Development and dissemination of Kanchan™ Arsenic Filter in rural Nepal


*Research Associate, Centre for Affordable Water and Sanitation Technology (CAWST), 12, 2916 Fifth Ave NE, Calgary, Alberta T2A 6K4, Canada (E-mail: tngai@caawst.org)

**Senior Lecturer, Massachusetts Institute of Technology (MIT) Civil and Environmental Engineering Department, 77 Massachusetts Ave, Room 1-290, Cambridge, Massachusetts 02139, USA (E-mail: murcott@mit.edu)

***Chief Technical Advisor, Water for Asian Cities Program – UN Habitat, UN Complex, Pulchowk, Kathmandu, PO Box 107, Nepal (E-mail: roshan.shrestha@undp.org)

****Engineers, Environment and Public Health Organization (ENPHO), New Baneshwor, Kathmandu, PO Box 4102, Nepal (E-mail: enpho@mail.com.np)

Abstract

In the rural Terai region of Nepal, many tubewell drinking water sources are microbially and/or arsenic contaminated and consequently, millions lack access to "safe" water. Those who drink contaminated water may suffer from preventable water-borne diseases such as diarrhoea, stunting, skin lesions, and cancer. To combat this problem, a team comprising researchers from Massachusetts Institute of Technology (MIT), together with two local partners, Environment & Public Health Organization (ENPHO), and Rural Water Supply and Sanitation Support Programme (RWSSSP), have developed an award-winning household water filter, the Kanchan™ Arsenic Filter (KAF), for simultaneous arsenic and pathogen removal. The KAF is constructed using locally available labour and materials and is optimised based on the local socio-economic conditions. The first part of this paper explains the technology development process and the technical details of this innovation. The second part of this paper describes the dissemination activities since 2004. This dissemination model not only built capacity in local people towards long-term, user-participatory safe water provision, but also made a contribution to the local economy. As of January 2006, over 25,000 people have gained access to safe water as a result of the implementation of the KAF.

Keywords

Arsenic; biosand filter; household drinking water treatment and safe storage (HWTS); implementation model; slow sand filtration

Introduction

Although access to safe drinking water is a basic human right, millions of people in Nepal are denied this right. Nepal is one of the poorest countries in the world, where the average per capita income is only USD 260 (World Bank, 2004). In the rural Terai region, basic safe water and health services are often poor. The infant and under-five mortality rates are high at 59/1000 and 76/1000 births respectively, and 51% of children suffer from stunting on account of water-borne diseases (UNICEF, 2006).

It is estimated that 90% of the 11 million rural Terai populations receive their drinking water supply from tube wells, but many of these sources are arsenic and microbially contaminated (Shrestha, 2003). In some places, the arsenic concentration is 10–20 times higher than the Nepali interim guideline value of 50 µg/L (World Bank, 2005). Arsenic is a poison that causes skin lesions and cancers (WHO, 2004). Water-borne pathogens can cause diarrhoea, cholera, and stunting (WHO, 2004).

Despite growing recognition of this crisis, few efforts existed to provide arsenic and microbially safe drinking water prior to the authors’ work, largely because of the lack of awareness, of appropriate technologies and of effective implementation schemes that took...
into account long-term sustainability, community demand, ownership and involvement. Many villagers were unaware of the health hazards of drinking contaminated water. Even for those who were concerned, few viable options existed. As a result, many had no choice but to continue to drink contaminated water. Children, the elderly, the sick and malnourished were the most vulnerable to these preventable water-borne diseases. Since these vulnerable populations could not afford to wait, realistic solutions that understood the local constraints needed to be developed and implemented quickly.

Research and development
To provide safe water and health improvement for the people affected by contaminated drinking water in the Terai, Massachusetts Institute of Technology Civil and Environmental Engineering Department (MIT), in partnership with Environment & Public Health Organization (ENPHO) and Rural Water Supply and Sanitation Support Programme (RWSSSP), have conducted collaborative research to develop and promote mitigation options. ENPHO is a prominent Nepali-based and operated non-governmental organization (NGO) experienced in the development and application of appropriate environmental technologies. RWSSSP was a joint program between the Finnish and Nepali government on water and sanitation provision in rural Nepal. Since 2000, this team emphasized household-scale technology, based on a 3-step approach including background research, Phase I evaluation, Phase II evaluation, followed by implementation.

(1) Background Research. The team first collected field data on water quality and health and socio-economic conditions from local villagers, health workers, government officials, business enterprises, and other stakeholders. MIT collected information from around the world on available arsenic treatment options such as scientific principles, technology performance, construction methods, operation & maintenance, cost, and other relevant data for 50+ technologies (Murcott, 2001, Murcott, 2003).

(2) Phase I Evaluation. Eight technologies in the database were selected based on preliminary screening: 3-Kolshi, jerry can, iron oxide coated sand, activated alumina, activated aluminium manganese oxide, coagulation system (2-Kolshi), arsenic-iron removal plants, and the Kanchan™ Arsenic Filter (KAF). These technologies were evaluated by MIT in the laboratory and in the field based on three criteria – technical performance, social acceptability and cost. Three of the eight technologies passed these criteria: the 3-Kolshi, the 2-Kolshi, and the KAF and proceeded to Phase II.

(3) Phase II Evaluation. This involved pilot studies of these three technologies in rural households for 3 to 12 months conducted by MIT, ENPHO and RWSSSP. The three technologies were subjected to more vigorous assessment in terms of technical, social, and financial criteria. A summary list of these criteria is shown in Table 1. The Phase II evaluation showed that the Kanchan™ Arsenic Filter is the best among the three technologies. For example, the 3-Kolshi filter was not durable as it was made with clay pots. The filter became clogged after a few months of usage, and the cleaning procedure was troublesome. For the 2-Kolshi, the distribution of the necessary chemical

<table>
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<tr>
<th>Technical performance</th>
<th>Social acceptability</th>
<th>Economic affordability</th>
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<tr>
<td>Arsenic removal</td>
<td>Locally available materials</td>
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<td>Iron removal</td>
<td>Local manufacturing</td>
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<td>Microbial removal</td>
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<td>Filtration rate</td>
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<td>Durability</td>
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coagulant additive was a challenge. This specialized chemical must be shipped from Kathmandu, reaching only large market centres, not the local marketplaces that are accessible to most rural villagers. Also, some users stopped using the system because of the amount of work required (e.g. add chemical, stir, wait 30 minutes, pour in another bucket, wait again).

**Kanchan™ Arsenic Filter (KAF)**

The Kanchan™ Arsenic Filter combines the concept of a slow sand filter for intermittent use (i.e. a biosand filter base) with the innovation of a diffuser basin containing (rusty) iron nails for arsenic removal. Large-scale slow sand filters were developed in the 1820s in Scotland and England and became successfully established in Europe by the end of the 19th century. Household scale, intermittent slow sand filters are a scaled down adaptation of an appropriate technology, developed at the University of Calgary in the early 1990s (Buzunis, 1995). Another type of household scale slow sand filter, based on the model of hand-pump attached iron removal plants, are found in Vietnam for iron and arsenic removal (Luzi et al., 2004).

This KAF is constructed of simple materials available in the local markets of Nepal – plastic containers, PVC pipes, non-galvanized iron nails, brick, sand, and gravel. This filter is manufactured by locally trained technicians using simple hand tools. The KAF does not require any externally imported input (e.g. power or chemical reagent) for its operation and maintenance. Figure 1 shows the components of the KAF (Ngai and Walewijk, 2003).

In the KAF, arsenic is removed by adsorption onto the surface of rusted iron nails, i.e. ferric hydroxide (Lackovic et al., 2000; Ahmed et al., 2001). Pathogens such as bacteria are removed mostly by physical straining provided by the fine sand layer, by attachment to previously removed particles, by biological predation occurring in the top few centimetres of the sand, as well as by natural die-off (Haarhoff and Cleasby, 1991; Weber-Shirk and Dick, 1997).

Over the course of the project, the KAF has been modified to improve its performance, user-friendliness, and cost. The latest Gem505 KAF version, as shown in Figure 2, was designed in March 2004. With a design filtration rate of 15 L/hr, the Gem505 is sufficient to supply a large family according to WHO water needs recommendations of 7.5 L/person/day (Howard and Bartram, 2003). In February 2004 and again in February 2005, blanket testing of all known KAF in the Terai region were conducted. Table 2 show the arsenic removal performance of the KAF during the 2005 testing period.

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"Kanchan™ is a Nepali trademarked word meaning refreshing, mountain spring-like water"
The average arsenic removal efficiency was about 90–93% (Ngai et al., 2006). Over 95% of the filters produced water within the Nepali guideline of 50 ppb. The remaining filters were later found to be defective in the installation process. A key lesson learned/re-learned from these monitoring results is the importance of proper filter construction and installation and users education to ensure proper performance (See further comments on this point in final section “Lessons Learned).

Bacterial removal efficiency evaluation by the Tribhuvan University (laboratory study) and the Kathmandu University (field study) showed 85% to 99% removal of total coliforms (Shrestha, 2004; Sharma 2005).

The cost breakdown of the Gem505 filter (as of Jan 2006) is shown in Table 3. Most entrepreneurs are selling the filter with a subsidy (typically up to 75%) provided by donors. One entrepreneur, targeting middle and upper class customers, is selling directly at full cost. The sole O&M cost is the cost to replace iron nails. Operating under the water quality

**Figure 2** A KAF Gem505 version in operation

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Table 2 Arsenic monitoring results for 1034 KAFs in Nepal in February 2005 (Figures show the number of filters)
conditions encountered in the Terai region of Nepal (total arsenic < 500 μg/l, phosphate < 2 mg/L, pH < 8) the iron nails can last 3 years before replacement is necessary.

Phase A implementation (January 2004 to June 2005)
The KAF has intentionally been disseminated as an “open source” innovation* and the lack of a formal patent/intellectual property rights has brought both rewards and challenges. In order to promote KAF throughout the Terai region, the MIT-ENPHO-RWSSSP team applied and won an award in the World Bank Development Marketplace (DM) Global Competition 2003, which enabled Phase A Implementation during the 18-month period from Jan 04 to Jun 05. Key activities, positive outcomes, and challenges of Phase A are summarized in Table 4. Table 5 shows the summary of the filter users survey results conducted in February 2005. As a result of the project activities, 3000 + KAF are in operation throughout the Terai region (as of January 2006), providing safe water to an estimated 25,000 rural people.

Phase B implementation (July 2005 to June 2007)
To expand this Phase A Implementation, and to address some of the problems/challenges encountered, the MIT-ENPHO team, together with their new partner – Centre for Affordable Water and Sanitation Technology (CAWST), obtained additional funding from various international sources. CAWST is a Canadian service-oriented, non-profit consultant specialized in training and education of water supply implementers in the developing countries. The main goal of the Phase B implementation during 24 months from July 2005 to June 2007 is to reach an additional 3000 to 5000 households and schools in 100 villages in a sustainable fashion (meaning staged scale-up, sustained use, proper oversight of operation and maintenance, financially viability). Villages that have the greatest need for safe water, and have the strongest interest and support towards this project, as in a demand-responsive model, are selected. There are four main activities in this period:

First, the team is expanding the education and awareness activities within the rural communities. The team is collaborating with local CBOs to conduct village-level small group discussions, school education programs, street dramas, woman-to-woman household-level trainings, as well as mass media campaigns, such as radio and posters, in order to effectively target different segments of the affected population. Second,
### Table 4: Key activities, positive outcomes, and challenges during Phase A Implementation

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<tr>
<th>Key Activities</th>
<th>Positive outcomes</th>
<th>Challenges</th>
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<td>• Established a KAF technology &amp; reference center at ENPHO in Kathmandu</td>
<td>• KAF information is readily available to the general public</td>
<td>Lack of long-term continuous funding to run and upkeep the KAF center</td>
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<td>• Developed information, education, and communications (IEC) materials on KAF project</td>
<td>• Improve dissemination of KAF</td>
<td>• Entrepreneurs are unwilling to pay for training</td>
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<td>• Maintained database of entrepreneurs trained and filters installed</td>
<td>• Improve coordination among government, NGOs, and other key stakeholders</td>
<td>• Some entrepreneurs lack motivation and skills to promote and sell filters</td>
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<td>• Trained and certified 20 local community-based organizations and private businesses (which are referred to as KAF entrepreneurs) from affected districts across Nepal in filter construction, maintenance, promotion, and sales techniques</td>
<td>• KAF available for sale from entrepreneurs through a demand-responsive model</td>
<td>• Difficult to ensure entrepreneur’s competency and filter quality</td>
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<td>• Conducted a follow-up training workshop 8 months after the initial training to reinforce proper construction technique</td>
<td>• Local capacity building, job creation, poverty- alleviation</td>
<td>• Users cannot afford full cost for the filter</td>
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<td>• Conducted health awareness workshops at 200 villages (wards) in collaboration with Red Cross and other local CBOs</td>
<td>• Facilitate networking among entrepreneurs</td>
<td>• Users not willing to buy until they have adequately observe their neighbours’ filters</td>
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<td>• Over 6,000 villagers attended these workshops to learn about water, health, hygiene, treatment options</td>
<td>• Learn about difficulties faced by entrepreneurs and offer support</td>
<td>• Many people are still unaware of water contamination and health effects</td>
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<td>• Villagers learned proper KAF operation and maintenance procedure through demonstrations</td>
<td>• Increase health awareness lead to informed decisions in obtaining safe water</td>
<td>• Follow-up visit is needed to ensure proper filter O&amp;M</td>
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<td>• Villagers were told where and how to obtain KAF</td>
<td>• Proper O&amp;M of the KAF will produce safe water that can improve health and worker productivity</td>
<td>• Many participants lack resources to promote the KAF</td>
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<td>• In collaboration with Red Cross, conducted health awareness workshops in 30 local governments jurisdictions (VDCs)</td>
<td>• Face-to-face contact between project staff and villagers builds trust</td>
<td>• Demo KAFs come into disrepair due to lack of maintenance by schools or health posts</td>
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<td>• 500 local officials, teachers, and leaders learned about water, health, treatment, and KAF</td>
<td>• Local officials and opinion leaders spread the health message to their local people</td>
<td>• Ongoing political conflicts disrupt many government activities</td>
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<td>• Promotional KAFs were given to local health post and schools for public demonstration purpose</td>
<td>• Students learn from teachers</td>
<td>• How to properly collect, document, analyze, and present the data for different stakeholders?</td>
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<td>• Conducted monitoring and evaluation of filter performance, user acceptance, and user feedback</td>
<td>• Locals can see real KAFs in operation before buying</td>
<td>• How to effectively communicate new information to all stakeholders?</td>
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<tr>
<td>• Established partnerships with national and international organizations</td>
<td>• Develop new filter versions of improved technical performance, better acceptance, and lower cost</td>
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<td>• Disseminate KAF information in through conferences, events, and internet</td>
<td>• Many organizations have adopted the KAF as the best available option, and are implementing it in their project areas</td>
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<td>• In collaboration with Red Cross, conducted health awareness workshops in 30 local governments jurisdictions (VDCs)</td>
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<td>• 500 local officials, teachers, and leaders learned about water, health, treatment, and KAF</td>
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<td>• Promotional KAFs were given to local health post and schools for public demonstration purpose</td>
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<td>• Conducted monitoring and evaluation of filter performance, user acceptance, and user feedback</td>
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<td>• Established partnerships with national and international organizations</td>
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<tr>
<td>• Disseminate KAF information in through conferences, events, and internet</td>
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the filter supply scheme is being strengthened. The team is providing advanced training to the existing local entrepreneurs in business management, marketing, promotion, and sales. The team is also developing guidelines to ensure filter quality and accessibility, including outreach to those seeking to “reinvent” the KAF in their own localities, as well as to optimise the reliability of the filter parts supply chain. Third, the team is developing micro-financing mechanisms in partnership with informal local savings groups. Group members interested in buying a KAF can obtain a small loan from their group to make a filter purchase. The team is also temporarily subsidizing some filter hardware parts, including the plastic bucket, diffuser, and piping parts, which amounts to about 50% of the over filter cost, in an attempt to increase the filter sales to generate a critical mass. Finally, the team is actively documenting and disseminating all project information as well as seeking funding for regional expansion, possibly into Cambodia, Vietnam, and Bangladesh. Figure 3 shows the implementation model of Phase B.

Is the project sustainable?
KAF has also taken some steps beyond an appropriate technology (simple, low cost, constructed of local materials, having a rural focus – Schumacher 1973) towards a sustainable technology implementation model. The implementation model is based on a demand-driven approach, on a social entrepreneur business model and on partnership among stakeholders. In particular, the capacity of existing local authorities like health posts and CBOs to support safe water initiatives are strengthened, rather than relying on the often ineffective remote central authority and/or top-down distribution. Also, the implementation scheme builds on pre-existing and functioning infrastructure rather then creating new networks; therefore reducing the risk of failure. These are good first steps towards a sustainable project.

Lessons learned
A number of important lessons were learned in the implementation of the KAF

(1) For profit, cost recovery or charity? The KAF coordination team has implemented the KAF following a cost-recovery model. However, many of the local entrepreneurs
are established as or funded by charities. They do not assume any risk and lack the motivation and skills to actively promote and sell the KAF for profit. Therefore, the team is now engaged in seeking out and training more private business entrepreneurs in order to target the early adopters, i.e. middle to higher economic class customers and opinion leaders, creating the momentum and critical mass necessary to quickly disseminate the KAF to all segments of the affected population.

(2) Microfinance: Currently 50% of the filter cost is subsidized as hardware subsidy, and the rest is paid by the customers in cash. Although this service delivery mechanism seems to be able to provide the KAF at the grass-root level more effectively than the former 75% cash subsidy model, more work is needed to demonstrate the long-term sustainability of this approach when external funding has dried up, and to develop a long-term scheme such that the poor can have easy access to the KAF.

(3) Open source technology: Since the KAF is an open-source technology, some organizations have constructed it without informing or receiving proper training from the MIT-ENPHO-CAWST team. They have made mistakes in the design and construction and obtained poor performance, then publicly discredited the technology. Others have claimed the KAF as their own invention in international competitions. The team will improve its information dissemination methods in the future, and will seek better coordination among stakeholders.

(4) Government approval mechanism: There is the lack of a government approval mechanism in Nepal to certify the KAF. As a result, local users are often confused and unconvinced, leading to slow technology dissemination. In response, the team will continue to advocate to the government, and to explore alternative venues (e.g. foreign or private agencies) to set regulations and accreditation mechanisms.

(5) Replicable model: This KAF dissemination model to equip local entrepreneurs with skills and users with knowledge and tools to solve their own problems may also be a solution for other arsenic-affected countries.

(6) Civil unrest: Due to strong coordination with local community-based organizations such as the district chapters of Nepal Red Cross Society and others, the project is running surprisingly well despite the on-going civil conflict.

Conclusions
The KAF is a modest but sincere attempt to provide a sustainable solution to the arsenic and microbial contaminated drinking water problems in Nepal. The KAF technology itself and the implementation plan are appropriate for the context of Nepal. This project has built capacity for local people towards long-term, user-participatory safe water provision, as well as contributed to the local economy. As of January 2006, 3,000 + KAF have served over 25,000 people. Better health contributes to higher quality of life, greater worker productivity, leading to overall growth of society, contributing to the Millennium Development Goals of halving the proportion of people without access to water by 2015. Lessons and challenges are being integrated in an adaptive manner with the aim of improved implementation. For more information, visit http://web.mit.edu/watsan.

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References
Bangladesh University of Engineering and Technology (BUET)/The United Nations University,
Bank Netherlands Water Partnership and the World Bank, Washington, USA.
OrganizationWHO/SDE/WSH 03.02.
watsan (accessed 29 Oct 05).
Chemosphere, 59, 377–386.
(EAWAG) and Hanoi University of Science, Vietnam National University, http://www.arsenic.eawag.ch/
publications (accessed 1 Apr 06).
removal. In Arsenic Exposure and Health Effects IV, Chappell, W.R., Abernathy, C.O. and Calberon,
Exposure and Health Effects, 18–22 June 2000, San Diego, USA.
design and innovation for the common good. In: Arsenic Exposure and Health Effects V. Proceedings of
the 5th International Conference on Arsenic Exposure and Health Effects, 14–18 July 2002, San Diego,
mit.edu/murcott/www/arsenic (accessed 29 Oct 05).
Drinking Water Filter for Rural Nepal, Research Report. Massachusetts Institute of Technology, USA,
4-weeks daily study. BSc Thesis. Kathmandu University, July 2005.
Shrestha, R.R. (2003). Groundwater arsenic contamination, its health impact and mitigation program in
Nepal. Environmental Science and Health. Part A—Toxic/Hazardous Substances & Environmental
Engineering, A38(1), 185–200.
Shrestha, P. (2004). Arsenic, iron and coliforms removal efficiency of household level biosand filters. MSc

