

12-2012

Educational Concerns of Implementing Biosand Water Filters in Rural Uganda

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<https://doi.org/10.33015/dominican.edu/2012.edu.12>

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Educational Concerns of Implementing Biosand Water Filters in Rural Uganda

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Submitted in Partial Fulfillment of the Requirements for the Degree

Master of Science in Education

School of Education and Counseling Psychology

Dominican University of California

San Rafael, CA

December 2012

Acknowledgements

Thank you to all of the people that helped me complete this project. Firstly, thank you to Madalienne Peters for her infinite amounts of patience and perseverance with me despite my frequent episodes of writer's block and disappearances. Thank you to Pearl Soloff for revising my paper at a busy time. Thank you to members of EWB Davis that helped me start this research: Bill Fleenor, Kristel Kranz, and Amelia Holmes. Also, thank you to the Ugandans that assisted me in my research; Ignitius Bwoogie, Sam Mwebe and Nassib Bugunyea. A special thank you to Gerhard Epke for his help in writing the method section.

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Abstract

The world is facing a shortage of clean drinking water. Current predictions, due to growing population, urbanization, and climate change estimate access to clean water to be further challenged in the coming years. Research has indicated that point of use (POU) technologies are likely to be the most efficient at delivering clean water (water cleaned of diarrhea causing microbes and bacteria) to rural populations. POU technologies, and specifically the biosand filter (BSF) are shown to be affordable, effective, and sustainable in rural areas. Many studies point to the need of proper education and follow-up with BSF users.

BSF technology has been used for the last 4 years in Nkokonjeru, Uganda by a partnership between Engineers Without Borders, Davis Branch and a local nongovernmental development agency, Rural Agency for Sustainable Development (RASD). Both quantitative and qualitative data were gathered at 10 sites with 23 water filters to identify the bacteria count before and after BSF use. Users at sites answered questions from a structured interview and demonstrated their BSF procedure. The survey indicated many BSFs were not being used or were not yielding clean water, due most likely to insufficient education and follow up. Implications of research led to the development of a training and implementation approach to improve the BSF program in Nkokonjeru, to modify RASD's ongoing program of BSF distribution.

Chapter 1 Introduction

In the fall of 2011 I found myself walking to a water spring with Fred Kazito, a headmaster at St. Paul's Primary school in Nkokonjeru – a small town in rural Uganda. We took the half-mile walk from the school down a hill through green agricultural fields. Fred described how children used this water source during the dry months; he said that students had to leave classes throughout the day to do this same walk, but with full 20 L. jerry cans, up and down to the school. We knew we were approaching the water source because we saw a herd of cows drinking water directly from the cloudy, gray, unprotected spring. We tested the water for pathogens and found it to be so extremely contaminated with *E. coli* and fecal coliform bacteria. Most people in Nkokonjeru, like a lot of the rest of the developing world, do not have access to any kind of central sewage system or consistent way to treat water; those who do treat their water generally boil it – which means they have to spend time cutting down or gathering wood for their fires – further contributing to deforestation. However, there are solutions. St. Paul's school had been issued 8 biosand filters (BSF) from a local NGO within the last 2 years. These BSFs are made from local materials; they are basically large concrete boxes filled with sand. When water is poured in the top, it trickles out an effluent tube treated and ready to drink. They cost about US\$18 to make in this region of Uganda. This is in sharp contrast with Dean Kamen's (the inventor of the Segway) Slingshot Water Filter that costs \$100,000 to make.

When we returned to the school we found the filters in each classroom standing in a corner. They are solid, concrete structures that stand about a meter high and look vaguely similar to the stone statues of Easter Island. Upon closer inspection, we found only 3 of the 8 filters to be working, and of those 3, all showed signs of improper use. The effluent tubes were too long allowing the

water to siphon out of the filter leaving the top layer of sand dry. The top biofilm layer on the top dies and ceases to decontaminate the water.

I was concerned and curious to find out why these filters weren't working. Over 400,000 BSFs have been distributed around the world and had proven to be a robust technology, effectively treating water. Yet these filters were standing unused while children were drinking from a source that was clearly contaminated. How did this happen, when there are fairly simple solutions to make these filters work again? Was there any follow-up from the NGO? No one at the school seemed to have any idea how to do the minimal maintenance required to keep these working. As a teacher, it became obvious to me that although the technology worked, an educational component was lacking. I wondered if among the research on these water filters, had there been an educational component or follow-up in other BSF distribution programs? If so, was there a clear educational curriculum that had been done with these filters that proved to be effective? Engineers, not educators, have done most of the research on BSFs. I thought that I was uniquely situated, given my experience as a teacher, to research, create, and facilitate an educational follow-up component to the BSF program in Nkokonjeru. Access to potable water is a fundamental human need, the technology not only exists, it is available in this community; I believed the improved functioning of these water filters is possible.

Statement of Problem

In 2010, it was estimated that nearly 1 billion people on earth lacked access to improved water sources (World Health Organization, 2011). The need for water in developing countries is a growing concern as water demands quickly exceed the capacity of developing countries to develop water resources. In many rural communities, water must be hauled over long distances from shared sources. Due to the lack of access to water treatment systems, people often consume

water without treatment or it is boiled using charcoal or wood sources, placing further strain on resources. Numerous health problems are closely tied to issues of water supply and water resources management. Diarrheal disease is the most important water related health problem as it impacts many people each year and is particularly devastating to children. Currently, 1.8 million people, 90% children, die every year due to diarrheal diseases and unsafe water supplies and poor sanitation account for 88% of diarrheal diseases (WHO, 2011).

Purpose Statement

The purpose of this study is to explore the efficacy and history of POU water filter use in the developing world and specifically BSFs in Nkokonjeru, Uganda. A primary focus is the history of water treatment programs in the town of Nkokonjeru, Uganda by EWB-Davis in conjunction with the Ugandan NGO, RASD. Another purpose is to examine the background of POU water treatment systems implemented in the developing world, considering the efficacy of the designs, implementation of the technologies, and educational needs identified. In reviewing documentation and evaluating success rates, the author will create a framework for teaching and training locals to improve implementation of biosand filter technology appropriate to the cultural and economic conditions in Nkokonjeru, Uganda.

Research Questions

What is the history of POU water treatment technologies implemented in developing countries comparable to rural Uganda? What is the history of the biosand filter as a means to meet clean water needs in developing countries? To what extent are educational and training processes missing? What are the training and educational procedures necessary to properly use this technology in rural Uganda?

Theoretical Rationale

The World Health Organization has concluded that access to clean water is one of the best and most efficient ways to improve health. Access to clean water also benefits people based on measures of efficiency and well-being: saved costs and time, convenience, privacy and safety.

Lack of sanitation is a serious health risk. It affects billions of people around the world, particularly the poor and disadvantaged. If the trend continues as currently projected, by 2015 there will be 2.7 billion people without access to basic sanitation. (WHO, 2011)

Assumptions

All humans need access to clean water. Piped water is not an option in much of the world due to the lack of infrastructure. Access to clean water is best when that access is convenient and takes fewer resources such as time, energy, and cost.

Aid work in developing countries is most effective when done in a sustainable manner. The term sustainable refers to work that is desired by the local population, easily maintained, and becomes a part of daily life and routines; a technology is sustainable if it continues to be used after the aid program ceases and is no longer giving logistical and/or economic support.

Assumptions about rural Uganda are that the population is relatively impoverished, has limited access to education and resources. The biosand filter is a viable technology that would work well in rural Uganda. It is also assumed that RASD has committed to distributing, maintaining and educating about the use of biosand filters.

Background and Need

The World Health Organization puts it most succinctly when describing the need for water treatment at the household level regarding the scale of the problem:

HOW MANY ARE AT RISK? 1.1 billion lack access to an “improved” drinking

water supply; many more drink water that is grossly contaminated. HOW MANY ARE GETTING SICK? 4 billion cases of diarrhoea occur annually, of which 88% is attributable to unsafe water, and inadequate sanitation and hygiene. HOW MANY ARE DYING? 1.8 million people die every year from diarrhoeal diseases, the vast majority children under 5. HOW MANY MORE CANNOT ESCAPE POVERTY? Lack of safe water perpetuates a cycle whereby poor populations become further disadvantaged, and poverty becomes entrenched. HOW MUCH OF THIS CAN BE PREVENTED? WHO estimates that 94% of diarrhoeal cases are preventable through modifications to the environment, including through interventions to increase the availability of clean water, and to improve sanitation and hygiene. (WHO, 2007, p. 7)

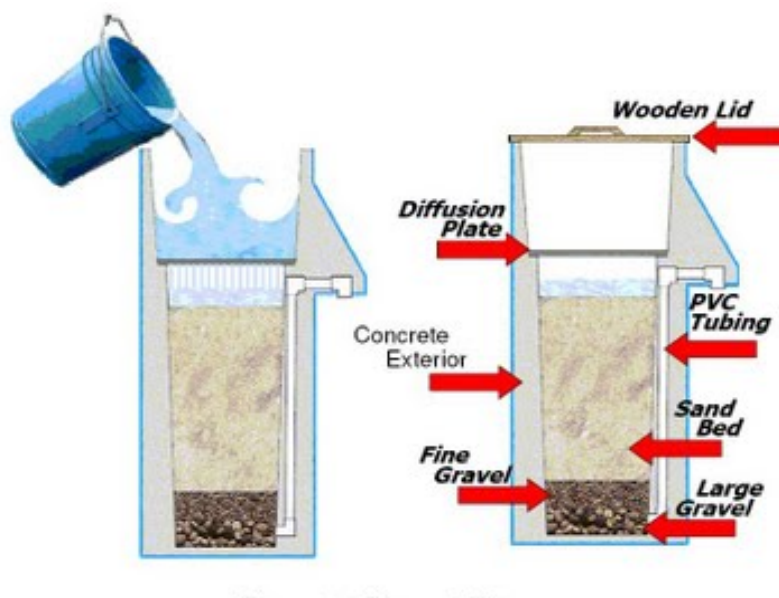
Furthermore, CAWST identifies the specific water borne pathogens that can be potentially removed via household water treatment:

Pathogens (disease-causing micro organisms) such as bacteria, viruses, protozoa and helminthes constitute the largest health risk, in most parts of the world and are generally transmitted through human or animal feces. In most instances, these pathogens cause gastrointestinal infections in the form of diarrhea, which kills around 2.2 million people globally each year, mostly children in developing countries. The following are examples of water related diseases caused by each category of pathogens: Bacteria - Typhoid fever, Cholera, Legionellosis, Salmonellosis. Viruses - Hepatitis A, Norwalk agent, Rotavirus. Protozoa – Cryptosporidiosis, Giardiasis. Helminthes: (intestinal parasites) – Ascariasis (roundworm), Taeniasis (tapeworm), Schistosomiasis (bilharzias- blood flukes) (CAWST, 2012, para. 5)

Figure 1 Biosand filter at St. Paul school in Nkokonjeru, Uganda. Notice the yellow plastic jerry cans.



Figure 2 Biosand Filter diagram from biosand filter.org



The biosand filter (BSF) is an adaptation of the traditional slow sand filter, which has been used for community drinking water treatment for almost 200 years (Centre for Affordable Water and Sanitation Technology, 2012). The biosand filter is small, about 3 feet tall and 1 foot wide, and adapted for intermittent use, making it suitable for use in people's homes. The filter container can be made of concrete or plastic and is filled with layers of specially selected and prepared sand and gravel. The sand layer removes pathogens and suspended solids from contaminated drinking water. Dr. David Manz developed the household biosand filter in the 1990s at the University of Calgary, Canada. Manz first implemented the filters in 1993 in Nicaragua, which mitigated the health effects of a regional cholera outbreak (CAWST, 2012).

Manz has trained many organizations on the design, construction, installation, operation and maintenance of the biosand filter. He also co-founded CAWST in 2001 to provide the professional services needed for the humanitarian distribution of the filter in developing countries. As of June 2012, CAWST estimates that well over 430,000 biosand filters have been implemented in more than 63 countries around the world (CAWST, 2011).

In rural Uganda, the town of Nkokonjeru, many families only have access to water of questionable quality for in-home use such as rainwater catchment, spring boxes, creeks, and standing pools. As with other underdeveloped places in the world, people often contract water-borne diseases, which can be debilitating or lethal.

Summary

The need for clean water is well established in the developing world. This is best implemented by using inexpensive, effective, water filtration systems. This study is a review of data on BSFs collected by EWB-Davis of BSFs that had been previously distributed into homes and schools by

RASD in Uganda. The following review of the literature examines accounts of point of use water filtration systems in developing countries. Issues associated with factors that effect factors in implementation are explored.

Chapter 2 Review of the Literature

Introduction

In the review of the literature, the following topics are examined: 1) Health needs effected by unclear water in the developing world, 2) prior use of water filtration systems in the developing world, 3) conditions in rural Uganda leading to the need of water filters, 4) the use of biosand filter technology in other venues, 5) the history of biosand filter use and EWB-Davis activities in Nkokonjeru, Uganda, and documented strategies of implementation and education of POU water systems in the developing world.

Historical Context

UNESCO recommends an integrated approach to managing water resources that includes cost effectiveness of local options and attention to vulnerable groups. Improving water sanitation can prevent almost one-tenth of global disease. The effects on Sub-Saharan Africa have been particularly acute: “Of the estimated 350-500 million clinical disease episodes occurring annually, around 60% are in sub-Saharan Africa, as are 80% of the deaths.” (UNESCO, 2012).

Review of the Previous Literature

Point of Use (POU) Water Treatment in Developing Countries

Dye, Apondi, Lugada, Kahn, Sandiford-Day, and Das Banerjee, (2011) concluded that large-scale water treatment systems, such as the water sanitation we see in the developed world, require more infrastructure and money than is currently available in poor rural areas, like

Nkokonjeru, Uganda. Diarrhea occurrence is directly related to the consumption of contaminated water.

The following statistics, as reported by the authors, illustrate the depth of the problem in Sub-Saharan Africa in 2006: 31% of people of the population had access to clean water, 884 million deprived of improved sources of drinking water, 4 billion annual cases of diarrheal illness, 1.8 million lives lost each year due to diarrheal disease, 443 million school days lost each year from water-related illness, 117 million disability adjusted life years (DALYs) lost annually due to diarrhea and intestinal worm infections. Furthermore, Dye et al. identify more need:

Several factors contribute to the lack of water sanitation in developing countries.

First, large-scale water treatment is expensive and requires infrastructure capabilities that are often absent in low-resource settings. Second, household-level interventions promoting water sanitation have obtained mixed results and are often cumbersome to implement and sustain. Third, it is difficult to motivate people to change their behaviors related to water access and consumption...

Point-of-use water filtration has been demonstrated to be feasible in low-resource regions in Africa (De Ver Dye et al., 2011, p. 1515).

De Ver Dye et al. conducted a study distributing point of use (POU) water treatment systems in Western Kenya. They gathered data through qualitative interviews with 34 subjects. Two systems were used, one a LifeStraw personal water filter, which is a large, thick straw worn around the neck allowing the user to suck water directly from a source. The other is a family LifeStraw filter that is a decanter that disperses treated water. They also conducted a qualitative study measuring attitudes about diarrhea. They found that most people's existing understanding of the source of diarrhea, unclean water, food, and conditions, was in fact accurate. The

participants reported a positive response from the water filters: less incidence of diarrhea, cleaner water, and less need to gather firewood to boil water. The researchers cited some problems with the study: small sample size and the sustainability of these filters. The filters in question much be purchased elsewhere. This study was conducted 2 months after the distribution of the water filters as part of a government program to distribute health-promoting materials called the Integrated Prevention Campaign, which included health education. The researchers concluded that water filtration was perhaps the best method of POU water treatment.

Clasen, Nadakatti, and Menon (2006) conducted a study in India using a household-based POU water treatment system and then assessed pathogens after use. They described research that POU water treatment systems have been “twice as effective in reducing endemic diarrhea as the conventional treatment at the source or point of distribution” (p. 1399). The researchers explained that POU water treatments are the most affordable and thus most sustainable. They conducted laboratory testing on the microbiological effectiveness of the Pureit water filter system made by Hindustan Lever Limited Company. The researchers were eager to test this technology in hopes of promoting a water treatment technology that was effective and affordable while promoting a commercially viable water filter. The study showed substantially reduced microbes from water. An advantage of this technology is that it utilizes both filtration and disinfection due to the use of chlorine. A disadvantage of this unit is the upfront cost and numerous parts requiring replacement and upkeep. The researchers suggest further research done in the field. They also suggest that users be well informed about the need to replace the filter cartridges inherent in this water filter technology. That is, there are potential problems with operator error when users do not conduct proper maintenance.

One would think that the ideal standard of research – a field study of water filters with a control group that has a placebo filter – would be impossible, but there is one such study. In 2010, Boisson, Kiyombo, Sthreshley, Tumba, et al. conducted such a study in the Democratic Republic of Congo, located adjacent to Uganda. Their goal was to rule out reporting bias and the placebo effect documented in field studies of water filters. The researchers conducted a randomized, double-blinded, placebo-controlled field trial in 240 households, over the course of 12 months. All of the households received a Lifestraw Family household-based gravity filter. Half of the households received a placebo filter with the chlorine tablets removed. The placebo filters produced filtered water indistinguishable from the water issuing from a functioning filter, but did not kill pathogens via chlorine disinfection. The researchers assessed diarrhea by visiting families every month asking primary caregivers of young children about diarrhea incidence. Diarrhea was defined as 3 or more loose stools in a period of 24 hours in the last 7 days. The researchers also asked about fever and cough in order to “further obscure the outcome of interest from the target population” (Boisson et al., 2010, para.16) to remove bias. The researchers tested influent and effluent filter water and found that the no placebo filters significantly reduced pathogens. However, they did not find a significant improvement in reported diarrhea in working filter households over placebo households. There was 15% reduction in diarrhea, but was not considered statistically significant given the parameters of the study. This shows that that self-report of diarrhea is a problematic area of research.

When researchers give 120 households in the DRC water filters that do not work, this raises obvious ethical concerns. The researchers gained approval from two institutional ethics committees and addressed ethical issues:

Written consent to participate in the research was obtained from community leaders and the head of each participating household. Investigators explained that half of the study population would be receiving effective microbiological purifiers while the others would receive placebos and that householders should continue their existing water management practices since their device may not be protective against microbial contamination. At the conclusion of the follow-up period, all placebo filters were replaced by effective filters. Following the completion of the study, the results were communicated to all study participants. (Boisson et al., 2010, para. 18)

Most field studies of filters do not use placebo filters for several reasons in addition to ethical concerns: pragmatic difficulties in creating nonworking filters, especially BSFs, logistical difficulties, resource and time limitations, and creating marketing and credibility problems with the local NGO or organization issuing filters.

Biosand Filter Literature

Kubare and Haarhoff (2010) identify the BSF (see figure 3) as an important POU water treatment system because it is self-sustaining, decentralized and affordable. The researchers give an excellent description of how the BSF works:

The filter consists of a bed of fine sand supported by a layer of gravel enclosed in a box with appurtenances to deliver and collect the water. When water is poured onto the top of the filter, particulate matter is trapped at the surface, where a biological layer (also called the *schmutzdecke*) develops

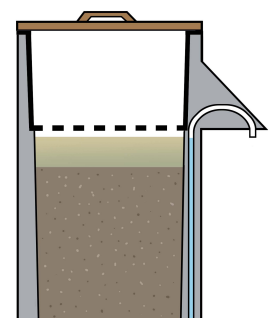
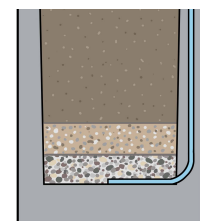


Figure 3: Biosand Filter



after a period of filter ripening. The biological layer is responsible for trapping and partly eliminating sediments, pathogens and other dissolved impurities from the water. Within the gravel support layer below the filter media are under-drains to remove the filtered water. (Kubare & Haarhoff, 2010, p. 1)

Tiwari, Schmidt, Darby, Kariuki, and Jenkins, (2009) conducted a study using intermittent slow sand filtration filter, comparable to BSFs, in the Nakuru District of western Kenya, adjacent to eastern Uganda. Interestingly, the authors discuss the placebo effect in water sanitation studies:

The trial was not placebo controlled primarily because of difficulties and costs associated with producing a reliable placebo filter. Thus, some portion of the observed health impact might well be attributed to a placebo effect. Bias is regarded as a considerable problem in water, sanitation and hygiene trials, highlighted by the observation that blinded POU trials have shown little evidence for a reduction in diarrhea (Tiwari et al., 2009, p. 1381).

They cited numerous advantages of the BSF system for poor populations, “The BSF has advantages of robust and durable design, simple user operation and maintenance with no recurring purchases, high flow rate (3–60 liters per hour) sufficient for domestic and drinking needs, ability to treat highly turbid waters, and local fabrication resulting in affordability (US \$15–25/unit)” (Tiwari et al., 2009, p. 1374).

The researchers conducted a controlled study with 30 intervention households and 29 control households, who were monitored for 6 months for self-report of diarrhea, and testing of water for bacteria. Local artisans were trained to construct Bushproof, a BSF oriented NGO, designed concrete circular filters, deliver it to users, and then monitor their use during the first month. The results indicated that households using the BSFs had a reduction of childhood

diarrhea. The authors cited disadvantages of the small sample size and relying on subjects' self report of diarrhea incidence. The researchers determined diarrhea incidence by asking users on a monthly basis about the frequency of diarrhea in the previous 7 days. The BSFs showed dramatic reductions of bacteria and self-reported diarrhea; the researchers stated BSFs are promising as a noncommercial, locally made, inexpensive POU water treatment technology. The study was done the following six months after deployment of the filters.

Stauber, Printy, McCarty, Liang, and Sobsey (2011) conducted a randomized control study examining biosand filter performance with 90 filter households and 99 control households not receiving filters. The researchers surveyed filters using plastic containers, utilizing the same slow sand filtration process as concrete framed BSFs. Both groups received hygiene education over an 8-month period. The filter group indicated a 59% reduction in self-reported diarrhea and water tests demonstrated improved quality after filtration. Significantly, this study showed a relationship between diarrhea incidence and filter use, but no relationship between turbidity and diarrhea reportages. This indicates a validity of the self-reporting diarrhea in these types of studies. If self-report of diarrhea was inaccurate, we would expect to see a higher correlation between the turbidity of the water and diarrhea, because it would be instinctive to associate the two. Clearly, it is a limitation of these field studies to rely on self-report of diarrhea, but it is hard to imagine a more objective measure of diarrhea that is practical. This was a rigorous study with a large sample and a control group. This study indicated that the plastic BSF has similar success rate of effectiveness as concrete framed filters. Plastic filters are lighter and cheaper – participants paid US\$10 for their filters. The disadvantage is that it may be subject to breakage greater than the concrete filters, and due to its greater portability, movement of the filter can reduce effectiveness.

CAWST's construction manual (CAWST, 2011) summarizes the overall success of the BSFs in prior published research. The following table shows the percentage of pathogens and turbidity removed by BSFs:

Table 1 - CAWST's summary of BSF effectiveness

	Bacteria	Viruses	Protozoa	Helminthes	Turbidity
Lab	Up to 98.5%	70 – 99%	>99.9%	Up to 100%	95% <1NTU
Field	87.9-98.5%	NA	NA	Up to 100%	85%

CAWST cites several studies that estimate the health impact of BSFs, usually information acquired via self-report of diarrhea. These studies indicate a 30-61% reduction in diarrhea in all ages (CAWST, 2011).

CAWST concludes that the advantages of the BSF are, “locally available material, high pathogen removal, high flow rate, designed for household use from locally available material” (2011, para. 18) The disadvantage is that it does not remove all pathogens.

The Center for Disease Control nicely summarizes the advantages and disadvantages of slow sand filtration:

Table 2: CDC's summary of BSF pros and cons

Advantages	Disadvantages
<ul style="list-style-type: none"> . Proven reduction of protozoa and most bacteria . High flow rate of up to 0.6 liters per minute . Simplicity of use and acceptability . Visual improvement of the water . Production of sufficient quantities of water for all household uses . Local production (if clean, appropriate sand is available) . One-time installation with low maintenance requirements <p>Long life (estimated >10 years) with no recurrent expenses</p>	<ul style="list-style-type: none"> . Not as effective against viruses . No chlorine residual protection - can lead to recontamination . Routine cleaning can harm the biolayer and decrease effectiveness . Difficult to transport due to weight - high initial cost

The CDC points out that “Slow sand filtration (SSF) is most appropriate where there is funding to subsidize the initial filter cost, available education for use and maintenance, locally-available sand, and a transportation network able to move the filter” (CDC, 2011 para. 5). To summarize, BSFs themselves have been demonstrated to be effective POU technology at reducing pathogens and diarrhea in a manner appropriate to many conditions in the developing world; the following research reviews the vicissitudes of implementing and sustaining their use.

Implementation and Follow-up to BSFs

Over a 4-year period from 2008 – 2011, Tearfund funded a project resulting in the production and sale of BSFs in Afghanistan (Burt, 2011). Local villagers identified household

water treatment as a need, because they drink water directly from canals. The development workers collaborated with locals to identify BSFs as the most appropriate water treatment. They used a demand-led approach to market and distribute BSFs. They provided the steel molds to two artisans and bought the first two BSFs for promotion. Information was distributed through radio reports in the evening promoting BSFs. The artisans demonstrated BSFs in mosques and schools to create demand. Buyers received training to operate and maintain the BSFs from the artisans. The researchers evaluated the program in 2011 and found increased coverage of BSF use, high reduction in *E. coli* bacteria, reduced reports of diarrhea, reports of improved health, and overall financial advantages. A challenge for this program was cultural considerations of women's role in the household to secure their participation.

The authors of Biosandfilter.org advocate a similar approach of making BSFs more sustainable by creating a commercially viable local means of production. They specifically cite examples in Kenya where local residents made a business out of producing BSFs and continue to make more (Biosandfilter.org, 2012). Biosand filters are seen as particularly useful in areas where there is turbidity in the water because it produces a visible improvement in the water.

Aiken, Stauber, Ortiz, and Sobsey (2011) made some general statements summarizing other follow-up research on BSFs:

Some evidence of BSF continued use has been documented, but few, if any, rigorous field studies have been conducted to assess sustained improvements in drinking water quality and user health. Among 107 households in Haiti in which the BSF had been implemented for more than 2 years, 105 households were found to still use the filter, with average *Escherichia coli* reduction of 98.5%. Among more than 300 households in Cambodia surveyed up to 8 years after

installation, 87.5% were found to still be using the BSF. (Aiken et al., 2011, p. 309)

They found in their own follow-up study of 328 households using BSFs in Cambodia, 90% of the BSFs were still in use indicating an 84-88% reduction in fecal indicator bacteria.

Many follow-up studies examining long-term use identify a need for improving the users' education about how to use the filters. In another follow-up study to evaluate the long-term sustainability of biosand filters Fewster, Mol, and Wiessent-Brandsma (2004) conducted a study in Kenya. They were interested in the performance of biosand filters in real life conditions in rural Africa after the experts have left. The researchers evaluated filters 4 years after installation. These particular filters had been introduced by Medair, a Christian relief NGO based in Switzerland, in 1999. The filters were constructed by local technicians and sold to individual households. Customers received a brief training in maintenance when they received the filter. As of 2004, 2000 filters had been sold at the price of 12 Euros (Fewster et al., 2004). They used the Bushproof improved round mold. The researchers evaluated 51 filters and found 70% of them producing water of good quality. Fewster et al makes an interesting observation about the relationship between the amount of pathogens in the water and actual illness in the drinker:

Based on these results it is interesting to discuss the relation between levels of pathogen reduction and the risk of catching water-borne disease.

Developing an illness depends on many factors, such as the general health of a person and his level of immunity. In addition, exposure to a significant 'infectious dose' is often needed. Therefore, if a poorly functioning filter removes a significant proportion of the pathogens present in raw water, but not all, the owner nevertheless would need to drink more water than before in order to ingest an

infectious dose. If this increased quantity of water is more than his normal consumption, then it is unlikely that this person will fall ill. (Fewster et al. 2004, p. 2)

The researchers commented on education as a way to improve filters' overall functioning, "the original project did not use intensive teaching methods and it is likely that better information, teaching of cleaning methods, or improved or more frequent follow-up will lead to much better results" (Fewster et al., p. 4) The researchers suggested better results would occur if the biosand filters were cleaned only when the flow rate decreased to an unacceptable level, using a method that does not disturb the biofilm layer. The researchers also pointed out those two positive marketing mechanisms of the filters: reduced turbidity and cooled effluent water.

Duke et al. (2006) investigated 107 of an estimated 2000 Manz Biosand filters that had been distributed in the Artibonite Valley of Haiti. The researchers hired and trained local workers out of a hospital in Haiti to conduct the surveys. They used a structured interview and took water 5 or 4 samples from the original water source to the family's drinking water container. The researchers gave a 20L water container as a thank you for the participants' time. In general, a successful filtration rate was indicated that *E. coli* removal at an efficiency of 98.5% and reduced turbidity. They found most filters to be working successfully after an average of 2.5 years since installation. The researchers found information pertinent to the long-term use and maintenance of the filters; many of the users did not know how to perform the maintenance procedure to improve flow, 36% indicated that they had not been visited by the local NGO, Community Development, since installation. Researchers found recontamination; *E. coli* concentrations were 7 times higher in the receptacle container than in the spout. The researchers final conclusion was, "Education about water-borne diseases, methods of safe water storage, and methods of

disinfecting the stored filtered water should accompany the installation of the filter.” (Duke et al., 2006, p. 9)

Earwaker conducted a long-term study of BSFs distributed in Ethiopia. The researcher examined BSFs that had been distributed 5 years earlier by Samaritan’s Purse, Canada through the Ethiopian Kale Heywet Church. He found an *E. coli* reduction rate of 87.9%. The usage rates varied from 44-100% among different villages. The low usage rates and poor performance was attributed to quality of maintenance, lacking needed education, and lacking outside support. The study also threw into question the sustainability of BSFs in this region; the researcher suggested increased commercialization. In Earwaker’s discussion, he points out that the BSFs would be much more efficient if they were properly maintained; users should use the proper cleaning procedure when the flow rate decreases. Other recommendations he makes are proper cleaning of the spout and more economically sustainable support structures. The researcher points out that the BSFs met with initial success due to the education that accompanied the BSFs but there was poor follow-up and reinforcement of educational messages. He concludes that, “Reinforcement of educational messages and distribution of promotional material could therefore be an effective and simple method to improve filter maintenance procedures and general hygiene behaviour” (Earwaker, 2006, p. 45).

Vanderzwaag, Atwater, Bartlett, and Baker (2009) conducted a follow-up study in Nicaragua investigating the condition of 234 filters three and eight years after installation. The researchers found only 10% of the filters were still in use after 8 years. Of those still being used they averaged a reduction of 98% total coliforms (Vanderzwaag et al., 2009). The researchers suggested the low use rate was a result of a failure of implementation and specifically the cracking of the earlier concrete filters. The authors also suggested that user training and filter

maintenance could improve filter performance. They observed, “much confusion among the filter users in Posoltega regarding filter maintenance, suggesting insufficient user training” (Vanderzwaag et al., 2009, para. 37). Vanderzwaag listed several failure mechanisms contributing to the BSFs disuse: cracks in the bodies, dislodged pipes, damage sustained when users moved the filters due to Hurricane Mitch, family dislocation, improper curing time in construction causing cracks, and improper unloading of the filter. There was no difference in performance between the filters that were three years old and eight years old. This indicates that this is a potentially sustainable, long-term technology. The researchers also suggested that there was a need for improved quality control of building and delivering the filters to reduce cracking of the concrete structures.

CAWST published a case study of implementation of Biosand filters in 2011. They reviewed a program conducted by Aqua Clara International (ACI), a non-profit NGO in USA and Kenya, in western Kenya, geographically adjacent to Nkokonjeru, Uganda. They distributed more than 1800 biosand filters between 2007-2011. ACI developed a filter using the same intermittent slow sand process but in a plastic container body. ACI endeavored to make this biosand filter as locally driven and sustainable as possible. They created and supported a local business that constructs and sells biosand filters, safe water storage containers, and hand washing containers through a local school. The businesses make money via the profits from selling each filter and received a financial incentive from ACI for monthly sales exceeding 5 filters. The business operators are responsible for training the user on how to use the filter, store water, and cleaning maintenance via the swirl and dump method. ACI also recruited local women, Community Health Promoters (CHP) to make household visits 30-60 days after They then did further training on general hygiene and sanitation.

CAWST reviewed the implementation of a biosand filter program conducted by CLEAR Cambodia, a local faith-based NGO in Cambodia. They are funded by Hagar and Samaritan's Purse and are supported by CAWST. As of November 2010, CLEAR has implemented 67,000 filters in Cambodia and have standing requests for 150,000 more (CAWST, 2011). CLEAR employs Cambodian staff to manufacture and distribute filters. They have a portable promotion and construction technique; they go to a village, conduct community outreach, promote demand, and construct filters until the demand is met. Clear subsidize the \$60 filter cost for those who cannot afford them. A village committee identifies the poorest households for subsidized filters. The recipients are required to pay at least US\$4, contribute labor, attend BSF health and hygiene meetings, and sign a contract that they will properly use and maintain the filters. If upon subsequent follow-up meetings, the filter is not being used properly, it is removed and the money is refunded. Local community health providers and CLEAR staff do follow-up and monitoring by 4 visits within 1 year of installation of the filters.

Education and Training of POU Water Systems

Sobsey (2002) identifies education and behavioral change as key in implementation of POU water treatment:

A number of studies and considerable field experiences have shown that the introduction of water treatment technology without consideration of the socio-cultural aspects of the community and without behavioral, motivational, educational and participatory activities within the community is unlikely to be successful or sustainable. Therefore, initiatives in water, hygiene and sanitation must include community participation, education and behavior modification.

(Sobsey, 2002, p. 49)

He cites the success and wide use of Participatory Hygiene and Sanitation Transformation (PHAST) program sponsored by WHO. He suggests this approach is advantageous because it promotes participation, concept-based learning, group learning, and promotion of investment to change water sanitation related behavior. PHAST is a step-by-step guide to change hygiene behaviors in developing world. It promotes community involvement in the identification of problems and solutions related to water sanitation. Sobsey also gives the example of MANAGE Dissemination system developed by the International Water and Sanitation Centre (IRC, 1999). He states this approach is favorable because it involves the community directly in decision-making.

Baker, Duke, Mazumder, and Nordin (2006) conducted a study in Haiti showing an improvement in water quality but cited that there was evidence of recontamination of the water in the drinking vessel after filtration. One of their recommendations is, “Education about water-borne diseases, methods of safe water storage, and methods of disinfecting the stored filtered water should accompany the installation of the filter” (p. 9). Similarly, in a study of BSF use in Nicaragua, Vanderzwaag, Atwater and Bartlett (2009) found that improper operator use contributed decreased effectiveness of the filter:

Unfortunately, much confusion was observed among the filter users in Posoltega regarding filter maintenance, suggesting insufficient user training. The users were divided almost equally into three groups: Those that wash their filter when the flow is slow; those that wash their filter when the top appears dirty; and those that wash their filter on a regular schedule... This suggests that filter users would benefit from training that included a more clearly defined maintenance frequency.

(p. 119)

Bushproof is an NGO that produces BSFs using the round design as opposed to the square design favored by CAWST. They also cite the importance of training on their page regarding operation and maintenance of BSFs: “Adequate training during installation and sufficient follow-up is perhaps a weak link in any biosand filter project, as householders tend to forget or ignore advice given regarding maintenance, contributing to sub-standard performance of filters.” (Bushproof, 2011, para. 10). Bushproof gives very specific advice on BSF maintenance:

It is important to remember that a ‘dirty’ filter actually can produce water of better quality. Due to a reduced flow rate better filtration takes place, while there is an increased contact time with a mature biological layer. Cleaning should therefore only take place when the outflow of water has become inconveniently slow. While a bio-sand filter ideally produces 1 litre per minute, filling a 20-litre jerry can in 2 hours can still be very convenient to an African family, even though this equals a flow rate of only 0.16 litres per minute. In some projects it is found that a majority of households will either forget or ignore cleaning advice. In such cases, bio-sand filters cannot be considered a 100% failsafe method of water purification despite their potential, but rather as a ‘better-than-nothing’ interim method of water treatment. This highlights the need for intensive teaching methods. It is likely that better information, teaching of cleaning methods, or improved or more frequent follow-up will lead to much better results. (Biosandfilters.org, 2012, para. 18)

The CDC reports that, “Experience has shown proper filter maintenance is necessary for optimal performance so proper user training and follow-up is critical to filter success. Since the filter is typically used without subsequent chlorination, training users to properly care for and maintain a safe storage container is necessary.” (CDC, 2011, para. 5)

Jenkins, Sangam, Tiwari, and Darby (2011) conducted a laboratory study in at the University of California – Davis to compare different designs and operation procedures to determine the relative effectiveness. They used 18 filters and filled them with water simulated to imitate water common in developing nations. They used water from the Sacramento River spiked with wastewater and viruses. They varied hydraulic head size (the volume of water in the top chamber), sand size and batch procedures (the frequency in which water is added to the filter). Like other studies, these tests showed an improvement in water quality; the filters removed 96% bacteria, 71% viruses, and 89% turbidity (Jenkins et al., 2011). Interestingly, this study showed that BSFs removed more viruses in less turbid waters. Significantly, this study was able to point to specific construction and operation techniques. This is important because among the widely dispersed use of filters there is a huge amount variation in construction and operation. Sand size was the most critical factor in performance. Often BSFs are built with the more affordable and available river sand versus the crushed rock sand recommended by Manz. The researchers found river sand and crushed sand to be of equal performance. The researchers' main findings were that using smaller sized sand was the single most important variable in BSF effectiveness. Smaller sized sand leads to a longer "residence rate" (or pause time) which is the amount of time that water sits in the filter. This allows the pathogen-consuming microbes in the biolayer more exposure to pathogens. The researchers recommend the BSF operator improve pause time by waiting a longer period of time between fillings. The researchers found very little impact on pathogen removal by cleaning the filter with the wet harrowing method. The researchers suggest a follow-up disinfection step due to poor virus removal, particularly with more turbid waters. These findings lead to the following recommendations for operation: Allow water to sit as long as possible between feedings, wet harrow the filter when the effluent rate is so low it is unviable.

This study was valuable because the researcher manipulated variables, but had the disadvantage of simulating developing world conditions, not being an actual field study.

CAWST (2011) manual has a section on educating the user:

It is very important that the users know how to use the filter. At the same time the filter is installed, someone must teach them how to use it, and how and when to clean it. There is a lot of information for users to remember. Repeat visits will be necessary to follow-up (p. 88)

This manual includes several sections: how to use the filter, how to clean the filter, safe water storage, how to clean the storage container, how to use the filtered water, and follow-up with the user, with a checklist form.

One implementer posted the following summary of implementing BSFs, “One thing we have learned since 2009 is the importance of "seguimiento" (follow-up) with the families who received their filters, helping them comply with the basic rules of good filter use, most importantly, #1. Use Your Filter Every Day, and #2. Keep Your Storage Bucket Clean.” (Google Group, 2012, para. 6)

According to Earwaker (2006) educational is crucial when distributing the filters:

There is clearly a need to reinforce the educational messages presented to villages during the construction of filters...

- Teaching of the wet harrowing technique as the sole means for cleaning the filter. It should stress the need to only harrow to 2-3cm, using clean water and continuing the process until the water being dumped runs clear.
- Teaching of the importance of correct cleaning of the spout using a clean cloth, sponge or brush with a soap or detergent.

- Distribution of printed materials such as posters and stickers to remind the attendee of the teaching they have been given and the process of using and maintaining the filter.
- Information regarding the ways in which the caretaker can help them if they have problems with the filter.
- Where possible the caretakers should be included in some of the teaching of filter use and maintenance. (Earwaker, 2006, p. 50)

History of POU use in Nkokonjeru, Uganda

Figure 3: Uganda's location in Africa



Figure 4: Arrow points to Nkokonjeru in Uganda



Engineers Without Borders – Davis Branch has been working in rural Uganda, Nkokonjeru – a small town east of the main city, Kampala, just north of Lake Victoria since

2007, to improve local hygiene conditions. Ogunyoku (2008) summarizes adverse conditions in rural Uganda, “Rural Uganda consists of 87 % of the country’s total population of 29.9 million. More than two-thirds of Uganda’s population that live in poverty is in rural communities. Lack of access to clean water, safe sanitation, and proper hygiene is strongly related to poverty” (Ogunyoku, 2008, p. 16). Ogunyoku describes a project between EWB-Davis and a small Ugandan run Non-Governmental Agency (NGO) the Rural Agency for Sustainable Development (RASD). EWB worked with RASD and local people to identify methods of POU water treatment and sanitation systems that sustainably address health problems in rural Uganda. EWB-Davis and RASD tested and sampled several water treatment (not including the BSF filter) and sanitation systems for viability and cultural appropriateness. The researcher asserts that sustainability is an important factor in introducing technologies. An introduced technology is sustainable if it is in accordance with the communities’ behavioral, educational, motivational, and participatory traits. A technology is more likely to be sustainable, if it is affordable, constructed and maintained locally, and inexpensive. In 2008, EWB-Davis conducted educational sessions to educate local children about water sanitation and hygiene. They had conducted a shoe drive; students were invited to attend the workshop and were given shoes at the conclusion. 103 children ages 3-16, attended the two-day seminar held on the RASD grounds. EWB-Davis employed numerous didactic techniques to teach water sanitation: group work, performing skits, songs, using CAWST produced posters, and games. The main theme was proper sanitation, hand washing, and proper storage of treated water. Proper storage of drinking water has been identified as a major issue in the water filtration process. EWB-Davis also used the WHO program, PHAST.

Ogunyoku, Nover, McKenzie, Joshi, and Fleenor (2011) summarize the five-year project EWB-Davis conducted working with RASD in Nkokonjeru to implement sustainable POU water treatment. EWB-Davis tested water sources such as surface water, unprotected springs, protected springs, and hand pumps. They found the water quality to be poor. After conducting unstructured interviews with Ugandan townspeople, they also determined that a POU water treatment system was in high demand. EWB tested the following systems: WaterGuard treatment, a chlorine based liquid that treats water by directly dropping into water, Silverdyne treatment, another solution that disinfects by direct application to water, SODIS, solar water disinfection – which is the surprisingly easy and effective process utilizing the sun's ultraviolet rays; one puts water into a clear plastic bottle and places it in the sun for over 24 hours, depending on sun conditions, and the Clay Filtron Pot, a commercially available plastic tub with a ceramic filter inside, and the biosand filter. All of these options were analyzed for effectiveness, viability, sustainability, cultural appropriateness and cost.

Table 3 Summary of EWB's evaluations of water treatment

Water treatment system	Pros	Cons
WaterGuard	Inexpensive. Available in market. Easy to use.	Chlorine taste disliked by locals. Does not work on giardia or cryptosporidium.
Silverdyne	Easy to use.	Expensive. Inconsistent availability in Uganda.
SODIS	Very inexpensive	Needs consistent sun. Does not work on turbid water. Takes too much time. Not credible.
Clay Filtron Pot	Well-received by populace. Improves look and taste of water.	Very Expensive and short longevity Not made locally. Fragile.
Biosand Filter	Well-received by populace. Improves look and taste of water. Made locally.	Expensive. Heavy and breakable.

After weighing the pros and cons of these POU approaches, and with consultation with RASD members, the biosand filter was considered the best approach. EWB had experience with biosand filters in Kenya utilizing a round design. EWB determined that a CAWST square design would be easier to construct. EWB determined that there were three major factors to consider in the implementation of the BSF: available materials, grain size of sand, and source water. EWB made determinations that it would cost 45,000 UGX (about US\$18) to produce the filter while a charge of 160,000 UGX (about US\$63) would be required to produce a sustainable business. (EWB Davis 2008). EWB procured CAWST BSF construction plans and steel molds through Connect Africa, a Uganda based NGO that promotes BSF use. A BSF was built at RASD and placed in a nearby health clinic. The effluent water was tested and determined to reduce 90% of coliform.

Figure 5: RASD water filters at RASD in Uganda



In a grant application to the U.S Embassy Community Grants Program to Combat HIV/AIDS, RASD applied for funds to produce dome slab toilets, a water tank, and BSFs. In the BSF component of the application, RASD proposed many reasons for BSFs in Nkokonjeru: waterborne disease is the leading cause of illness and death for children under 5 years, RASD will provide training to local laborers, the program will be commercially sustainable, and clean water is especially important to HIV/AIDS affected families. RASD gave statistics about the three existing BSFs constructed with EWB Davis; they removed 80.3%, 97.0%, and 99.1% of pathogens (RASD 2009). RASD explained the relatively lower score of 80.3% was a result of cleaner influent water.

RASD received a grant from U.S Embassy in Kampala to construct 50 biosand filters for HIV/AIDS impacted families and placed them in 2009-2010. In 2010 EWB-Davis surveyed 30 of the placed biosand filters determining their functionality, customer satisfaction, and health

benefits. To test the efficacy of the filters, EWB used 3M Petrifilms to detect the presence of fecal coliforms. According to the U.S EPA's National Primary Drinking Water Regulations, the acceptable amount of coliforms in drinking water is zero (EPA website, 2012). While the presence of coliforms is not necessarily a health threat, they are an indicator as to whether pathogenic bacteria are present. Fecal coliforms come only from human or animal waste. Since most water borne diseases are carried via fecal waste, this is the best indicator of potential water contamination. Manz, Eng, and Ag report:

The preferred quantitative method to evaluate the presence of bacteria (all types) is using a technique that uses an actual count. If the quantity of indicator bacteria in the untreated water is measured and compared with the quantity of indicator bacteria in the filtered water, the performance of the filtration can be determined as a percent reduction. (2007, p. 33)

This research concluded that most people were happy with the benefits of the filters and that most worked successfully. Exceptions were that some leaked, and some were being used improperly due to a flaw in the length of the output hose. Ogunyoku et al conclude:

The major limitations of our efforts are related to the continued need for technical and financial capacity to sustain the biosand filter program. In addition to initial costs, lack of marketing to the general public and inadequate education operation remain major barriers to long-term project success. Increased training in operation and maintenance as well as long-term marketing and microfinance will be necessary to drive project sustainability into the future. (2011, p. 31)

Samuel Mwebe is a consultant for RASD. He recently submitted a report to Agri-Link in October, describing a biosand filter training and implementation program in a rural area adjacent

to Nkokonjeru, Uganda (Mwebe, 2012). This program emphasized both practical and theoretical components of hygiene and biosand filter use. Recipients of BSFs were taught how they work both procedurally and conceptually; they described the filtration action of the sand and biolayer to consume pathogens. Mwebe suggested the challenges to this program were reduced attendance due to hardships such as death and funeral obligations, and the lower attendance of males. Mwebe suggests better mobilization of participants through providing transportation. He also said participants were happy to participate in the program because of a lack of access to firewood to boil water. The BSFs are a good alternative to obtaining treated water.

Personal Communication

In an interview with Amelia Holmes (personal communication, October 15, 2012 – see appendix C) EWB-Davis past president, she suggests the problems with the biosand filter program implemented by RASD is due to a lack of follow-up. She believes that such a program is not sustainable over time. She says that BSFs have proven to be a robust technology. Biosand filter distribution by RASD has to be modified. She suggested hiring a local Ugandan who lives in the village to construct, follow-up, and educate users about filters.

Bill Fleenor PHD (personal communication, October 25, 2012) echoes a similar sentiment as Holmes. He discussed a way to implement the BSFs in a sustainable way, which is currently not being done by RASD. There appears to be financial incentive to build and distribute the filters, but not to follow-up. Ideally, this would be done by some self-sustaining local business that distributes and maintains the filters.

Sam Mwebe (personal communication, November 5, 2012) RASD employee, describes the process by which RASD has been distributing BSFs. They have been distributing the BSFs for free as they are paid for by grants. He describes their education and follow-up procedure:

All beneficiaries of filters are gathered and trained in the water handling practices, then sand filtration and how to maintain their filters. In the grants we got to disseminate the filters, there was some money to cater for follow up, and George was paid to check on the filters once every two months, but he stopped because the funding stopped. However we go to the field once in a while to check whether the users are maintaining their filters and we tell them that they should not always wait for RASD in case they want to change the sand in their filters since they know what to do. (Mwebe, personal communication, November 5, 2012)

Chapter 3 Method

Introduction

This study was a follow-up as part of a longitudinal study to assess the functionality of the biosand filters (BSFs) distributed in Nkokonjeru, Uganda in 2009. The research was collected in September and October of 2011 in Nkokonjeru. Data were collected by on site observations and interviews with recipients of BSFs from the Rural Agency for Sustainable Development (RASD). The subjects answered questions from a structured interview and were observed using the BSFs; then water was sampled before and after filtration. We encountered numerous examples of recontamination from the water receptacle container, so we altered our latter visit procedure. We interviewed the subjects and sampled the water, then gave hygiene education after the interview and sampling. We also cut the tubes on containers that were over 5 cm.

Our interviews consisted of the same questions Geetika Joshi used the previous year; primarily a mix of household demographics and biosand filter use, but over the course of a few visits, we moved to a more flexible interview protocol in order to be more practical in helping the subjects with their filters.

Sample and Site

We visited households and schools that had received BSFs in 2009 from RASD. The filters had been developed in conjunction with EWB-Davis, and funded by the U.S Ugandan embassy in Kampala. BSFs were distributed to households depending on need, impoverishment, and HIV/AIDS impact, as determined by RASD.

Most studies were conducted over two weekends when it was assumed more residents would be home. The data was also gathered while doing a follow-up study on dome-slab toilets. The households were accessed via walking or renting motorcycle rides, known locally as “boda-

bodas”. Liz Ssemwogerere and Jackie Dumba also helped lead us to our destinations and to translate. Most interviewees spoke Luganda and were translated by Liz, Jackie, or George.

The biosand filter study was conducted in Nkokonjeru – as described in Ogunyoku et al. (2011):

Rural Uganda accounts for 87% of the country’s total population of 29.9 million.

The rural poor make up more than two-thirds of Uganda’s impoverished people and lack of access to clean water and adequate sanitation are closely tied to poverty... Nkokonjeru is an agricultural community located in the Buikwe district about 30 km east of the capital city Kampala. Nkokonjeru and the immediate surrounding area of 11 villages have approximately 12,000 inhabitants.

Nkokonjeru’s town center is the business hub of the region with a market place and main street with many small shops. The surrounding villages are more rural and most of the economy is based on subsistence farming. Drinking water quality continues to be an issue that affects the general health and economy of the entire region. (p. 12)

CIA World Facts (2012) identifies the degree of risk from infectious diseases in Uganda to be very high. The most common food or waterborne diseases are bacterial diarrhea, hepatitis A, and typhoid fever.

RASD identified drinking water quality and waterborne pathogens as an area of major concern for the region. Drinking water originates from a variety of sources including municipal piped water (limited to a small geographic area in Nkokonjeru proper), hand pumps, protected spring-boxes, collected rainwater, and surface water. A private operator manages the municipal piped water system with some financial support from the Ugandan government. The piped

water is untreated and tested bi-annually by the private operator. Our test results demonstrated the water to be of high quality (2 and 0 CFU/100 mL total and fecal coliforms). However, connections and usage charges are expensive and only function sporadically, and it was common for the farther connections to run dry during frequent water shortages. The system has been unreliable, some years being out of service from months, and under several operators has failed to ever be a self-supporting business. Also, frequent electricity outages contributed to the unreliability of this water source. This source was rarely working during the 2 months of our stay.

Owing to these limitations, the vast majority of the region's water, particularly outside the town center, comes from protected springs, hand pumps, or surface water. The region has two wet-dry cycles each year, and just after the wet periods, the springs produce sufficient water, however collection lines can be quite long. During the dry period, spring water becomes less available and in some cases disappears entirely. Additionally, some springs were reported to shift over time, causing the protected spring outlet pipe to be ineffective in spite of ample flow elsewhere. Long lines, shifting springs, and decreased flows during the dry period were all reported to cause households to become increasingly reliant on surface water during certain times, it was found to be considerably worse quality than the springs and municipal system. We did our study during one of the two wet seasons known as the long wet season. The long dry season where water needs are most stressed is in July. The general water condition during this study is considered to be relatively good because water is available from roof catchment systems.

Table 4 Seasons and Rainfall in Kampala, Uganda; BBC Weather

Short Dry Season		Short Wet Season			Long Dry Season			Long Wet Season			
Jan	Feb	March	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
46 mm (1.81 in)	61 (2.4)	130 (5.12)	175 (6.89)	147 (5.79)	74 (2.91)	46 (1.81)	86 (3.39)	91 (3.58)	97 (3.82)	122 (4.8)	99 (3.9)

Ethical Standards

This paper adheres to ethical standards in the treatment of human subjects in research as articulated by the American Psychological Association (2010).

Access and Permissions

All permissions have been obtained from EWB – Davis.

Data Gathering Strategies

Figure 6 typical Biosand filter set up in a Ugandan home.



The researchers visited households, schools, and an orphanage/residential school for children with disabilities to assess the functioning of the BSFs. We interviewed users, observed the BSF in use, and tested the water before and after filtration for bacteria. Coliform and *E. coli* are indicator organisms that indicate fecal contamination. Any evidence of *E. coli* or coliform indicates the water is unclean by WHO standards (WHO, 2011).

Where possible, we took water samples and plated them on 3-M coliform/*E. coli* Petrifilms to test the efficacy of the biosand filters. Using falcon tubes, we collected water samples from source waters, directly from the biosand filters, and from the receptacles for treated water in order to learn more about the efficacy of the entire treatment process for the whole household. We rinsed each falcon tube three times with sample water before taking the sample. We did not do any dilutions, which made sampling and plating much easier, but afforded less precision in quantifying the extent of higher contamination levels. We also did not have access to a consistently functioning incubator. One ml of each sample was plated onto three Petrifilms within 24 hours of collection, and the films were incubated at approximately 37 degrees Celsius (body temperature) for 24 hours. For one of the incubations, we used a make-shift incubator fashioned from a foam cooler, sand as a heat mass, a temperature switch and an electric heating element, but the device was frequently broken (perhaps due to power outages) so we incubated instead with body heat. This was done by placing the Petrifilms inside a bag and kept against the researchers' skin inside the clothes.

After 24 hours we counted the numbers of *E. coli* and total coliform colonies. From these results we reported the average number of colonies from the triplicates. Plates which exhibited more than ~100 colonies per milliliter are called 'too numerous to count', or 'TNTC'.

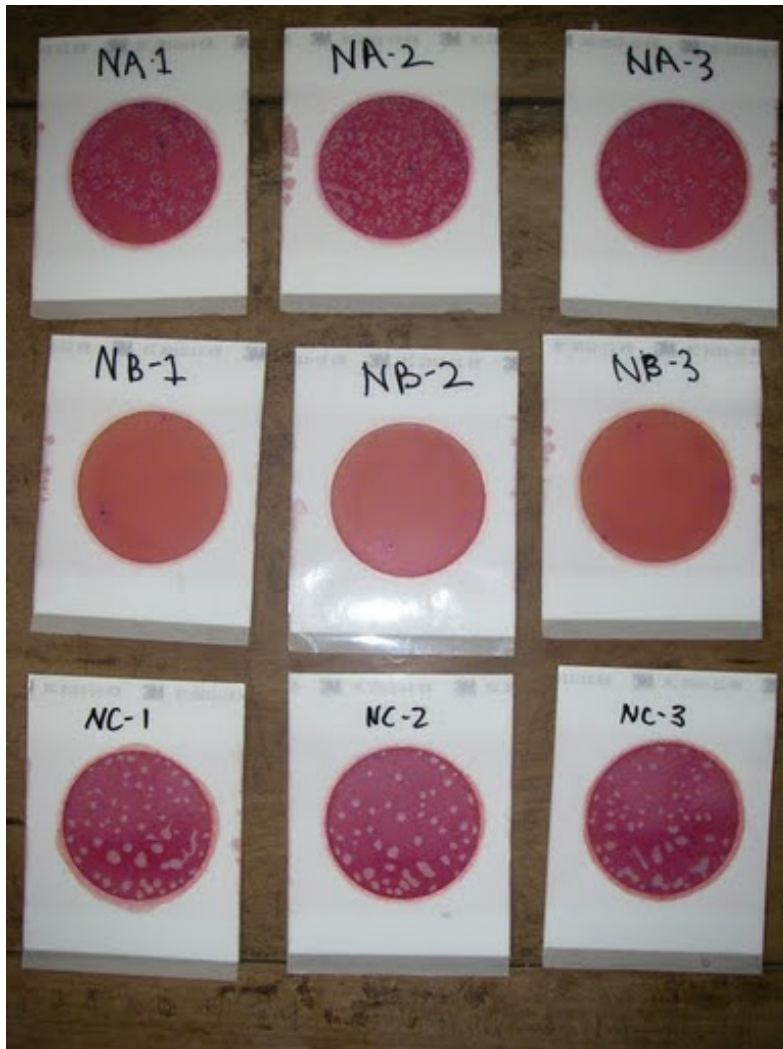
Figure 7: Petrifilms indicating level of water contamination.

Figure 8 shows a typical result of water testing. We produced 3 Petrifilm plates from each source to improve accuracy. The white dots indicate the presence of coliform, and the blue dots indicate *E. coli*. We typically took 3 samples at each location: one from the source water such as a spring (NA 1-3), then one from the water as it comes out of the BSF (NB 1-3) and finally from the end use storage container (NC 1-3). These results were typical of working BSFs. The water from the source had some contamination, but the water was much cleaner after filtration – notice how NB

1-3 are relatively clear of contamination. NC 1-3 shows the common phenomenon of recontamination by the end-use container.

Chapter 4 Findings

Data Analysis Approach

Data were reviewed and information categorized by location, types of bacteria. We examined data to see what degree the water was clean after going through BSFs. Additional qualitative information documented from each site was gathered and analyzed to see how the filters were actually used. For the purposes of this study we did not do much content analysis of the flexible interviews. We observed whether the filter was being used properly, and tested the water to see if there was an improvement after filtration.

Description of Site, Individuals, Data

George identified the location of the BSFs. George said he chose the sample of filters to survey based on their accessibility to the center of town, and whether he believed the users to be at home. There were two types of BSF location: private residences or institutions. Some were located in a residential school called the Providence Home, and there were some located at St. Paul's primary school. Of the filters located in private homes, most were located in small houses or structures in the more rural areas outside of Nkokonjeru. Most users had had some family impact from HIV/AIDS, as the filters were built with funds from the US embassy for supporting families impacted by HIV.

Overall Findings, Themes

Table 5: Summary of Filter Survey

Number of filters surveyed	22
Number in use	12
Number in use properly (not dry)	8
Number showing improvement of water quality	6

Of the 22 filters we visited at 12 locations, 12 filters were in use at our arrival. 8 of them were being used properly, that is, there was standing water above the sand biolayer when we arrived. Of those 8, 6 filters indicated an improvement of the water after it issued from the BSF. As discussed above, the efficacy of the BSF depends on the “ripening” of the microbes in the biolayer to consume pathogens. These microbes live in water, but require food and oxygen to survive. If a BSF is left idle for a long time and the top layer is dry, it should not have any pathogen filtering effect. Therefore we did not test water from a filter that was found to be dry. Of the filters that were not in use or functioned poorly, these are the following results:

Table 6: Summary of BSFs not in use.

Reason not in use or not working properly	# BSFs
School summer vacation, not in use.	3
School summer vacation, not in use (but reportedly did not work, reason unclear)	3
BSF broken or leaks.	3
Allowed to go dry (reason unclear)	2
No functioning end-use container (at Providence Home)	2
BSF clogged (water doesn't issue from tube)	1
User stopped using because she reported getting sick after use.	1

The highest number not in use are those BSFs located in St. Paul's K-8 elementary school. The school has an enrollment of 500 but was not in session during our survey. The filters were locked unused in classrooms. The headmaster reported of the 6 that appeared functional only 3 worked properly. We were unable to test these 3 because they had been unused over a period of weeks, and results would not be indicative of their performance when school is in session. St. Paul's school had 3 end-use containers given to them by RASD. It was impossible to assess procedural use of the BSFs due to the absence of teachers and students.

The school has two water sources, one is a rainwater catchment system, and it tested at fairly clean, 0.33 coliform and 0.33 E. coli. During the dry season when the rainwater runs out, students and teachers carry water in jerry cans from an unprotected spring. Our tests found it fairly contaminated; the Coliform was TNTC and E. coli at 0.33. They use the unprotected spring water during the two dry seasons, February/March and July. The headmaster said the quality of water in the springs was worse during dry seasons.

In general, those people who had functioning filters gave positive reviews of the filters when asked questions in the flexible interview format. People generally said the household had improved health after being issued the filters. They reported that the water had improved color, smell, and taste. Most people also reported reduced incidence of diarrhea and improved health. It was the researchers perception that responses skewed towards positive reports of filters due to the subjects' desire to please the researchers.

Table 7: Results from testing contamination of water before and after filtration

Location	Condition of Filter	Avg. Coliform (CFU/mL) Before Filtration	Avg. <i>E. coli</i> (CFU/mL) Before Filtration	Avg. Total Coliform (CFU/mL) After filtration	Avg. <i>E. coli</i> (CFU/mL) After	Improved ?	Recon-tamination ?
GOG School	Wet, dripping	SB 11.33	SB 1.33	TNTC	0.67	Coli no E. coli yes	yes
Mr. Issa	Wet,	SB 7.67	0	1	0	Yes same	yes
Deborah Namusisi	Wet sand, no water	TNTC	2	1	0.33	Yes yes	yes
Serujoggi Ahmed	Wet,	Nabinye SB** Sampled?	Nabinye SB Sampled?	57.33	0	No? No?	yes
PH BSF1	In use, wet	7.67 or 5.0*	3.0 or 0.33*	0	0	Yes yes	NA
PH BSF 2	In use, wet	7.67 or 5.0*	3.0 or 0.33*	0	0	Yes yes	NA
PH BSF 5	In use, wet	7.67 or 5.0*	3.0 or 0.33*	0	0	Yes yes	NA
PH BSF 6	In use, wet	7.67 or 5.0*	3.0 or 0.33*	0	0	Yes yes	NA

TNTC = too numerous to count. PH = Providence Home.

***Nabinye SB = spring box was not sampled*

** Two coliform and E. coli amounts are given at the Providence Home, because it is unclear which source was used for the BSFs in question. There are several water catchment systems and a pump at this location.*

The above table shows that of the 8 filters that appeared to be working, had standing water in the top, and were issuing water 6 of those showed an improvement in both coliform and *E. coli* levels. The Glory of God (GOG) school filter did not show improvement. It was the researchers theory that the filter had been out of use but had been filled just before the visit. In this case, if the filter had been dry, we would not expect positive results from the testing. 4 of the 6 functioning filters are located in the Providence Home, an orphanage/residential home for children with disabilities run by Franciscan nuns. Interestingly, the BSFs there had long tubes for

water effluent, which normally results in drying of the filters. However, the nuns elevated the end-use container with a wooden stool, thus elevating the tube and reducing the drying siphoning effect. Sister Juliet said she did that because it would be more hygienic if the drinking water container was elevated off the floor.

Recontamination was shown to be present in all water systems where tested.

Recontamination is indicated if the water from the end-use container is more contaminated than its source water from the BSF. In some cases, the water quality in the end-use container was worse than that of the original source, even if the water had been filtered. The absolute worst water quality was measured from a clean-water vessel at Glory of God School, which had an average of 25 Colony-Forming Units (CFU) of *E. coli*, and too numerous to count total coliform per ml. At the Serujoggi Ahmed household we saw that a cup was dipped into the end-use container for use, which is a probable cause of contamination. We did not test the Providence Home containers for recontamination due to time and resource constraints; also their end-use water container system appeared hygienic.

Adam Senogo had clean water (e.g., no contamination or 0 CFU/mL total coliform and *E. coli*) from the biosand filters. Adam Senogo also had no contamination in his clean water vessels. His BSF had a long tube, which angled directly into his end-use container. He did not want to have it cut because the existing long tube created an enclosed system from filter to end-use container. Interestingly, despite yielding positive test results, Adam Senogo's BSF was dry when we found it.

The original sources of the water were either rain catchment systems, a spring box, or an unprotected well. The Average colony counts from all spring-boxes were 5 CFU total coliform

and 0.2 CFU *E. coli* per ml. In general the best water quality was from rainwater tanks, and the worse was from unprotected wells.

Table 8: Condition of all BSFs surveyed with notes.

	Filter Location	Use?	Condition	Notes
1.	Glory of God School	Y	Wet	Dripping when we arrived, we suspected they added water in anticipation of us coming. Used by family and students.
2.	St. Paul school BSF1	N	Wet	Functions, summer vacation out of use
3.	St. Paul BSF 2	N	Wet	Functions, Summer vacation, disuse
4.	St. Paul BSF 3	N	Wet	Functions Summer vacation, disuse
5.	St. Paul BSF 4	N	Dry	Summer vacation, disuse
6.	St. Paul BSF 5	N	Dry	Summer vacation, disuse
7.	St. Paul BSF 6	N	Dry	Summer vacation, disuse
8.	St. Paul BSF 7	N	Dry	Leaks, Summer vacation, disuse
9.	St. Paul BSF 8	N	Dry	broken Summer vacation, disuse
10.	Josephine Twekise	N	Dry	Trash inside. No lid. "Never worked, leaked at bottom", 10 cm tube, Sam fixed it but still didn't work.
11.	Adam Senogo	Y	Dry	15 cm. tube. He objected to cutting the tube because it connects filter to jerry can receptacle.
12.	Mr. Issa	Y	Wet,	15 cm outlet tube. Cut hose to 3 cm.
13.	Deborah Namusisi	Y	Wet	Results = Removes pathogens. We cut her hose.
14.	Bazira Muhammed Kikwayi town	N	Dry	"used to work, but filter clogged" We blew in tube, and it started water dripping.
15.	Serujoggi Ahmed	Y	Wet	15 cm tube
16.	Mava Miliam	N	Dry	Doesn't use filter because she got sick after using it. She agreed to use it after we maintenance it.
17.	PH BSF1 Admin dining room	Y	wet	20 cm tube to elevated water container, very slow outflow, only possible when enough head, pour water to filter overnight
18.	PH BSF 2 Boys Dorm	Y	wet	20 cm tube to elevated water container
19.	PH BSF 3 OT Room	Y	Wet,	20 cm tube to elevated water container
20.	PH BSF 4 Main Hall	N	Dry	30 cm. tube No lid, no receptacle container
21.	PH BSF 5 Girls Dorm 1	Y	wet	30 cm tube to elevated water container

22.	PH BSF 6 Girls Dorm 2	N	Dry	30 cm tube to elevated water broken water container Filled with an active ant colony.
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PH = Providence Home

The above table is a comprehensive listing of all the BSFs surveyed, and is summarized above.

Additionally, the table shows that many of BSFs surveyed had a long tube coming from the “nose” of the filter.

Figure 8: BSF at St. Paul's School shows effluent tube.



Most filters in Table 8 indicate tubes of 15 – 30 cm of length. The tube length had been identified as an issue between RASD and EWB-Davis. When the tube is lower it effectively lowers the water level elevation in the water filter below the biolayer, thus drying it and rendering it ineffectual. Some users reported liking having a longer tube in order to connect it to an end-use container. Sometimes this resulted in elevating the tube and hence water level, but sometimes it did not.

Chapter 5 Discussion/Conclusions

Summary of Major Findings

It is important to note that this study was done as a case study, examining the efficacy of a small sample of filters already distributed by RASD. If one looks at the literature review indicating the importance of education and follow-up, one could have predicted our poor results. In previous studies, the biosand filter has been demonstrated to be a robust, sustainable, effective and long-lasting technology. However, this small survey of biosand filters indicated overall poor functioning. After 2 years, of the 22 filters surveyed, only 6 appeared to be improving the water quality. 27% improvement of water conditions is significantly worse performance than other BSF follow-up studies. The major reasons the BSFs surveyed were not functioning were: inadequate follow-up to make sure filters were working properly, insufficient understanding by the user how to get help or replacement for nonworking filters, insufficient understanding of the user how to maintain and keep the filter working properly, and inadequate observance of personal hygiene and keeping end-use containers clean by the users. However, this is not all bad news. The fact that the most of the filters that were actually working proved to be reducing pathogens from the water, and users expressed satisfaction and health improvements, shows that this technology can be successful. Most of the intervention required to improve the other filters is better follow-up and education, which are not insurmountable obstacles.

A problem occurring in BSF use in Nkokonjeru was the result of the configuration between the effluent tube and the end-use container. Two common problems we saw were that effluent tubes were often too long which resulted in draining of the filter below the biolayer.

Also, recontamination from a dirty end-use container was extremely common (and often observed in previous literature).

Figure 9 Providence Home filter and filtered water container configuration.



Observe in figure 9 above that there is a long tube from the BSF to the end use container. This was the configuration of choice at the Providence Home, the site that had the most success with the BSFs. This configuration is successful because there is an end-use container that is dedicated to only filtered water. An advantage is it creates a closed system between filter and ultimate drinking water source. The closed lid and spigot helps reduce the chance of recontamination. The lid prevents dipping of cups and hands and also can be removed for cleaning of the end-use container. The bright color and distinct spigot prevents the container from being used for other purposes. Many times we observed typical jerry cans being used for end-use containers. These same jerry cans were often put to other unhygienic uses and contaminated. By happenstance, the nuns had the stools placed under the containers to elevate them off the floor to improve hygiene.

This produced the unintended and happy effect of lifting the elevation of the tube and thus increasing the elevation of the standing water above the sand biolayer. The danger of having a long tube without this configuration, is the tube goes down and siphons out water. Also if the container is removed for any reason, such as cleaning, the water is temporarily drained below the biolayer reducing its efficacy.

Figure 10: BSF with long effluent tube

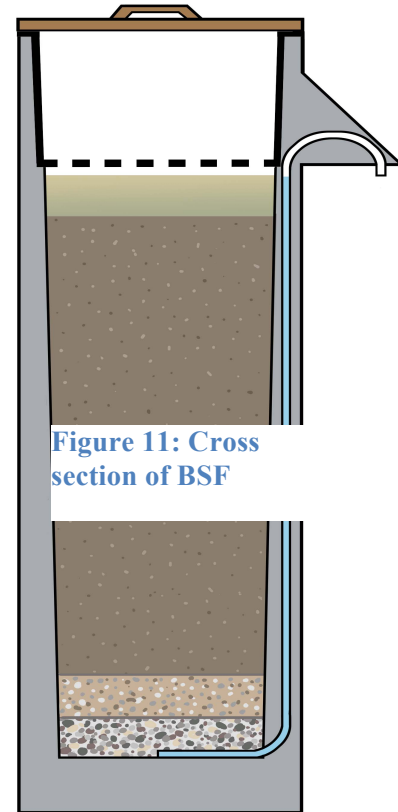


Figure 11: Cross section of BSF

The filter in figure 10 above has a long tube. The tube naturally goes down when the end-use container is removed draining the water below the biolayer. As a result of siphoning, the water

level goes down to the same elevation as the outlet of the tube. Figure 11 on the right shows the typical short length of the tube, which maintains the water level (the top layer) around 5 cm over the biolayer. The 5 cm. height is essential to keep the biolayer wet and oxygenated. Any successful BSF system requires a strong end-use container component. This could be challenging, because in our survey, we observed numerous configurations and types of end-use containers. A successful BSF program would either issue an end-use container with the BSF and educate about maintenance, or follow-up to make sure the household has used the best possible configuration in the home. In addition to there being contamination after the water is filtered, we found evidence of contamination between the water source and BSF. After examining numerous jerry cans that appeared unclean and mossy inside, researchers concluded that jerry cans should not be used at all as an end-use container.

Comparison of Findings to Previous Research

Our research findings indicated considerable worse performance of BSFs compared to other follow-up studies. We found 27% of BSFs were in use and improving water after 2 years. Aiken et al. (2011) found 90% of filters still in use after 1 year, eliminating 88% of pathogens. Baker et al (2006) conducted a study in Cambodia, finding 105 out of 107 filters still in use after 8 years. In Kenya, a region not far from this study's region, Fewster et al. (2004) found 70% of filters producing good quality water after 4 years. Earwaker (2006) found a use rate ranging from 44-100% depending on the village in rural Ethiopia after 4 years. The only study reviewed showing less use of BSFs after time was Vanderzwaag et al (2009) in Nicaragua where 10% were still in use; but this study assessed the BSFs after a longer period of time, 3-8 years. Also, the researchers noted an intervening hurricane that impacted households.

This marked difference shows that the technology is sound, but programmatic interventions are needed with the Nkokonjeru BSFs. It is possible that there were problems in construction; 8 of the 16 filters were reportedly not working, which could have been due to construction problems. However, such problems are often reparable, improved through altered use and cleaning, or could have been solved due to proper follow-up.

Our study found many themes similar to those of other studies. Many subjects indicated contentment with the filters saying the water was clearer, smelled better, and was better tasting. Other studies also found similar problems with recontamination. Similar to our research, Duke et al. (2006) found 7 times amount of *E. coli* in the end-use container. The need for improved education and follow-up has been a ubiquitous theme in the research. Many of the problems we identified also would be improved through proper training and follow-up.

Limitations/Gaps in the Study

There were several limitations to this study do its ex post facto nature. One obvious limitation was the study was conducted prior to a literature review, which could have added some improvement to the research design. The purpose of this study had initially been established to be more pragmatic than purely academic. As soon as we found results, we conducted interventions with families to improve the success of their BSFs.

In comparison with the experimentally designed ideal study, such as the double-blinded, placebo-controlled study undertaken by Boisson et al. in the Congo, this study lacks a control group and placebo.

The small survey sample was not random or comprehensive. We surveyed only 22 of the 50 BSFs built by RASD and have no way of knowing the success rate of all the filters. These filter households were chosen by an RASD employee who did not have an organized accounting

of where the filters were located. There is also the possibility that the sample selection was biased by the RASD employee choosing filters that could show a more favorable result (though it is hard to imagine there being a worse sample of filters). The BSFs were also chosen due to constraints of time and distance. The interviews themselves may have been biased by the fact that users were reporting results to an RASD employee who had distributed the filters. This employee who translated the results may have been invested in a favorable outcome. One interesting result of our survey, was that we visited homes in a somewhat random nature. Households were not expecting our visit, and generally did not expect follow-up. In the other studies there was a structured follow-up procedure done by investigators. One could speculate that recipients of filters expecting follow-up would be more compliant with operating instructions and in general have a greater investment in using the filters. This could skew the results towards more favorable use of filters.

There were other logistical problems in gathering our data:

1. Since water coming from filter is that which has been already residing in the filter, should the effluent be compared with the source water, the water coming from container poured into filter, or the standing water in top of filter prior to pour.
2. We did not dilute water samples as recommended, so were unable to find meaningful percentages of decreased coliform and *E. coli*. In some cases there was such high evidence of coliform that we could not get a realistic count. We labeled such results as “Too Numerous to Count” (TNTC).
3. Objective measures of diarrhea are difficult.
4. Our incubation system was limited by the fact that our field incubator had broken, and due to frequent power outages, we could not fashion a new one. We used “body incubators” where we

placed the samples against a researchers skin for 24 hours. This may have affected outcomes.

This method did yield outcomes of *E. coli* and coliform growth.

The ideal standard of research would be a double blind randomly controlled trial with a placebo group. This would be impractical to do in field research, not too mention issuing a nonworking water filter would have some ethical problems.

Other Questions to be Researched:

During the course of this study, many other issues and questions were elicited that were beyond the scope of this particular study. Many questions evoked are more of a public health, epidemiological, or development nature.

1. How could there be recontamination in receptacle water container if coliform and *E. coli* does not thrive outside of the gut of a warm-blooded mammal – how is it living in a jerry can or other end-use container?
2. What is the prevalence of water borne viral infection in Uganda – those infectious elements with which the BSF is less effective?
3. What is the amount of bacteria or viruses needed to be ingested to get sick? If a BSF only filters 97% of bacteria or 70-90% of viruses is the remaining amount enough to cause illness?
4. What do we do about the fact that most recommend disinfection after water comes from the BSF, realistically, the BSF is generally used without a disinfection step due to cost and convenience?
5. What about the paradox: Increased turbidity reduces virus filtration – but the BSF is most indicated where turbidity is high?

Implications for Future Research and BSF Programs

Through this research, it has become clear that the technology of the BSF is sound, the changes that need to be made are behavioral and programmatic. I am a teacher by profession and as I found results, it became clear that a strong educational component was missing from these biosand filters. It was also interesting that several of these filters were located in school settings, so there could be additional opportunities to teach how to use these filters properly and concomitantly teach hygiene and science. Below I make suggestions for an educational and follow-up program to coincide with the distribution of BSFs.

Recommended Educational, Training, Maintenance Program

Based on the research and our results, modifications of the program will be recommended to follow up with the water filters distributed in Nkokonjeru with RASD. The recommendations fall into the following categories: ideal initial implementation of the water filters (this point may be moot in Nkokonjeru as many water filters are already distributed), educational input given to users of filter, maintenance of the filter procedures, and follow-up procedures for the BSF issuing agency.

1. Implementation Recommendations: Promotion and Marketing for Implementation:

I recommend using the approach of creating an economically approach similar to the one utilized above in Afghanistan and in Kenya. This approach engenders continued use of the filters after the aid workers are gone. Initially, micro financing should set up some local workers in business to make the BSFs. The aid workers can donate molds, plans and training and purchase the first few BSFs from the workers to place them in high visibility places, such as churches, restaurants, and schools. Careful attention should be paid to construction because of noted problems with cracking of cement, length of effluent tubes, and, most critically, sand size. We will market the

desirability, correct use, and hygiene practices by demonstrating them in public settings such as the Monday market, churches, and schools. I have formed relationships with many teachers, nuns, and shopkeepers to facilitate this. During my previous stay I conducted English lessons at one of the many schools in Nkokonjeru, worked with the headmaster of St. Paul's school to rehabilitate their water filters, and conducted a hygiene and BSF education session at the Providence Home.

Also, given problems with contamination, it is important that a closed end-use container be included with the filter and the system be reviewed. Ideally, Community Health Providers will be hired in the town to make a home visit when the BSF arrives in the household. They will use the checklist provided by CAWST. The BSF will include laminated instructions on use. In order to keep track of filters, they will be noted via GPS and labeled.

2. Education and training given to BSF user:

The CHPs will provide many services to the user upon delivery of the BSF. They will demonstrate the use of the filter, and demonstrate the cleaning method. They will also ensure that there is a dedicated end-use container marked only for clean water. Training of the CHPs will be done using procedures recommended by the CAWST training manual for Zambia.

As a result of this study the CHPs will be encouraged to emphasize the following recommendations. Place the filter in a protected place away from animals, children and other contaminating sources. It should be moved as little as possible. The effluent spout is the most important part to keep clean. The water source should be as clean as possible, and come from the same source. If water is turbid, let it settle before pouring into the BSF. Upon first use, the water should be allowed to sit in the filter for at least 7 but ideally 14 days prior to drinking. When the filter is in use, it should be kept wet, and ideally there be a 5 cm head of water above the sand. The ideal use of the filter is once a day with about 10 liters of water added per day. The “pause

period” has proved to be important, in that the water is allowed to sit in the filter for at least 12 hours between fillings with a maximum of 48 hours between fillings.

General instructions about personal hygiene should be given, in terms of washing hands and cleaning the end-use container, the lid and diffuser, to avoid recontamination.

3. Maintenance Recommendations

Many past BSF programs have cited inadequate maintenance as a contributor to BSF failure. The user of the BSF should be instructed in proper maintenance of the BSF. There are two types of cleanings of BSFs, one is the “swirl and dump” or “wet harrowing” that can be easily done by the user and then there is a full “tune-up” that should be done by trained BSF personnel. The advantage of the BSF is that it should work for a long time. The cleaning done by the user is the swirl and dump technique. This should be done when the effluent from the spout has slowed to a trickle that produces inadequate water for the household. A slow trickle is generally a good thing, because it increases water contact time with the biofilm layer. However, it may become so slow as to be impractical or if the water is stopped. The basic cleaning technique is: add water to the top of the filter, swirl the water gently without disturbing the biofilm, then ladle or scoop the water out of the filter. Repeat this process until water flows out of the tube at a sufficient rate. If it continues to not issue, contact RASD for a full cleaning.

4: Follow-up by CHP or BSF Agency

I recommend there should be 3 visits by the CHP after installation; the first is 1-2 months, the second is 12 months, and the third 24 months later. The CHP should observe the user fill the container, and observe one cleaning by the user during the visit. Also, the CHP should observe the end-use container for potential recontamination. The CHP should use the maintenance form, see appendix D

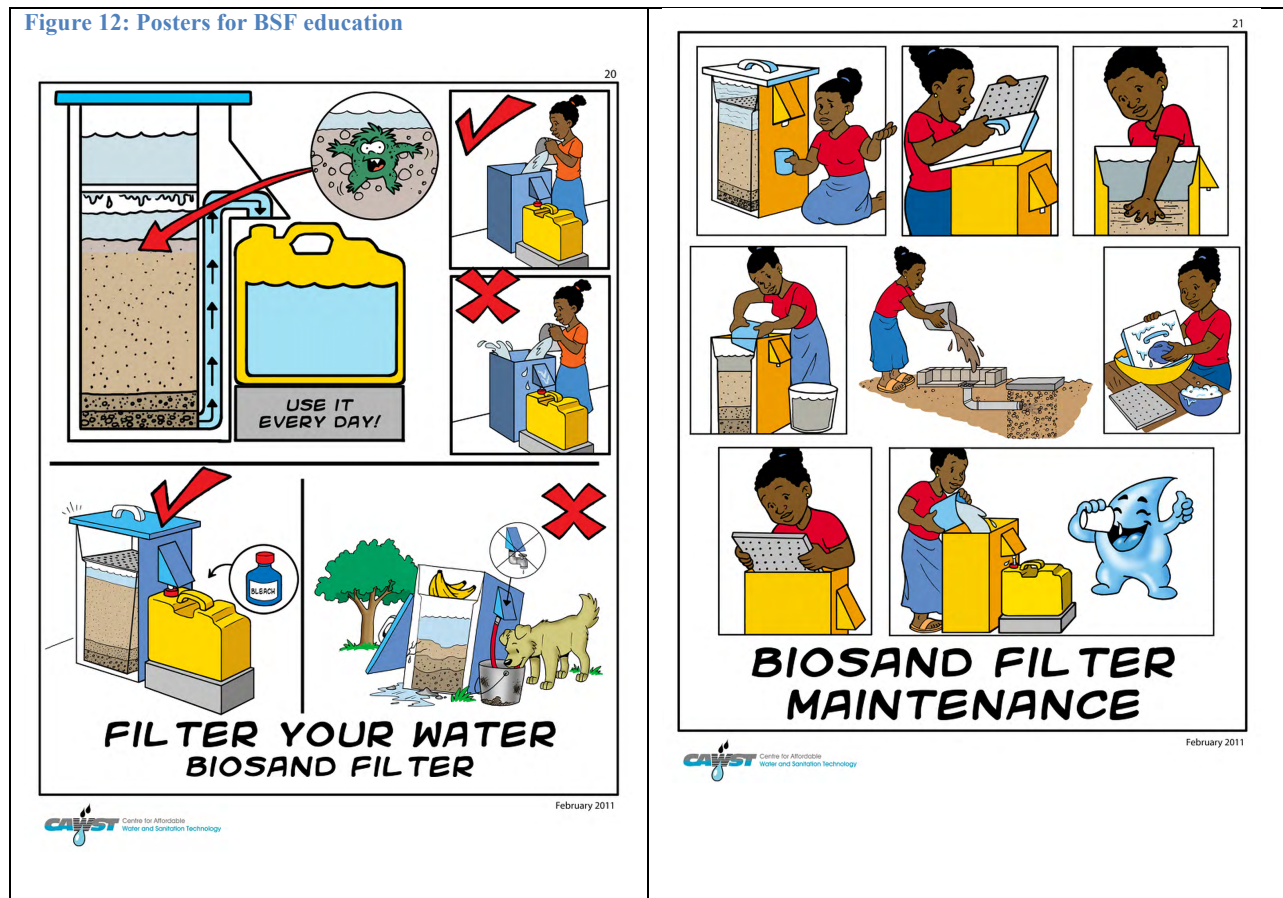
After completing this study I have had contact with CAWST who have evolved many excellent educational protocols and materials to promote proper use of BSFs and implementation of programs. They have many useful resources for BSF programs: A construction manual that contains important messages to the users, a training manual for organizations to train CHPs in hygiene and sanitation, and picture posters, as shown in figure 12.

<http://www.cawst.org/en/resources/pubs/training-materials/file/212-bsf-construction-manual-complete-2012-eng>

<http://www.cawst.org/en/resources/pubs/training-materials/file/82-participant-manual-complete-eng>

<http://www.cawst.org/en/resources/pubs/education-materials/file/51-africa-posters-low-eng>

Figure 12: Posters for BSF education



Similarly, CAWST has sent me an unpublished document that is a training manual for CHPs in Zambia, Africa, Community Health Promotion A & BA CAWST TRAINER MANUAL June 2012 Edition. They have also put me in touch with their coordinator of Uganda BSF programs and with a local agency that successfully distributes BSFs in Uganda, Connect Africa.

There are some special considerations in improving the RASD BSF program in Nkokonjeru given the cultural, socio-economic and political characteristics of the community. Most successful BSF programs require users to pay for the BSF to engender investment in the user, but RASD gave them away because they were funded by a grant. I think this has contributed to the fact that so many filters are inert. The challenge is to incorporate a follow-up element into RASD's existing program. It is currently unclear how RASD is following up with the filters it continues to distribute at the time of this writing. One approach could be to delicately point out to RASD that in their grant application to the U.S embassy they stated they would monitor the filters in a sustainable manner. RASD is currently economically incentivized to produce and distribute BSFs; they don't have the economic incentive to monitor filters that have already been distributed.

Overall Significance of the Study

Although this study was a small sample of BSFs, the results inform many potential changes to RASD's ongoing plan of distributing water filters. Sam Mwebe currently estimates that, as of November 5, 2012, 200 BSFs have been distributed in the Nkokonjeru area. These recommendations will be brought to RASD and we will work together to incorporate them into the BSF program.

This winter the plan is to return to Nkokonjeru with a small team from EWB-Davis with the following goals:

- 1.) Create a comprehensive list of all BSFs distributed by RASD indicating status, history of follow-up, pending concerns, and GPS location.
- 2.) Visit as many BSFs on location as possible to survey their use, test the water, troubleshoot end-use container issues (possibly give away end use containers), and educate the users about maintenance, general hygiene, and who to contact with problems.
- 3.) Hire a Ugandan Community Health Provider (CHP), to accompany EWB personnel on those visits, so they can continue to visit and monitor BSFs, and potentially train other CHPs. Ultimately, finding a funding source for paying a CHP should be found, or making a provision for that salary through future RASD grants.
- 4.) Conduct education sessions about hygiene and BSFs at highly attended events in the community, such as market day, church services and at school assemblies.

In conclusion, I conducted this study for several purposes. The literature review familiarizes the reader with Biosand Filter technology success in the developing world. I have endeavored to focus on the identification of training and sustainable shortcomings pointed out by past researchers. Many researchers, being engineers, have ended their studies pointing out improved education of the users is needed. I have also traced the history of BSF use in Nkokonjeru Uganda with the local NGO RASD and provided a case study of our recent evaluation of BSFs distributed there. Our results were predictable based on the research; a successful BSF program needs a strong educational and follow-up component. The challenge is to create a mechanism that is sustainable given the political, economic, and cultural realities of

the region. With this information in hand, I plan to continue to work with RASD to better supply the people of their region with access to clean water and resulting improved health.

About the Author

Matthew Spowart is an elementary school teacher who lives in San Francisco. He has a BA in Psychology and Philosophy from the University of Maine, and a California teaching credential from Dominican University of California. He has spent 3 months in Uganda working with Engineers Without Borders – Davis Branch, and the Ugandan NGO Rural Agency for Sustainable Development

References

- Aiken, B.A., C. E. Stauber, G. M. Ortiz, and M. D. Sobsey (2011). An Assessment of continued use and health Impact of the concrete biosand filter in Bonao, Dominican Republic. *American Journal of Tropical Medicine and Hygiene*, 85(2), 309-317.
- Baker, D.L., Duke, W.F., Mazumder, A. and R. Nordin. (2006). Performance of BSF in Haiti: A field study of 107 households (2006). *Rural and Remote Health*. 6: 570. (Online), 2006.
- Biosandfilter.org. (2012). Biosand filters; operation and maintenance. Retrieved October 1, 2012, from <http://www.biosandfilter.org/biosandfilter/index.php/item/299>
- Boisson, S., Kiyombo, M., Sthresley, L., Tumba, S., Makambo, J., Clasen, T. (2010). Field assessment of a novel household-based water filtration device: A randomised, placebo-controlled trial in the democratic republic of Congo. *Plos Clinical Trials; PLoS ONE* 5(9): E12613. Doi:10.1371/journal.Pone.0012613, November, 2012.
- Burt, M., & Keiru, B. J. (2012). *Water, advocacy, sanitation and hygiene; lessons learnt from Tearfund's global water, advocacy, sanitation and hygiene programme 2007–2012*. UK: Tearfund.
- Center for Disease Control and Prevention (CDC). (2012). The safe water system, household treatment, slow sand filtration. Retrieved October 1, 2012 from <http://www.cdc.gov.ezproxy.dominican.edu/safewater/sand-filtration.html>
- Centre for Affordable Water and Sanitation Technology (CAWST). (2010). Summary of field and laboratory testing for the biosand filter. Retrieved May 9, 2012, from <http://www.cawst.org/en/resources/pubs/file/41-field-and-lab-testing-for-bsf>
- CAWST. (2012). *Biosand filter construction manual, august 2012 edition*.
- CAWST. (2012). Resources: Biosand filter. Retrieved May 9, 2012, from <http://www.cawst.org/en/resources/biosand-filter>
- CAWST. (2012). *Household water treatment and safe storage factsheet*. Retrieved November 2 from <http://www.cawst.org/en/resources/biosand-filter>
- CAWST. *Water treatment implementation for developing countries*. Retrieved November 7, 2012 from <http://www.cawst.org/en/resources/biosand-filter>
- CIA World Factbook. (2012). Uganda. Retrieved May 8, 2012, from <https://www.cia.gov/library/publications/the-world-factbook/geos/ug.html>
- Clasen, T., Nadakatti, S., & Menon, S. (2006). Microbiological performance of a water treatment unit designed for household use in developing countries. *Tropical Medicine & International Health*, 11(9), 1399-1405. doi: 10.1111/j.1365-3156.2006.01699.x

- Duke WF, Nordin RN, Baker D, Mazumder A. (2006). The use and performance of BioSand filters in the artibonite valley of Haiti: a field study of 107 households. *Rural and Remote Health*. 6: 570. (Online), 2006.
- Dye, T. D. V., Apondi, R., Lugada, E., Kahn, J. G., Sandiford-Day, M., & Das Banerjee, T. (2011). A qualitative assessment of beliefs, attitudes, and behaviors related to diarrhea and water filtration in rural Kenya. *American Journal of Public Health*, 101(8), 1515-1520. doi: 10.2105/AJPH.2011.300127
- Earwaker, P. (2006). *Evaluation of household BioSand filters in Ethiopia*. (Unpublished Master of Science). Cranfield University, Silsoe.
- Engineers Without Borders (EWB) Davis Branch. (2008). *Biosand filtration, Uganda background*. Unpublished manuscript.
- Epke, G. (2012). *Biosand filter survey report, engineers without borders – UC Davis student chapter*. Unpublished manuscript.
- Fewster, E., Mol, A., & and Wiessent–Brandsma, C. (2004). *The long term sustainability of household bio-sand filtration*. 30th WEDC International Conference, Vientiane, Lao PDR, 2004.
- Google Group. Biosand filter best practices in implementation. Retrieved September, 2012, from <https://groups.google.com/forum/?fromgroups=#!topic/bsf-best-practices/Td7mXESg3s0>
- Jenkins, M.W., S.K.Tiwari, J. Darby. (2011). Bacterial, viral and turbidity removal by intermittent slow sand filtration for household use in developing countries: Experimental investigation and modeling. *Water Research*, 45, pp. 6227-6239.
- Kubare, M., & Haarhoff, J. (2010). Rational design of domestic biosand filters. *Journal of Water Supply: Research & Technology-AQUA*, 59(1), 1-15. doi: 10.2166/aqua.2010.008
- Manz, E., and Ag. (2007). *BioSand water filter technology household concrete design*.
- Murphy, H. M., Sampson, M., Farahbakhsh, K., & McBean, E. (2010). Microbial and chemical assessment of ceramic and BioSand water filters in rural Cambodia. *Water Science & Technology: Water Supply*, 10(3), 286-295. doi: 10.2166/ws.2010.221
- Mwebe, S. (October, 2012). *Training report on the construction and use of bio- sand water filters*.
- Ogunyoku, T. A. (2008). *The education dissemination of water, sanitation, and hygiene practices and the implementation of hand washing stations in Nkokonjeru, Uganda*. Unpublished manuscript.
- Ogunyoku, T. A. (2008). *Treatment and sanitation systems in rural Uganda*. (Unpublished M.S. Environmental Engineering). University of California Davis.

- Ogunyoku, T., Nover, D. M., McKenzie, E. R., Joshi, G., & Fleenor, W. E. (2011). Point-of-use drinking water treatment in the developing world: Community acceptance, project monitoring and revision. *International Journal for Service Learning in Engineering*, 6(1), 14-32. Retrieved from <http://library.queensu.ca/ojs/index.php/ijse/article/view/3207>
- Rural Agency for Sustainable Development. (2009). Bwoogie I. (Ed.), *United States embassy - Uganda, community grants program to combat HIV/AIDS application*.
- Sobsey MD, M. D. (2002). Managing water in the home: Accelerated health gains from improved water supply. *Water, Sanitation and Health Department of Protection of the Human Environment World Health Organization Geneva*.
- Stauber, C.E., E.R. Printy, F.A McCarty, K.R. Liang, M.D. Sobsey. (2011). Cluster randomized controlled trial of the plastic biosand water filter in Cambodia. *Environmental Science and Technology*.
- Tiwari, S. K., Schmidt, W., Darby, J., Kariuki, Z. G., & Jenkins, M. W. (2009). Intermittent slow sand filtration for preventing diarrhoea among children in Kenyan households using unimproved water sources: Randomized controlled trial. *Tropical Medicine & International Health*, 14(11), 1374-1382. doi: 10.1111/j.1365-3156.2009.02381.x
- United Nations Scientific Educational Cultural Organization (UNESCO). (2010). World water assessment programme. Retrieved May 8, 2012, from <http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/facts-and-figures/water-supply-sanitation-and-health/>
- United States Environmental Protection Agency (EPA). (2012). National primary drinking water regulations. Retrieved September, 29, 2012, from <http://water.epa.gov/drink/contaminants/index.cfm>
- Vanderzwaag, J. C., Atwater, J. W., Bartlett, K. H., & Baker, D. (2009). Field evaluation of long-term performance and use of biosand filters in Posoltega, Nicaragua. *Water Quality Research Journal of Canada*, 44(2), 111-121. Retrieved from <http://search.ebscohost.com.ezproxy.dominican.edu/login.aspx?direct=true&db=eih&AN=46795595&site=ehost-live>
- WHO Library Cataloguing-in-Publication Data. (2011). *Guidelines for drinking-water quality - 4th ed.* World Health Organization.
- World Health Organization (WHO). PHAST step-by-step guide: A participatory approach for the control of diarrhoeal diseases. Retrieved 09/11, 2012, from http://www.who.int/water_sanitation_health/hygiene/envsan/phastep/en/
- WHO. (2011). 10 facts on sanitation. Retrieved May 8, 2012, from <http://www.who.int/features/factfiles/sanitation/en/index.html>

World Health Organization: The International Network to Promote Household Water Treatment and Safe Storage T. (2007). *Combating waterborne disease at the household level*.

Appendix A

Glossary

Biolayer: The biological layer formed at the sand-water interface of slow sand filters. It is colonized by microorganisms including bacteria, protozoa, algae, and diatoms. Also called the schmutzdecke and the biolayer

Disinfection: Any process that removes, deactivates or kills pathogens found in water. It is last step of the household water treatment process, after sedimentation and filtration.

Hydraulic head: The driving force which causes water to move from one place to another due to its pressure and elevation. Head is usually measured as a water surface elevation, expressed in units of length.

Turbidity: Caused by suspended solids, such as sand, silt and clay, floating in water. Turbidity is the amount of light that is reflected off these suspended solids which make the water look cloudy or dirty. Turbidity is measured in nephelometric turbidity units (NTU).

Sedimentation: The process used to settle out suspended solids in water under the influence of gravity.

POU: Pont of Use

Appendix B

St. Paul Boys Primary School

Fred, Headmaster When we first visited, school was not in session and the school appeared to be empty. Matt, Liz, and I checked at a nearby home to see if we could find the headmaster, Fred (approximately 40 years old). He came by and told us that the biosand filters were at the school but he didn't have the keys. He asked us to return later in the afternoon so that he could get the keys and open up the school for us. As we walked back towards town, we peeked into a couple of the classrooms and found two with biosand filters. Both appeared unused and completely dry inside. Trash was in both and both were not lidded. Both biosand filters had extended tubes from the outlets. Fred explained to us that eight classrooms were given biosand filters, and of the eight, only three function properly. When he removed the grate to show us, we observed that the grate was bent out of shape. Fred also explained that the concrete was cracked and that the biosand filters leaked.

Upon returning in the afternoon, Fred said the tap from the rainwater catchment system is better quality water than from the biosand filter. Apparently, they don't boil or filter the rainwater. Fred said that they never tasted the filtered spring water. Gerhard and Matt had gone to see the water source and to sample it, and according to their description, it was highly contaminated. The school children retrieve water from that source during the dry months of the year and get water from the rainwater tank during the wet months of the year. The Filters go dry when school is not in session and are used 6 days per week when school is in session. Fred was not aware that lids for the biosand filter even existed. Fred appeared to know how to use it but didn't understand why the hose extension needed to be cut. He mentioned that when school is in session, about 20L of water per day are put into the filters, but the long walk limits it. He said that he received a water vessel from Ignitius at RASD.

Twekise Household

Josephine Twekise (approximately 35 years old) and daughter, Sarah Nanyange (approximately 15 years old) The second home we visited was the Twekise household. There were about five children at home ranging in age from about 3 to 12, not including Sarah. Sarah showed us a room at the front of the house that contained the biosand filter. It was dry inside and there was trash inside of it. There was no lid. Sarah said that the biosand filter had never worked because of leaking at the bottom. About 10 cm of tubing extended from the outlet. We asked to sample the water that the family used for drinking and they brought us a cup of water from the back of the house. We took a sample of this water and asked to see the container that it came from. Inside, we found a jerry can that was coated on the inside with what appeared to be algae. We took a sample. Kajumba's Well, less than half a kilometer walking distance from the home is where we went next to collect a sample from the home's water source. When we returned to the house, Sarah and Josephine said that they had asked RASD to fix the biosand filter and that Sam came to fix it. However, the filter still didn't work. They said that Sam promised them a new one but nothing has happened yet. We gave a pencil and eraser to each child and presented educational information about hand washing, boiling water, and using clean storage containers.

Glory of God School

This family also had a biosand filter that appeared to be working beautifully. It had its lid on; the bucket into which the water was dripping had a lid. Unfortunately, the biosand filter had an extended tube of about 5 cm, but it was dripping when we arrived, although I suspect that the family was informed ahead of time that we were coming because Josephine Twekise was present at the Gutaka Household. I suspect she warned the Gutaka family that we were coming to inspect their water filter. The biosand filter was located at the Glory of God School but is shared by the Gutaka family. Faith told us that they wash the bucket three times per day, that the water from the filter is cleaner, and that the kids don't get sick anymore now that they use the biosand filter. It seemed pretty clear that Faith (only 11 years old) was telling us what she thought we wanted to hear. According to Faith, they use the water from the biosand filter for drinking, brushing teeth, and cooking. She also said that they filter about 35 liters per day (no complaints). They took us to the spring box where they collect their water, about ¼ km from the house. We took samples. We observed that they used a dipped cup to retrieve water from the clean water container. We gave the children each a pencil and educated them on both technologies with Jackie and Liz' translation.

Deborah Namusisi (About 55 years old)

Deborah is the adopted mother of two children. She received the biosand filter in 2009. We observed that the lid was on, the grate was in, and the sand was wet but not immersed. She demonstrated pouring water into the filter tap. She used a yellow jerry can, which she said she fills at a nearby well. It took about 45 seconds before water came out of the outlet. The plastic tube extended about 10 cm beyond the outlet. Deborah received the filter for free and said that she probably wouldn't have paid money for it even though the biosand filter improves the taste, smell, and appearance of her water and reduces the amount of money she spends on firewood and time on boiling water. She uses the filter for drinking, brushing her teeth, but not for cooking and not for washing dishes. Deborah said that she fills the biosand filter with 10 to 20 liters of water per day and said that it is usually circulating water. She said that she cleans her filtered water container with soap and grass. She told us that she was advised to drill a hold in the lid of her jerry can so that the hose could go directly into the can, but we cut her hose and advised her to get a lid without a hole so the kids wouldn't recontaminate it. Her container was not elevated. We advised her to continue using it every day. She seemed knowledgeable about and happy with the filter. She was a model recipient.

Bazira Muhammed

On September 10th Matthew, George, Jackie and I (Gerhard) took boda-bodas to Kikwayi, a town

overlooking Lake Victoria to the south of Nkokonjeru. We visited the house of Bazira Muhammed but only three of his daughters were home. Kyolaba Alwizia, a 22 year old and the eldest sister of 4 answered our questions. Her mother had died and her father was away farming. She said the BS filter used to work, but the tube has been clogged so it is not used anymore. The Filter has been in the home for 2 years but it only worked for about 4 months before it clogged. When it worked the smell of the water was good and it did 'improve health', it was used for drinking water only. Now water is boiled before being drunk. By blowing through the tube I managed to unclog it, temporarily at least (a trick that worked more than once) and, with water flowing through, we gave a full lesson on sanitation and using the filter. Since the biosand filter was not in use and the biofilm would not have been developed, we took water samples from the local spring box, BAZ-A, and the boiled water from their home, BAZ-C. The daughters say they use Waterguard to sanitize their treated water vessel every time it is empty, but that it is locked away and they can't access it without their father being around. Petrifilm results indicated that the boiled water had nine times as many red colonies as the water straight from the spring box; a recurring situation which indicates the overwhelming problem of clean water vessels being contaminated.

Appendix C

A Amelia Holmes, MS. Environmental engineering, UC Davis. Former President of EWB Davis, 2011-2012. She led the EWB Davis visits to Nkokonjeru, twice, 2010, 2011. She is currently a Junior Specialist in Environmental Civil Engineering focusing on decentralized wastewater treatment and reuse. October 5, 2012

1. What is the history of EWB-Davis and Nkokonjeru?

We started a program in 2007, originally doing assessment to do an initial trip that assesses the community needs. We looked at household scale technologies for drinking water. We did a hygiene education workshop and trials of drinking water treatment in 2010. We had been talking to town council for a few years about the toilet. They did an eco-san toilet at RASD.

2. Why was the biosand filter chosen?

We went through EAWAG point of use water treatment document options. BSF filters were not originally piloted because they were too complex to maintain in a home. But people liked the idea that it was a physical process, as opposed to the UV light used in SODIS disinfection. During the rainy season the exposed water can be turbid, in that case UV disinfection doesn't work well. It was a more robust technology for the people there. We used Connect Africa for the BSF materials and model.

3. What are advantages of the BSF?

It can be easy to use and has demonstrated performance to remove pathogens if they are being used right and have a clean dedicated water storage vessel.

In 2010, Geetika did surveys and water testing. It was part of the EWB process, after you implement a program. RASD got a grant to build 50 of these filters. When Geetika was surveying the filters with George, she felt that she was being shown only the working water filters, we only found 36. We noticed an issue of the tubes not being cut, you have to cut the tubes! EWB Davis is in a partnership with RASD, to make sure there is a local agency to keep it sustainable. We

didn't hire anyone to follow-up. RASD probably did not do a lot of follow-up. RASD hires volunteers who work inconsistently. Younger kids in high school that don't have much training. There is a power dynamic going on because these same high school kids had attempted to sell stoves. It makes it difficult to go back to people's homes without us. Bill lectured Sam and Ignitius that they have to cut these tubes, but the next year, they hadn't cut the tubes. The problem is that they are not being paid for follow-up so there is little motivation. Also there were problems with bad workmanship in that some of the BSFs were cracked and didn't work after being delivered. So it's a big problem if people have one that doesn't work and tell their neighbors they don't work

In 2011 we surveyed and tested the BSFs again to further assess as whether RASD had remedied the situation and had fixed the filters. We wanted more data to see if they were working. Having another group go back and talk to families, you get more real information. Otherwise, it's easy to visit someone's house once and they lie to you about whether it's working. I thought it was helpful to actually cut the tubes and fix them. Time is short, and it helps to do this process many times to tease out what has actually happened. It helps to show up year after year.

4. What do you recommend for future work on the BSFs?

I suggest doing another technical workshop with RASD with a new technical lead to do tasks with BSFs where they follow-up, take water samples, repair, and interview. The main thing is to hire someone, you'd need to provide some funding. Ideally, this person would be a Ugandan who has some skills who knows enough about how to construct them and replace broken ones with new ones. You don't want broken technology sitting around someone's house. You should train RASD employees on how to properly pour the molds, do at least 3 follow-ups, take samples, and see how they perform. Bill wants to do a plastic sand filter.

5. What are the disadvantages of BSF?

It takes a lot of water to clean the sand and it has to be sieved to specific particle size distributions. We had to buy the screens in the U.S. Not sure if available in Uganda.

6. What is the suggestion re. disinfecting water after filtration?

From a water treatment perspective, disinfection is necessary, according to US standards. Sedimentation is necessary only if it's very turbid. Most people are getting bacterial illness, which is more effectively treated by the BSFs, viruses are less common. By definition it is not a disinfection process. It doesn't remove viruses. You should consider talking to Temi Ogunyoku and Erika Campbell.

B. Bill Fleenor PHD Associate Professional Researcher, UC Davis, EWB Davis faculty advisor. October 15, 2012

1. What is the history of BSF use in Nkokonjeru, Uganda?

We were interested in working with RASD to improve sanitation and POU water. We went to Nkokonjeru in 2008 and provided the technology and training and molds to construct BSFs. We had done extensive field research in Kenya where these filters worked where the water quality is worse than in Uganda. They often use standing water as a water source. We built the round ones there. The advantage of the round BSFs is they are lighter and use less concrete. It turns out that constructing the round ones in the developing world is a nightmare. It is easier to build them using the square mold. We got the molds from Connect Africa, which were made in Kampala. We supervised the building of the BSFs in 2008 using CAWST adapted plans. We figured the filters could be built at the cost of \$US35 each. We started by micro financing RASD to build 10 BSFs for \$350. We trained them in the construction and use of the filters, I think they did that in the

first 6 months. They received funding from the U.S Embassy to give away 50. I didn't return in 2009, but received photos that indicated the tubes were too long (causing drainage of the filters) In 2010, I returned and saw the tubes still hadn't been cut. In 2011, they weren't cut. I spoke with Ignitius directly about the need to follow up with the filters, each time and he said he would.

2. What have been the challenges of doing aid work in Nkokonjeru?

The problem with the BSFs is like the problems we've had in maintaining pumps in Nkokonjeru. In 2008 we fixed one pump and thought this would be another good source of water for the town. We developed an MOU (A Memorandum of Understanding – a bilateral agreement between two parties) with the town council. We would fix the 13 pumps in the town and the town council would supply a plumber to maintain them and keep them working. When we returned, only two pumps worked and one of them because the sister at the Providence Home had had it fixed. When RASD received the funding to give away the 50 BSFs it's a problem. If you give things away, people will expect the next ones to be free, and it conflicts with the idea of creating a business in a sustainable way.

3. What do you recommend for future work on BSFs in Nkokonjeru

I recommend we put someone else in business to distribute the BSFs. The recontamination issue is often caused by the way recontamination happened when I was a kid. We'd pour water from a pump into a bucket and we would ladle water out or dip our cups into it. If one kid got sick, we all got sick. The way to prevent that is make sure there is a closed container that has a built in spigot, so people don't dip their cups into it and drink from the cups. At the very least, use a container with a narrow neck where the user has to pour the water out, there is no dipping. The disinfection issue: the BSF does a very good job of improving water quality, but it isn't perfect. Chlorination isn't perfect, but the BSF is the current best solution for developing world POU water treatment. If you don't have stitches, use a Band-Aid. Though BSFs don't work as well on viruses, viruses are less prevalent in standing water (typical of water sources in Uganda). People should do one pour of 20 liters per day. If a BSF sits unused, it needs to be ripened again because the biofilm has been inactive and isn't feeding. The source water affects BSF performance.

People to contact, Sangum Tiwari who wrote dissertation on this, and Tex Tychon of Connect Africa, based in Kampala, Uganda.

C. Sam Mwebe, RASD Coordinator of BSF program. November 5, 2012

1. What is the history of Biosand Filters (BSF) use by RASD? (How many? Where are they now? When did you start?

RASD first learnt about BSFs in 2008 when Prof. Bill and the EWB UC Davis team implemented a point of use-water treatment project in Nkokonjeru, testing for efficacy of different treatment and purification methods. Bill put us in touch with Mr. Tex who lives in Kampala, a man with vast experience in making BSF molds, training BSF users and selling BSFs. Tex trained RASD members in all aspects of the BSF use and making. Since then, RASD had directly made 120 filters and distributed them to 3 sub counties of Nkokonjeru, Ngogwe and Ssi-Bukunja. RASD has since 2009 trained other NGOs and CBOs in the BSF technology and rented out BSF molds to them to make and distribute filters. However, we don't know how many of these have been distributed.

2. What is the general design you use, construction procedure, and materials?

We use a rectangular metallic mold. We smear margarine inside the mold to break the bond between concrete and the mold. In construction, we use 18 litres of sieved lake sand, 12 litres of

coarse gravel and 12 litres of cement plus water. We mix concrete and cast it in the mold, wait for 24 hours and then get it out of the mold and leave it to cure for 14 days.

3. How and to whom do you distribute them?

We work with the health personnel of the sub counties to select beneficiaries and then we deliver the filters to their households. Most beneficiaries are people affected by HIV/AIDS, people whose water sources are very contaminated and those who directly buy the filters from us. However the orders we get are very few.

4. How do you train people and follow-up with the filters?

All beneficiaries of filters are gathered and trained in the water handling practices, then sand filtration and how to maintain their filters. In the grants we got to disseminate the filters, there was some money to cater for follow up, and George was paid to check on the filters once every two months, but he stopped because the funding stopped. However we go to the field once in a while to check whether the users are maintaining their filters and we tell them that they should not always wait for RASD in case they want to change the sand in their filters since they know what to do.

5. What are the advantages and disadvantages of the BSFs?

The advantage with the BSFs is that it is a quick way of filtering water for all purposes, cools water and filters large volumes in a few minutes.

The disadvantages are that it is heavy to lift in case one needs to relocate the home, the sand needs to be cleaned quite often and users seem not to do it efficiently, Some people still doubt it yet we don't have testing materials to prove to them its efficiency, and people also want to get filters free of charge yet its materials are quite expensive.

6. What should be the proper training and follow-up for the filters?

Training should be scaled down to household level so that all users including children learn how to take care of the filter and appreciate its importance to the entire family. Children seem to be very keen with protecting what belongs to them compared to adults!

7. What are your future plans for the BSFs?

RASD will continue training other organisations and linking them to suppliers of the molds so that they disseminate the filters in their areas of jurisdiction. We shall also continue to monitor the ones we already distributed.