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Death by heat: the *Chulli* treatment system

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The chulli system is an innovative technology for household treatment of microbiologically contaminated water. A metal coil is built into a traditional clay oven, and during cooking events water is passed through the coil, raising the effluent temperature to at least 60° C and effectively pasteurizing the water. The capital costs are low, and no additional time or fuel is required to treat the water. Although first developed for use in arsenic-affected areas of Bangladesh, it is now finding wider application in coastal areas affected by cyclone Sidr, where surface water is the main source of drinking water.

Background

In 2003, a professor of chemical engineering at Rajshahi University in Bangladesh was trying to develop new technologies to provide safe drinking water in arsenic-affected areas. Professor Fakhrul Islam realized that when rural Bangladeshis cook food on their clay stoves (*chulli*), much of the heat generated by the fire is wasted. If this heat could be captured and used to heat water, bacteria and other pathogens could be inactivated. The water would not need to be brought to a boil: raising the temperature to approximately 70° C would cause effective pasteurization. Most faecal pathogens (including *E. coli*, *C. jejuni*, *V. cholerae*, *Salmonella typhimurium*, *Shigella dysenteriae*, rotavirus, and *Cryptosporidium* oocysts) are highly vulnerable to heat treatment (Islam and Johnston, 2006).

Using locally available aluminium tubing (2.5 m in length, 12 mm internal diameter), Professor Islam formed a helical coil which could be built into the clay ovens. By passing water through the coil during cooking, water could be rapidly and efficiently heated. The *chulli* treatment system comprises three components (see Photograph 1):

- An influent reservoir partially filled with sand (to reduce turbidity and gross particulate matter);
- The aluminium coil embedded within the clay oven; and
- An effluent line connected to a tap for flow control.

Approximately 200 mL of water is contained within the coil and in contact with the oven heat at any time; with a flow rate of 500 mL per minute the hydraulic residence time within the oven is 25 seconds, which is in most cases adequate to raise the temperature to at least 70°c. The effluent tap, the height difference servoir bucket and the tap, and the amount and type of sand placed in the reservoir can all be adjusted to optimize flow rate and effluent temperature. All system components are available in Bangladesh, for a total cost of approximately US$ 6. The system is described in detail by Islam and Johnston (2006).

Photograph 1. *Chulli* system components

Source: Islam and Johnston (2006)

Application in arsenic-affected areas

Development and scaling up

The *chulli* system was developed and tested at the field office of a local NGO, Integrated Approach for Community Development (IACD). Initial tests showed that *chulli* treated water contained no measurable total coliform bacteria, even when source waters contained more than 500,000 cfu/100 mL. In mid-2004, IACD began distribution of *chulli* filters in arsenic-affected households where their field workers had been promoting arsenic awareness and the importance of taking arsenic-safe water for drinking and cooking. Over a three month period (Phase 1), UNICEF and its government counterpart, the Department of Public Health Engineering (DPHE), supported IACD in the installation of 169 systems, with beneficiary households contributing approximately 50% of the system cost. Caretakers were given training in operation and maintenance, with emphasis on hygiene promotion and safe handling of treated water. In early 2005 (Phase 2), another 447 *chulli* systems were installed in other arsenic-affected areas where IACD was already active in arsenic mitigation. In all, 616 *chullis* were installed in six villages from three sub-districts.

Raw and treated water was tested for thermotolerant coliforms (417 tests each), using potable incubators (Wagtech Potatest); no treated water samples were coliform-positive, though raw water contained up to 4,550 cfu/100 mL (median 340). However, when stored water was tested in a small number of households, (n=24), re-contamination was noted in 13% of cases, with a maximum thermotolerant coliform level of 350 cfu/100 mL. Beneficiaries were reportedly happy with the systems, in terms of quantity and quality of water produced. People also expressed their satisfaction to have hot water on tap within the household, for general cleaning purposes (Islam and Johnston, 2006).

On the basis of the positive experience in these six villages, the *chulli* technology was introduced into 15 arsenic-affected sub-districts (including the initial 3) where DPHE and UNICEF were implementing arsenic mitigation activities, through other NGO partners. In 2005 and 2006 (Phase 3), nearly 3,000 filters were distributed in these sub-districts, providing arsenic-free drinking water to approximately 15,000 people.

Evaluation

In September 2005, an independent evaluation of the *chulli* systems was made in one of the Phase 1 sub-districts (Gupta et al., 2008). 114 households where *chullis* had been installed were visited by a trained female survey team. Within two weeks of the survey, a microbiological team visited the households to collect samples for measurement of *E. coli* using standard membrane filtration in a Dhaka laboratory.

The survey teams interviewed members of 101 households (88%). *Chulli* systems had been installed in these households a median of 12 months earlier. Respondents were well aware of arsenic contamination, and nearly half personally knew of someone affected by the skin lesions characteristic of arsenicosis. However, only 21% of respondents reported regularly using *chullis* for treating drinking water. 27% reported using rainwater (a focus of the earlier intervention by IACD) with the remainder using tubewell water, which in most cases was contaminated by arsenic.

The most common reason cited for not using *chullis* was ‘mechanical problem or breakage’ (49%) followed by ‘complexity or inconvenience’ (35%). Among those reporting mechanical problems, the most common were ‘sand in the system’ (55%), ‘air in the system’ (37%), ‘leakage of water’ (37%), and ‘breakage of the aluminium coil’ (22%). Respondents were nearly four times more likely to report *chulli* usage when they had sought out a *chulli* system themselves, rather than gotten one through promotion by IACD. More respondents mentioned access to hot water (65%) than safe drinking water (48%) as advantages of the *chulli* system.

When the microbiological team revisited the 21 households which had earlier reported regular use of the *chulli* system, they found that 17 households currently reported irregular or improper *chulli* use. In 15 cases, households were collecting water from the *chulli* without a fire burning, or without waiting for the effluent water to become hot. Therefore, water testing was conducted only in the four households where *chullis* were seen to be in regular use. In these households, water samples were collected on four separate occasions, from the raw water reservoir, at the effluent tap, and from a household storage container (after cooling). Raw water was in all cases contaminated with *E. coli* (median: 5,000 cfu/100 mL). In five of sixteen effluent samples the water temperature was under 60° C (minimum 50° C); three of these were positive for *E. coli*. No *E. coli* was detected in other effluent samples. In nine of sixteen cases, stored water was positive for *E. coli*, with a median of 100 cfu/100 mL.

The high drop-out rates noted were very discouraging, but the evaluation showed that when operated correctly, the *chulli* treatment system gave very effective *E. coli* reduction (median log reduction: > 5; range: 0.4 to > 5). In order to address some of the mechanical problems identified, some aspects of the system were re-designed, including improvements in connections to reduce the possibility of sand or air entering the coil, or water leakage.

Application in cyclone response

On November 15, 2007, Cyclone Sidr struck southern Bangladesh with winds of up to 240 km/h, killing more than 3,000 people and causing heavy damage to water and sanitation infrastructure. In most of Bangladesh, easy access to shallow groundwater has led to a high level of drinking water coverage (in spite of widespread arsenic contamination). However, in some coastal areas, shallow aquifer is saline and people rely on surface water or rainwater (with or without treatment). In some of the areas worst affected by the cyclone, the reserved ponds used as drinking water sources were filled with fallen trees, carcasses, and other debris. In a relatively few number of cases, the storm surge left brackish water in the ponds. UNICEF and DPHE supported significant emergency response and early recovery works, including provision of water and sanitation infrastructure through NGOs.

Oxfam and several local NGOs demonstrated *chulli* systems in affected areas and found high public interest in the technology. Throughout 2008 at least 17,000 households were supplied with *chulli* systems. Design improvements reduced the number of complaints regarding leakage and breakage. Public acceptance of the system appears to be higher than in the arsenic-affected areas, since people are already accustomed to drinking surface water, and in some cases treating water (most often by boiling or use of alum; community slow sand filters are also widespread). Some further refinements to the design have been made, including reducing and simplifying the parts used at junctures; even though the original fittings are available within Bangladesh, they are not always available at the village level.

Spot checks of treated water have shown effective inactivation of thermotolerant coliforms, though in some cases households are collecting water below 60° C. However, to date these assessments have been made by the implementing NGOs, and need to be confirmed through an independent evaluation, which is planned for 2009.

Discussion and conclusions

The *chulli* system is an emerging option for household treatment of microbiologically contaminated drinking water. The system is still evolving and has significant limitations. Many users have reported mechanical problems and inconvenience as drawbacks. During distribution, users are instructed to always keep water flowing through the coil during treatment; this is seen as a significant nuisance, as the volume of water produced greatly exceeds the amount required for household use. Treated water must be cooled before drinking, and there is a high chance for recontamination to take place before consumption. Some of these concerns can be mitigated through design improvements (e.g. leaking junctions), but some are inherent to the technology (e.g. long cooling time required). However, the system offers many attractive features, especially the low capital cost, high volume of water treated, and lack of additional time or expense required for water treatment. The technology has not proven popular in arsenic-affected areas of Bangladesh, where users have ready access to abundant, cool groundwater. The technology is more likely to be accepted where there is a tradition of drinking surface water, especially after household treatment (e.g. boiling).

Although the system was developed for application in arsenic-affected areas of Bangladesh, knowledge about the technology has started to diffuse into emergency response applications, and to neighbouring countries. Attempts to replicate the *chulli* system have been made in Cambodia, Pakistan, and Nepal, and possibly other countries. It is hoped that through presentation at WEDC and other international events, more such attempts can be made. Undoubtedly, as others experiment with the technology, significant improvements will be made and some of the technical problems identified to date can be addressed.

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