Household Water Treatment for Arsenic Removal Fact Sheet: Adsorption

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 filter. The buckets are in series and both filled with an American-made activated alumina media. The media has been developed by MAGC Technologies and Alcanof US; and it is produced by thermal dehydration (at 250-1150˚C) of an aluminium hydroxide.

How Does It Remove Arsenic?

The Magc-Alcan filter removes arsenic by adsorption (adhesion or sticking together) of the arsenic to the enhanced activated alumina which is porous and has a high surface area.

Removal rates can be sensitive to varying pH levels, so additional equipment may be required to control pH levels.

Operation

- Place two buckets (with taps) filled with activated alumina media in series using a stand
- Place a safe water container after the second tap
- Pour water in the top bucket with all of the taps open

Similar Tchnology: Nirmal Filter

A similar filter called "Nirmal Filter" also exists in India. It uses arsenic adsorption on an Indian-made activated alumina and it is followed by filtration through a ceramic candle. It is less expensive than a Magc-Alcan filter ($10-15 capital cost) but it needs to be regenerated every 6 months.
Efficiency: 80-90% arsenic removal.

Magc-Alcan Filter   Nirmal Filter

(Photo Credit: Ngai)

Key Information

Treatment Efficiency	Production	Cost	Lifespan
Magc-Alcan: 80-85% arsenic removal Nirmal: 80-90% arsenic removal	100 litres/hour	$35-50 capital cost	6 months to 1 year

Household Water Treatment for Arsenic Removal Fact Sheet: Adsorption

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 (adhesion or sticking together) of the arsenic to the iron on the coated brick chips, which works as well as iron coated sand. The bricks are coated by treatment with a ferrous sulphate solution (Ahmed, 2005). The filter can hold up to 30 litres of 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 media (20 kg) filters 4,000 litres of arsenic-contaminated water reducing arsenic concentrations to undetectable levels and supplying an average family with 25-32 litres of safe drinking water per day.

Operation

Pour the water into the filter and allow it to pass through the filter medium.

The used filter media is non-toxic and can be disposed of safely without danger to the environment or human health. The media container is re-useable and easily maintained.

(Photo Credit: Ngai)

Key Information

Efficiency	Production	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: Adsorption

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Available at:
http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/EXTSAREGTOPWATRES/0,,contentMDK:20450010~pagePK:34004173~piPK:34003707~theSitePK:494236,00.html

Further Information

Magc-Alcan Filter:

www.buet.ac.bd/itn/pages/outcomes/ALCAN%20WSP%20Jul%2001_2007%20v1.pdf

www.wateraid.org/documents/plugin_documents/arsenicweb.pdf

http://books.google.ca/books?id=Mo9Btfy95H0C&pg=PA41&lpg=PA41&dq=alcan+household+filter+description&source=bl&ots=tdH8hr1kfp&sig=uIPcNRy3ifGTPrTwUQRnwofBxhc&hl=en&ei=xgasSZuOMZqqtQP2sOD3Dw&sa=X&oi=book_result&resnum=4&ct=result#PPA42,M1

Shapla Filter:

www.jalmandir.com/arsenic/shapla/shapla-arsenic-filter.html

Household Water Treatment for Arsenic Removal Fact Sheet: Coagulation-Flocculation

Bucket Treatment Unit (BTU)

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Most pathogens • Turbidity • Taste, odour, colour	• Arsenic	• Chemicals

What Is Bucket Treatment Unit (BTU)?

The Bucket Treatment Unit has been developed within the DPHE-Danida project. It consists of oxidation (loss of electrons of As(III) to form As(V)) and coagulation (clumping of particles to promote sedimentation) processes using potassium permanganate and aluminum sulphate respectively. The water is then filtered through cloth into a second bucket that contains a sand filter. The BTU can be constructed from locally available materials.

How Does It Remove Arsenic?

Arsenic is removed by:

- The oxidation of As(III) to As(V) by applying an oxidizing agent (potassium permanganate)
- Coagulation and flocculation by applied flocculant (alum)
- Adsorption of arsenic on flocs
- Sedimentation
- Cloth and sand filtration.

Coagulation/flocculation can also be obtained by iron chloride/iron sulfate.

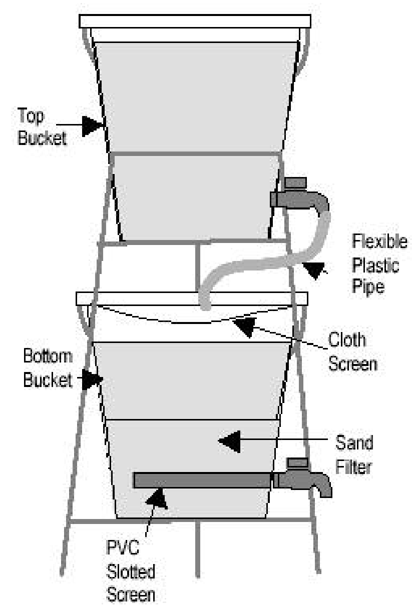
Operation

The unit consists of a two bucket system. The upper bucket is filled with raw water. Chemicals are added and the water is stirred fast for approximately 25 seconds with a wooden spoon provided with the unit.

Recommended chemical doses are (Tanhura et al.):

- 200 mg/L aluminum sulphate
- 2 mg/L of potassium permanganate

The mixture is then allowed to settle for 1-2 hours. The tap is then turned on so that the water can pass through a cloth screen and a sand filter in the lower bucket.



(Photo Credit: Ngai)

Key Information

Treatment Efficiency	Production	Cost
~ 60% arsenic removal	20 litres/hour	$10 capital cost $15-20 chemical cost/year

Household Water Treatment for Arsenic Removal Fact Sheet: Coagulation-Flocculation

2-Kolshi Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Pathogens • Taste, odour, colour		• Chemicals

What Is 2-Kolshi?

2-Kolshi is an arsenic removal method using two buckets. The first step is a coagulation process using a specific amount of iron sulphate and enough sodium hypochlorite to create a distinctive chlorine odour upon stirring in a normal bucket of water, followed by a filtration in a ceramic filter.

How Does It Remove Arsenic?

Coagulation/filtration is a traditional treatment process that adds a chemical coagulant (typically iron sulfate or iron chloride) to contaminated water. The coagulant modifies the physical or chemical properties of dissolved or suspended contaminants so that they settle from solution by gravity or can be removed by filtration. As part of the coagulation process, arsenic is co-precipitated with the iron. The stirring process helps to build the flocs into larger particles.

The 2-Kolshi technique oxidizes As(III) to As(V) by stirring the water, co-precipitates As^{5+} with iron chloride and ash, and then it filters the water to remove the formed particles.

(Photo Credit: Ngai)

Key Information

Treatment Efficiency	Production	Cost
90% arsenic removal 99% microbial removal	3-5 litres/hour	\$10 capital cost \$15-20 chemical cost/year

Operation

- Add ENPHO chemical (iron sulphate, sodium hypochlorite and ash) to a bucket of water
- Stir water for a few minutes
- Let settle for one hour
- Pass the water through a ceramic filter

Household Water Treatment for Arsenic Removal
Fact Sheet: Coagulation-Flocculation

References

Hwang, S.K. (2002). Point-of-use arsenic removal from drinking water in Nepal using coagulation and filtration. MIT Master of Engineering Thesis. June 2002

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Phase I Report: www.wateraid.org/documents/phs1report.pdf
Phase II Report: www.wateraid.org/documents/phs2fullrpt.pdf

Further Information

Bucket Treatment Unit (BTU):

www.unu.edu/env/arsenic/tahura.pdfhttp://www.asce-susdev.org/files/pdf/efsdec07.pdf

www.ubu.dk/Arsenic%20project/household_treatment.htm#bucket%20treatment%20unit

2-Kolshi Filter:

www.epa.gov/etv/pubs/600s07007.pdf

www.betv-sam.org/documents/nepal_workshop/presentations/11-TNgai_FindingsonArsenicMitigationTechnologiesTestingandEvaluationinNepal.pdf

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

Sono Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Arsenic • Bacteria • Turbidity • Chemicals • Taste/odour/colour		

What Is a Sono Filter?

The Sono Filter is a three bucket system with a composite iron matrix (CIM) as the active arsenic removal component. It creates surface complexation of arsenic on the CIM followed by a filtration.

The filter is manufactured from indigenous materials and it works without chemical treatment, without regeneration, and without producing toxic waste. It is efficient to remove arsenic and 22 other heavy metals as well as bacteria.

How Does It Remove Arsenic?

The primary active material is the composite iron matrix (CIM) made of cast iron. Manganese in CIM catalyzes oxidation of As(III) to As(V), all of which is removed by a surface-complexation reaction between the surface of hydrated iron (FeOH) and arsenic species thereby removing the arsenic from the water. FeOH is also known to remove many other toxic species.

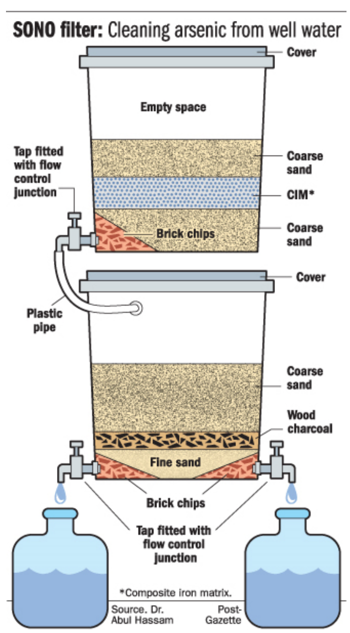
In combination with CIM, the sand, charcoal and the optimum arrangement of the materials in the filter removes arsenic, iron, manganese and many other inorganic species to a potable water quality.

Operation

Each bucket has different media and functions:

- Top bucket: 3 kg iron filings and 2 kg coarse sand
- Middle bucket: 2 kg fine sand, 1 kg of wood charcoal and brick chips
- Bottom bucket: water collection container

The water first flows through the coarse river sand and a composite iron matrix (CIM). The water flows into a second bucket where it again filters through coarse river sand, then wood charcoal to remove organics, and finally through fine river sand and brick chips to remove fine particles and stabilize water flow.



(Photo Credit: www.robrasa.com)

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

Key Information

Treatment Efficiency	Production	Cost	Lifespan
90-95% arsenic removal	20-30 litres per hour	$40-50 capital cost	Replace unit after 3-5 years

References

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www.physics.harvard.edu/~wilson/arsenic/remediation/ETVAM%20Poster.ppt

Further Information

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www.asce-susdev.org/files/pdf/efsdec07.pdf

www.robrasa.com/files/sono_filter_study.pdf

www.physics.harvard.edu/~wilson/arsenic/remediation/SONO/Narrative_Grainger_AH.pdf

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Last Update: October 2009

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

Kanchan™ Arsenic Filter

Potential Treatment Capacity

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

What is a Kanchan™ Arsenic Filter?

The KanchanTM Arsenic Filter (KAF) is an adaptation of the biosand filter (BSF). 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 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.

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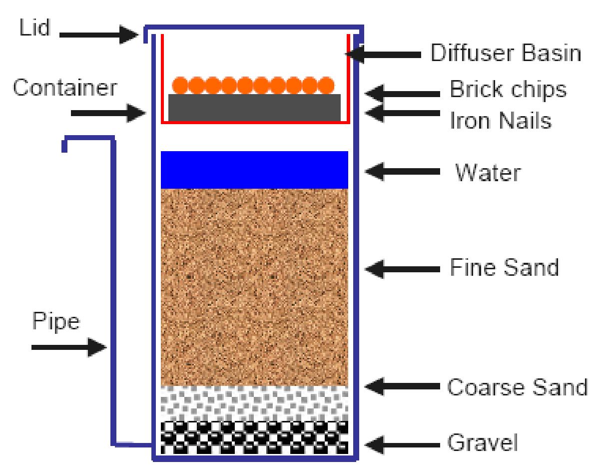
The diffuser basin is filled with 5 to 6 kg of non-galvanized iron nails for arsenic removal. A layer of bricks on top of the nails prevents displacement of the nails when water is poured into the filter.

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

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

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.

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.

The rusted iron nails are essential for removing arsenic. The nails need to be evenly distributed to avoid the water from short-circuiting. A layer of bricks on top of the nails prevents displacement of the nails when water is poured into the filter. As well, users should pour the water slowly and carefully into the filter to prevent the nails from moving around.

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

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

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

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

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

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

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

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

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

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

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

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. (2006)
10 Ngai et al., (2007)
11 Uy et al., (2008)

- Treatment efficiencies provided in the above table require an established biolayer; it takes up to 30 days to establish the biolayer and 2 weeks to establish rust on the nails depending on inlet water quality and usage
- Filter must be used almost every day to maintain the biological layer (maximum pause period is 48 hours)
- Best performance requires a consistent water source; switching sources may decrease treatment efficiency
- Normal cleaning will reduce filter efficiency until the disturbed biolayer re-establishes itself
- Appearance and odour of treated water is generally improved
- Cannot remove pesticides or fertilizers (organic chemicals)
- Cannot remove salt, hardness, and scale (dissolved compounds)
- Does not provide residual protection to minimize recontamination

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
< 0.4 litres/minute*	12-18 litres	24-36 litres**

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

* 0.4 litres/minute is the maximum recommended flow rate for the CAWST Version 10 concrete biosand filter. The actual flow rate will fluctuate over the filter cleaning cycle and between filters.
** Based on 2 batches per day to ensure effective arsenic removal

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

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

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

Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

- Concrete filters are heavy and difficult to move and transport

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

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Household Water Treatment for Arsenic Removal Fact Sheet: Surface Complexation

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Further Information

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

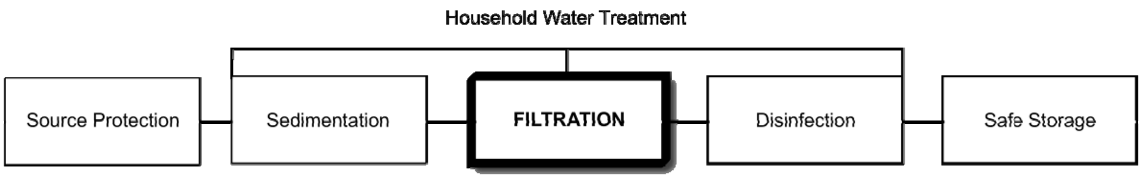
Environment and Public Health Organization (ENPHO):
www.enpho.org/drinking_water_quality.htm

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

CAWST (Centre for Affordable Water and Sanitation Technology)
Wellness through Water.... Empowering People Globally
Calgary, Alberta, Canada
Website: www.cawst.org
Email: cawst@cawst.org
Last Update: October 2009

Household Water Treatment and Safe Storage Factsheet: Kanchan™ Arsenic Filter

Treatment Type



Potential Treatment Capacity

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

What is the 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.

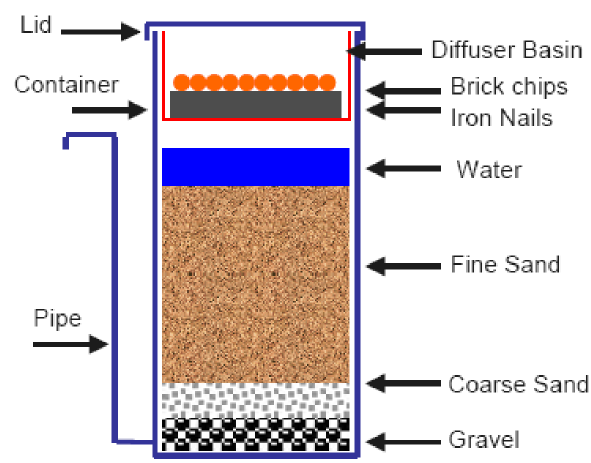
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

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.

The diffuser basin is filled with 5 to 6 kg of non-galvanized iron nails 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 strong 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

Household Water Treatment and Safe Storage Factsheet: Kanchan™ Arsenic Filter

In addition, 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.

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.

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. The recommended pause period is 6 to 12 hours with a minimum of 1 hour and maximum of 48 hours.

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 concrete KAF is 0.6 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 BSF 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.

Brick chips and nails in a Kanchan™ filter

Household Water Treatment and Safe Storage Factsheet: Kanchan™ Arsenic Filter Key Data

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. (2006)
10 Ngai et al., (2007)
11 Uy et al., (2008)

- Sand and iron nail selection and preparation are critical to ensure flow rate and 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 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 efficiency until disturbed biolayer is re-established
- Taste, odour and colour of filtered water is generally improved

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
< 0.6 litres/minute*	12-18 litres	24-36 litres**

* 0.6 L/min is the maximum recommended flow rate; 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

Robustness

- No moving or mechanical parts to break
- In concrete models, piping is embedded in concrete, protecting it against breaks and leaks
- 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; cracks can sometimes be repaired
- Filters should not be moved after installation

Household Water Treatment and Safe Storage Factsheet: Kanchan™ Arsenic Filter Key Data

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:
- Concrete KAF design is freely available from CAWST, Canada

Local Production (for concrete KAF):
- Local production of concrete filters is common
- Molds for concrete filters can be borrowed, rented, bought or welded 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 steel mold
- Anyone can be trained to construct and install the filter

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

Maintenance

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

Cost

Capital Cost	Operating Cost	Replacement Cost
US$12-30	US$0/year	US$1-2[1]

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

[1] Nails need to be replaced every 2-3 years

Household Water Treatment and Safe Storage Factsheet: Kanchan^{TM} Arsenic Filter Key Data

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Further Information

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

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

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

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Last Update: July 2009

CAWST Centre for Affordable Water and Sanitation Technology

Centre for Affordable Water and Sanitation Technology

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 is based on oxidation mechanisms of iron compounds that naturally reduce the arsenic content of groundwater. Naturally occurring dissolved $Fe(OH)_2$ in the groundwater undergoes a natural chemical process called oxidation (when an element loses electrons) to produce a solid form or precipitate of $Fe(OH)_3$ which attracts arsenic to stick to it, a process called adsorption (Ahmed, 2002). This adsorption produces a co-precipitate of $Fe(OH)_3$ and arsenic that settles to the bottom of the container thereby removing the arsenic from the water. This technology does not require chemicals, but rather is based on the passive oxidation process and subsequent sedimentation.

Passive oxidation is seen as an easy technology, because of the natural habits of rural people to store their water in pitchers, before they drink it. Nevertheless, its performance at removing arsenic at 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 (Ahmed, 2002). The method is based on coprecipitation with iron upon oxidation and sedimentation. It does not require the use of chemicals, but aeration and settling of iron rich water.

The amount of arsenic removed depends on the concentration of iron in water.

Operation

- Stir the water for 2 minutes
- Leave water overnight in an open container

(Photo credit: Ngai)

Key Information

Treatment Efficiency	Production	Cost
Typically 30 to 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 one but with use of lemon juice. Sunlight as a source of UV causes the oxidation (loss of electrons) of As(III) to As(V). The resulting As(V) is strongly attracted to iron hydroxides particles present in the water and sticks to these particles. The As(V)/$Fe(OH)_3$ co-precipitate then settles to the bottom of the container.

How Does It Remove Arsenic?

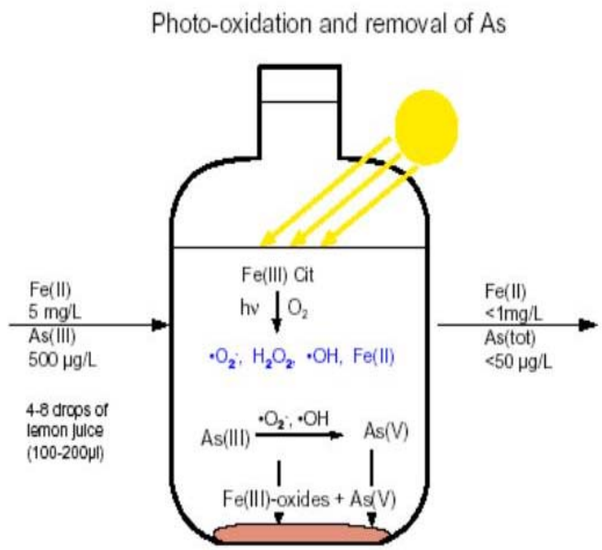
SORAS removes arsenic in a two-step procedure:

- First step: As(III), which only weakly adsorbs to iron hydroxides, is oxidized to the strongly adsorbing As(V)
- Second step: Fe(III) hydroxide precipitates formed from naturally present iron are allowed to settle to the bottom of the container with the adsorbed As(V) and the clear water is decanted

Instead of adding chemical oxidants such as chlorine or permanganate, reactive oxidants are produced photo chemically with 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
- The water can then be filtered through textile cloth or clay filters



(Photo Credit: Ngai)

Key Information

Treatment Efficiency	Production	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

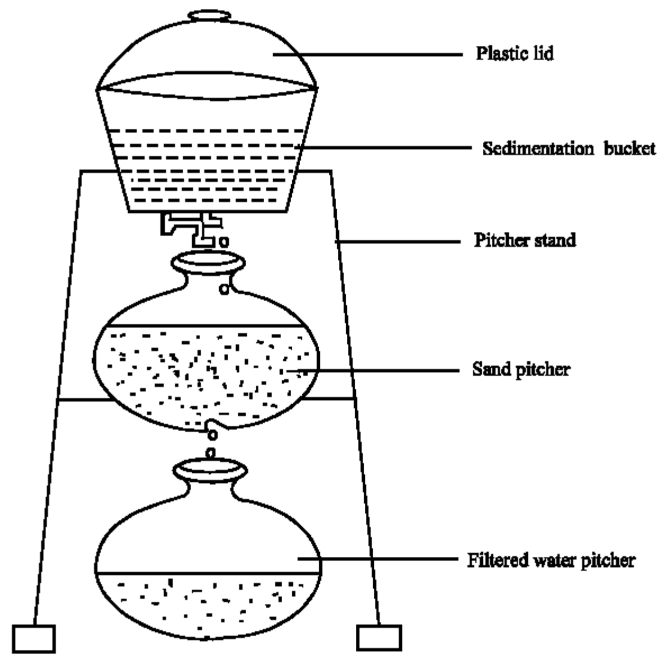
Asia Arsenic Network Filter

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 three plastic buckets) that are positioned so water flows from one container to the next. The process consists of manual aeration, oxidation of natural iron in water and the formation of the co-precipitate of the arsenic and the $Fe(OH)_3$. Arsenic removal depends on $Fe(OH)_3$ concentrations in water. The process is completed by filtering the water through sand.



(Credit: Asia Arsenic Network, 2001)

How Does It Remove Arsenic?

Water added to the upper bucket is stirred and allowed to settle. During this process, the dissolved iron compound $Fe(OH)_2$ in the groundwater undergoes a natural chemical process called oxidation (when an element loses electrons) to produce a solid form or precipitate of $Fe(OH)_3$ which attracts arsenic to stick to it, a process called adsorption (Ahmed, 2002). This adsorption produces a co-precipitate of iron (III) hydroxide and arsenic that settles to the bottom of the container thereby removing the arsenic from the water.

Operation

- Pour raw water into the top bucket and manually stir for 2 minutes
- Let water settle for 6 hours
- Transfer the water through the tap to the middle pitcher that contains 2 kg of coarse sand
- Lastly, the filtered water passes in to the third and lowest pitcher

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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Further Information

Solar Oxidation and Removal of Arsenic (SORAS):

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Asia Arsenic Network Filter:

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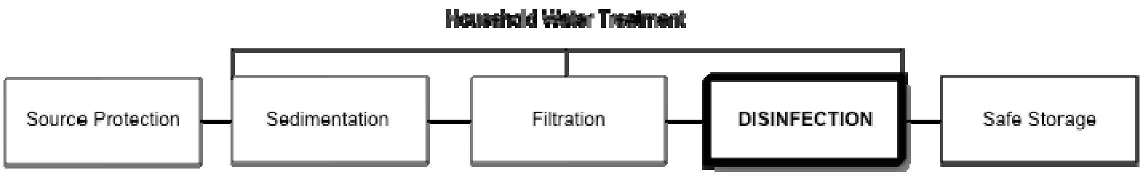
CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Boiling

The Treatment Process



Potential Treatment Capacity

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

What is Boiling?

Boiling is considered the world's oldest, most common, and one of the most effective methods for treating water. If done properly, boiling kills or deactivates all bacteria, viruses, protozoa (including cysts) and helminths that cause diarrheal disease.

How Does It Remove Contamination?

Pathogens are killed when the temperature reaches 100 degrees Celsius.

Operation

Water is heated over a fire or stove until it boils. Different fuel sources can be used depending on local availability and cost (e.g. wood, charcoal, biomass, biogas, kerosene, propane, solar panels, electricity).

Water bubbling as it boils provides a visual indicator does away with the need for a thermometer.

Recommended boiling times varies among organizations. The World Health Organization recommends that water be heated until it reaches the boiling point (WHO, nd). The Centers for Disease Control and Prevention, recommends a rolling boil of 1 minute, to ensure that users do not stop heating the water before the true boiling point is reached (CDC, 2009). CAWST recommends boiling water for 1 minute and adding 1 minute per 1000 metres of elevation.

Recontamination of boiled water is a major problem. Water is often transferred from the pot into dirty storage containers which then make it unsafe to drink. It is recommended to store boiled water in its pot with a lid to reduce the risk of recontamination.

Boiled tastes flat to some people. This is caused by dissolved oxygen escaping from the water as it boils. The flat taste can be reduced by vigorously stirring or shaking cooled water to increase its dissolved oxygen content.

Boiling water (Credit: Phitar, 2005)

Household Water Treatment and Safe Storage Fact Sheet: Boiling Key Data

Inlet Water Criteria

- Any water can be boiled

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	100%	100%	100%	100%	0%	0%[3]
Field	97-99%[1,2]	Not available	Not available	Not available	0%	0%

[1] Clasen, T. et al (2007)
[2] Clasen, T. (2007)
[3] May precipitate some dissolved chemicals

- Pathogens are killed when the temperature reaches 100 degrees Celsius

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Depends on container size	Depends on container size and availability of fuel

- Boil water for 1 minute and add 1 minute per 1000 metres of elevation
- Boiled water should be kept in the pot covered with a lid until it is consumed

Robustness

- Almost all households have the equipment required to boil water
- Requires fuel supply
- Users may not consistently boil water to save fuel and effort

Estimated Lifespan

- On-going requirement for fuel
- Pots used for boiling need may need to be replaced over time

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- Fuel (e.g. wood, charcoal, biomass, biogas, kerosene, propane, solar panels, electricity)
- Stove or heater
- Pot and lid

Fabrication Facilities:
- Not applicable

Labour:
- Regular collection of some fuels (e.g. wood, charcoal, other biomass)

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

Hazards:

- Potential for burn injuries; caution should be maintained around stoves and fires and when handling hot water
- Cause of respiratory infections associated with poor indoor air quality; improved stoves can be used to improve indoor air quality and reduce illness and death

Maintenance

- Pot and lid should be cleaned on a regular basis

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$0[1]	US$0-0.06/10 litres[2]	US$0[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] Households are assumed to already have a pot and fire/stove for cooking
[2] Clasen (2007)

Other

- Boiled water tastes flat to some people. This is caused by dissolved oxygen escaping from the water as it boils. The flat taste can be reduced by vigorously stirring or shaking cooled water to increase its dissolved oxygen content.

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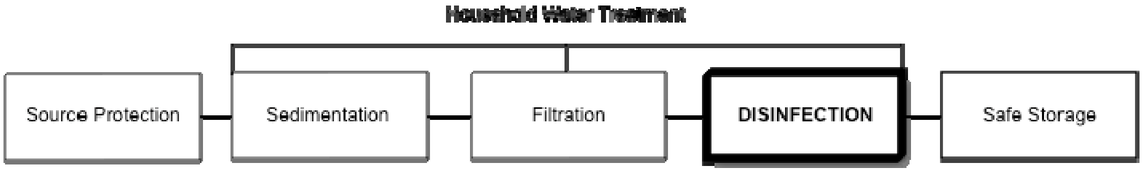
Last Update: October 2009

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets)

The Treatment Process



Potential Treatment Capacity

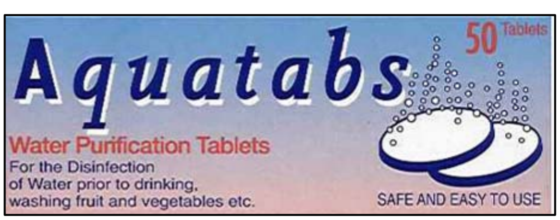
Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses	• Some protozoa • Helminths	• *Cryptosporidium parvum* • Toxoplasma oocysts • Turbidity • Chemicals • Taste, odour, colour

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. 3.5 mg to 8.68 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 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

Robustness

- Free residual chlorine protects against recontamination
- Most users cannot determine the dosing quantity themselves; proper use requires following instructions from the manufacturer
- Users often 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

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets) Key Data

Materials:
- Tablets and packaging materials

Fabrication Facilities:
- Workshop space for packaging the tablets

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; study on sodium hypochlorite)

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Household Water Treatment and Safe Storage Fact Sheet: Chlorine (NaDCC Tablets) Key Data

Further Information

Medentech Ltd: www.aquatabs.com or www.medentech.com

Website: www.cawst.org Email: cawst@cawst.org

Wellness through Water.... Empowering People Globally

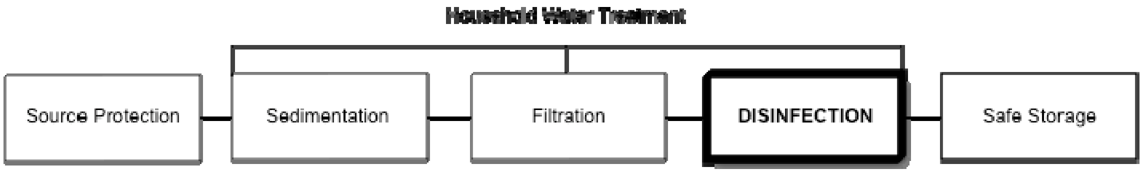
Last Update: October 2009

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite)

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses	• Some protozoa • Helminths	• *Cryptosporidium parvum* • Toxoplasma oocysts • Turbidity • Chemicals • Taste, odour, colour

What is Sodium Hypochlorite?

Chlorine began to be widely used as a disinfectant in the early 1900's. It revolutionized drinking water treatment and dramatically reduced the incidence of waterborne diseases. Chlorine remains the most widely used chemical for water disinfection in the United States.

Sodium hypochlorite is one form of chlorine used for water disinfection. It can be manufactured in most locations since it can be obtained through the electrolysis of salt water.

Bottles can be purchased for household water treatment from many manufacturers in various sizes. Chlorine concentrations range from 0.5 to 10% and each product should have its own instructions for correct dosing of contaminated water. Liquid household bleach also contains sodium hypochlorite, and is widely available.

How Does it Remove Contamination?

Chlorine forms hydrochlorous acid when added to water which reacts through oxidization with microorganisms and kills them.

Three things can happen when chlorine is added to water:

1. Some chlorine reacts through oxidization with organic matter and the pathogens in the water to kill them. This portion is called consumed chlorine.
2. Some chlorine reacts with other organic matter, ammonia and iron and forms new chlorine compounds. This is called combined chlorine.
3. Excess chlorine that is not consumed or combined remains in the water. This portion is called free residual chlorine (FRC). The FRC is the most effective form of chlorine for disinfection (particularly for viruses) and helps prevent recontamination of the treated water.

Air Rahmat, Indonesia
(Credit: Tirta/JHUCCP)

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite)

Operation

There are several different brands of chlorine products that have been manufactured specifically for household water treatment. Each product should have its own instructions for correct dosing and contact time.

Clorin sold in grocery stores, Zambia

Liquid household bleach products are also commonly used to disinfect drinking water. The strength of the product must be known to calculate how much bleach is needed to disinfect a given volume of water. See CAWST's *Technical Brief on Chlorine Disinfection of Drinking Water* for information on how to determine the chlorine dose and contact time using household bleach.

The effectiveness of chlorine is affected by turbidity, organic matter, ammonia, temperature and pH.

Turbid water should sedimented or filtered before adding chlorine. These processes will remove some of the suspended particles and improve the reaction between the chlorine and pathogens.

Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite) Key Data

Inlet Water Criteria

- Low turbidity
- pH between 5.5 and 7.5; disinfection is unreliable above a pH of 9

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	High[4]	High[4]	Low[4]	Ineffective[5] – Moderate[6]	0%
Field	Not available	Not available	Not available	Not available	0%

[1] Bacteria include *Burkholderia pseudomallei, Campylobacter jejuni, Escherichia coli, Salmonella typhi, Shigella dysenteriae, Shigella sonnei, Vibrio cholerae, Yersinia enterocolitica.*
[2] Viruses include enteroviruses, adenoviruses, noroviruses, rotavirus.
[3] Protozoa include *Entamoeba histolytica, Giardia lamblia, Toxoplasma gondii, Cryptosporidium parvum.*
[4] CDC (2007)
[5] AWWA (2006) shows that chlorine is ineffective for *Ascariasis lumbricoides* ova.
[6] Mercado-Burgos et al.(1975) show moderate effectiveness for *Schistosoma* species. Assume moderate effectiveness for *Dracunculus medinensis.*

- *Toxoplasma* oocysts and C*ryptosporidium parvum* oocysts are highly resistant to chlorine disinfection (CDC, 2007). Chlorine alone should not be expected to inactivate these pathogens.

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Need to follow manufacturer's instructions for specific sodium hypochlorite products
- Required dose and contact time varies with water quality (e.g. turbidity, pH, temperature)
- Very turbid water should be sedimented or filtered prior to chlorination
- Use a 30-minute minimum contact time
- If the pH is above 7.5, a higher FRC concentration of 0.6 mg/litre should be used and the contact time should be extended to 1 hour
- 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 often 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 products should used within 3 months of being manufactured

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

References

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Household Water Treatment and Safe Storage Fact Sheet: Chlorine (Sodium Hypochlorite) Key Data

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Further Information

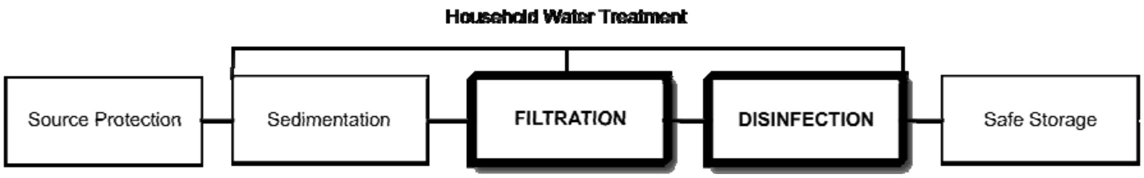
Centers for Disease Control and Prevention:
www.cdc.gov/safewater/publications_pages/pubs_chlorine.htm

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

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

Household Water Treatment and Safe Storage Fact Sheet: Chulli Pasteurization

The Treatment Process



Potential Treatment Capacity

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

What is Chulli Pasteurization?

Pasteurization is the process of disinfecting water by heat or radiation. Typical water pasteurization achieves the same effect as boiling, but at a lower temperature (usually 65-75°C), over a longer period of time.

The chulli stove system combines two water treatment processes: filtration and pasteurization. Water flows first through a rapid sand filter and then into aluminium tubing coiled inside a traditional clay stove (chulli). From the stove, the water flows through heat resistant plastic tubing to an outlet tap, where it is collected in a container.

The water is pasteurized during daily cooking. By regulating the flow, the water temperature can be maintained at 70°C; sufficient for pasteurization as it flows through the coil.

How Does It Remove Contamination?

Larger pathogens (e.g. protozoa, helminths), suspended particles (e.g. sand, silt. clay), and iron are removed through the filter. Pathogens are killed or inactivated at 65°C.

Operation

The source water is poured into the top of the rapid sand filter (20-25 litre container filled with clean sand). The water flows through the aluminium tubing coiled within the chulli stove, and collected in a heat resistant container.

Whenever the stove is being used for cooking, the outlet tap must be open. There must also always be water in the system. This will prevent super-heating the water and tubing inside the chulli, which may cause breakage or leaks.

The height difference between the filter and the outlet tap should be adjusted, and the maximum flow rate at the outlet tap set to 0.5 litres/minute, to regulate the water temperature at 70°C.

Chulli Pasteurization (Credit: Johnston, UNICEF)

Household Water Treatment and Safe Storage Factsheet: Chulli Pasteurization Key Data

Inlet Water Quality

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	100%[1]	100%[3]	100%[4]	100%[4]	Not available[5]	0%
Field	> 100%[1,2]	Not available	Not available	Not available	Not available	0%

[1] Islam and Johnston (2006)
[2] 12.5% of households tested in Phase II showed some bacteria in the treated water (unknown removal rates), the rest showed zero
[3] Not tested but other research suggests that viruses will be killed at a temperature of 70°C maintained for 45 seconds
[4] Not tested, but other research suggests that many helminths and protozoa are too large to pass through the rapid sand filter or will be killed at a temperature of 70°C if maintained for 45 seconds
[5] Not tested; turbidity removal will be high in the rapid sand filter

- Pathogens are killed when the temperature reaches 65 degrees Celsius
- Appearance of treated water is generally improved

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
0.5 litres/minute[1]	20-25 litres (rapid sand filter)	60-90 litres[2]

[1] The actual flow rate will vary in the field; the maximum suggested flow rate is 0.5 L/min
[2] From field measurement where families cook for 1.5-2 hours, 2-3 times a day, producing 30 litres each time

- Lab experiments showed that adjusting the tap to a flow of 0.5 litres/minute provided a residence time inside the coil of about 45 seconds, and water at 70°C
- Systems should not be used with the tap closed, water should not be collected/consumed without a fire burning, and systems should not be allowed to run dry

Robustness

- The system requires no additional inputs for operation after installation; may require maintenance/repair (Gupta et al., 2008)
- Leakage and breakage of the plastic or aluminum tubing may occur; repairs may mean breaking the stove apart and rebuilding (Gupta et al., 2008)
- Plastic taps in the lower container can break, metal taps last longer but increase cost

Estimated Lifespan

- This is an emerging technology and lifespan has not been determined yet

Manufacturing Requirements

Worldwide Producers:

- Developed by Prof. Mohammad Fakhrul Islam at Rajshahi University, and has also been researched and supported by UNICEF (Bangladesh) and Wagtech International (Bangladesh)

Household Water Treatment and Safe Storage Factsheet: Chulli Pasteurization Key Data

Local Production:
- This device may be built with off-the-shelf parts available throughout most countries. Anyone can be trained locally to build the chulli stove pasteurizer.

Materials:
- 20-25 litre plastic container
- Clean sand
- Heat resistant tubing
- Hollow aluminium tubing for coil (approximately 2.5 m long; 12 mm diameter)
- Heat resistant tap
- Sealants
- Suitable mud for making the chulli stove
- Specialist tools required for making aluminium coil
- Miscellaneous tools

Fabrication Facilities:
- Workshop space to manufacture coils and rapid sand filter

Labour:
- Anyone can be trained to construct and install the system

Hazards:
- No specific manufacturing hazards

Maintenance

- Repairs to leaks and tubing as required
- Standard maintenance of the chulli stove

Cost

Capital Cost	Operating Cost	Replacement Cost
US$6-7.50	US$0/year	Not available

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

References

Gupta, S. K., M. S. Islam, R. Johnston, P. K. Ram, and S. P. Luby (2008). The Chulli Water Purifier: Acceptability and Effectiveness of an Innovative Strategy for Household Water Treatment in Bangladesh. Am. J. Trop. Med. Hyg., 78(6), 2008, pp. 979-984.

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Household Water Treatment and Safe Storage Factsheet: Chulli Pasteurization Key Data

Further Information

Changemakers: www.changemakers.net/node/6647

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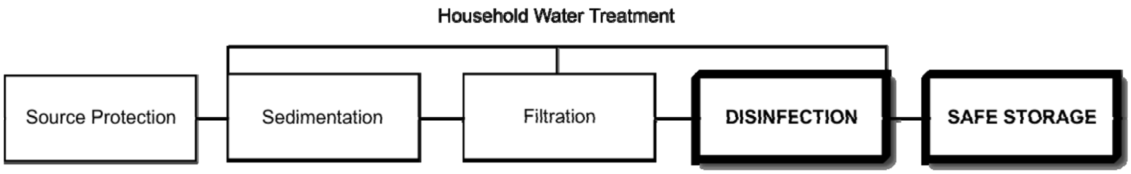
Centre for Affordable Water and Sanitation Technology

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

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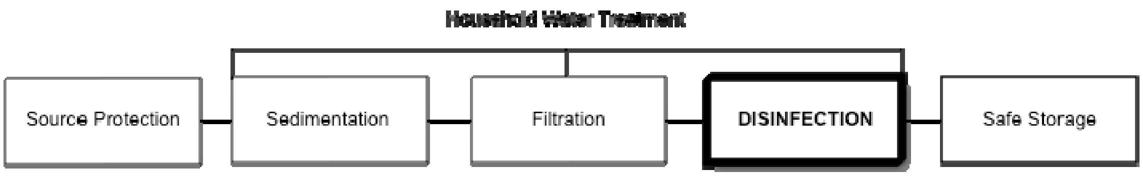
Further Information

Centers for Disease Control and Prevention:
http://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 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	Dependent on container size	4-12 litres

Andreatta (1994)

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

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

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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

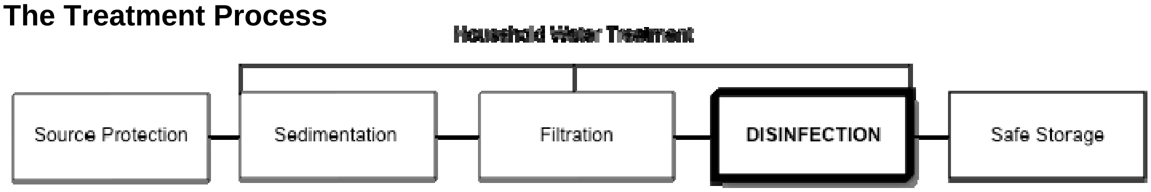
Solar Cooking Archive: www.solarcooking.org
http://solarcooking.wikia.com/wiki/Water_pasteurization

Safe Water Systems, Hawaii, USA: 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.

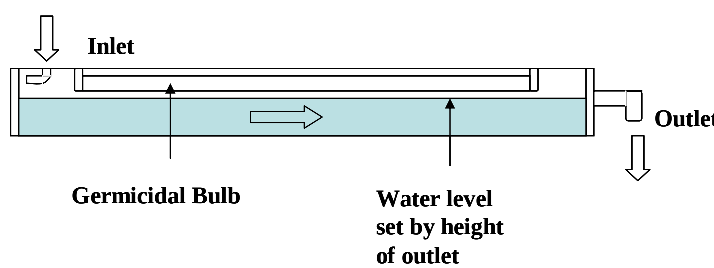
How Does It Remove Contamination?

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 manufacture 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

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

Materials:
- Feed container
- PVC tubing, or metal, pottery or cement channel
- Stainless steel sheet metal
- Various tubing connectors, valves and taps
- Electrical wires and connectors
- Miscellaneous tools for construction and installation

Fabrication Facilities:
- Workshop space for construction of UV units

Labour:
- Skilled workers with basic construction and electrical expertise can be taught to manufacture UV units

Hazards:
- Water and electricity in combination are potentially dangerous
- Necessary safety precautions should be taken both during manufacture and in the home
- Precautions should be taken to prevent the UV bulb and electrical components from getting wet if it is not enclosed with a protective quartz sleeve

Maintenance

- Clean the bulb if it gets dirty (frequency depends on source water quality)
- Replace the bulb every 12 months

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$60-150	Depends on cost of electricity	US$10-25/year[1]

Note: Program, transportation and education costs are not included. Costs will vary depending on location.
[1] UV bulbs need to be replaced every 12 months, bulb price varies

References

Cohn, A. (2002). The UV Tube as an Appropriate Water Disinfection Technology: An Assessment of Technical Performance and Potential for Dissemination. Masters Project for Energy and Resource Group, University of California, Berkeley.

Lang, M., Kaser, F., Reygadas, F., Nelson, K., and D. Kammen (2006). Meeting the Need for Safe Drinking Water in Rural Mexico through Point-of-Use Treatment. Center for Latin American Studies. University of California, Berkeley.

Gadgil, A., Greene, D., Drescher, A., Miller, P. and N. Kibata (1998). Low Cost UV Disinfection System For Developing Countries: Field Tests In South Africa. Water Health International, Napa, CA, USA.

Further Information

Renewable and Appropriate Energy Laboratory, University of California Berkeley: http://uvtube.berkeley.edu/home

WaterHealth International, Inc.: http://waterhealth.com

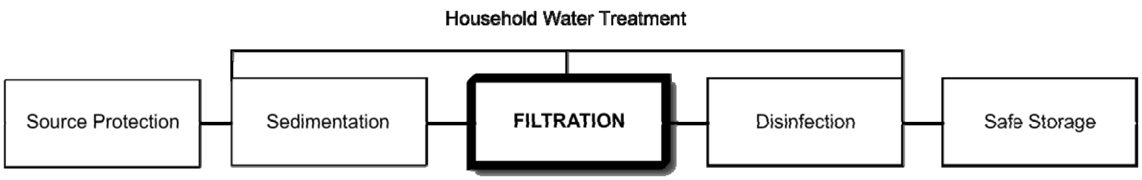
Household Water Treatment and Safe Storage Factsheet: Ultraviolet (UV) Disinfection Key Data

CAWST (Centre for Affordable Water and Sanitation Technology)
Calgary, Alberta, Canada
Website: www.cawst.org Email: cawst@cawst.org
Wellness through Water.... Empowering People Globally
Last Update: October 2009

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter

The Treatment Process



Potential Treatment Capacity

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

What is a Biosand Filter?

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

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

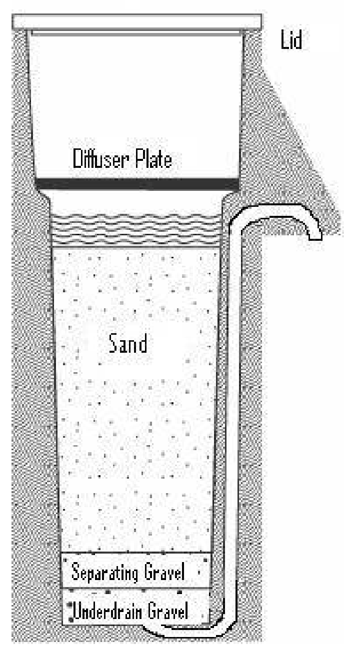
The container is filled with layers of sieved and washed sand and gravel (also referred to as filter media). There is a standing water height of 5 cm above the sand layer.

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

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

How Does It Remove Contamination?

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



Cross-Section of Concrete Biosand Filter

Household Water Treatment and Safe Storage Fact Sheet: Biosand Filter

Cross Section of Plastic Biosand Filter (Credit: International Aid)

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 Stauber et al. (2006)
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 (2009) 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

- 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$12-40	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.

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

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

Further Information

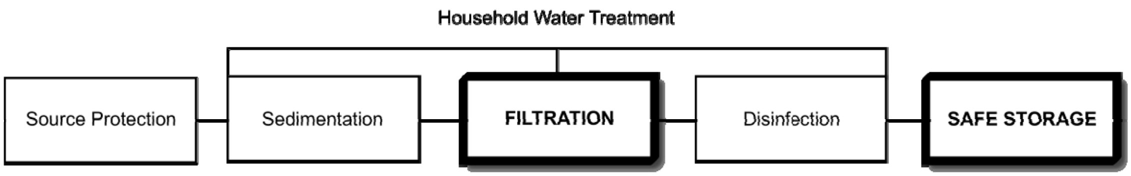
CAWST (Centre for Affordable Water and Sanitation Technology): www.cawst.org

International Aid: www.internationaid.org or www.hydraid.org

Centre for Affordable Water and Sanitation Technology

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

The Treatment Process



Potential Treatment Capacity

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

What is a Ceramic Candle Filter?

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

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

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

How Does It Remove Contamination?

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

Ceramic Candle Filter (Credit: USAID, Nepal)

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

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

Operation

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

Filter with one ceramic candle

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

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

Different types of ceramic candles

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

Inlet Water Quality

- Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

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

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

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

Operating Criteria

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

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

Robustness

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

Estimated Lifespan

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

Manufacturing Requirements

Worldwide Producers:

- Produced by different manufacturers around the world

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

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

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

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

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

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

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

Maintenance

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

Direct Cost

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

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

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

Other

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

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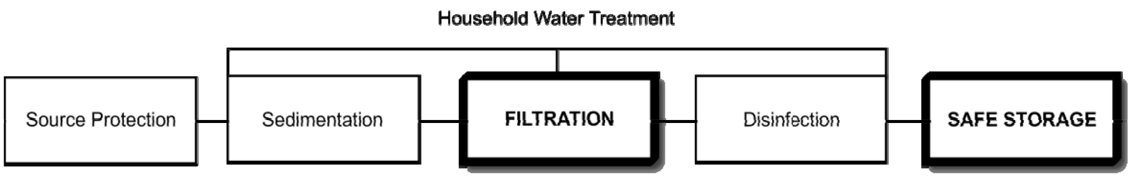
Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter

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

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What is a Ceramic Pot Filter?

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

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

The ceramic pot typically sits or hangs in the top of a larger plastic or ceramic container (20-30 litres), which is fitted with a tap at the bottom. A lid is placed on top of the filter to prevent contamination. The system both treats the water and provides safe storage until it is used.

Ceramic pots are usually made from local clay mixed with a combustible material like sawdust, rice husks or coffee husks. The clay and combustible material are sieved through a fine mesh, and then mixed together with water until it forms a homogeneous mixture. The mixture is pressed into shape using a mold. When the pot is fired in a kiln, the combustible material burns out, leaving a network of fine pores through which the water can flow through.

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

Some ceramic pot filters also include activated charcoal in the clay mixture to improve odour, taste, and colour.

How Does It Remove Contamination?

Pathogens and suspended material are removed from water through physical processes such as mechanical trapping and adsorption. Colloidal silver breaks down the pathogens' cell walls causing them to die.

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

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter

Operation

Contaminated water is poured into the ceramic pot. The water slowly passes through the pores and is collected in the lower container. The treated water is stored in the container until needed, protecting it from recontamination. The user simply opens the tap at the base of the container when they need water.

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

The filter pot should be regularly cleaned using a cloth or soft brush to remove any accumulated material. It is recommended that the filter pot be replaced every 1-2 years. This is in part to protect against fine invisible cracks which may have developed over time. Any cracks will reduce the effectiveness since water can short-circuit without being filtered through the ceramic pores.

Cross Section of Ceramic Pot Filter (Credit: Filter Pure Inc)

Round Bottom Ceramic Pot Filter (Credit: Filter Pure Inc)

Flat Bottom Ceramic Pot Filter (Credit: Potters for Peace)

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter Key Data

Inlet Water Quality

- Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iron
Laboratory	>98%[1]-100%[4]	19%[1]->99%[6,7]	>100%[8]	>100%[8]	83%[1]–99%[5]	Not available
Field	88%[2] to >95.1%[3]	Not available	>100%[8]	>100%[8]	<5 NTU[2]	>90%[5]

1 Lantagne (2001)
2 Smith (2004)
3 Brown and Sobsey (2006)
4 Vinka (2007)
5 Low (2002)
6 Van Halem (2006)
7 Some additives to the clay may increase virus removal
8 Not researched, however helminths and protozoa are too large to pass between the 0.6-3 μm pores. Therefore, up to 100% removal efficiency can be assumed.

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

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
1-3 litres/hour	8 litres	20-30 litres

- Flow rate is highest when the pot is full
- Flow rate declines with use and accumulation of contaminants within the filter pores

Robustness

- Lower container can be used as a safe storage container
- There are no moving or mechanical parts to break
- Small cracks can occur which are not visible to the naked eye, but which allow pathogens to pass through the filter
- Poor transportation of filters can lead to cracking and/or breakage
- Plastic taps in the lower container can break, metal taps last longer but increase cost
- Requires supply chain and market availability for replacement filters and taps
- Requires construction quality control process to ensure effectiveness
- Recontamination is possible during cleaning; care should be taken to use clean water, not to touch the ceramic with dirty hands, and not to place the filter on a dirty surface

Estimated Lifespan

- Up to 5 years, generally 1-2 years
- Filter needs to be replaced if there are visible cracks

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter Key Data

Manufacturing Requirements

Worldwide Producers:
- Free press and kiln designs are available from Potters for Peace

Local Production:
- Local production of the filters is common and preferable
- Requires quality control process to ensure filter effectiveness
- The lower container, lid and tap can usually be purchased locally

Materials:
- Clay
- Combustible material (e.g. sawdust, rice husks, coffee husks)
- Colloidal silver (optional)
- Lid
- 20-30 litre ceramic or plastic container with tap

Fabrication Facilities:
- A ceramic factory requires at least 100 square metres of covered area
- 15 to 20 ton hydraulic press (can be fabricated locally)
- Filter molds (can be fabricated locally)
- Mixer for clay and combustible material (can be fabricated locally)
- Hammer mill (can be fabricated locally)
- Kiln with an internal area of at least 1 cubic metre (can be fabricated locally)
- Racks
- Work benches
- Miscellaneous tools (e.g. traditional pottery tools)

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

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

Maintenance

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

Household Water Treatment and Safe Storage Factsheet: Ceramic Pot Filter Key Data

Direct Cost

Capital Cost	Operating Cost	Replacement Cost
US$12-25	US$0	~US$4[1]

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

[1] Filter pots generally need to be replaced every 1-2 years

References

Brown, J. and M. Sobsey (2006). Independent Appraisal of Ceramic Water Filtration Interventions in Cambodia: Final Report, Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, USA.

Lantagne, D. (2001). Investigation of the Potters for Peace Colloidal Silver Impregnated Ceramic Filter Report 2: Field Investigations. Alethia Environmental for USAID, USA.

Low, J. (2002). Appropriate Microbial Indicator Tests for Drinking Water in Developing Countries and Assessment of Ceramic Water Filters', Master of Engineering thesis. Department of Civil and Environmental Engineering, Massachusetts Institute of Technology. Cambridge, Massachusetts, USA.

Napotnik, J., Mayer, A., Lantagne, D. and K. Jellison. Efficacy of Silver-Treated Ceramic Filters for Household Water Treatment. Department of Civil and Environmental Engineering, Lehigh University, USA. Available at: www.filterpurefilters.org/files/pdf/silver.pdf

Smith, L. (2004). Ceramic Water Filter Use in Takeo, Cambodia – Operational Issues and Health Promotion Recommendations. Submitted in partial fulfilment as a requirement for a Master of Science in Control of Infectious Diseases, London School of Hygiene and Tropical Medicine, London, England.

Van Halem, D. (2006). Ceramic silver impregnated pot filters for household drinking water treatment in developing countries. Masters of Science in Civil Engineering Thesis, Department of Water Resources, Delft University of Technology, Netherlands.

Vinka, A. et al. (2007). Sustainable Colloidal-Silver-Impregnated Ceramic Filter for Point-of-Use Water Treatment. Environmental Science & Technology, Vol. 42, No. 3, 927–933

Further Information

Centers for Disease Control and Prevention:
http://www.cdc.gov/safewater/publications_pages/options-ceramic.pdf

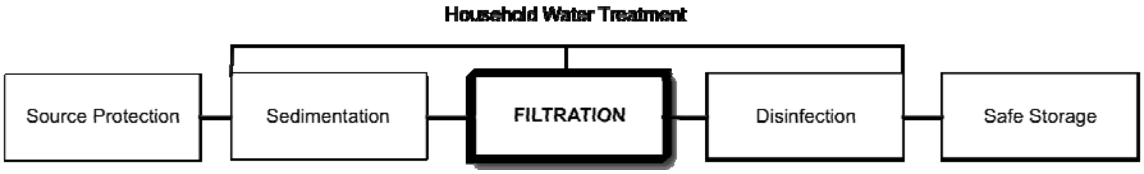
Filter Pure, Inc: www.filterpurefilters.org

Potters for Peace: www.pottersforpeace.org

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: LifeStraw®

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Protozoa (Family LifeStraw) • Helminths (Family LifeStraw) • Turbidity (Family LifeStraw)	• Turbidity (Personal LifeStraw)	• Protozoa (Personal LifeStraw) • Helminths (Personal LifeStraw) • Heavy metals

What is the Lifestraw® Personal?

LifeStraw® Personal is a portable water filter that effectively removes bacteria and viruses responsible for causing common diarrheal diseases.

The outer shell is composed of high impact polystyrene. Inside the filter is a halogenated (containing iodine) resin that releases active halogen into the influent water to inactivate the bacteria and viruses. There is also a strong base anion exchange resin and a silver-impregnated granular activated carbon that adsorb any residual active halogen.

Also contained within LifeStraw® *personal* is a two stage particle filtration system that filters particles from 125 microns down to a minimal of 15 microns.

LifeStraw® *personal* can filter 2 L/day for a year or 700 L and requires no electrical power or spare parts and can be carried around by the individual user.

How Does It Remove Contamination?

LifeStraw® contains a chamber with a specially developed halogenated resin (containing iodine) that kills bacteria and viruses on contact, thereby enhancing the killing effect. Micro-filters within the system are also used to remove all particles down to 15 microns. Activated carbon adsorbs residual iodine thereby improving the taste of water.

The filter pores are not small enough to remove protozoa or helminths from the influent water. Some but not all turbidity will be removed. The filters and purifier cartridge will require more cleaning if the source water is turbid.

Operation

The user dips LifeStraw® *personal* into a water source and sucks on it like a straw to draw the purified liquid up.

At regular intervals, it is recommended to do 'backwashing' that can be done by blowing out some air through the LifeStraw®. This will clean the pre-filters of whatever sand, silt and debris that might have been deposited in the filters.

Household Water Treatment and Safe Storage Fact Sheet: Lifestraw®

What is the LifeStraw® *family*?

LifeStraw® *family* is a water filtration and disinfection system that uses gravity to move water through the system. The untreated water is poured into a bucket with removable and cleanable prefilter to remove turbidity. Water then passes through a chlorine chamber containing low elusion halogenated media where disinfection occurs killing bacteria, viruses, protozoa and helminths.

Clean and safe water is then ready to flow from the attached tap. Dirt accumulated in the membranes can be released from the bottom of the device by pressing the squeeze bulb after use.

LifeStraw® Family system removes all particles up to 20nm, making the water clear of any turbidity. It can filter 6-8 L/hr up to a total of 18,000 L and requires no electrical power or spare parts.

How Does It Remove Contamination?

LifeStraw® Family contain micro-filters within the system that as the influent water passed through the membranes all particles down to 0.02 microns are removed water making water contaminant free and clear of any turbidity.

Operation

As LifeStraw® Family relies on gravity the filtration of untreated water begins when it is poured into the pre-filter bucket at the top of the system. Gravity forces the water through a tube and into the purification cartridge, which contains millions of tiny pores called capillary membranes that trap contaminants. The treated water travels down a tube connected to an outlet tap and is ready to be used.

LifeStraw® Family has been designed to be very user-friendly. The pre-filter bucket can be wiped clean with a simple soft cloth. The purification cartridge can be cleaned by closing the tap and squeezing the bulb attached to the side of the cartridge, forcing dirt and muddy water to leave through the bottom exit.

Household Water Treatment and Safe Storage Fact Sheet: LifeStraw® Key Data

Inlet Water Criteria

- LifeStraw® Personal Turbidity not specified
- LifeStraw® Family Turbidity < 50 NTU (Nephelometric Turbidity Units)

Treatment Efficiency

LifeStraw® Personal	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Iodine
Laboratory	>99.9999%[1]	99-99.8%[1]	Not available[2]	Not available[2]	Not available	0-1.5 ppm
Field	Not available	Not available	Not available	Not available	Not available	Not available

[1] Sobsey (Unknown date)

[2] Due to 0.02 micron removal capacity it is assumed that large protozoa and helminths would be removed as well

LifeStraw® Family	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	>99.9999%[1]	99.99%[1]	99.9%[1]	Not available[2]	Not available[3]	Not available
Field	Not available	Not available	Not available	Not available	Not available	Not available

[1] Vestergaard Frandsen

[2] Due to 0.02 micron removal capacity it is assumed that large helminths would be removed as well.

[3] Vestergaard Frandsen States that turbidity is removed yet no quantitative data is provided

- Turbidity removal of varying degrees depending on the system used
- Taste, odour and colour of treated water is generally improved with the Family system

Operating Criteria

System	Flow Rate	Batch Volume	Daily Water Supply
LifeStraw® Personal	< 0.6 litres/minute*	Not available	
LifeStraw® Family	Average of 10L/hour*	Not available	15 - 60 litres**

Note: *The actual flow rate will fluctuate over the filter cleaning cycle and the lifespan of the filters.
** Based on family daily needs

- Daily volumes depend on the users need; There is no daily limit mentioned just a lifespan volume for the systems
- Very turbid water should be sedimented before using either system.

Robustness

- No moving or mechanical parts to break
- Plastic may be susceptible to wear and cracks in extreme temperature conditions
- LifeStraw® Personal system made of high impact polystyrene
- LifeStraw® Personal can be stored for three years at a maximum temperature of 30 degrees
- Light, easy to transport to new locations

Estimated Lifespan

- LifeStraw® Personal – 700 L; 1 year at 2 litres/day

Household Water Treatment and Safe Storage Fact Sheet: LifeStraw® Key Data

- LifeStraw® Family - 18,000 L; 3 years at 15 litres/day

Manufacturing Requirements

Worldwide Producers:
- Purchased from Vestergaard Frandsen and imported, distributed or sold locally
- Regional offices located in parts of Africa and Asia

Local Production:
- n/a

Materials:
- n/a

Fabrication Facilities:
- n/a

Labour:
- n/a

Hazards:
- n/a

Maintenance

LifeStraw® Personal
- Regularly blow through it after drinking to keep the filters clean and to prevent them from clogging

LifeStraw® Family
- Clean cartridge every day by filling bucket then squeezing the red bulb three times, each time waiting until the bulb has refilled
- Then open the red exit and wait 5 seconds before closing

Cost

System	Capital Cost	Operating Cost	Replacement Cost
LifeStraw® Personal	US$3	US$0/year	US$3
LifeStraw® Family	US$25-40	US$0/year	US$25-40

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

References

Sobsey, M. (Unknown). LifeStraw® Personal: Summary of Test Data Received from the University of North Carolina, USA.

Further Information

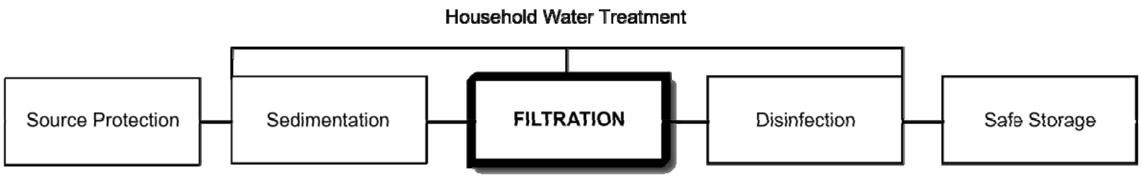
Vestergaard-Frandsen: www.vestergaard-frandsen.com/lifestraw.htm

Household Water Treatment and Safe Storage
Fact Sheet: LifeStraw® Key Data

Wellness through Water.... Empowering People Globally
Last Update: July 2009

Household Water Treatment and Safe Storage Fact Sheet: Straining

The Treatment Process



Potential Treatment Capacity

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

What is Straining?

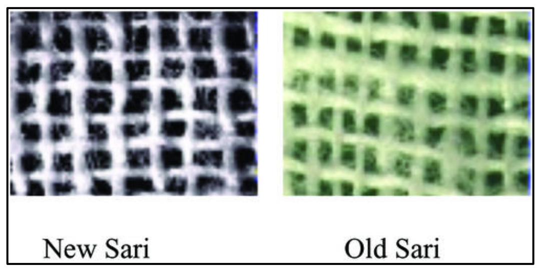
Straining water through a cloth has been widely used for household water treatment in many cultures for centuries. A common sari cloth is usually used for this in South Asia, for example.

How Does it Remove Contamination?

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

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

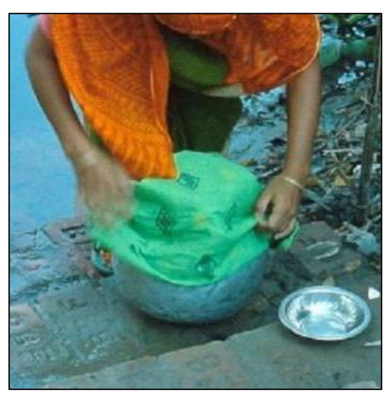
Old sari cloth made of cotton was found to be most effective in removing cholera based on laboratory experiments (Colwell et al., 2002). After several launderings, threads of an old sari become soft and loose, reducing the pore size, compared with new sari cloth.



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

Operation

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



A woman uses a sari cloth to strain water

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

Inlet Water Criteria

- No specific limits

Treatment Efficiency

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

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

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

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

Robustness

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

Estimated Lifespan

- Cloth may need to be replaced if there are holes

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Not applicable

Materials:
- Cloth
- Containers

Fabrication Facilities:
- Not applicable

Labour:
- Traditional practice done in the household

Maintenance

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

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

Direct Cost

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

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

References

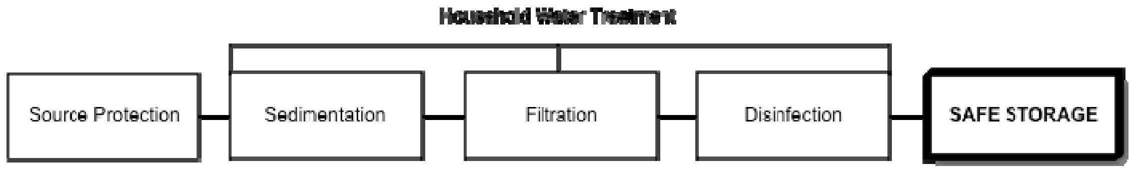
Colwell, R., Huq, A., Sirajul Islam, M.S., Aziz, K.M.A., Yunus, M., Huda Khan, N., Mahmud, A., Sack, R.B., Nair, G.B., Chakraborty, J., Sack, D.A., and Russek-Cohen, E. (2002), Reduction of Cholera in Bangladeshi Villages by Simple Filtration. Proc Natl Acad Sci USA. 100(3): 1051–1055. Available at: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

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

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Fact Sheet: Safe Storage and Handling

Treatment Type



Potential Protection Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Preventing recontamination of safe water	• Keeping water cool • Preventing algae growth	• Removing existing contaminants

What is Safe Storage and Handling?

Households do a lot of work to collect, transport and treat their drinking water. Safe water must be handled and stored properly to protect it from becoming recontaminated. Promoting safe storage and handling of water in the home is a critical component for safe drinking water. Recontamination of safe drinking water is a common issue around the world and has been documented in several cases.

What Causes Recontamination?

Water can become recontaminated through several different mechanisms, such as:

- Using the same container for water collection and storage
- Dipping a dirty cup or hand into the container
- Drinking directly from the container
- Children, animals or insects accessing the container
- Poor cleaning and hygiene practices

Recontamination is more likely to occur in uncovered containers that have wide openings (e.g. buckets, pots). Using chlorine can provide residual protection against recontamination, however, proper storage and handling are still essential for keeping water safe to drink.

Safe Storage and Handling Practices

Safe storage means keeping treated water away from sources of contamination. There are many designs for water containers around the world. A safe water storage container should be:

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

Safe storage containers should also have pictorial and/or written instructions describing how to properly use and clean the container. Ideally the instructions are permanently affixed to the container, or they can be provided as a separate document to the household.

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

Safe water handling practices include:

- Using a separate container to collect source water

Household Water Treatment and Safe Storage Fact Sheet: Safe Storage and Handling

- Using a proper safe storage container for treated water, and never use this container for untreated water
- Cleaning the safe storage container frequently with safe water and soap or chlorine
- Storing treated water off the ground in a shady place in the home
- Storing treated water away from small children, animals and insects
- Pouring water from the safe storage container of using the tap when needed instead of dipping or scooping water from it
- Using the treated water as soon as possible, preferably on the same day

Examples of Safe Storage Containers

A number of internationally manufactured containers, locally produced containers, and locally adapted traditional containers can be used to store water safely.

Safe storage containers should always be evaluated in-country for their cost, availability, robustness and user acceptability.

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

CDC Safe Water System *(*Credit: Centers for Disease Control, USA*)*

Ceramic Filter Container *(*Credit: Potters for Peace*)*

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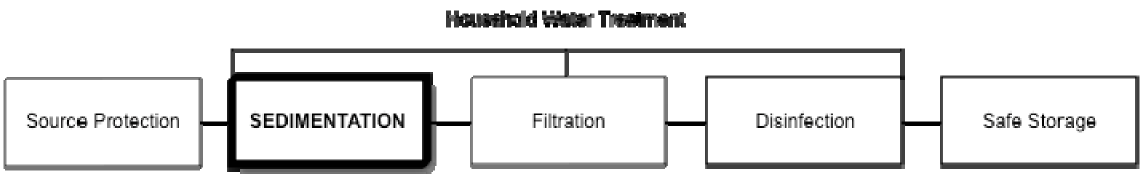
Calgary, Alberta, Canada
Website: www.cawst.org
Email: cawst@cawst.org
Last Update: October 2009

Household Water Treatment and Safe Storage Factsheet: Chemical Coagulants

The Treatment Process



Potential Treatment Capacity

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

What are Chemical Coagulants?

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

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

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

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

How Does it Remove Contamination?

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

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

Operation

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

Alum block (Credit: www.cdc.org)

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

Inlet Water Quality

- No specific limits

Treatment Efficiency

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

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

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

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

- Need to follow manufacturer's instructions

Robustness

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

Estimated Lifespan

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

Manufacturing Requirements

Worldwide Producers:
- Many producers around the world

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

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

Direct Cost

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

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

Other

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

References

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

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

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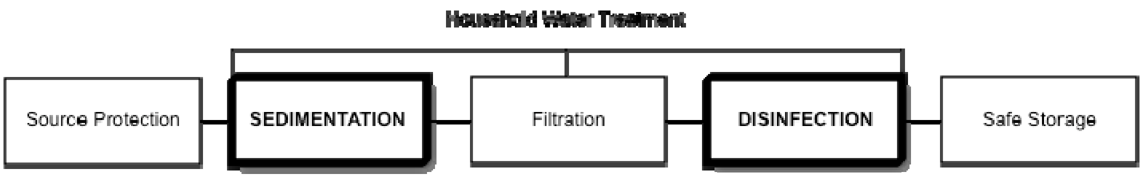
Household Water Treatment and Safe Storage Fact Sheet: PUR

The Treatment Process



Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
• Bacteria • Viruses • Some protozoa • Helminths • Turbidity	• Some heavy metals (e.g. arsenic, chromium, lead) • Taste, odour, colour	• *Cryptosporidium parvum* • Toxoplasma oocysts • Dissolved chemicals

What is PUR?

PUR is a combined flocculant-disinfectant. The PUR 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.

PUR is a powder which contains both coagulants and a timed release form of chlorine. PUR is sold in single packets designed to treat 10 L 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. 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.

As well, chlorine forms hydrochloric acid when added to water which reacts through oxidization with microorganisms and kills them.

PUR Packet (Credit: P&G)

Household Water Treatment and Safe Storage Fact Sheet: PUR

Operation

The contents of a PUR packet is added to 10 L of water and stirred vigorously for five minutes. The water is then left for several minutes to settle. If the water does not become clear it is stirred again for a few minute before being left once again.

Once the water becomes clear and the flocs have all settled to the bottom, the water is decanted and filtered through a cloth. The water should then be left for 20 minutes before it is consumed. This gives time for the chlorine to disinfect any remaining pathogens.

Contaminated source water

Formation of flocculant after introduction of PUR

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 PUR (Credit: Population Services International)

Household Water Treatment and Safe Storage Fact Sheet: PUR 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]	> 99%[1,2]
Field	> 100% [2]	Not available	Not available	Not available	87%[4]	85-99%[2,3]

[1] Allgood (2004)
[2] Souter et al (2003)
[3] Norton et al (2003)
[4] Norton et al (2003)

- Can remove some organics and some pesticides (Allgood, 2004)
- Can remove significant quantities of heavy metals including arsenic, lead and chromium (Allgood, 2004)
- *Toxoplasma* oocysts and *cryptosporidium 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	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

Maintenance

- Products should be protected from exposure to temperature extremes or high humidity

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

Direct Cost

Capital Cost(s)	Operating Cost(s)	Replacement Cost
US$0	US$0.10/10 litres[1] US$73/year[2]	US$0

Note: Program, transportation and education costs are not included. Costs may vary depending on location.
[1] Clasen (2007)
[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

References

Allgood, G. (2004). Evidence from the Field for the Effectiveness of Integrated Coagulation-Flocculation-Disinfection. IWA World Water Congress 2004. Marrakech, Morocco. Workshop 33.

Clasen, T. (2007). Presentation. London School of Hygiene and Tropical Medicine.

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.

Norton, D.M et al. (2003). A Combined Flocculent-Disinfectant Point-of-Use Water Treatment Strategy for Reducing Arsenic Exposure in Rural Bangladesh. 10th Asian Conference on Diarrhoeal Diseases and Nurtition , Dhaka, Bangladesh.

Norton, D. M. et al. (2003). Field Trial of a Flocculent-Disinfectant Point-of-Use Water Treatment for Improving the Quality and Microbial Safety of Surface Pond Water in Bangladesh. 10th Asian Conference on Diarrhoeal Diseases and Nutrition Dhaka, Bangladesh.

Further Information

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

Proctor & Gamble: www.csdw.org/csdw/pur_packet.shtml

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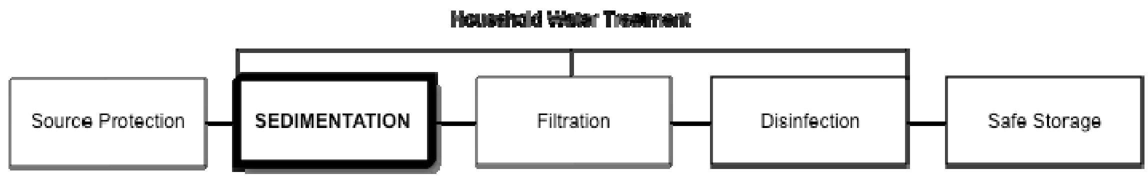
Last Update: October 2009

CAWST Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Natural Coagulants

The Treatment Process



Potential Treatment Capacity

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

What are Natural Coagulants?

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

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

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

How Does it Remove Contamination?

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

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

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

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

Household Water Treatment and Safe Storage Fact Sheet: Natural Coagulants

Operation

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

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

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

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

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

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

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

Inlet Water Quality

- No specific limits

Treatment Efficiency

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

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

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

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

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

Operating Criteria

Flow Rate	Batch Volume	Daily Water Supply
Not applicable	Unlimited	Unlimited

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

Robustness

- Availability depends on local conditions

Estimated Lifespan

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

Manufacturing Requirements

Worldwide Producers:
- Not applicable

Local Production:
- Harvested and prepared locally

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

Fabrication Facilities:
- Prepared in households

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

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

Maintenance

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

Direct Cost

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

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

Other

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

References

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

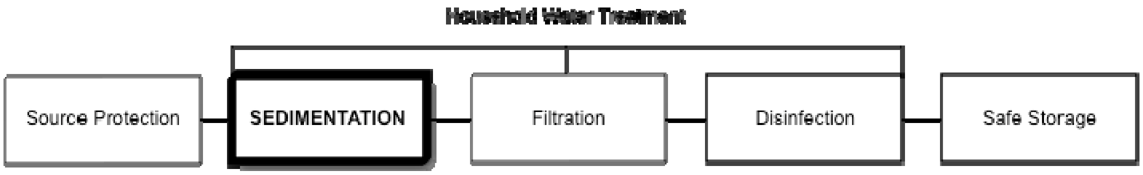
Sobsey, M. (2002). Managing Water in the Home: Accelerated Health Gains from Improved Water Supply, Water, Sanitation and Health, Department of Protection of the Human Environment, World Health Organization, Geneva, Switzerland.

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

Centre for Affordable Water and Sanitation Technology

Household Water Treatment and Safe Storage Factsheet: Settling

The Treatment Process



Potential Treatment Capacity

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

What is Settling?

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

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

How Does It Remove Contamination?

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

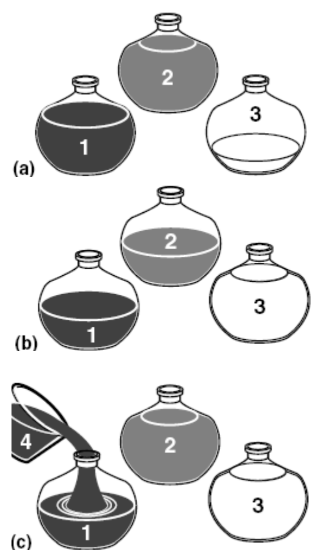
Storing water for at least one day will also promote the natural die-off of some bacteria.

Operation

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

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

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



Household Water Treatment and Safe Storage Factsheet: Settling Key Data

Inlet Water Quality

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity
Laboratory	Up to 90% Error! Reference source not found.	Up to 90% Error! Reference source not found.	> 90% Error! Reference source not found.	> 90% Error! Reference source not found.	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.

Household Water Treatment and Safe Storage Factsheet: Solar Distillation

HHPotential Treatment Capacity

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

What Is Solar Distillation?

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

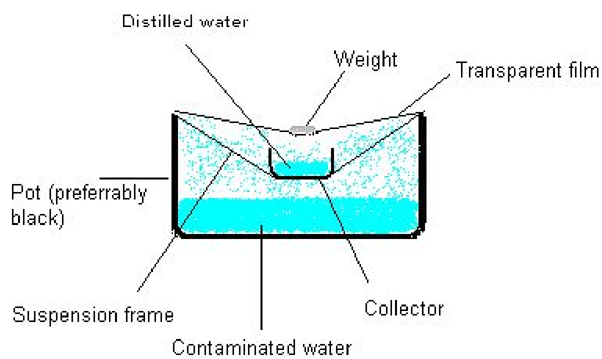
There are many different designs for solar distillation units (also known as stills). The simplest are a piece of plastic stretched over a container with the source water in the bottom. The plastic is weighted down in the middle so that the condensate can drip into a smaller collection container inside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

A simple design requiring some basic construction, but yielding more water, is that of a flat bed, basin or box solar still. It consists of a shallow reservoir containing water covered with an angled piece of clear glass or transparent plastic sheet. The sunlight heats the water through the glass or plastic, and the water vapour collects and condenses on it, drips down, and flows into the collection channel.

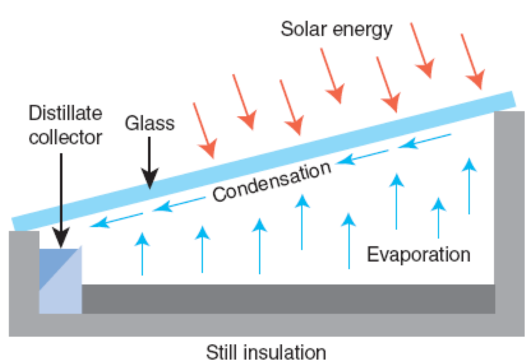
Another simple still uses a removable plastic cone rimmed on the inside edge with a collection channel. The condensed water flows down the sides of the cone into the channel. Water is removed by opening a cap at the apex of the cone, and turning the still upside down into a container.

How Does it Remove Contamination?

As the radiation from the sun heats the water, it evaporates leaving behind any contaminants, including pathogens, chemicals and minerals. The contaminants collect in the bottom of the still and are periodically flushed or cleaned out.



Container Still (Credit: www.ehow.com)



Box Still (Credit: Smith, 2005)

Household Water Treatment and Safe Storage Factsheet: Solar Distillation

Operation

Flat Bed/Box Still:

The still is filled daily with two to three times as much water as will be produced. This is so that the excess, using the built-in overflow outlets, will flush the unit clean each day (to remove accumulated salts and other contaminants). Treated water is collected in a safe storage container placed under the outlet.

If systems are not designed to be self cleaning and flush out accumulated contaminants, the reservoirs should be regularly cleaned using soap and clean water.

Flat Bed Still
(Credit: www.planetkerala.org)

Cone Still:

1.
Pour salty / brackish Water into pan. Then float the Watercone® on top. The black pan absorbs the sunlight and heats up the water to support evaporation..

2.
The evaporated Water condensates in the form of droplets on the inner wall of the cone. These droplets trickle down the inner wall into a circular trough at the inner base of the cone.

3.
By unscrewing the cap at the tip of the cone and turning the cone upside down, one can empty the potable Water gathered in the trough directly into a drinking device.

How to Use the WaterCone® (Credit: www.watercone.com)

Household Water Treatment and Safe Storage Fact Sheet: Solar Distillation Key Data

Inlet Water Criteria

- No specific limits

Treatment Efficiency

	Bacteria	Viruses	Protozoa	Helminths	Turbidity	Chemicals
Laboratory	> 99.9%PP[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®, community distillation system, The Netherlands: www.waterpyramid.nl

CAWST (Centre for Affordable Water and Sanitation Technology)
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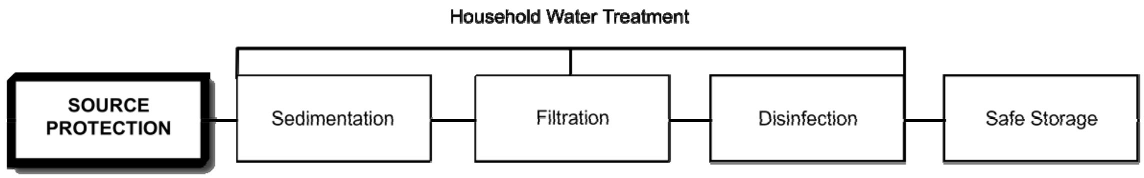
Household Water Treatment and Safe Storage Factsheet: Source Protection

The Treatment Process



Potential Treatment Capacity

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

What is Source Protection?

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

What Causes Contamination?

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

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

Source Protection Practices

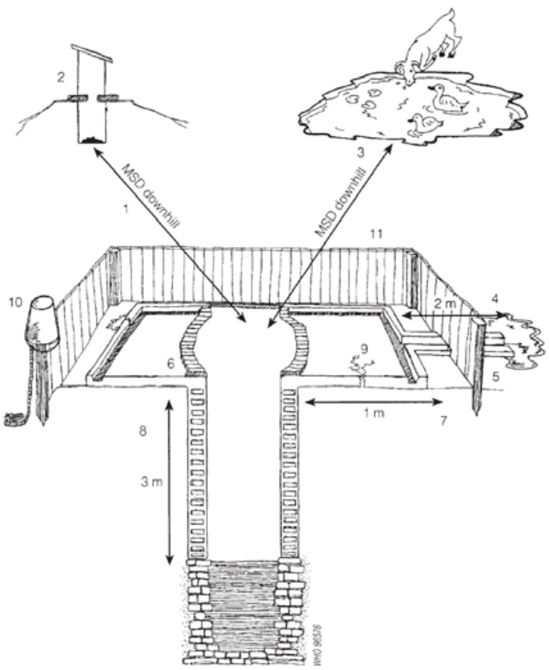
The following provides suggestions on several things that can be done to protect different water sources from contamination and improve the quality.

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

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

Household Water Treatment and Safe Storage Fact Sheet: Source Protection

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



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

Wells, Tubewells and Boreholes:

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

Springs and Gravity Fed Piped Systems:

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

Rivers and Lakes:

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

Rainwater Harvesting:

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

Water Collection and Transport

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

Household Water Treatment and Safe Storage Fact Sheet: Source Protection

Further Information

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

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