# An assessment of long-term biosand filter use and sustainability in the Artibonite Valley near Deschapelles, Haiti

Andrew J. Sisson, Peter J. Wampler, Richard R. Rediske and Azizur R. Molla

## ABSTRACT

A non-randomized assessment of long-term biosand filter (BSF) use and sustainability in the Artibonite Valley near Deschapelles, Haiti was conducted during March, 2011. Of the 55 BSFs visited, 47% were no longer in use. Filter lifespan ranged from <1 year to systems still in use after 12 years. Interviews with BSF owners revealed problems related to intermittent filter use due to travel for employment or personal matters; broken or missing filter parts; and fears that the filter would not be effective against cholera. In addition, 17 BSF field studies were reviewed to identify common issues impacting usage. Culturally appropriate technologies and education materials explaining proper maintenance and operation are essential for improved filter performance and sustainability. For Haiti, education materials should be provided in Creole and French and should include, (1) diagrams and descriptions of how the BSF works, (2) how to troubleshoot common problems, (3) how to properly maintain filters, and (4) a contact in case of questions. Operational problems can be minimized by providing long-term technical support, periodic water quality monitoring, and maintenance assistance for filter users.

**Key words** | biosand filtration, Haiti, point-of-use filtration, slow sand filtration, water

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## INTRODUCTION

Over 780 million people world-wide lack access to safe drinking water sources (World Health Organization/ United Nations Children's Fund [WHO/UNICEF] 2012). Contamination of drinking water through poor sanitation and hygiene is a major health risk in underdeveloped countries and is responsible for 88% of diarrheal disease in the world (WHO 2003). In the Republic of Haiti, child mortality rates are 15 times higher than in the United States, largely due to inadequate access to clean water, proper sanitation, and hygiene (WHO 2006). While some strides have been made toward providing improved, safe drinking water sources to Haitians since the 1990s, 49% of rural Haitians still use unimproved sources for drinking water (WHO/UNICEF 2012).

Over the past decade major advances have been made toward understanding and addressing water, sanitation, and hygiene issues in Haiti, and globally through government and non-governmental organization (NGO) collaboration (WHO/UNICEF 2012). UNICEF-led Multiple Indicator Cluster Surveys (MICS) and Water Sanitation and Hygiene (WASH) clusters have fostered collaboration and data sharing between the Haitian National directorate for safe water and sanitation (DINEPA) and regional health units (UNICEF 2011; WHO/UNICEF 2012). WASH clusters in Haiti, NGOs, and national organizations such as the Haitian Rotary share information and facilitate community development initiatives (Johnson, Hôpital Albert Schweitzer, personal communication 2011).

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In Haiti and other underdeveloped countries, many NGOs and aid agencies have turned to Point of Use (POU) water treatment methods to provide clean water (Sobsey *et al.* 2008; UNICEF/WHO 2009). POU technologies treat small volumes of water and remove pathogens and contaminants through biological, chemical, solar, coagulation, and filtration methods. The most widely used include; liquid or tablet chlorine, solar water purification (SODIS), ceramic filters, biosand filters (BSFs) and PUR© disinfectant and turbidity flocculation powder (Clasen 2008a). In a review assessing sustainability of POU technologies, Sobsey *et al.* (2008) concluded that in addition to being one of the most widely distributed POU technologies, the BSF is one of the most reliable for treatment and removal of harmful diarrhea-causing bacteria and turbidity, and was a highly sustainable technology over long-term use. However, some studies suggest that research conducted on POU technologies such as the BSF are biased, lack hard scientific evidence from double blind tests, and that the current trend of world-wide distribution is premature (Hunter 2009; Schmidt & Cairncross 2009). Vanderzwaag (2008) suggested that without a proper implementation strategy, the BSF may not be an appropriate technology and can adversely affect how receptive a population is to future aid. It is estimated that more than 140,000 BSFs are used by half a million people world-wide (Clasen 2008b).

Laboratory studies have demonstrated BSF efficacy, but field performance and usage studies require surveys and user feedback. Many BSF field studies lack data regarding observations and problems leading to BSF disuse (Center for Affordable Water and Sanitation Technology [CAWST] 2010). The common reasons for the failure of POU water treatment projects are often centered on the lack of consistent NGO support and education, improper maintenance and repair, the absence of user incentives, and the failure to integrate proper POU technology use into daily routines in a culturally sensitive manner (Gadgil & Derby 2003).

Government and NGOs have implemented many different POU treatment technologies in Haiti (Oates *et al.* 2003; Duke *et al.* 2006; Lantagne & Clasen 2010). However, there continues to be a critical need for additional efforts to provide clean and safe water (Wampler & Sisson 2010; Wampler 2011). Between 1999 and 2010 over 2000 cement BSFs were distributed throughout the Artibonite Valley of central Haiti by Hôpital Albert Schweitzer (HAS) and other NGOs. During early 2005, Canadian researchers visited 107 of these filter sites and found only four that were not working properly (Duke *et al.* 2006). More information on filters distributed by HAS can be found in Duke *et al.* (2006). The research presented here summarizes the results of a survey of 55 BSFs in the Artibonite Valley near Deschapelles, Haiti in March 2011, examines the causes of filter abandonment, and provides a review of BSF field studies to identified important factors to facilitate long-term sustainable BSF use.

## METHODS

In March 2011, we traveled to HAS located in Deschapelles, Haiti to examine sustained use and efficacy of cement BSFs distributed by HAS, Faith In Action International (FIAI), and the Agency for Technical Cooperation and Development (ACTED). The study area included 14 communities, and extended ~50 km up the Artibonite Valley (Figure 1). The communities were primarily located 16 km from Deschapelles, with the furthest sample point 30 km from the city. We initially collaborated with HAS personnel to identify communities which had a concentration of filters in a small geographic area.

Sample selection methods were similar to the 2005 study of the Artibonite Valley (Duke *et al.* 2006). Homes were selected in a non-random manner based on information from HAS, NGO records, and asking members of the community which households had filters. Assessments were conducted regardless of filter status. In general each community was assessed for half a day (~ 4 filters), while a few larger communities were done in a full day (i.e. Deschapelles and Petite Riviere). All visits were unannounced. This resulted in 55 total BSFs assessed. The time since filter installation was primarily found using HAS installation records ($n = 41$), NGO information ($n = 9$), and in some cases filter user reporting ($n = 5$). For non-functioning filters, duration of use was determined by user reporting.

An HAS filter installation technician was employed as our interpreter and guide. The technician did not select the communities or areas within the communities. He only assisted in locating the individual homes in the communities

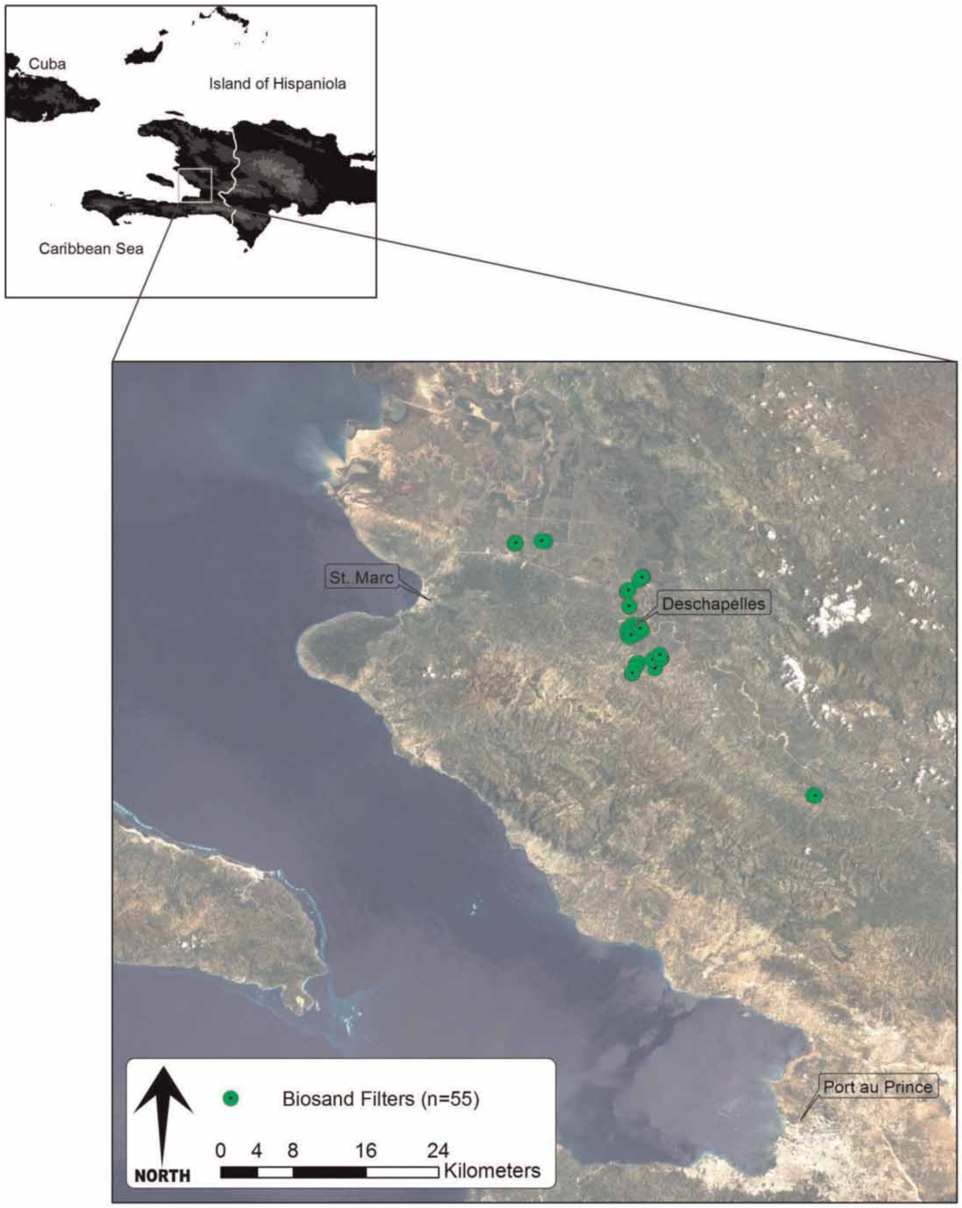


**Figure 1** | Map of the study area and GPS locations of households with biosand filters visited in Artibonite Valley.

we selected. Observations and surveys were used to document common BSF usage problems. At each household, users were questioned regarding filter installation date; filter use and maintenance frequency; number of people using the filter; post-filtration disinfectant usage; and water source. Non-functioning BSFs were evaluated through interviews to determine reasons for discontinued use, duration of service discontinuation; filter use frequency and maintenance; and involvement of filter technicians. The initial response given for disuse by the BSF user was recorded.

In addition to field work, 37 studies were chosen from a comprehensive review of BSF studies. These studies were chosen because they contained significant field evaluation allowing us to compare and further substantiate our findings with the broader BSF literature. Studies were found using Google Scholar, Web of Knowledge$^{SM}$ article database, and the 'Summary of Field and Laboratory Testing for the

Biosand Filter' (CAWST 2010). While not all studies were peer-reviewed journal articles they are all easily accessible in electronic format. Non-peer-reviewed studies were master's thesis, doctoral dissertations, or organization and governmental project reports. A subset of 17 field studies were chosen because they contained data relating to BSF distribution, performance, reasons for filter disuse, and reduced filtration efficiencies. The reviewed literature studies mostly focused on filter design optimization, reporting contamination removal rates, user acceptability, and the effectiveness of filter adaptations such as a double sand layer for reducing turbidity or adding iron for arsenic removal (ex. Ngai et al. 2007; Barnes et al. 2009; Collin 2009; Stauber et al. 2009).

## RESULTS

Of the 55 households visited, 26 filters were not in use. Nearly two-thirds (65%) of non-functioning filters were reported as in use for less than seven years (Figure 2). Primary reasons leading to filter disuse are summarized in Table 1. BSF owners mentioned difficulty using the filters daily due to frequent prolonged travel to larger cities for work or hospital visits ($n = 5$). This eventually led to sporadic filter usage and abandonment. In two cases, a broken collecting bucket spigot was mentioned as the reason for stopping use. One owner claimed the January 2010 earthquake caused the filter to fall and break, while another owner stopped using the filter because the lid broke. In two of the cases, filters were installed but never used. Filter owners said the filter was provided free of charge, but they were required to buy their own bucket as a way of encouraging ownership of the filters. In a third case, a bucket was supplied as part of a year-long trial period but after it broke, filter use was discontinued. Each of these households said they could not afford a new clean water bucket which costs ~160 Gourde ($4 USD).

Ant infestations occurred in two homes where owners mentioned using filters only once a week. Filter clogging was mentioned in three homes that used hand dug wells which resulted in reduced flow rates and led to filter neglect or malfunction. BSF owners, on average, claimed to clean their filters 2–3 times per year but answers ranged from never to almost weekly. Several owners mentioned cleaning only occurred when a filter technician came to visit. The cholera outbreak in December 2010 was the reason three households stopped using their filters, stating they were told not to rely on the BSF to protect against cholera. These users bought treated water instead. Reasons for

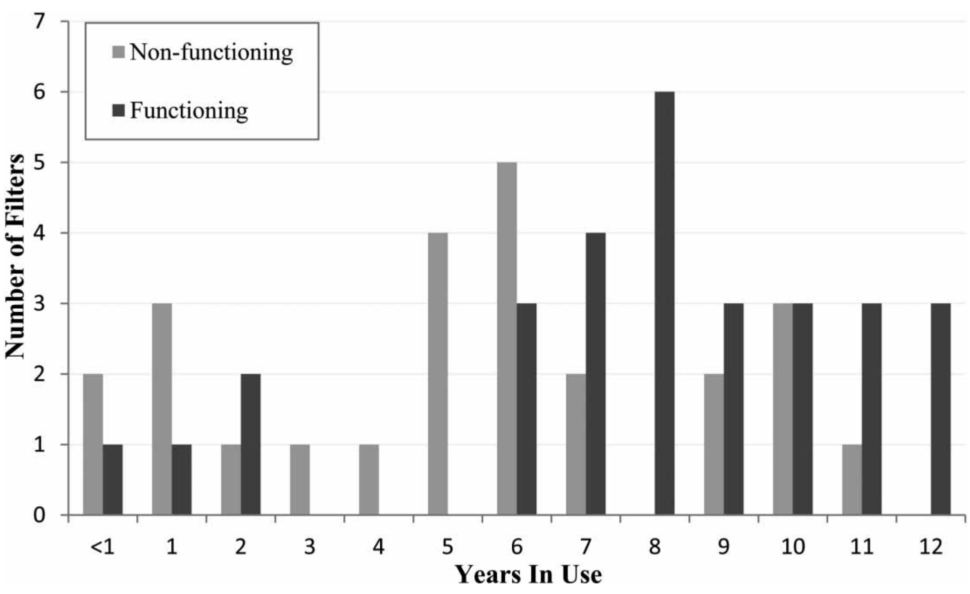


**Figure 2** | Number of non-functioning and functioning filters at the time of study and number of years filters were in use ($n = 54$). One non-functioning filter was not included as installation date and stopping date were unknown.

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**Table 1** | Summary of operational problems based on observations in Haiti, March 7–19, 2011

| Operational problems | Number (%) of filters problem was observed ($n = 26$) |
|---|---|
| Ant infestation | 2 (7.7) |
| Bad smell and taste | 3 (11.5) |
| Broken Part/or crack in filter | 4 (15.3) |
| BSF not-compatible with lifestyle | 5 (19.2) |
| Filter clogging/stopped functioning | 3 (11.5) |
| Inadequate resources for bucket | 3 (11.5) |
| Stopped use because of cholera scare | 3 (11.5) |
| Other | 3 (11.5) |

stopping use were not given for two filters and chlorination of source water was given once.

An additional concern mentioned on four occasions involved chlorination of water prior to filtration. In one case, the homeowner had stopped using his filter two weeks prior to our visit as a result of smelling chlorine in his water. The source water in this case was a capped spring which was piped to a large reservoir. After the cholera outbreak, a local NGO added a chlorine dispenser to the reservoir without informing the HAS community development center, who originally built the reservoir, or the community members. HAS records showed as many as 20 BSFs could have been affected by reservoir chlorination. The three remaining cases were in a different community where filter users were adding chlorine tablets prior to filtration.

Many issues, related to sustainability and effective use, were in agreement with previous studies. Factors affecting sustainable and effective BSF use from studies in 14 different countries included improved BSF owner education; poor understanding of the linkage between water quality and sanitation; source water causing filter clogging; water recontamination due to animal or human contact; and inadequate maintenance (Table 2).

## DISCUSSION

We recognize that some error is likely associated with the duration of filter use, as it was determined by user reporting, but note that exact installation dates were obtained from implementing organizations for all but one of the non-functioning filters and that this does not interfere with the issues given for filters no longer being used. It is also important to note that while 47% of filters were non-functioning at the time of this study, all but one (broken beyond repair) could be brought back into use with biofilm re-establishment and/or other minor maintenance. Our sample size was comparable to previously published studies on BSF use (median = 67.5, Table 2). Issues identified both in our study and previously published studies can be grouped into common themes, education and technical support, cultural sensitivity and BSF suitability, and organization collaboration. In consideration of the lack of randomization in the sample design, the 47% non-functional filters we determined should not be considered representative of the communities within the Artibonite Valley. Since the previous study of the Artibonite Valley (Duke *et al*. 2006) also used non-randomized methods and yielded different results (only four of 107 not functioning), a randomized study is needed to determine the actual extent of filters still in use.

### Education and technical support

Culturally appropriate, initial and follow-up education of users regarding BSF parts, the importance of daily usage, and need for periodic maintenance are essential for sustainable and effective BSF use (Lukacs 2002; Baker 2006; Vanderzwaag 2008; Clasen 2008b; Liang *et al*. 2010). Many of the 17 reviewed studies and the present study identify the need for improved education in the areas of BSF function and maintenance, effective education techniques, or the proper combined use of chlorination with BSF.

In Haiti, issues like recontamination of filtered water, filtered water buckets left uncovered, cracks in the filters, loss of sand, and increased paused water depth could be addressed through education materials presented in Creole and French. Ability for BSF owners to troubleshoot and address their own operational problems would be improved by knowledge and understanding of how filters work and what parts are required for maintenance and proper operation. Cleaning too often can be detrimental to maintaining a viable biofilm and cause significant loss of sand, while not cleaning may lead to clogging and eventual

**Table 2** | Biosand filter field studies chosen and common problems mentioned as leading to filter disuse or improper functioning of filters. Median number of filters studied is 67.5.

| References | Country of study | Common problems | # of filters in study |
|---|---|---|---|
| Current study | Haiti | 2, 6, 7, 8 | 55 |
| Aiken *et al.* (2011) | Dominican Republic | 7, 8 | 328 |
| Baker (2006) | Haiti | 2, 4 | 80 |
| Clasen (2008b) | Lao PDR | 4 | 320 |
| Collin (2009) | Ghana | 4 | 25 |
| Duke *et al.* (2006) | Haiti | 2, 4 | 107 |
| Earwaker (2006) | Ethiopia | 2, 4, 7, 8 | 37 |
| Fewster *et al.* (2004) | Kenya | 5, 6, 8 | 51 |
| Fiore *et al.* (2010) | Nicaragua | 4, 5, 8 | 199 |
| Hurd *et al.* (2001) | Nepal | 3 | 39 |
| Kaiser *et al.* (2002) | Kenya, Cambodia, Mozambique, Vietnam, Honduras, Nicaragua | 1–6, 8 | 600 |
| Klopfenstein *et al.* (2011) | Cameroon | 1, 2 | 89 |
| Lantagne & Clasen (2010) | Haiti | 8 | 46 |
| Lee (2001) | Nepal | 6, 8 | 39 |
| Liang *et al.* (2010) | Cambodia | 2, 4 | 336 |
| Lukacs (2002) | Nepal | 1,2 | 12 |
| Mahmood *et al.* (2011) | Pakistan | 3 | 42 |
| Vanderzwaag (2008) | Nicaragua | 2, 5, 7, 8 | 234 |
| **Total** | **14 countries** | | **2639** |

[1]Knowledge of filter maintenance varied by household and between household members.
[2]Insufficient/improper training/education.
[3]Poor understanding of linkage between water, sanitation, and hygiene and illness.
[4]Post-filtration recontamination.
[5]Filtered water was accessible to animals.
[6]Clarity of source water causing filter clogging.
[7]Poor distributor/caretaker follow-up.
[8]Cracks in filter body/Loss of sand/Slow flow rates.

disuse. In several other field studies, long-term use and regular cleaning was shown to lead to a decrease in sand height and increase the paused water depth (Lee 2001; Kaiser *et al.* 2002; Fewster *et al.* 2004; Earwaker 2006; Fiore *et al.* 2010).

In Haiti, ineffective maintenance, lack of understanding BSF operation, and uncertainties about cholera removal efficiency have resulted in distributions of Aquatabs® and Clorox® disinfectant powder to BSF users. Survey results revealed a risk to BSF owners who were uninformed about chlorination of the water sources and improperly used chlorine prior to filtration. This highlights the need for further education to address the proper use of chlorination with BSFs. Similar concerns of BSF owners using chlorine disinfectant were expressed by Lantagne & Clasen (2010) in their draft report for UNICEF. We speculate that chlorination prior to BSF filtration and sporadic chlorination of source water may pose potential health risks to BSF owners; however, further research regarding the use of chlorination and its effects on the filter biofilms is needed. Adding pre-chlorinated source water to a BSF may compromise the function of the biofilm by killing those organisms necessary for proper filter function. There also is a risk in sole use of chlorine to treat water as *Giardia* and *Cryptosporidium* cysts have increased resistance to chlorination (Korich *et al.* 1990; Lisle & Rose 1995; Betancourt & Rose 2004). The best practice is utilizing chlorination as a post filtration step to deactivate any potential harmful organism that may have survived sand filtration (Lantagne *et al.* 2006).

Several studies have noted that regular follow-up by technicians lasted for the first few years after initial installation, and then the lack of funds and other issues led to discontinued technical support (Fewster *et al.* 2004; Clasen 2008a; Fiore *et al.* 2010). Consistent and continued technician follow-up is clearly helpful in fixing problems and encouraging continued BSF use (Earwaker 2006). For the majority of the filters in this study, funds supporting HAS follow-up programs ran out after several years. Unfortunately, the support program was assigned to another organization specializing in BSFs that also ran out of funds (Johnson, Hôpital Albert Schweitzer, personal communication 2011). Information and training provided to teachers, nurses and doctors, pastors, and others who routinely interact with BSF users may be an effective approach to enhance sustainability. For Haitians, a phone call or text-in service number could be very beneficial as many Haitians own or have access to a cell phone. It is clear from this study and others that educational efforts should be focused toward the primary operators of the filter (Lukacs 2002; Kaiser *et al.* 2002; Klopfenstein *et al.* 2011 ).

## Cultural sensitivity and BSF suitability

In order for BSFs to be properly and reliably used they must be placed in settings where BSF use is compatible with source water and cultural practices. Some of the most commonly observed problems leading to filter disuse in Haiti were associated with Haitian culture, lifestyle, and beliefs. Haitians commonly mentioned the incompatibility, or difficulty of continually using the BSF due to the travel requirements of their lifestyle.

A similar problem leading to the disuse of several filters was noted in the Dominican Republic (Aiken *et al.* 2011). Several BSF owners noted they had stopped using their filter because they regularly spent extended time away from home, and it became a nuisance to maintain the recommended charging and maintenance regime for proper biofilm function. For many rural Haitians, their lifestyle includes extended periods of time away from home for work, personal or family illness, or visiting family and friends. Intermittent use may pose a health risk to users whose biofilm is not regularly maintained. In such situations, BSF owners should allow for a (re)start-up period in addition to utilizing post-filter chlorination to disinfect water before drinking. Bottled water also could be consumed during the start-up period. While unexpected travel due to illness and work may not be predictable by BSF distributors, having a good understanding of the culture and lifestyle of the target users will result in providing the most appropriate water treatment technology (Sobsey *et al.* 2008).

Survey results from our study indicate that there is still a lack of understanding of the connection between water and illness, and how the BSF functions to prevent water-borne disease. As cited in the literature and noted in this study, it is very important to connect the effects of water, sanitation, and hygiene (Gadgil & Derby 2003; Molla 2008; Mahmood *et al.* 2011). A lack of data and accurate information about BSF effectiveness for cholera removal resulted in several filters falling into disuse over time. More studies are needed to evaluate BSF effectiveness for specific pathogens such as *Vibrio cholerea*. Haitian culture and beliefs often associate illness with religion or political suspicion rather than unsafe water, sanitation and hygiene (Smith 2001; Grimaud & Legagneur 2011). Current education campaigns are working to understand people's perceptions of cholera while providing proper education as to the cause of the disease and the need for improved water, sanitation and hygiene (Grimaud & Legagneur 2011). In addition to culturally sensitive education campaigns linking these concepts together, it is important for BSF owners to understand how and why their filters work to clean their water of harmful microorganisms to increase owner trust and foster continued use of the technology.

Rural Haitians often experience financial hardship which can make proper maintenance of a BSF difficult. Based on the literature review, the three BSF owners who were unable to use their filters because they could not afford buckets represent a unique situation. Organizations may choose to provide BSFs for free, for a heavily subsidized price, or at full price based on project funding ( Fewster *et al.* 2004; Duke *et al.* 2006; Earwaker 2006; Aiken *et al.* 2011; Stauber *et al.* 2011). Some charge a small fee to motivate and instill a sense of ownership, value, pride, and trust in using the technology. While this practice has been widely recognized and believed to improve user acceptability in some regions, there are questions as to whether charging a fee actually improves the likelihood of sustainable filter performance or addresses the needs of the most vulnerable populations (Kaiser *et al.* 2002; Clasen 2008b; Fiore *et al.* 2010). Regardless of the financial model used to distribute filters, it is important for organizations to evaluate individual user needs and means to make appropriate filter recommendations (Lantagne *et al.* 2009).

### Organization collaboration

In order for effective and sustainable water project implementation cultural knowledge, sensitivity, and community and organization collaboration are vital. This will help reduce duplication of efforts and benefit BSF users. An example of collaboration and communication is shown by the WASH cluster systems implemented by UNICEF and DINEPA throughout Haiti to improve the responsiveness and effectiveness of aid relief and development. Similar partnerships between organizations and local universities, schools, or churches also have great potential for creating long-lasting relationships that result in more reliable funding and long-term BSF sustainability.

## CONCLUSIONS AND RECOMMENDATIONS

Insights gained through the literature review and field study in Haiti indicate three critical areas that need to be addressed in future BSF implementation projects to increase filter longevity and provide the greatest benefit to users: (1) distributors must provide long-term educational and technical support upon distribution and throughout the project's lifetime; (2) distributors must continually seek a better understanding of changing societal needs, cultural beliefs, lifestyle habits, and BSF suitability; and (3) continued improvement in collaborative work through partnerships with established community groups, local governments, and other organizations working in the same area. Specific recommendations based on our field study include the development of educational materials in Creole and French, family lifestyle assessment to provide most appropriate technology, and the development of ways to enhance collaborations between distribution organizations and local universities, hospitals, and community groups.

An unfortunate reality is that NGOs, implementers, and stakeholders often struggle for ways to convince funders that long-term monitoring, evaluation, and technical support are not financial black holes, but these efforts are equally valuable in the effective and sustainable installation of POU treatment devices (Gadgil & Derby 2003). It is generally accepted that sustainable public health systems and education require ongoing contact with the people they serve, but this is often an inconsistent feature of water and sanitation projects. Many of the problems observed in Haiti were not due to neglect or lack of effort from the implementing organizations. Many of the recommendations made here were implemented but had to be discontinued due to lack of funding. In Haiti, governmental agencies and NGO's have started working together through the DINEPA and WASH cluster programs to address water, sanitation, and hygiene needs. Hopefully these collaborations will continue and expand to include more academic institutions in Haiti and abroad.

Lastly, understanding water resources from an ecological, biological, geological, and anthropological context by region is needed to ensure that suitable water interventions are implemented. Every year, thousands of new BSFs are shipped around the world to remote communities. A generalized distribution plan is unlikely to meet the individual needs of all the families in the region and provide a sustainable solution to clean water needs. Incorporating scientific studies, observations, and recommendations in these efforts, especially in the area of culturally appropriate education, follow up, and maintenance will make sure these efforts are effective.

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