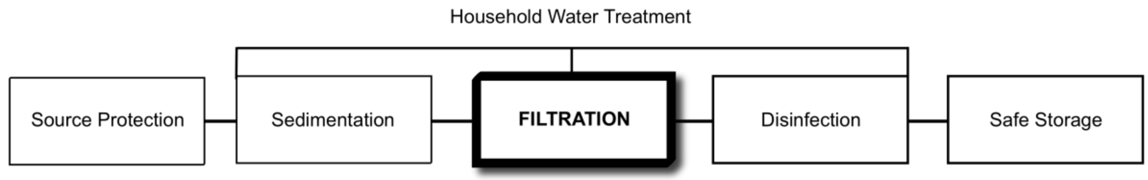
Further Information

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

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.

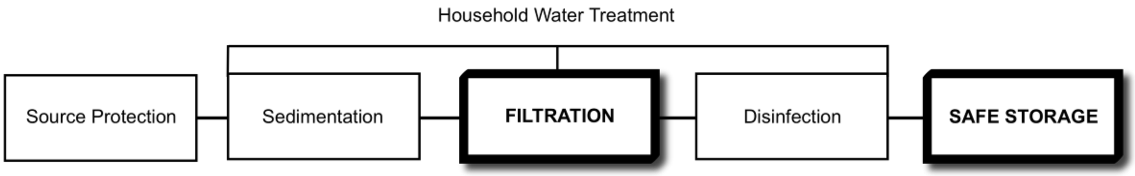
Further Information

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.

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.

Filter with one ceramic candle

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

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

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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.

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CAWST (Centre for Affordable Water and Sanitation Technology)
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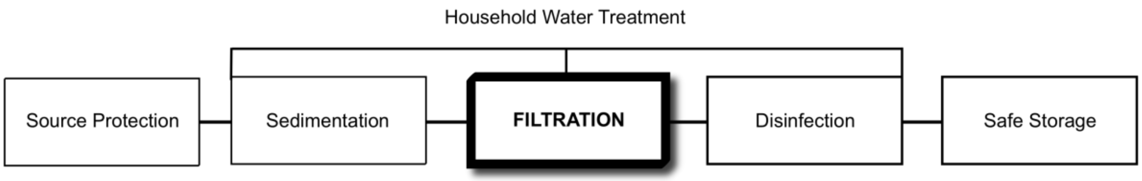
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: June 2011

CAWST Centre for Affordable Water and Sanitation Technology

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.

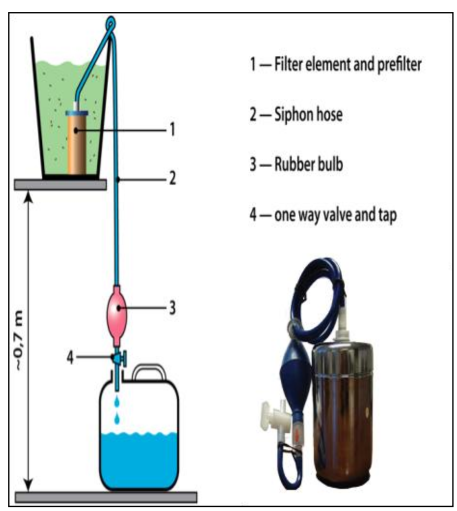
Manufacturer: Basic Water Needs India Pvt Ltd, Pondicherry, India

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

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

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.

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

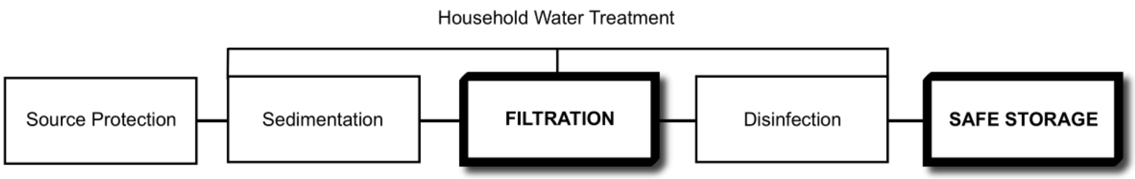
Basic Water Needs BV/Pty. Test results from independent laboratories (2010-2011) and product information published on filter manufacturer’s website: www.basicwaterneeds.com

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

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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

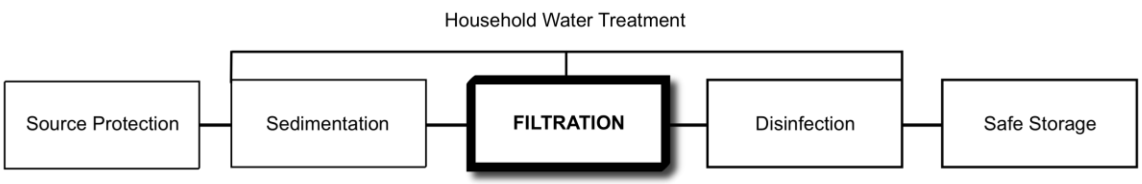
CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org Email: cawst@cawst.org
Last Update: June 2011

CAWST Centre for Affordable Water and Sanitation Technology

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.

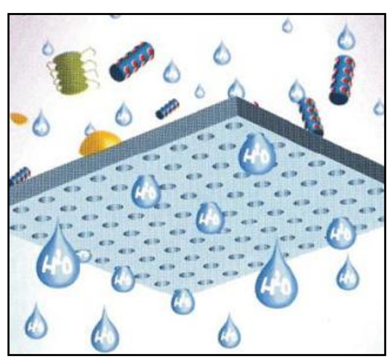
Filtration Type	Pore Size (µm / nm)	Molecular Weight (Daltons)
Microfiltration (MF)	0.1-10 µm (1-1000 nm)	
Ultrafiltration (UF)	0.01-0.1 µm (1-100 nm)	10,000-500,000
Nanofiltration (NF)	<0.001 µm (<1 nm)	200-1,000
Reverse osmosis (RO)	<0.001 µm (<1 nm)	<100

(Wagner, 2001 and US EPA, 2005)

Ultrafiltration is the most common membrane filtration in household drinking water treatment.

How Does It Remove Contamination?

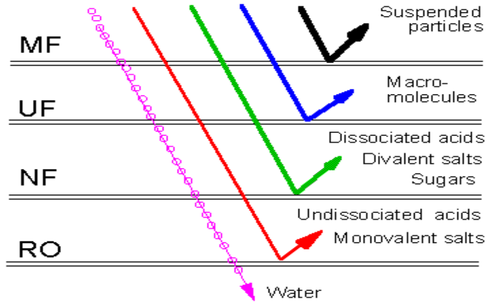
As water passes through the membrane, pathogens and other contaminants are removed because they are too big to fit through the membrane pores. Pressure is required to force the water through the membrane. For microfiltration and ultrafiltration, gravity alone may provide enough pressure to make the water flow through the filter.



Filter Membrane Illustration
(Credit: www.firstprinciples.com)

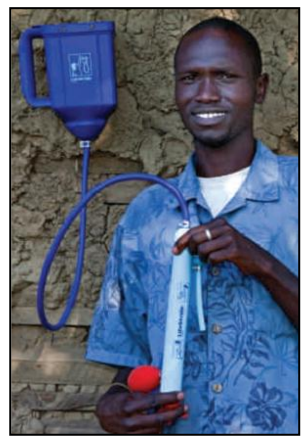
Household Water Treatment and Safe Storage Factsheet: Membrane Filters

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)

Sawyer Filter
(Credit: www.sawyerpointonefilters.com)



Lifestraw Family Filter
(Credit: www.vestergaard-frandsen.com/lifestraw)

Nerox-02 Filter
(Credit: www.scan-water.org)

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.

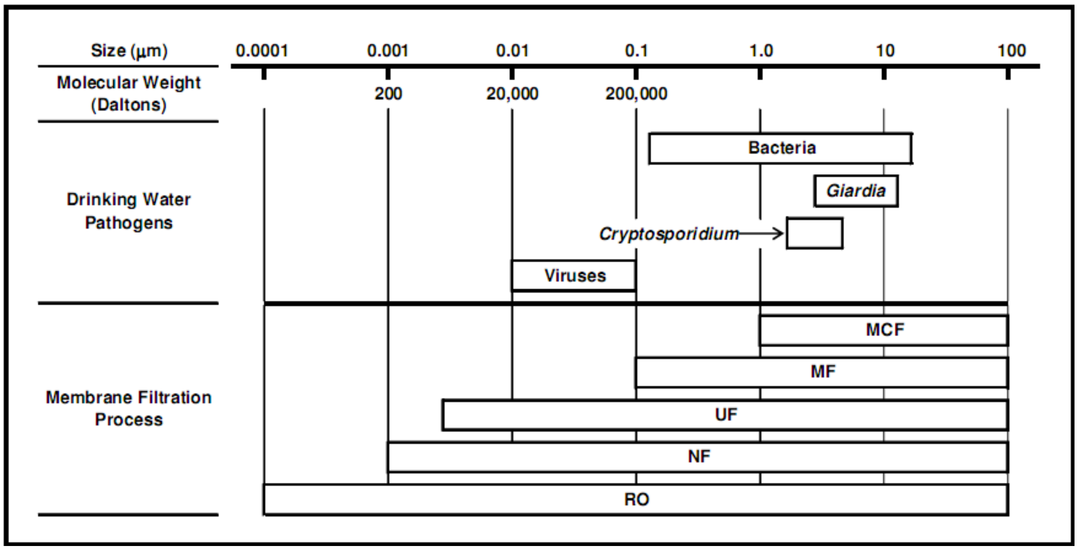
Household Water Treatment and Safe Storage Fact Sheet: Membrane Filters Key Data

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

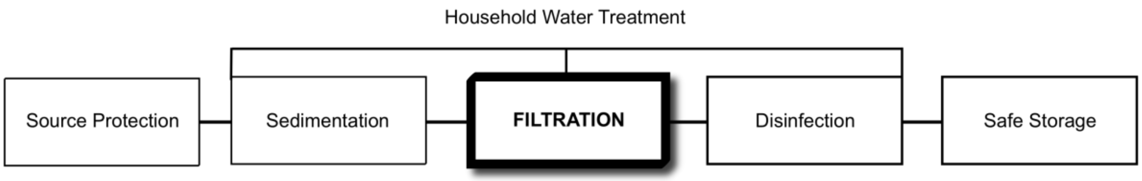
Wagner, J. (2001). Membrane Filtration Handbook. Second Edition, Revision 2. Osmonics, Inc. USA. Available online at: www.ionics.com/content/pdf/1229223-%20Lit-%20Membrane%20Filtration%20Handbook.pdf

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)

Household Water Treatment and Safe Storage Product Sheet: LifeStraw® Family

Approximate Dimensions: Upper container capacity: 2 litres
Plastic hose length: 1 metre

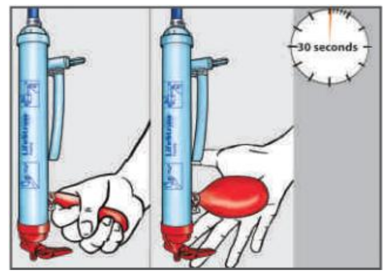
Approximate Weight: Not available

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

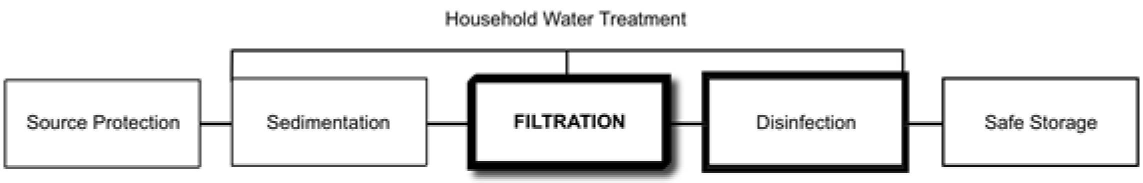
Clasen, T. et al. (2009). Laboratory assessment of a gravity-fed ultrafiltration water treatment device designed for household use in low-income settings. Am. J. Trop. Med. Hyg., 80(5), 2009, pp. 819–823.

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

Centre for Affordable Water and Sanitation Technology

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)

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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

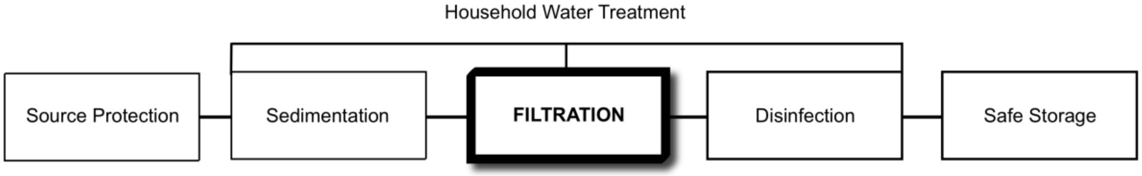
Sobsey, M. (no date). LifeStraw® Personal: Summary of Test Data Received from the University of North Carolina, USA.

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

Centre for Affordable Water and Sanitation Technology

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

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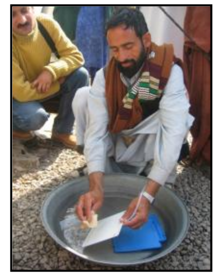
Household Water Treatment and Safe Storage Product Sheet: Nerox®- 02 Drinking Water Filter

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

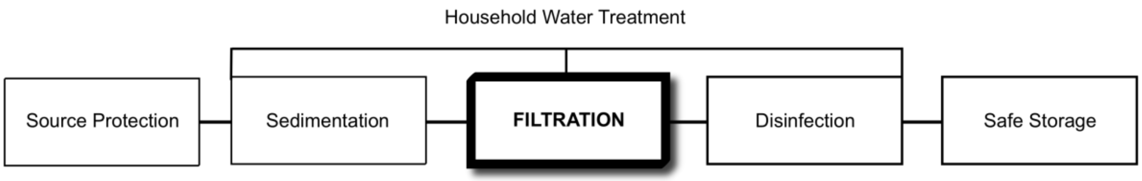
Scan Water: www.scan-water.com
Information brochure: www.scan-water.com/products.php?vareid=103

Simpex/Filter-systems: www.filter-systems.com

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Product Sheet: Sawyer Point One™ Filter

Treatment Type



Product Name: Sawyer Point One™ filter

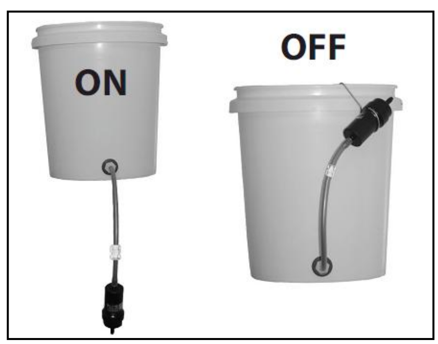
Manufacturer: Sawyer Products Inc., USA

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™ 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.

Sawyer PointOne™ Bucket Filter
(Credit: www.sawyer.com/gallery.htm)

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.

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.

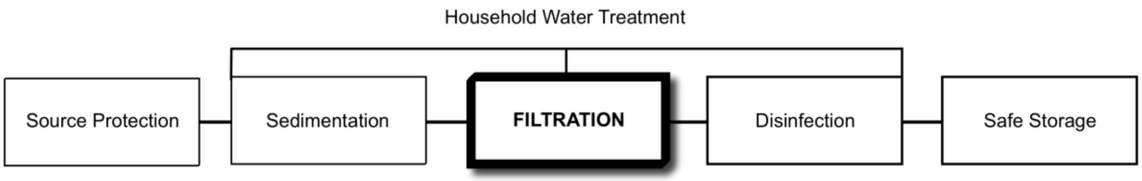
References

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)

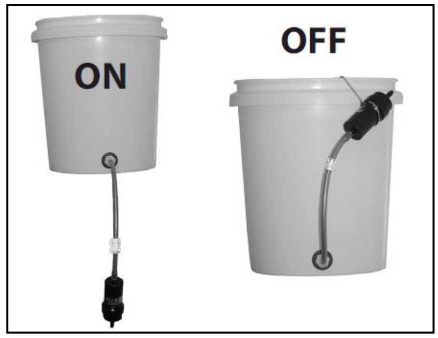
Availability: Available online. Cannot be exported internationally through Sawyer Products. They recommend contacting an international logistic company for shipping outside of North America.

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^{TM} Purifier

Approximate Dimensions: Cylindrical filter: length 22 cm, diameter 7 cm. Plastic tube length: 90 cm (3 feet); other lengths are available.



Sawyer Filter Operation
(Credit: www.sawyer.com)

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.

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^{TM} filter; the Point Zero Two^{TM} 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^{TM} filter; the Point Zero Two^{TM} 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

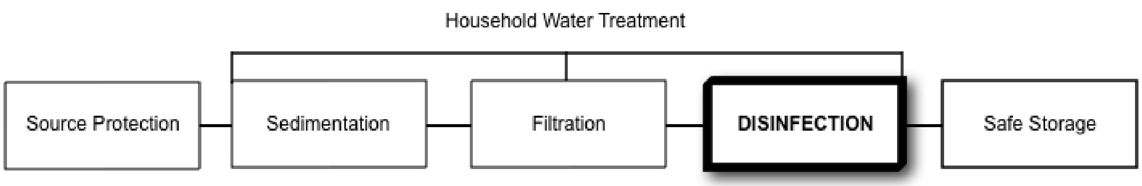
Hydreion LLC. (2005). Microbiological Testing of the Sawyer 7/6B Filter. USA. Available at: www.sawyerpointonefilters.com/downloads/MicrobiologicalTest_HydreionLabReport_12-01-2005_76BFilter.pdf

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.

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.

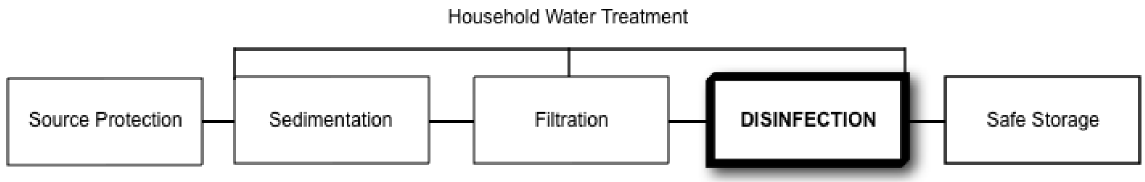
Clasen, T., Thao, D., Boisson, S., and O. Shipin (2008). Microbiological Effectiveness and Cost of Boiling to Disinfect Drinking Water in Rural Vietnam. Environmental Science and Technology; 42(12): 42:55.

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

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.

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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

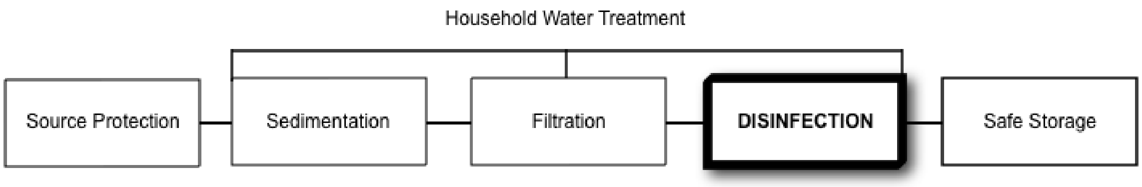
CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: June 2011

CAWST 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.

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.

Clorin sold in grocery stores, Zambia

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

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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

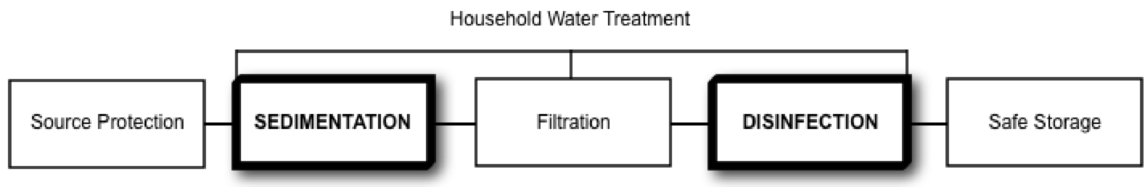
Centers for Disease Control and Prevention:
www.cdc.gov/safewater/publications_pages/pubs_chlorine.htm

Environment and Public Health Organization (ENPHO):
www.enpho.org/product_treatment_piyush.htm

Population Services International (PSI): www.psi.org/child-survival/

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

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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

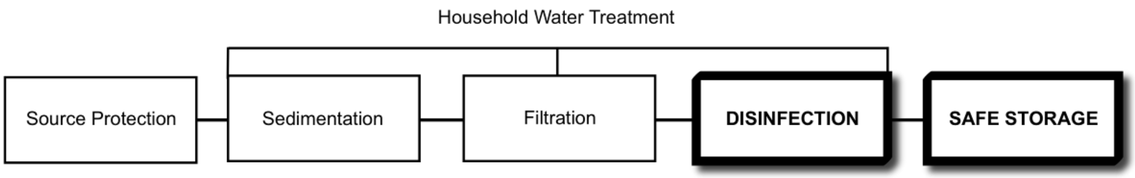
http://news.pg.com/press-release/pg-corporate-announcements/pg-underlines-commitment-its-childrens-safe-drinking-water-

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org, Email: cawst@cawst.org
Last Update: January 2012

CAWST Centre for Affordable Water and Sanitation Technology

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 *Cryptosporidum 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 *Cryptosporidum 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)

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Household Water Treatment and Safe Storage Fact Sheet: Solar Disinfection (SODIS)   Key Data

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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.

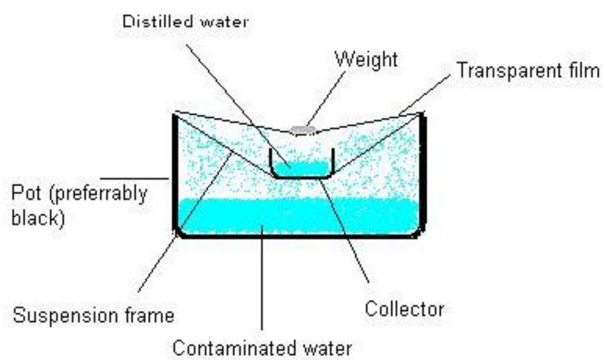
There are many different designs for solar distillation units (also known as stills). The simplest are a piece of plastic stretched over a container with the source water in the bottom. The plastic is weighted down in the middle so that the condensate can drip into a smaller collection container inside 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.

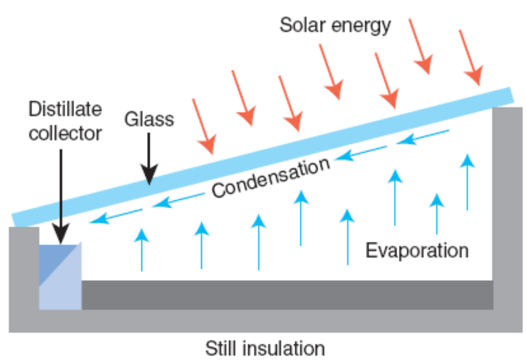
Another simple still uses a removable plastic cone rimmed on the inside edge with a collection channel. The condensed water flows down the sides of the cone into the channel. Water is removed by opening a cap at the apex of the cone, and turning the still upside down into a container.

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

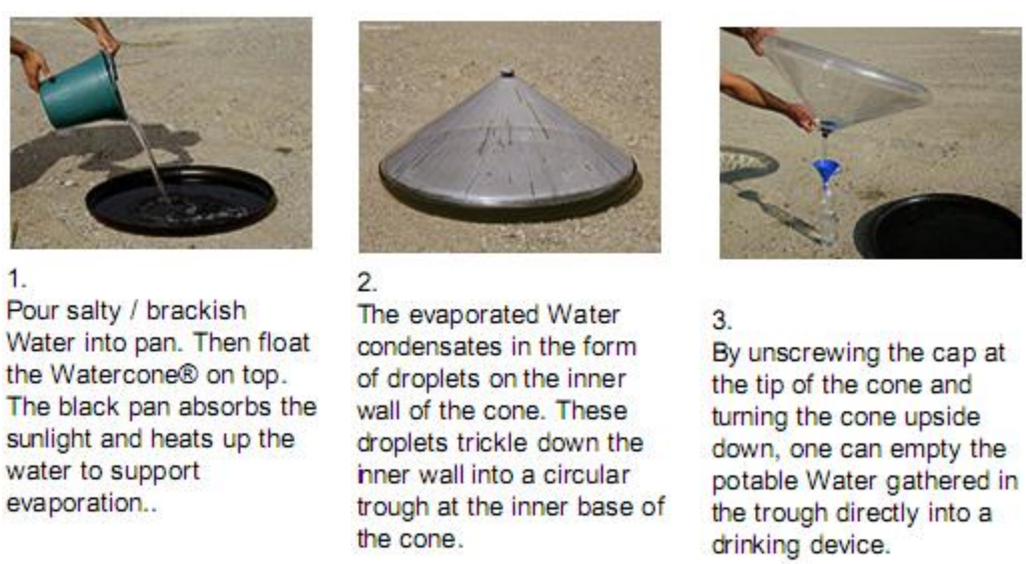
Flat Bed/Box Still:

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:



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

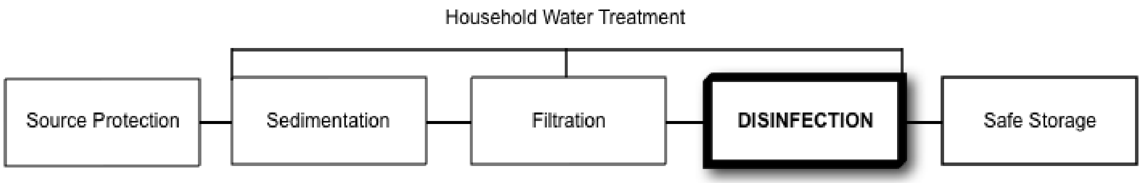
AquaCone™: www.solarsolutions.info/main.html

Watercone®, Germany: www.watercone.com

Waterpyramid®, The Netherlands: www.waterpyramid.nl

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

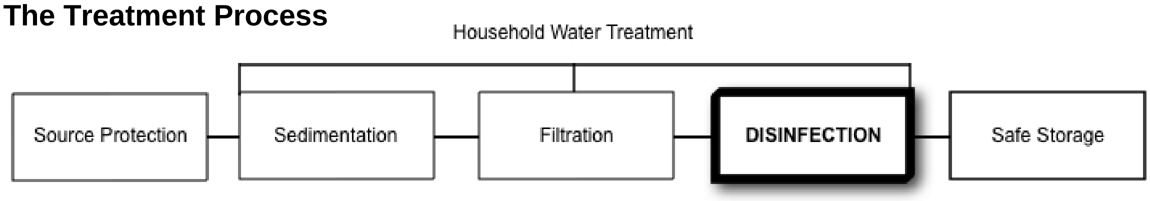
Solar Cookers International: http://solarcookers.org

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.

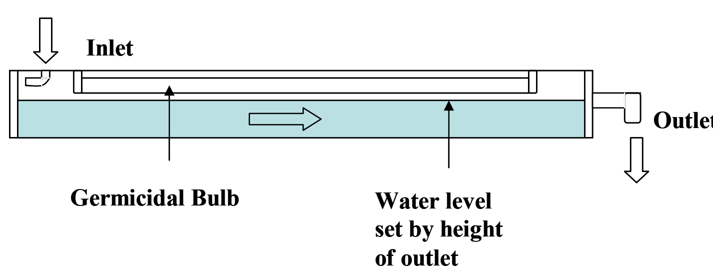
How Does It Remove Contamination?

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

Household Water Treatment and Safe Storage Factsheet: Ultraviolet (UV) Disinfection Key Data

- 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.

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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.

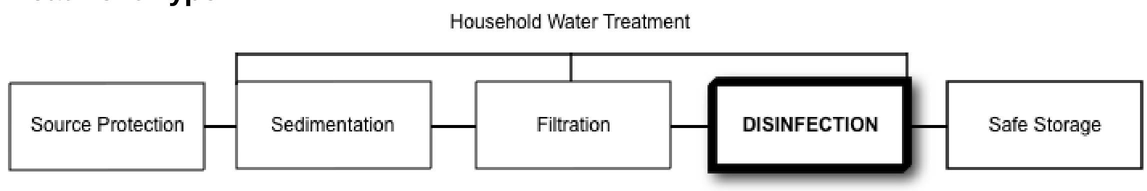
Further Information

University of California Berkeley: http://uvtube.berkeley.edu/home

WaterHealth International: http://waterhealth.com

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)

Centre for Affordable Water and Sanitation Technology

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

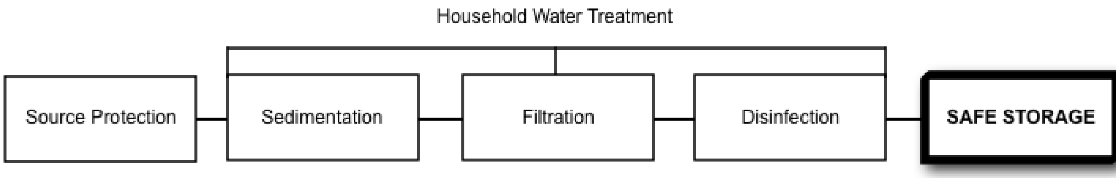
Further Information

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)

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

Oxfam Bucket Used Mainly in Emergencies *(*Credit: Oxfam*)*

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.

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

CAWST Centre for Affordable Water and Sanitation Technology

Centre for Affordable Water and Sanitation Technology

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

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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.

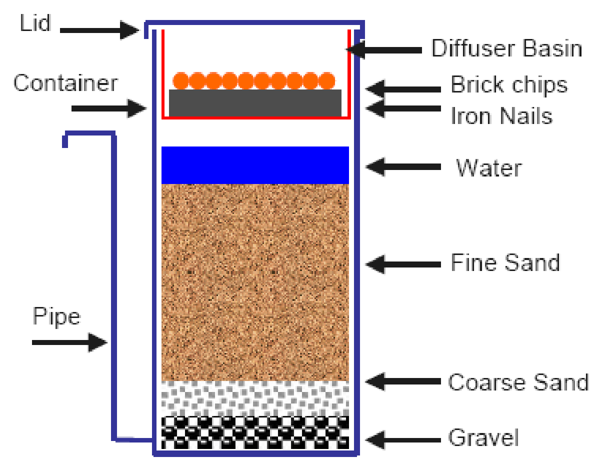
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

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.

Centre for Affordable Water and Sanitation Technology

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

Centre for Affordable Water and Sanitation Technology

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

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Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

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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

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?

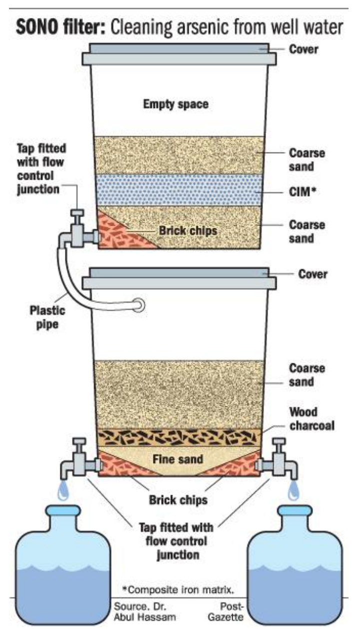
The primary active material is the composite iron matrix (CIM), made of cast iron. Manganese in the CIM catalyzes oxidation of As(III) to As(V). Arsenic (V) is removed by a surface-complexation reaction (strong adsoption) between the hydrated iron (FeOH) molecules in the CIM and Arsenic (V). FeOH is 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

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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

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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

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(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

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?

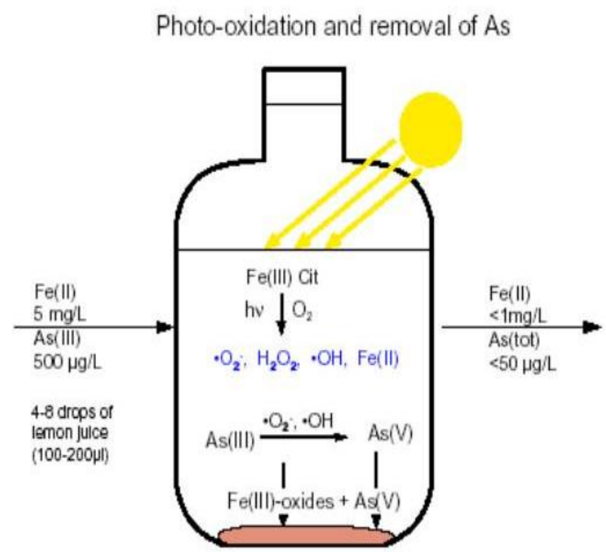
SORAS removes arsenic using a two-step procedure:

- 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

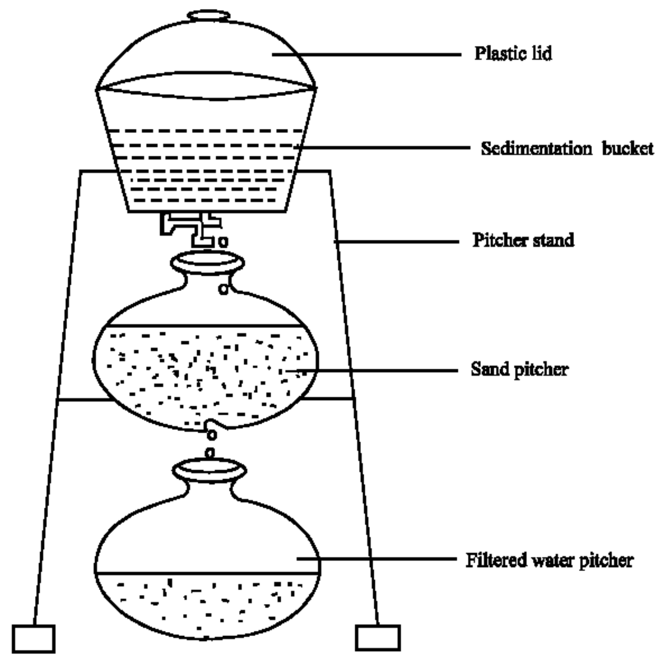
Asia Arsenic Network Filter

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

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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.

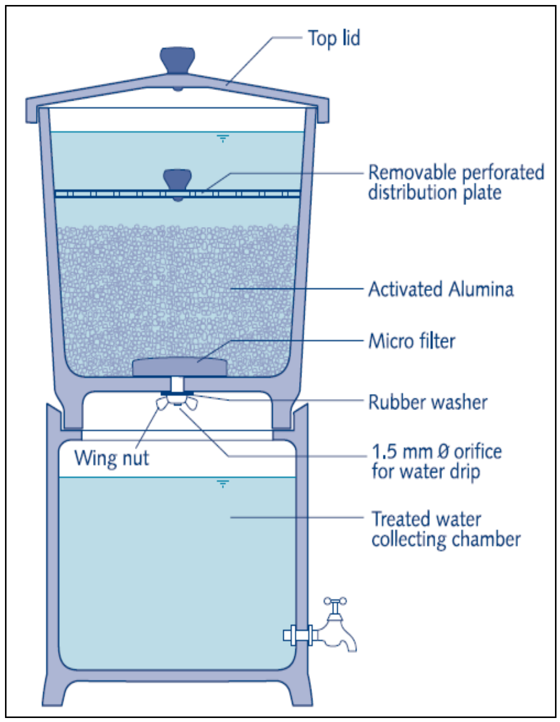
Activated alumina grains are packed in a filter like sand. When water passes through it, certain contaminants in the water adsorb (stick) to the activated alumina. Activated alumina removes fluoride from water, and can also be used for arsenic removal (see the corresponding Arsenic Removal by Adsorption 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.

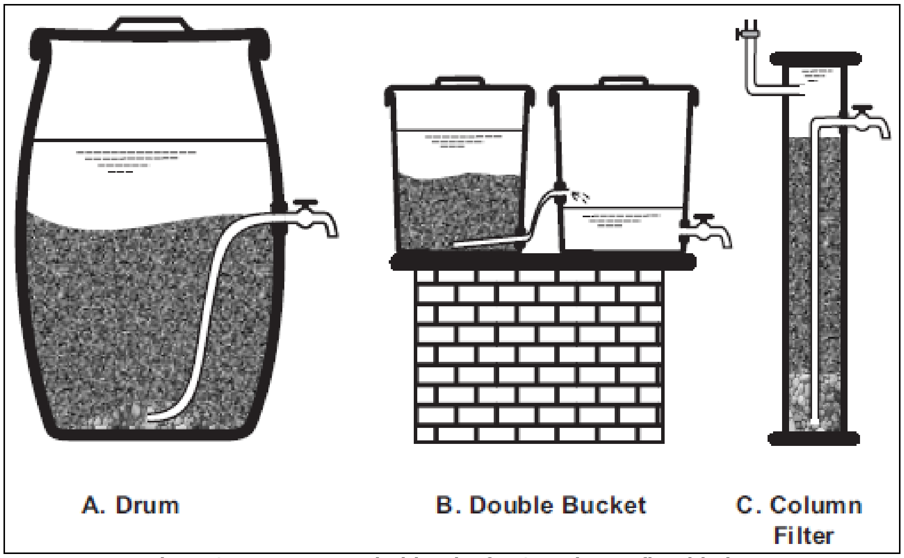
Household Water Treatment for Fluoride Removal Factsheet: Activated Alumina Filter

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.

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Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Fluoride Removal Factsheet: Bone Char Filter

Potential Treatment Capacity

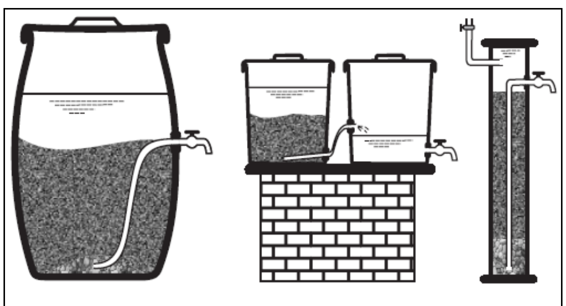
Very Effective For:	Somewhat Effective For:	Not Effective For:
• Fluoride • Taste, odour, colour	• Turbidity • Other Chemicals	• Bacteria • Viruses • Protozoa • Helminths • Hardness

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

<u>Bone Char Production</u>

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).

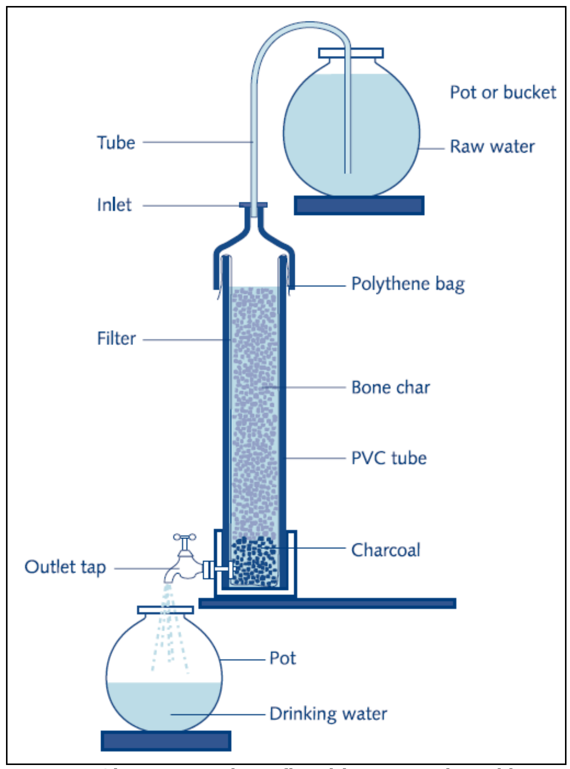
Single and Combined Bone Char Filter (Credit: Eawag, 2006)

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

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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?

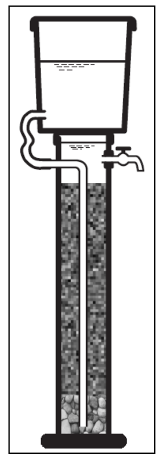
Clay is a good flocculent and absorbent for removing fluoride, because of its relatively high density (the particles are heavy).So once the fluoride attaches to the clay particles, it settles out well.

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)

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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.

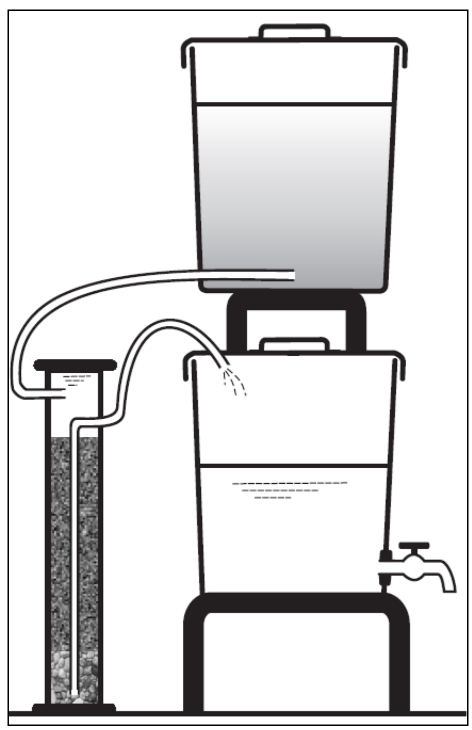
How Does It Remove Contamination?

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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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.

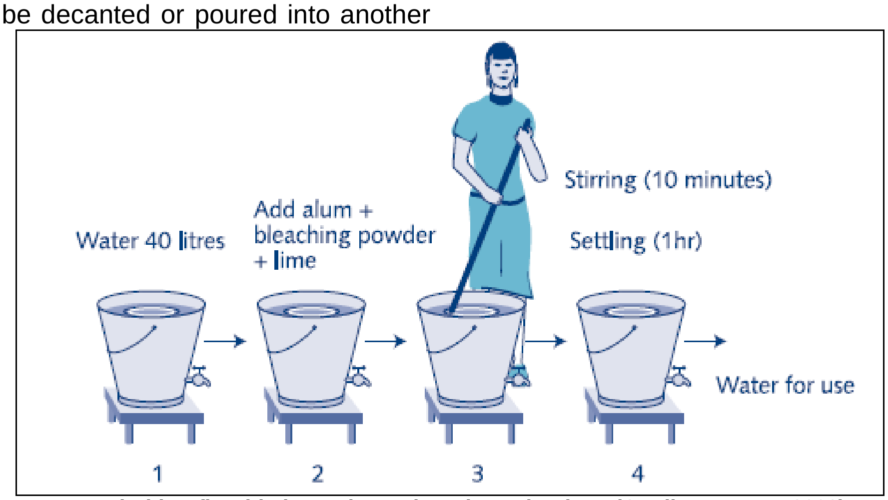
After treatment with the chemicals, the treated water can be decanted or poured into another container. The water may be passed through a filter or cloth while decanting to ensure that no sludge particles escape with the treated water.

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.

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