Global Livestock CRSP

Point-of-Use Treatment Options for Improving Household Water Quality Among Rural Populations in the River Njoro Watershed, Kenya

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Rural access to improved water supplies in Kenya stands at 46%. Consequences are apparent in the River Njoro watershed, where a majority of households fetch and use polluted river water for some or all of their domestic water needs, suffering high rates of diarrhea, typhoid, and other water-borne diseases. Responding to expressed needs for improving water quality in the watershed, the SUMAWA Project launched work to develop low-cost water treatment for household use. This brief reports findings from screening six point-of-use (POU) water treatment technologies applicable in developing countries. Operating characteristics, performance, costs, procurement, and local sustainability were reviewed and suitability of use with river water by households in the Njoro watershed was assessed. Intermittent slow-sand filtration (known as the "BioSand Filter" or BSF), ceramic clay filtration ("Filtron" pot), and chlorine disinfection were identified as suitable. Among these, the BSF was selected as most promising for application development in the Njoro watershed on the basis of robust design, easy of use, no recurrent costs, high flow rate, and ability to treat highly turbid river water. A program to develop and trial the BSF for use by high-risk households to treat polluted River Njoro water was launched in 2006 jointly with the Nakuru District Ministry of Health's Public Health Division, and Civil and Environmental Engineering Departments of UC Davis and Egerton University. As the program wraps up, results and practical learning will be shared in upcoming research briefs.

Background

The River Njoro watershed, located in Nakuru and Molo Districts near Nakuru Municipality, is typical of many productive parts of rural Kenya that have and continue to undergo population growth and subsequent land use change. Unmanaged water and land resource impacts and inadequate development of public services result in severe negative consequences for human and ecosystem health and well-being. During participatory rural appraisal in 2003-04, undertaken by the SUMAWA Project, watershed communities identified poor domestic water quality, human and livestock diseases due to consumption of polluted river water, and water scarcity among priority problems.

Various water quality investigations confirmed the river's unsuitability for ingestion or human contact (Jenkins, 2008). Turbidity levels of 125 NTU and fecal coliform levels of 8 x 10^3 cfu/100 ml, averaged over time and space along the river, greatly exceed the World Health Organization (WHO) recommended turbidity of 5 NTU and fecal coliform concentration of under 10 cfu/100 mL for unimproved drinking water, and the US EPA fecal coliform level of 200 cfu/100 ml for safe human contact. Genetic evidence for the presence of the zoonotic water-borne fecal-oral pathogen *Cryptosporidium* spp., known to cause severe diarrhea in very young, old and immuno-compromised human and cattle populations, was found in 78% of tested water samples taken from sites throughout the river.

A SUMAWA survey revealed the majority of households within the watershed depend on River Njoro water for some or all of their water needs. Those with access to improved sources at home or in their neighborhood, such as roof rainwater catchments, kiosks selling borehole water by the jerry can (3-5 Ksh/20 liters), community-operated taps, and in rare cases, piped water connections, must still use the river in times of rationing, shortage, in-operation and other common causes of non-availability (GLCRSP 2005). At the 38 public access river watering points identified along the River Njoro, activities include: livestock watering, domestic water collection, washing laundry, children bathing, washing bicycles and cars, washing produce for sale in the market, and commercial collection of water for distribution and sale or for productive activities such as construction and drilling. Discharges of untreated and poorly treated wastewater from small and medium-size sewerage, canning, dairy and other commercial operations located along the river can make up a significant portion of the stream flow in the middle and lower sections of the river during the dry season.

A review of registered cases at government clinics found diarrhea diseases and typhoid to be endemic in the watershed, concentrated in neighborhoods and communities with the poorest water supply and sanitation conditions (GLCRSP, 2005). Diarrhea reported among children under five, in a 2-week prevalence survey of households using river water, ranged from 19 to 11% across the watershed and showed a clear link with lack of safe water for drinking. Diarrhea rates of 22% were seen among children in homes using river water for drinking, compared to diarrhea rates of 9%, 8% and 13% among children in homes who, while using river water for other domestic needs, used piped water, roof-collected rainwater and borehole water, respectively, specifically for drinking. Bacterial river water quality (fecal coliform counts) measured at watering and monitoring sites along the river, 2-week child diarrhea prevalence among river-using households, and water supply and sanitation conditions across the watershed (Table 1), illustrate the important need for safer water supply for household health in the Njoro watershed.

Water treatment in the home at the point of use, known as point-of-use (POU) treatment, has received a great deal of attention as a potential way to rapidly and affordably improve the water quality and quality of life for the 1.1 billion people living in developing countries who do not have ready access to a safe improved water supply (Sobsey, 2002). A decentralized approach to improved water supply, focused at the household level, may be both more environmentally sustainable and operationally feasible than centralized systems in rural areas of developing countries like Kenya. A variety of low-cost POU methods for use in developing countries has emerged based on 1) filtration techniques (slow sand, ceramic of various kinds, and filters made from local materials such as burned rice husks or cloth), 2) chemical disinfection (including chlorine, generally in the form of sodium hypochlorite), 3) solar disinfection or disinfection by ultraviolet (UV) light, 4) bone-char (to remove fluoride), and 5) chemical flocculation (using products like Alum, Moringa seeds, or chemicals). In places like the United States, more "advanced" treatment methods such as reverse osmosis membranes are used in homes but are inappropriate in Kenya because they require electricity. Health impact trials in developing countries of POU technologies have shown diarrhea diseases reductions of 30% (Fewtrell, et al., 2005).

Through an in-depth literature review POU options were identified and evaluated against a list of performance and implementation considerations (Tiwari, 2006). Design and operating characteristics and advantages and disadvantages were then compiled for each POU option in the context of treating river water in homes of Njoro watershed residents. The goal was to select the most suitable option for further development, local adaptation, and eventual household trials in the Njoro watershed.

Major Findings

The most appropriate, acceptable and feasible POU methods for a given context will vary with the variety of situations encountered in less developed countries. POU technologies must be selected, tested, adapted and promoted on the basis of satisfying local water safety issues, cultural issues, cost issues and water demand (volume) issues. Many considerations must be taken into account when choosing an appropriate POU household drinking water treatment system for a particular local context and target population in a developing country. First are water quality considerations for developing an effective treatment regime. Major ones include: 1) pathogen removal, 2) turbidity reduction and 3) flow rate or size of batch (volume treated) for batch processes. Secondary water quality considerations include: 1) residual disinfection capability/possibility of recontamination, 2) removal of organics, 3) removal of potentially harmful inorganic constituents such as arsenic, lead and fluoride and 4) finished water odor, taste and color. Non-water quality considerations are equally important and include such things as: 1) ease of

Table 1. Median fecal coliform in river water, diarrhea cases and water supply/sanitation conditions by zone and community in the River Njoro Watershed.

Watershed Zone & Communities	Fecal Coliform Median Count /100 ml (5 - 95 percentile)	Child Diarrhea 2-week incidence (Jun 2004)	Household Water Supply, Sanitation, and Poverty Conditions
Upper Catchment: Nessuit Area	2,457 (289-57,511)	19%	No improved water supplies; 35% no latrine; poverty highest; dispersed agricultural community
Upper Middle: Beeston, Mwigito, Njokerio	9,593 (3,978-201,389)	15%	Limited availability of improved water supplies; 98% have latrine or toilet; rapid un-planned peri-urban growth
Middle: Njoro Town, Rumwe	6,912 (1,750-67,639)	13%	Improved supplies available but cost a barrier and interruptions common; 98% have latrine or toilet
Lower Middle: Piave, Ngata, Ingabor	4,855 (936–53,556)	Unavailable	Improved supplies available but cost and distance a barrier; 98% have sanitation
Lower Catchment: Mogoon, Baruti, Kaptembwa, Ronda	31,608 (4,793–385,000)	11%	Improved supplies available but cost and distance a barrier; 100% have sanitation; higher incomes and greater employment opportunities, with slum-like living conditions in some neighborhoods

use, 2) cost (both initial investment and periodic costs), 3) practical considerations such as availability of power supply, proximity to water source and local availability of materials and services and 4) social acceptability of the system. Secondary non-water quality considerations include: 1) maintenance requirements and 2) durability/longevity of the system.

Low cost POU options identified for consideration included: 1) intermittently operated slow-sand filters, known as the BioSand filter (BSF), 2) clay pot filters with silver treatment, known as "Filtron" filters, 3) ceramic candle filters, with or without silver treatment, manufactured by a wide range of companies in Europe, India and Latin America, 4) chemical disinfection using sodium hypochlorite liquid, sold in Kenya under the brand "WaterGuard" and "AguaGuard," 5) SODIS, simple passive solar disinfection, requiring clear 1 liter plastic bottles (PET) placed in the sun for 6 or more hours, and 6) combined chemical coagulation-flocculation and disinfection powder, sold in packets under the brand name PUR[1]. Ceramic candles, BSF, and chemical treatment and disinfection are now commercially available in many developing countries, including in Kenya. BSF and Filtron filters can be manufacturer locally as cottage industries, requiring some capital investment and specialized equipment.

Practical Implications

After reviewing the literature with particular attention to performance relative to river water characteristics, and issues of local access to consumables and products, volume and flow rate, and ease of use, the BSF, Filtron, and chlorine disinfection using WaterGuard were selected for further consideration as potentially suitable in the context of needs and situation of high-risk communities within the Njoro watershed. These three methods encompass POU technologies with extremely low capital cost ($5-25) and no to low recurrent costs (0 to $1.00/month), good potential for local production or procurement, general ease of use, and long-term sustainability within the Njoro watershed. Unique reasons for selecting the BSF and chlorine included: local availability of materials and technology to produce them or to purchase key inputs; possibility of high throughput for the large volumes of river water needing treatment for drinking and other domestic needs in some households; and effective removal of pathogenic organisms such as protozoa, in the case of BSF, and high viral and bacterial destruction with formation of a residual in the case of chlorine.

Candle filters are also potentially appropriate for drinking purposes but only for better off households, due to higher capital and recurring costs associated with regular candle replacement. They have also been extensively tested elsewhere. The technology to produce Filtron filters, a much cheaper version of candle filters, is not yet available in Kenya, making these difficult to manufacture for the moment. They also have low throughput and are suitable for treating drinking water volumes only. PUR was not explored further because of high costs given monetary constraints of poor households, limited local availability, and difficulties of use. River Njoro water tends to be high in turbidity thus SODIS was not a viable POU option. Chlorine was eliminated as a stand alone treatment, given large seasonal variations in river water turbidity and the implications for correct chlorine dosage, but retained as a complementary supplemental treatment, given its local availability, high effectiveness especially on bacteria and viruses, ease of use and very low cost. Thus, intermittently operated slow sand filtration, the BSF, despite some disadvantages, provides the most appropriate and suitable option likely to meet water quality improvement needs of poor agricultural and peri-urban households using river water for drinking and other purposes in the Njoro watershed.

Dr. David Manz of University of Calgary, Alberta, first proposed the BSF by adapting the traditional slow sand filter for intermittent household use by raising the under drainpipe to 5 cm above the sand to maintain a saturated system (Palmateer, et al., 1999). While the original container design was plastic, most ISSF units promoted and in use in developing countries are constructed of concrete using local materials at a commercial cost of US $15-25 per filter. The BSF is designed to hold 20 liters in the upper portion of the container above the sand and the depth of sand was chosen to have sufficient pore space to hold 20 liters, the volume of a jerry can, when sitting idle. Once set up, the filter has proven to be easily operated and maintained by the household in other settings for many years without additional costs.

For poor populations in developing countries who lack access to improved water supplies like those in the Njoro Watershed, the BSF has several key advantages over other POU methods, including: (1) robust design, unlike the ceramic filters such as the Filtron which can break easily; (2) no recurring costs, as required by chemical treatment and no regular replacement costs, such as with ceramic candle filters; (3) simple operation and maintenance easily mastered by the household; (4) relatively high flowrate, 3-60 L/hr, as compared to the ceramic Filtron and candle filters which have flow rates of 1-2 L/hr and 0.3-0.8 L/hr, respectively; (5) tolerates highly turbid waters, > 100 NTU, at levels for which chlorine and SODIS become ineffective; (6) locally available construction materials and skills making this technology sustainable within isolated communities; and (7) affordable to the poor. A survey by CAWST in 2005 revealed 80,000 concrete BSF units in use in over 36 countries.

[1]PUR is a commercial product manufactured by Proctor & Gamble, sold in Kenya at a subsidized price of 10 Ksh per packet, enough to treat 10 liters of water.

Having identified the BSF as the most promising option for improving the quality of river water used in homes in the Njoro, Dr. Jenkins designed a three-phase research program to develop and adapt the technology for local production and eventual testing in actual homes and brought UC Davis Environmental Engineer Sangam Tiwari into the SUMAWA Project to undertake the work for her PhD. Phase one, consisting of bench-scale laboratory testing at UC Davis to explore design and operating improvements for the BSF, was followed by phase two, local production and confirmatory pilot scale testing at Egerton University using river Njoro water. Phase three, the final test of applicability, proposed a six-month household trail of filters in volunteer homes of high-risk river-using households. To secure a successful and sustainable program, a memorandum of understanding between the SUMAWA Project and the Nakuru District Ministry of Health's Public Health team was signed and collaboration from Dr. Saenyi of the Civil and Environmental Engineering Department and his staff and students at Egerton University secured to work collaboratively to carry forward the three phases of work. The BSF research program is nearing completion. Development and trail results and findings will soon be shared in future research briefs.

Further Reading

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The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multi-disciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watersed in Kenya. The project Principal Investigator is Dr. Scott Miller. Dr. Marion Jenkins, University of California, Davis serves as the project's Co-PI. Email: mwjenkins@ucdavis.edu.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in West Africa, East Africa, Central Asia and Latin America.

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