A SIMPLE SOLUTION FOR ARSENIC PROBLEM

Kanchan™ Arsenic Filter

कञ्चन आर्सेनिक फिल्टर

Kanchan™ Arsenic Filter

ENPHO

Contents

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Message

At the United Nations Millennial Summit in New York in 2000 and again at the United Nations Summit on Sustainable Development in Johannesburg in 2003, the international community signed on to the Millennium Development Goals, recommitting itself to sustainable development and the elimination of poverty. The seventh of the eight Millennium Development Goals is to halve by 2015 the proportion of people without sustainable access to safe drinking water and adequate sanitation.

In response to this challenge, the MIT Water and Sanitation in Developing Countries Projects, collectively known as "Clean Water for 1 Billion People!" (H2O-1B!) was created in 1999. Fifteen teams of MIT Master of Engineering (M.Eng) students, in multi-disciplinary teams also including students from the Sloan Business School, Urban Studies and Policy, Mechanical Engineering and Materials Science as well as from other universities, including Harvard, Tufts and UC-Berkeley, have done engineering thesis and related project work on household drinking water treatment in seven different countries: Nepal, Brazil, Haiti, Dominican Republic, Nicaragua, Peru, and Kenya.

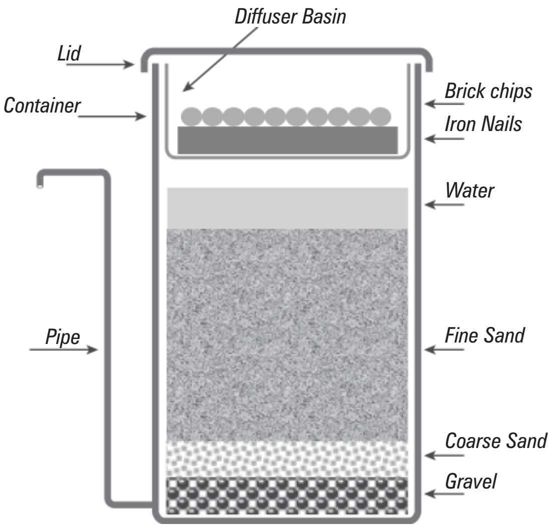
The MIT Nepal Water Project is one of the most successful projects because of the excellent partnership with local organizations such as ENPHO and RWSSSP. Over 30 students and faculty have traveled to Nepal to collaborate with our partners, undertaking a wide range of activities including water quality investigation, technology design and innovation, pilot projects, technology evaluations, technology transfer, implementation and scale-up, management and finance, and socio-economic evaluation and surveys. The development and implementation of the *Kanchan*™ Arsenic Filter is a result of this fruitful partnership.

We look forward to extending the partnership with ENPHO, as we believe this is one of the most effective ways to bring safe water and sanitation to those in need.

Susan E. Murcott
Principal Investigator, Lecturer andResearch Engineer
Massachusetts Institute of Technology

What is the *Kanchan*™ Arsenic Filter?

The *Kanchan*™ Arsenic Filter (KAF) is an innovative household drinking water treatment device for removing arsenic, pathogens, iron, turbidity, odour, and some other contaminants in drinking water. This filter was developed by researchers at Massachusetts Institute of Technology (MIT), Environment and Public Health Organization (ENPHO) of Nepal, and Rural Water Supply and Sanitation Support Programme (RWSSSP) of Nepal, based on slow sand filtration and iron hydroxide adsorption principles. This technology is a result of five years of multi-disciplinary research and is optimized taking into account the socio-economic conditions in rural Terai. This filter won prestigious awards at the MIT IDEAS Design Competition 2002 and at the World Bank Development Marketplace Global Competition 2003. The current Gem505 version is the 4th generation design, promoted since March 2004.



2 How does the filter work?

The operation is very simple. First, place a collection container below the filter outlet. Then, remove the lid. Pour water from your best available source into the top diffuser basin. Water should be poured slowly, not to disperse the brick chips and iron nails. Water passes over the brick chips, then the nails, through the sand and comes out of the spout. Ideally, the collection container should have a narrow mouth (e.g. gagri or kolshi) and/or a lid. Also, the collection container should be kept clean and hygienic. This will reduce re-contamination of water by bacteria. The design flow rate of the Gem505 version is 15 -20 liters per hour, which is adequate even for a large family of 20 people.

Pour water into top basin. Water will pass through filter and flow up the pipe

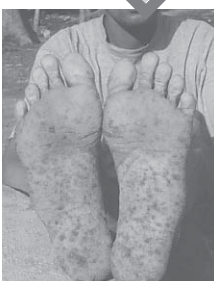
Collect water at the filter outlet

What is arsenic?

Arsenic is a naturally occurring element found in the ground water in some parts of the Terai region of Nepal and in other countries. Long-term exposure to this poison through drinking water and/or food can results in adverse health effects including dermal diseases such as melanosis (dark and light spots on the skin) and keratosis (hardening of skin on hands and feet); vascular diseases; birth defects; low IQ; cancer of lung, kidney, skin, and others.

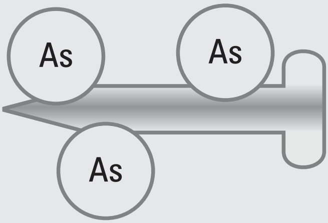
Due to differences in geology, chemistry, environmental conditions, and human activities, arsenic concentration in the Terai ground water varies widely. In the most seriously affected districts of Nawalparasi, Rupendehi, Kapilvastu, Bardiya, Kailali, Rautahat, Bara, and Parsa, the arsenic concentration found in the tube well water can be 2 to 20 times greater than the Nepali Interim guideline of 0.05 mg/L or 10 to 100 times greater than the World Health Organization guideline of 0.01 mg/L.

A keratosis victim



How does the filter remove arsenic?

In the KAF, iron nails are exposed to air and water, and rust very quickly, producing ferric hydroxide particles. Numerous international studies have shown that ferric hydroxide (iron rust) is an excellent adsorbent for arsenic. When arsenic-containing water is poured into the filter, surface complexation reaction occurs, and arsenic is rapidly adsorbed onto the surface of the ferric hydroxide particles. The arsenic-loaded iron particles are then flushed into the sand layer below. Because of the very small pore space in the fine sand layer, the arsenic-loaded iron particles will be trapped in the top few centimeters of the fine sand layer. As a result, arsenic is effectively removed from the water. Field research by MIT and ENPHO showed arsenic removal is in the range of 85-95%. Independent field studies of the KAF in Nepal by the Tribhuvan University, Kathmandu University, and United States Peace Corp showed 87-95+% arsenic removal rate.



Arsenic (As) particles are effectively adsorbed on the rusted iron nails surface.

How does the filter remove pathogens?

Groundwater usually contain no to very low level of natural pathogens contamination, as indicated by the lack of E.Coli or thermotolerent bacteria. Occasional high pathogens contamination is often a result of poor hygiene and sanitation practices and/or improper tube well installation.

Pathogens removal in a KAF is similar to a slow sand filter, which consists of mainly four removal mechanisms – physical straining, attachment, predation, and natural die off.

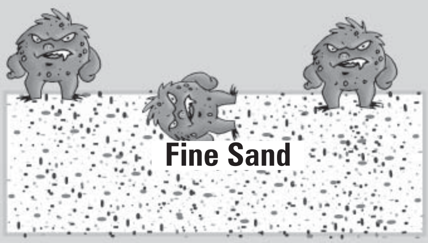
Physical straining refers to trapping of large particles because they are too big to pass the small pores of the fine sand. This process can remove parasite, cysts and some larger bacteria. Some bacteria and viruses are too small, therefore, are removed by other means, such as predation and attachment.

Attachment refers to the process by which the foreign particles are adsorbed to each other and to the filter medium (i.e. sand). This process is affected by a variety of physical interactions between microbial cells and porous media including hydrophobicity (i.e. polarity) and surface charge.

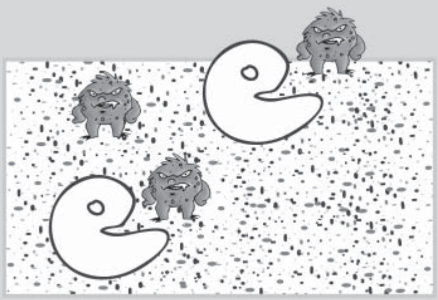
Due to physical straining, foreign particles such as dirt and organic substances will be trapped on top of the fine sand layer as a filter cake. Together with the dissolved oxygen and nutrients in the influent water, a biological population (i.e. biofilm) will grow within the filter cake, around each grain of sand in the top layer of sand, and in the top few centimeters of the fine sand. The population consists of algae, bacteria, protozoa, and small invertebrates. When microbially contaminated water is poured into the KAF, predator organisms that reside in the biofilm layer will consume the incoming pathogens.

Finally, pathogenic microorganisms may die naturally. This can be due to many factors such as stress and old age. The lack of oxygen as they get deeper in the filter may also cause them to die off – especially during the pause period.

Laboratory scale studies at MIT showed this filter can remove 95-99% total coliform. Field studies in Nepal by MIT, ENPHO, and RWSSSP showed 60-100% removal of E. Coli and total coliform. A study by Tribhuvan University Civil Engineering Department showed 88% total coliform removal and 82% E. Coli removal. Other international studies of the biosand filter in Bangladesh, Vietnam, Cambodia, Haiti, Dominican Republic, Nicaragua, Brazil, and Canada showed 90-99% removal of E. Coli and thermotolerent coliform. If the international standard of 0 colony forming units of E. Coli per 100 milliliter of sample tested is the desired level of treatment, it is recommended that the KAF filtered water should be treated by an additional process such as Solar Water Disinfection (SODIS) or household chlorination such as Piyush™.



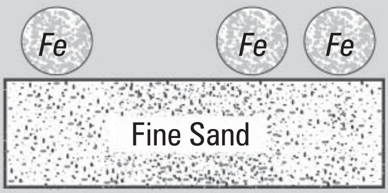
Larger pathogens will be trapped on top of the sand layer by physical straining.



Smaller pathogens are removed by predation by microorganisms residig near the top sand layers.

How does the filter remove iron and turbidity?

Ground water sometimes can contain high concentration of iron. As the water is pumped to the ground surface and is exposed to oxygen in the air, the soluble iron is usually rapidly oxidized to orange-colored insoluble iron particles in suspension. In addition, groundwater may sometimes contain other fine dust particles in suspension (e.g. turbidity). When this water is poured into the filter, most of the iron particles and turbidity are trapped on top of the fine sand by physical straining. Field research by MIT and ENPHO showed iron and turbidity removal is in the range of 93-95+%. Other independent studies showed 90-99+% of iron and turbidity can be removed.



Iron particles are trapped on top of the fine sand layer by physical straining (i.e. too large to pass)

How to maintain the filter and how frequent?

Over a long period of use, particles and dirt will be collected on the top of the fine sand layer. These filtered materials tend to clog the filter and the filtration rate will be reduced. If the filtration rate is too low that the filter cannot produce sufficient water, then the filter should be maintained/cleaned according to the procedure below. Depending on the quality of the incoming water (e.g. turbidity, iron concentration), usage, and seasons (e.g. monsoon), the filter may need to be maintained/cleaned once every month to once every 6 months.

1 *Wash your hands with soap*

2 *Remove diffuser basin and set on a clean surface*

3 *Stir the uppermost ½ inch of sand with fingers*

4 *Remove turbid water with a cup. Replace the basin and add more water. Repeat the stirring process for two additional times*

5 *Discard the turbid water in a dug hole with some cow dung in it*

6 *Now the filter can be used again*

8 What are the advantages of this filter compared to other arsenic mitigation options?

OPTIONS	BRIEF DESCRIPTION	ADVANTAGES	DRAWBACKS
Arsenic-Safe Wells	• Collect arsenic-safe water from neighbor's well	• No cost	• Inconvenience and cultural restrictions • Safe wells not always found in neighborhood
Dug Well	• Tie a rope to a bucket to collect water from a wide-mouth traditional well	• Simple technology • Generally arsenic-safe	• Likely contamination of bacteria, agricultural chemical, and sewerage • May dry up in dry season
Deep Well	• Drill a well to extract water from a deep aquifer that is arsenic-safe	• Generally arsenic and microbial-safe	• Arsenic level may increase in the long term • Such aquifers not found everywhere
Coagulation & Precipitation	• Add iron chloride powder to water in a pot/bucket • Stir and wait for the sludge to settle, then decant into a ceramic filter	• High arsenic removal rate if properly operated	• Iron chloride not locally available • Time consuming and complicated procedures • Slow flow rate (1L/hr)
Simple Aeration	• Let water settle in a bucket for a day • Remove the sludge	• Simple to operate • Cheap	• Poor arsenic removal rate • Easily contaminated by bacteria and viruses
Special Adsorption Media	• Pass contaminated water through a column of the media	• Excellent arsenic removal rate	• Expensive (US$ 2000+) • Media not available in rural area
3-Kolshi zero-valent iron	• Pass water through a bucket of iron filings (i.e. iron scrap) • Collect water at bottom of bucket	• Iron filing widely available • Excellent arsenic removal rate • Cheap	• Difficult cleaning/ maintenance • Clogging • Slow flow rate (3L/hr) • Bacteria contamination
Kanchan™ **Arsenic Filter**	• **Pour water into the top diffuser basin** • **Collect water at the outlet**	• **Excellent arsenic removal rate** • **Removal of iron, bacteria, etc.** • **All construction materials easily available** • **High flow rate** • **Easy operation and maintenance**	• **May not remove100% bacteria** • **May not remove some agricultural chemical contamination**

What do filter users think about the *Kanchan*™ Arsenic Filter?

Here are the results from 424 KAF users surveys conducted in December 2004 to January 2005.

	Better	Same	Worse
Appearance of KAF filtered water vs. tube well water	93%	7%	0%
Taste of KAF filtered water vs. tube well water	95%	5%	0%
Smell of KAF filtered water vs. tube well water	89%	11%	0%
User's health conditions after drinking filtered water	78%	22%	0%

	Yes	No
Filter still in use after 1 year	94%	6%
Users think the operation is easy	74%	26%

Some of the common comments from the users are:

- Tube well water makes rice black whereas rice cooked in KAF filtered water is white
- KAF filtered water is cleaner, cooler and better to taste
- KAF filtered water does not stain utensils
- After drinking KAF filtered water other water tastes bad

10 Where can I obtain a filter?

MIT & ENPHO have trained and certified entrepreneurs from various Terai districts in KAF manufacturing and sales. The entrepreneurs gather all necessary materials from a local market, construct the filters at their offices, and sell the filters at cost plus 10% profit. For the most updated list of entrepreneurs' location and contact information, contact ENPHO.

How much does it cost?

The price of the filter including transportation and 10% profit ranges from 1400 to 1800 NRs (about US$20), depending on location.

For more information, contact:

Kanchan Arsenic Filter Reference Center

Environment and Public Health Organization (ENPHO)

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11 Frequently Asked Questions

1. **Can I use the KAF for dug well water, rainwater, spring water, arsenic-free tube well water, and other water sources?**
Yes. Besides arsenic removal, the KAF can remove iron, turbidity, bacteria, pathogens, odour, and some other common contaminants. The purpose of the iron nails is solely for arsenic removal. If the incoming water source contains no arsenic, then iron nails are unnecessary.

2. **What is the flow rate of the latest Gem505 filter model?**
The design flow rate is 15-20 L/hr. A higher flow rate (greater than 30 L/hr) may compromise the arsenic, iron, pathogens, and turbidity removal efficiency. A flow rate too low (less than 5 L/hr) may be inconvenient for the user. Initially, just after filter installation, the flow rate can be as high as 30 L/hr. The flow rate will drop over time, to about 15 –20 L/hr in a month or two. The World Health Organization recommends a minimum of 7.5L/capita/day for basic health and hygiene. A filter operating for 12 hours a day at 15 L/hr can produce sufficient water (180L) for a family of 24 people.

3. **How long can the iron nails last before the arsenic adsorption capacity is finished?**
The nails' arsenic adsorption capacity is dependent on the amount of iron nail surface area available. We have a number of filters installed in 2002 and the capacity of the iron nails to remove arsenic is not yet exhausted. We hypothesize that as the iron nails get rusted, the rusted iron particles become exfoliated and fall to the fine sand layer. This exfoliation exposes new iron surface, allowing more arsenic to be adsorbed. Annual washing of the iron nails can help to expose additional iron surface for improved adsorption capacity.

4. **How often should I clean/ wash the iron nails?**
If the diffuser basin is severely clogged by iron dust and/or rust making the flow rate too low, then it is necessary to clean or wash the iron nails and the basin. Otherwise, clean the iron nails and the basin once every year. Cleaning the iron nails can expose new iron surface for increased arsenic adsorption capacity.

5. **The iron nails will get jammed into one single mass over time. Is this going to cause clogging of the filter?**

The jamming of the iron nails into one single mass will not affect arsenic removal or cause clogging. Clogging of the diffuser basin occurs if small iron particles adhere to each other and form an impermeable layer/film. Generally, this will not happen if the nails are well washed before installation. The small iron particles should also fall to the fine sand layer, instead of accumulating in the basin. However, if the iron particles are clogging the basin, then simply empty the nails from the basin, thoroughly clean the basin, break apart the jammed nails, and put the individual nails back into the basin. The clogging problem will be solved.

6. **Can I attach a tap to the filter outlet to control the flow?**

NO! The biofilm layer is a key mechanism for pathogen removal. To keep the biofilm layer healthy, the standing water above the fine sand layer should be maintained at 5 cm such that sufficient oxygen from the air can be diffused to the biofilm layer. If a tap is attached, then the standing water level will inadvertently be increased. Insufficient oxygen supply to the biofilm will reduce the filter's effectiveness. It is recommended to place a narrow mouth container (e.g. gagri or kolshi) under the filter outlet to collect filtered water. This will reduce bacteria re-contamination.

7. **Can I attach a flexible tubing to filter outlet?**

NO! Due to air pressure, if a flexible tube is attached to the filter outlet, the standing water level inside the filter will drop. If there is no standing water level, then the biofilm will die. Also, the lowering of the water level inside the filter will introduce air bubbles within the fine sand layer, and cause clogging.

8. **Will the presence of phosphate in water affect the arsenic removal?**

This is possible if phosphate is greater than 2 ppm. We have monitored phosphate in water from over 1000 tube wells from a number of districts. Only 1 tube well contains greater than 1 ppm of phosphate.

9. **What is the purpose of the brick chips?**

The purpose of the brick chips is to protect the iron nails from spreading due to the force of the incoming water. Ideal size of the brick chips is 10 cm diameter. Brick chips should completely cover the iron nails in the basin. Alternatively, big stones or any perforated plate made with wood, plastic, or metal can be used in place of brick chips as long as the plate can protect the underlying iron nails.

10. **How much bacteria can be removed by the filter?**

For the Gem505 filter, preliminary research shows 60-100% total coliform and E.Coli removal. Based on results from biosand filters installed in other countries, physical

straining can remove 60-70% of bacteria (because bacteria are often attached to particles). The development of the biological layer (i.e. biofilm) in the fine sand layer will improve the bacteria removal efficiency up to 90 - 99%. Depending on the influent water quality, temperature and other environmental factors, the biological layer can be developed in as little as a few days to as long as a few months.

Although the KAF may not remove 100% bacteria, ground water usually contains no to low bacteria contamination, especially when proper hygiene and sanitation practices are observed in the household. If 100% bacteria removal is the desired treatment level, then the filtered water should be treated by an additional process such as Solar Water Disinfection (SODIS) or household chlorination (e.g. Piyush™).

11. Is the sand layer depth of the Gem505 filter too little for effective bacteria and iron removal?

The design value for relevant parameters such as contact time, flow velocity, and flow rate in the Gem505 filter is at least as good (if not better) than the previous arsenic biosand filter versions that also have good bacteria and iron removal.

12. How long can the Gem505 filter last?

Gem plastic manufacturer suggests that the plastic should be kept away from direct sunlight to minimize damage to the plastic from UV rays. After installation, the filter is very heavy. The filter should not be relocated or moved in order to avoid potential mishandling and breakage of the plastic container.

13. What is the maximum arsenic concentration in the influent can the filter treat?

Filter monitoring results show that water containing up to 0.5 mg/L of arsenic can be reduced to less than 0.05 mg/L. For water containing over 0.5 mg/L, it is advised to add more iron nails or to filter the water two times.

14. What is the maximum iron concentration in the influent that the KAF can treat?

Filter monitoring results show that even for water with 10 mg/L of iron, the filter can reduce the iron content to less than 0.3 mg/L.

15. If there is already high iron in the influent water, are the iron nails necessary for arsenic removal?

Technically speaking, if there is already high iron in the influent water, iron nails may not be necessary for arsenic removal. However, in the context of implementation, if one household has high iron in the water and were not given nails, but their neighbor has low iron in the water and were given nails, then the users may get confused (or one may even feel cheated). To avoid this social issue, we recommended that all filters should have the prescribed quantity of iron nails.

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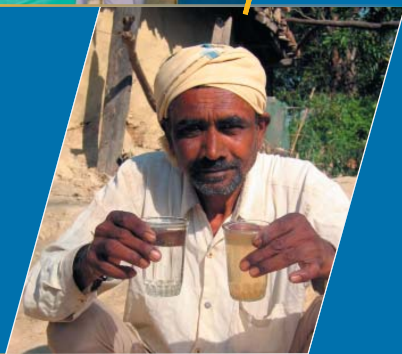

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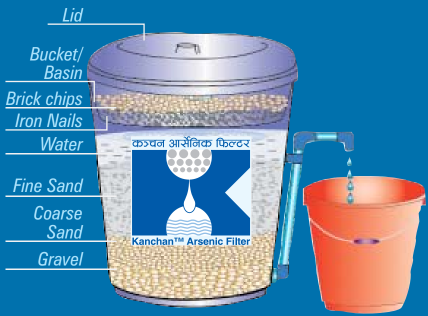
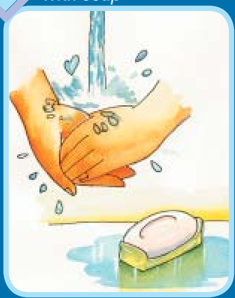
Kanchan™ Arsenic Filter



Things to be remembered:

- *Keep the filter away from the direct sunlight. The sanitary condition in and around the filter should be always good.*
- *Don't pour the water directly onto the sand layer. Always place the diffuser basin before pouring water in the filter.*
- *The filter should be maintained/cleaned only when the flow rate is too low (if filtered water is not sufficient for drinking and cooking purposes).*
- *There should be always resting water level above the sand layer.*
- *The filtered water collection container should be kept clean and hygienic.*
- *After installation of the filter, the filter should not be moved or shifted. If the filter needs to be shifted to another place, remove all the materials and reinstall the filter in the new place.*

1 *Wash your hands with soap*



2 *Remove diffuser basin and set on a clean surface*

3 *Stir the uppermost ½ inch of sand with fingers*

4 *Remove turbid water with a cup. Replace the basin and add more water. Repeat the stirring process for two additional times*

5 *Discard the turbid water in a dug hole with some cow dung in it*

6 *Now the filter can be used again*

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