

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Kanchan™ Arsenic Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
<ul style="list-style-type: none"> • Arsenic • Bacteria • Protozoa • Helminths • Turbidity • Taste/odour/colour 	<ul style="list-style-type: none"> • Viruses • Iron 	<ul style="list-style-type: none"> • Chemicals

What is a Kanchan™ Arsenic Filter?

The Kanchan™ Arsenic Filter (KAF) is an adaptation of the biosand filter. The KAF has been designed to remove arsenic from drinking water, in addition to providing microbiological water treatment. Arsenic removal is achieved by incorporating a layer of rusty nails in the diffuser basin of the filter.

The filter container can be constructed out of concrete or plastic. The container is about 0.9 m tall and either 0.3 m square or 0.3 m in diameter.

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

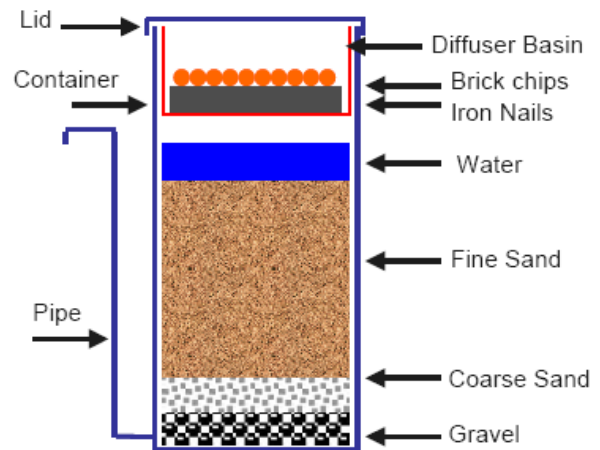
Similar to slow sand filters, a biological layer of microorganisms (also known as the biolayer or schmutzedecke) develops at the sand surface, which contributes to the microbiological water treatment.

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

How Does it Remove Contamination?

Arsenic from the water is rapidly adsorbed onto the rust on the iron nails. The rust and arsenic flake off the nails, and are caught in the sand

filter and retained. This is a very tight bond; re-suspension of arsenic into the water, or re-mobilization of the arsenic from the waste produced from cleaning the filter has shown to be negligible.



Cross-Section of Kanchan™ Arsenic Filter

In addition, pathogens, iron and suspended material are removed from water through a combination of biological and physical processes. These occur both in both the biolayer and within the sand bed. These processes include: mechanical trapping, adsorption/attraction, predation and natural death.

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Operation

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

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

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

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

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

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

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

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

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

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

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

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

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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 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 Sharma (2005)

9 Ngai et al. (2004)

10 Ngai et al., (2007)

11 Uy et al., (2008)

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

Operating Criteria

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

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

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

** Based on 2 batches per day to ensure effective arsenic removal

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

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Robustness

- There are no moving or mechanical parts to break
- In concrete models, piping is embedded in concrete, protecting it against breaks and leaks
- Concrete has been shown to last in excess of 30 years
- Concrete filters are heavy (70 – 75 kg for thin wall version and 135 kg for heavy wall version)
- Poor transportation of concrete filters can lead to cracking and/or breakage
- Filters should not be moved after installation
- Cracks can be sometimes be repaired

Estimated Lifespan

- Unlimited; biosand filters are still performing satisfactorily after 10+ years
- Lids and diffusers may need replacement
- Nails need to be replaced every 2-3 years to ensure effective arsenic removal

Manufacturing Requirements

Worldwide Producers:

- Free mold designs are available from CAWST

Local Production (for concrete KAF):

- Local production of concrete filters is common
- Molds for concrete filters can be borrowed, rented, bought or constructed locally
- Concrete filters can be cast at a central production facility, or in the community
- Filter sand and gravel can be prepared (sieved and washed) on-site or nearby

Materials (for concrete KAF):

- Steel mold
- Sand, gravel, and cement
- Filter sand and gravel
- Copper or plastic outlet tubing
- Metal or plastic for the diffuser basin
- 5 to 6 kg of non-galvanized iron nails
- Metal or wood for the lid
- Water is needed during for cement mix and to wash filter sand and gravel
- Miscellaneous tools for construction and installation (e.g. wrench, nuts, bolts)

Fabrication Facilities (for concrete KAF):

- Workshop space required for filter construction

Labour (for concrete KAF):

- Skilled welder required to fabricate molds
- Anyone can be trained to construct and install the filter
- Individual householders can assist in constructing their own filters

Hazards (for concrete KAF):

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

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Maintenance Requirements

- Required when the flow rate drops to a level that is inadequate for the household use
- Swirl and dump maintenance for the top layer of sand is simple, takes a few minutes and can be done by household users
- Frequency of swirl and dump depends on turbidity of inlet water
- Outlet, lid and diffuser should be cleaned on a regular basis

Direct Cost

Filter Type	Capital Cost	Operating Cost	Replacement Cost
Concrete	US\$12-40	US\$0/year	US\$0
Plastic	US\$75 ¹	US\$0/year	US\$0

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

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

Other

- Sand and iron nail selection and preparation are critical to ensure flow rate and treatment
- Filters should not be moved after installation

References

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Further Information

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

AKVOpedia: www.akvo.org/wiki/index.php/Kanchan_Arsenic_Filter

Massachusetts Institute of Technology (MIT):

http://web.mit.edu/watsan/tech_hwts_chemical_kanchanarsenicfilter.html

CAWST (Centre for Affordable Water and Sanitation Technology)

Calgary, Alberta, Canada

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

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Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Sono Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
<ul style="list-style-type: none"> • Arsenic • Turbidity • Taste/odour/colour 	<ul style="list-style-type: none"> • Chemicals 	

What is a Sono Filter?

The Sono Filter is a three bucket system developed in Bangladesh. It uses a composite iron matrix (CIM) from zero valent iron filings (cast iron turnings) to remove arsenic.

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

How Does It Remove Arsenic?

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

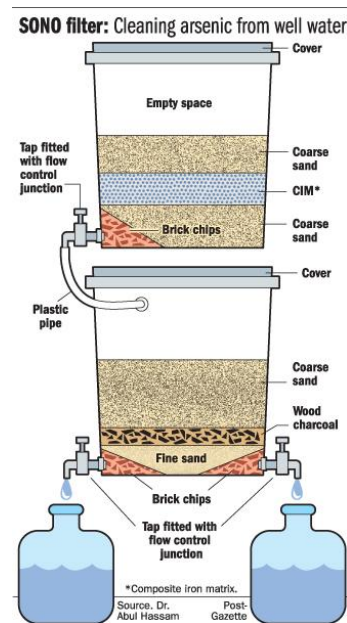
Each of the three buckets contains different media:

- Top bucket: 3 kg cast iron filings from a local machine shop, 2 kg coarse sand
- Middle bucket: 2 kg sand, 1 kg of wood charcoal and 2 kg of brick chips
- Bottom bucket: water collection container

Operation

The inlet water is poured into the first bucket containing coarse river sand and the composite iron matrix (CIM). Then it flows into a second bucket where it is filtered through another layer

of coarse sand, wood charcoal to remove organics, fine sand and brick chips to remove fine particles and stabilize water flow. The unit should be replaced every 3-5 years.



Sono Filter
(Credit: www.robrasa.com)

Key Information

Treatment Efficiency	Output	Cost
90-95% arsenic removal	20-30 litres per hour	\$40-50 capital cost

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

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Further Information

Summary poster of several arsenic mitigation technologies (MIT):
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Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Magc-Alcan Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
<ul style="list-style-type: none"> • Arsenic • Turbidity • Taste, odour, colour 		

What Is a Magc-Alcan Filter?

The Magc-Alcan is a two bucket arsenic filter. The buckets are in series (water flows from one bucket into the other). Both buckets are filled with an activated alumina media made in the United States. The media was developed by MAGC Technologies and Alcan of the USA; it is produced by thermal dehydration of an aluminium hydroxide at 250-1150°C.

How Does It Remove Arsenic?

The Magc-Alcan filter removes arsenic by adsorption (adhesion or sticking together) of the arsenic to the media, which is porous and has a large surface area.

The arsenic removal rate can be sensitive to pH level, so additional equipment may be required to control pH levels.

Operation

- Place two buckets in a stand so that one empties into the other. Each bucket should have a tap at the bottom and be filled with activated alumina media
- Place a clean container at the outlet of the second bucket for collecting treated water
- Pour arsenic contaminated water into the top bucket with all of the taps open, and collect arsenic-free water in the container at the bottom

Similar Technology: Nirmal Filter

A similar filter called the “Nirmal Filter” exists in India. Arsenic is adsorbed using an Indian-made activated alumina media. Water is then filtered

through a ceramic candle. The filter needs to be regenerated every 6 months.



Magc-Alcan Filter

Nirmal Filter

(Credit: Ngai)

Key Information:

Treatment Efficiency	Output	Cost	Lifespan
MAGC-ALCAN FILTER			
80-85% arsenic removal	100 litres/hour	\$35-50 capital cost	6 months to 1 year
NIRMAL FILTER			
80-90% arsenic removal	Not Available	\$10-15 capital cost	Not Available

Household Water Treatment for Arsenic Removal Fact Sheet: Sorption

Shapla Filter

Potential Treatment Capacity

Very Effective For:	Somewhat Effective For:	Not Effective For:
<ul style="list-style-type: none"> • Arsenic • Turbidity 		

What Is a Shapla Filter?

The Shapla filter is an earthen household arsenic removal technology developed by International Development Enterprises (IDE), Bangladesh. It is based on adsorption of the arsenic to the iron on brick chips inside the filter. The brick chips are coated using a ferrous sulphate solution. The filter can hold up to 30 litres of inlet water.

How Does It Remove Arsenic?

As water passes through the filter, arsenic from the water is rapidly adsorbed by the iron on the brick chips. The filter will reduce arsenic concentrations to undetectable levels.

Operation

Pour the water into the filter and allow it to pass through the filter and out the outlet. Collect treated water in a clean container for drinking.

Each filter has 20 kg of media (brick chips), which will treat 4,000 litres of arsenic-contaminated water. The filter can supply 25-32 litres of treated drinking water per day. The brick chips must be replaced every 3 to 6 months.

The used brick chips are non-toxic and can be disposed of safely without danger to the environment or human health as the arsenic is attached strongly to the iron. The earthen filter container is re-useable and easily maintained.



Shapla Filter
(Credit: T. Ngai)

Key Information

Treatment Efficiency	Output	Cost	Lifespan
80-90% arsenic removal	25-32 litres/day	\$10 capital cost \$10-15 media replacement cost/year	Short media lifespan (3-6 months)

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Arsenic Crisis Newsletter and Discussion Group:
<http://tech.groups.yahoo.com/group/arsenic-crisis/>
(Search for "Shapla" to view messages related to the Shapla filter)