Kanchan™ Arsenic Filter (formerly Arsenic Biosand Filter)

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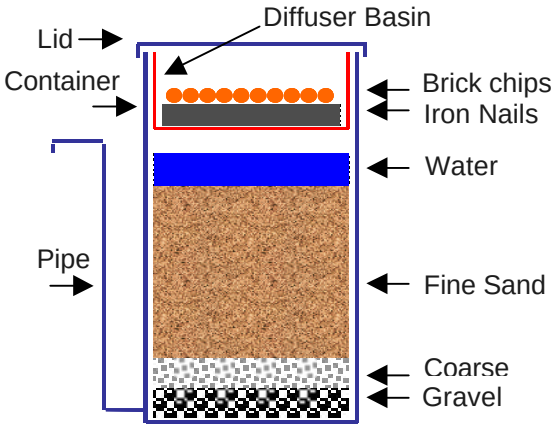
What is the *Kanchan*™ Arsenic Filter?

The *Kanchan*™ Arsenic Filter (KAF) is an innovative device for removing arsenic, bacteria, iron, turbidity, odour, and some other contaminants in drinking water. This filter was developed by researchers at Massachusetts Institute of Technology (MIT) of USA, Environment and Public Health Organization (ENPHO) of Nepal, and Rural Water Supply and Sanitation Support Programme (RWSSSP) of Nepal. This filter won prestigious awards at the MIT IDEAS Design Competition 2002 and World Bank Development Marketplace Global Competition 2003. The current Gem505 version is the 4th generation design, promoted since March 2004.



Major components of the *Kanchan*™ Arsenic Filter

A *Kanchan*™ Arsenic Filter (Gem505 version) in operation

How does the filter work?

The operation is very simple. First, remove the lid. Then, pour raw water into the top diffuser basin. Water should be poured slowly, not to disperse the brick chips and iron nails. Then, place a collection container below the filter outlet. 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 liters per hour, which is adequate even for a large family of 20 people.

What is arsenic?

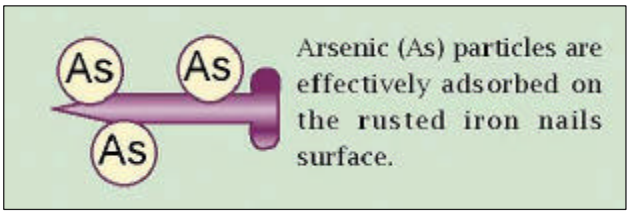
Arsenic is a naturally occurring element found mainly the ground water of the Terai region of Nepal. Long-term exposure to this poison through drinking water and/or food can results in adverse health effects including dermal diseases such as melanosis (dark and light spots on the skin) and keratosis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

A keratosis victim

Due to differences in geology, chemistry, environmental conditions, and human activities, arsenic concentration in the Terai 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.

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, whereas 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 by Department of Water Supply and Sewerage (DWSS) and US Peace Corp showed 91-95+% arsenic can be removed.



How does the filter remove pathogens?

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.

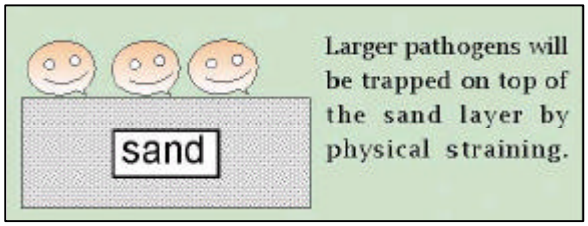
Physical straining refers to trapping of large particles because they are too big to pass the small pores of the fine sand. This process can remove cysts and bacteria. Viruses are too small, therefore, be removed by other means, such as predation and attachment.

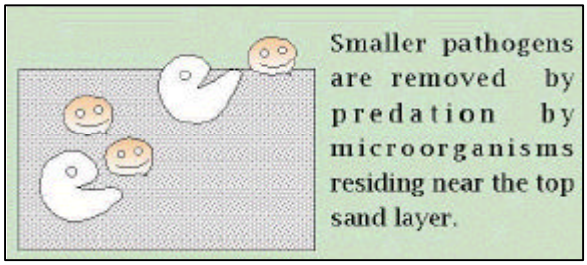
Attachment refers to the process by which the foreign particles are adsorbed to the filter medium (i.e. sand). This process is affected by a variety of chemical interactions between microbial cells and porous media including hydrophobicity (i.e. polarity) and surface charge.

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, biological population (i.e. biofilm) will grow within the filter cake and in the top few centimeters of the fine sand. The population consists of algae, bacteria, protozoa, and small invertebrates. When microbial contaminated water is poured into the KAF, predator organisms that reside in the biofilm layer will consume the incoming pathogens.

Finally, microbial may die naturally. This can be due to many factors such as stress and old age.

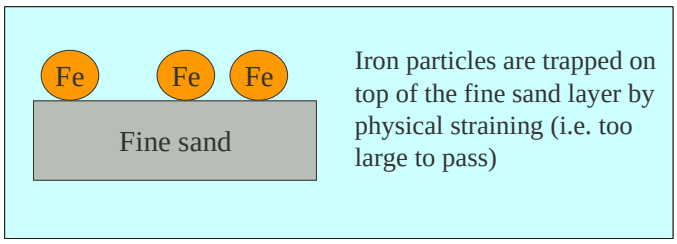
Laboratory scale studies at MIT showed this filter can remove 95-99% total coliform, which is an indicator of pathogen contamination. Field studies in Nepal by MIT, ENPHO, and RWSSSP showed 60-100% removal of total coliform and fecal coliform. A study by Department of Water and Sewerage showed 94% total coliform removal. Other international studies in Vietnam, Cambodia, Haiti, Dominican Republic, Nicaragua, and Canada showed 90-99+% removal of total coliforms. If 100% pathogens removal is desired, it is recommended that the filtered water should be treated by SODIS or chlorination.





How does the filter remove iron and turbidity?

Because of the anoxic condition in the subsurface environment, ground water sometimes can contain high concentration of iron. As the water is pumped to the ground surface and is exposed 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 researches by MIT and ENPHO showed removal is in the range of 93-95+%. Other independent studies showed 90-99+% iron and turbidity can be removed.



How to maintain the filter and how frequent?

Over a long period of use, particles and dirt will be collected the top of the fine sand layer. These filtered materials tend to clog the filter. The filtration rate will be reduced. If the filtration rate is so 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. Removal diffuser basin

3. Stir the uppermost ½ inch of sand with your 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

What are the advantages of this filter compared to others 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 sit in a bucket for a day for settling • 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	• Not 100% bacteria removal • May not remove some agricultural chemical contamination

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

Here are the results from 424 KAF users surveys conducted in Dec 04 to Jan 05.

	Better	Same	Worse
Appearance of filtered water vs. tube well water	92.8%	6.9%	0.2%
Taste of filtered water vs. tube well water	95.0%	5.0%	0.0%
Smell of filtered water vs. tube well water	89.9%	11.1%	0.0%
User's health conditions after drinking filtered water	77.5%	22.5%	0.0%

	Yes	No
Filter still in use after 1 year	93.7%	6.3%
Users think the operation is easy	73.6%	26.4%

Some of the common comments from the users are:

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

Where can I obtain a filter?

MIT & ENPHO have trained and certified 15 entrepreneurs on 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. The list is shown below. For further information and inquiry, contact ENPHO in Kathmandu.

S.N.	*Name of Entrepreneur*	*Address*	*Phone*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
	Environment and Public Health Organization (ENPHO)	New Baneshwor, Kathmandu	1-4468641 1-4493188

NOT AVAILABLE YET

How much does it cost?

The price of the filter including transportation and 10% profit ranges from 1400 to 1800 NRs, depending on location. For further information, contact ENPHO in Kathmandu.

For more information, contact:

Kanchan Arsenic Filter Reference Center
Environment and Public Health Organization (ENPHO)
New Baneshwor, Kathmandu
P.O. Box 4102
Nepal
Phone: +977-1-4468641, 4493188

Bipin Dangol, Engineer, ENPHO (bipindan@hotmail.com)
Tommy Ngai, Research Affiliate, MIT (ngait@mit.edu)

Frequently Asked Questions

Q1. *Can I use the KAF for dug well water, rain water, spring water, arsenic-free tube well water, and other water sources?*

A1. Yes. Besides arsenic removal, the KAF can remove iron, turbidity, bacteria, 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.

Q2. *What is the flow rate of the Gem505 filter?*

A2. The design flow rate is 15 L/hr. A higher flow rate (greater than 30 L/hr) may compromise the arsenic, iron, bacteria, 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 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 can produce sufficient water (180L) for a family of 24 people.

Q3. *How long can the iron nails last before the arsenic adsorption capacity is finished?*

A3. The nails' arsenic adsorption capacity is dependent on the amount of iron nail surface available. We have a number of filters installed in 2002 and they are still working fine. The arsenic adsorption capacity has not been exhausted yet. We think that as the iron nails get rusted, the rusted iron particle will be exfoliated and falls to the fine sand layer. This exfoliation exposes new iron surface, allowing more arsenic to be adsorbed. Annual washing of the iron nails will help to expose additional iron surface for improved adsorption capacity.

Q4. *How often should I clean/ wash the iron nails?*

A4. If the diffuser basin is severely clogged by iron dust 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.

Q5. *The iron nails will get jammed into one single mass over time. Is this going to cause clogging of the filter?*

A5. The jamming of the iron nails into one single mass will not affect arsenic removal nor 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 happened if the nails were 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 particle is really 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.

Q6. *Can I attach a tap to the filter outlet to control the flow?*

A6. NO. The biofilm layer is a key mechanism for pathogens 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 biofiom will cause its death.
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.

Q7. *Can I attach a flexible tubing to filter outlet?*

A7. NO. Due to air pressure mechanics, 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 bubble within the fine sand layer, and cause clogging.

Q8. *Will the presence of phosphate in water affect the arsenic removal?*

A8. 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.

Q9. *What is the purpose of the brick chips?*

A9. 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 basin. Alternatively, 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 mails.

Q10. *How much bacteria can be removed by the filter?*

A10. For the Gem505 filter, preliminary research shows 60-100% total coliforms 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 turbidity). The development of the biological layer (i.e. biofilm) in the fine sand layer will improve the bacteria removal efficiency to up to 99+%. Depending on the influent water chemistry, the biological layer can be developed in as little as a few days to as long as a few months.

Q11. *Is the sand layer depth of the Gem505 filter too little for effective bacteria and iron removal?*

A11. The design value for relevant parameters such as contact time, flow velocity, flow rate, etc. in the Gem505 filter is at least as good (if not better) than the previous filter versions that has good bacteria and iron removal.

Q12. *Will the Gem plastic leach out toxic substance into the water?*

A12. Gem plastic manufacturer suggests that the plastic should be kept away from direct sunlight. Gem plastic manufacturer claims their plastic passed international quality and safety standards.

Q13. *What is the maximum arsenic concentration in the influent can the filter treat?*

A13. Filter monitoring results showed that water containing up to 500 ppb of arsenic can be reduced to less than 50 ppb.

Q14. *What is the maximum iron concentration in the influent can the filter treat?*

A14. Filter monitoring results showed that even for water with 10 ppm of iron, the filter can reduce the iron content to less than 0.3 ppm.

Q15. *If there is high iron in the influent water, are the iron nails necessary?*

A15. Technically speaking, for arsenic removal, iron nails may not be necessary. 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 iron nails.