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Sustainability and scale-up of household water treatment and safe storage practices: Enablers and barriers to effective implementation

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ABSTRACT

Household water treatment and safe storage (HWTS) provides a solution, when employed correctly and consistently, for managing water safety at home. However, despite years of promotion by non-governmental organizations (NGOs), governments and others, boiling is the only method to achieve scale. Many HWTS programs have reported strong initial uptake and use that then decreases over time. This study maps out enablers and barriers to sustaining and scaling up HWTS practices. Interviews were carried out with 79 practitioners who had experience with HWTS programs in over 25 countries. A total of 47 enablers and barriers important to sustaining and scaling up HWTS practices were identified. These were grouped into six domains: user guidance on HWTS products; resource availability; standards, certification and regulations; integration and collaboration; user preferences; and market strategies. Collectively, the six domains cover the major aspects of moving products from development to the consumers. It is important that each domain is considered in all programs that aim to sustain and scale-up HWTS practices. Our findings can assist governments, NGOs, and other organizations involved in HWTS to approach programs more effectively and efficiently.

Introduction

According to the WHO and UNICEF (2014) Joint Monitoring Programme report, more than 700 million people in the world do not use improved drinking water sources, that is, sources "that, by nature of their construction, are protected from outside contamination, particularly fecal matter." Analyses accounting for drinking water quality have shown that hundreds of millions with "improved" drinking water do not have access to a source that is microbiologically safe to drink (Onda et al., 2012; Bain et al., 2012). The majority of those using unsafe water reside in developing regions and lack access due to the limited financial, institutional, and informational capacity to treat and provide safe water to households. As a result, the burden of disease from contaminated water falls heavily on developing countries. In 2012, there were approximately 842,000 diarrheal deaths as a result of inadequate water, sanitation, and hygiene (WaSH) practices worldwide and approximately 380,000 of these deaths were children under the age of five (Prüss-Üstün et al., 2014). Consuming unsafe water also has adverse effects on school attendance and economic development as illnesses like diarrhea lead to high rates of school absenteeism, missed workdays, and increased expenditures on healthcare (Hutton and Haller, 2004; Monse et al., 2013).

Providing universal access to safe, pathogen-free, reliable piped water supplies into households is the ideal solution to waterborne illness. However, the high capital and maintenance costs of piped supply systems mean that universal safe piped water is likely decades away for many developing regions. Household water treatment and safe storage (HWTS) practices – like boiling, chlorination, and filtration – provide an interim solution for managing water safety at home if carried out consistently and correctly (Sobsey, 2002). Some studies have shown that HWTS practices yield improvements in drinking water quality and reductions in diarrheal disease (Sobsey et al., 2008; Sobsey, 2002; Clasen et al., 2007; Elsanousi et al., 2009). However, there have been studies that show that HWTS practices are not as effective in diarrheal disease reduction as is often claimed, especially when assessed over periods longer than those typical of HWTS studies (Boisson et al., 2013; Hunter, 2009). The success of HWTS interventions in preventing disease is a function of many factors including efficacy of the practiced method at removing or inactivating pathogens of concern, rates of consistent and correct use, and the presence of other

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pathogen exposure routes (Enger et al., 2013; Brown and Clasen, 2012). HWTS has the potential to improve water safety but does not increase access; as a result, it is a partial and interim solution to unsafe water while coverage of safe, pathogen-free, and reliable piped water is increased.

Humans have been treating drinking water through filtration, boiling and coagulation for centuries (Sobsey, 2002). In recent years, the availability and promotion of diverse HWTS products by governments, NGOs, industry and international organizations has increased markedly. Despite the introduction of diverse products and the advocacy and implementation efforts by NGOs, boiling is the only HWTS practice to achieve scale (Clasen, 2008). Additionally, many HWTS programs and studies have reported high initial uptake and use that declines rapidly over time (Sobsey et al., 2008; Brown et al., 2009). An analysis of Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) data from numerous countries by the WHO and UNICEF shows that the burden of unsafe water supplies falls heavily on the poor. However, the proportion of the population that employs HWTS practices increases as wealth increases even though wealthy populations have access to improved water sources and as a result do not necessarily need to employ HWTS practices (WHO and UNICEF, 2011a). There have been numerous studies on the factors that influence the adoption of specific HWTS technologies, (e.g., POUZN Project, 2007; EAWAG SANDEC, 2002) but few studies on the factors relevant to holistically scaling up HWTS (e.g. Clasen, 2008, 2009).

This paper maps out enablers and barriers to sustaining and scaling up HWTS practices with the aim of improving decision making by HWTS practitioners and providing a useful resource to those planning and implementing HWTS programs. For the purposes of this study, sustainability refers to the ability to maintain an HWTS practice or technology in a community or country in a manner that does not require those external contributions that are unsustainable in the long-term. Scale-up refers to the extent to which HWTS can be made available to the target population as well as the extent to which it is adopted by that population and used correctly and consistently (Clasen, 2009). The results from this study add valuable information to the limited body of evidence currently available on the factors that affect the sustainability and scale-up of HWTS practices.

Methods

Key informant interviews, focus group discussions and online surveys were used for data acquisition. Only one of the aforementioned was used for each interviewee and the method used was based on interviewee-selected preferences. The interviews and focus group discussions were conducted using a semi-structured interview and semi-structured focus group guide, respectively. The online survey was structured such that the conversational form of the interview allowed interviewees to elaborate on their responses and give more detailed descriptions of their experiences. The interview and focus group guides and online survey had two sections: the first focused on enablers to sustainability and scale-up and comprised questions on enablers to uptake of HWTS products, implementation of HWTS programs, and sustainability of HWTS practices. The second focused solely on barriers. Questions in the interviews and online surveys were open ended.

Interviews were conducted over the course of six months with three weeks of interviews taking place in each of Ghana and Tanzania. These countries were chosen because of the advanced state of government involvement in HWTS activities; presence of NGOs in the countries carrying out HWTS activities; and the diversity of HWTS products used. The countries also have similar socio-economic characteristics.

The inclusion criterion for study participants was personal experience with HWTS programs. All interested individuals that met this criterion were interviewed regardless of the regions in which they worked, type of organizations to which they belonged, and their role in the HWTS program. Participants were asked to give responses based solely on their own experiences and not based on perceptions or information from other sources. Participants were recruited through announcements at the October 2011 University of North Carolina at Chapel Hill Water and Health conference, through the WHO and UNICEF co-hosted HWTS Network listserv, and through personal contacts in government agencies and NGOs.

An online survey was developed using Qualtrics software. Interviews were recorded, transcribed and coded based on enablers and barriers identified by the interviewees. Responses from the online survey were also coded based on identified enablers and barriers. Two data management processes were carried out on the identified enablers and barriers. The first grouped enablers with their counterpart barriers, when present. A counterpart barrier is the negative equivalent of an enabler. The frequency of each factor was determined based on the number of times a distinct factor was identified by interviewees. This is referred to as the identification frequency (IF) in later sections of this report. The factors were then further grouped into domains based on the overarching category into which they belonged. This is a method used in similar studies about improved cook stoves (Rehfuess et al., 2014; World Bank, 2011), a type of product used in developing countries that is in many ways similar to HWTS. The IF for a domain is the sum of the IFs for each of the factors that falls under that domain.

The responses from the interviews could not be independently verified; therefore, the triangulation method was used to validate interviewee responses. Evidence from HWTS literature, when available, was used to support interviewee responses. When evidence from HWTS literature was unavailable, literature on general water, sanitation, and hygiene (WaSH) practices were used, if available, and the links to HWTS explained. In cases where these validation methods were not possible, this is indicated. Sources and impacts of bias are discussed.

Results

Description of interviewees

A total of 79 individuals were interviewed. Interviewees had experience in several regions of the world and in different settings (rural, urban, and peri-urban). They also worked for a range of organization types – academia, UN agencies, government agencies, etc. The majority of interviewees had carried out HWTS programs in Africa. Table 1 illustrates the experience of the interviewees.

Enablers and barriers: Identification, grouping into counterpart factors, and aggregation into domains

Twenty-two enablers and twenty-five barriers were identified by the interviewees. A review of the identified enablers and barriers revealed that many of these enablers and barriers, collectively represented one factor with both positive and negative aspects. For example, “affordable products” was mentioned as an enabler and “cost of products” was mentioned as a barrier but these represent one factor – “affordability of products” which can either be positive or negative. The number of distinct factors for sustaining and scaling up HWTS practices decreased to 23 after accounting for counterparts. These 23 factors are shown in Table 2 along with

Table 1
HWTS work experience of interviewees by region and organization type.

Organization type	Region				
	Africa	Asia	Latin America	Other	**Total***
NGO (implementing)	24	7	7	1	**29**
NGO (non-implementing)	2	2	1	0	**2**
Private sector organizations (implementing and sales)	7	5	1	1	**10**
Academia	7	6	2	1	**10**
Government	8	1	1	2	**10**
Sales (Retail and Wholesale only)	8	0	0	0	**8**
UN agency	1	1	0	1	**3**
Manufacturing	2	0	0	0	**2**
Other	3	2	2	3	**7**
Total	**62**	**24**	**14**	**9**	

* The total score for organizations given reflects the number of interviewees from that organization type. This cumulative sum for all organizations is less than the cumulative sum across regions because several interviewees had worked in multiple regions.

Table 2
Identified factors that influence sustainability and scale-up of HWTS practices.

Identified factors (grouped by counterparts)			Domains
Enablers	Barriers	Counterpart factors[a]	
User demand for HWTS (20)*	Lack of motivation to improve health (5) Lack of understanding of economic benefits of HWTS (2) Diarrhea not seen as a problem (2)	**User demand for HWTS (29)**	User preferences (51)
Technology type (6)	Not understanding user preferences (8) Difficulty in incorporating into normal routine (2)	**User technology preferences (20)**	
Aspirational products (2)	Lack of aspirational products (1) Cultural barriers causing misunderstanding of individual needs (1)		
Field trials to gauge preferences (2)	–	Field trials to gauge preferences (2)	
Partnerships (14) Leaders (community leaders, health workers, etc.) advocating HWTS (7)	Lack of partnerships (2)	**Partnerships (23)**	Integration and collaboration (41)
Integration into other programs (e.g. health, schools, etc.) (8)	–	**Integration into other programs (8)**	
Community participation (4)	Lack of community ownership (1)	Community participation (5)	
Longstanding residence of implementers in communities (4)	–	Integration of organization into community (4)	
Private sector participation (1)	–	Private sector participation (1)	
Favorable political climate for HWTS (9)	HWTS not a government priority (5) HWTS not a long-term solution (3)	**Political climate for HWTS (17)**	Standards, certification, and regulations (32)
Quality control carried out on HWTS products (2)	Ineffective technology (6)	**Product standards (9)**	
–	Location & climate not conducive to technology (1)		
–	Import barriers (3)	Import regulations (3)	
Certification of HWTS products (2)	–	HWTS product certification (2)	
–	Lack of agency/ministerial home (1)	HWTS specific home-agency(1)	
Affordable products (2)	Cost of products (11) Continuous purchase of consumables (2)	**Affordability of products (15)**	Resource availability (32)
Available resources (human, money, etc.) (7)	Limited resources (8)	**Organizational availability of resources (15)**	
Cost effective implementation (1)	–	Cost effective implementation (1)	
–	No land tenure (negatively influencing HWTS investment) (1)	Household land tenure (1)	
Presence of a supply chain (10) Products made with local materials (3)	Lack of available spare parts (9)	**Supply chain (22)**	Market strategies (30)
–	Undermining competing technologies (6)	Competition between technologies (6)[b]	
Financing (no free distribution) (1)	Free distribution (1)	HWTS financing (2)	
Training on how to use HWTS products (8)	Lack of capacity building activities (3)	**Training on product use and HWTS practices (12)**	User guidance on HWTS products (24)
–	Limited information to make decisions (1)		
Carrying out behavior change programs (4)	Long time behavior change takes (3)	Behavior change activities (7)	
Household follow-ups (specifically for interventions) (5)	–	Household follow-ups (5)	

–: No counterparts identified.
* Numbers in parentheses represent the number of times the factors were identified during interviews.
[a] Bolded factors are ten most identified factors. This is done simply to show the most identified factors and not to prioritize factors (prioritization is discussed under "All domains matter").
[b] Although none of the interviewees mentioned the positive impacts of fair market-based competition, there are documented examples of competition driving down prices and creating more options for HWTS users (Rangan and Sinha, 2011).

the 47 enablers and barriers. Some of the 47 enablers and barriers did not have counterparts while some had multiple counterparts. It is for this reason 23 does not factor perfectly into 47. Table 2 illustrates the aggregation of the 23 factors into six overarching domains.

Description of domains

The 10 most identified factors are bolded in Table 2 above; each domain includes at least one of the ten most identified factors.

User preferences

This domain refers to the preferences of the target individual, household or community with regard to HWTS practices[1]. Three factors fell into this category: user demand for HWTS, user technology preference, and preliminary field trials to gauge preferences. User demand for HWTS was the most identified factor of all with an identification frequency (IF) of 29. User demand refers to non-technological factors that drive demand for HWTS practices. Technology preferences were identified by 20 interviewees; these referred to ease of use of technology, ease of incorporating practice into normal routine, time taken to employ practice, and other technology characteristics that influence people's preferences. This domain had a total IF score of 51 (29 + 20 + 2).

Integration and collaboration

Although employing HWTS practices is a personal/household practice with primarily personal benefits and consequences, numerous actors are needed to make sustaining and scaling up HWTS practices possible (Ojomo et al., 2014). Collaboration is therefore essential. Two factors under this domain – partnerships (IF 23) and integration into other programs (IF 8) – were among the ten most identified domains. Other factors under this domain include community participation, private sector participation, and longstanding presence of implementing organizations in target communities. Domain related factors were identified by interviewees 41 times.

Standards, certification, and regulations

This domain refers to the formal rules that guide individuals and organizations and are enforced by police and the courts; as well as voluntary standards by organizations that have been systematically developed. The total IF for this domain was 32 and there were 5 subfactors under this domain: favorable political climate for HWTS, presence of standards for HWTS products and technology, certification of products and technology, favorable import regulations, and the presence of a governmental "home" for HWTS affairs. The most identified of the factors in this domain was favorable political climate; identified 17 times, it was the third most identified factor overall. "Standards for HWTS products and technologies" was also in the ten most identified factors with an IF of 8.

Resource availability

This domain refers to the availability of economic and human resources necessary for sustaining and scaling up HWTS practices. These are resources of HWTS product and technology users and organizations that carry out HWTS programs. The identified factors under this domain were organizational resource availability, affordability of products, cost-effective implementation, and willingness to invest based on permanency of home (e.g. land tenure). Affordability of products and organizational resource availability were two of the ten most identified factors, each with an IF of 15. The IF for this domain was 32.

Market strategies – Product supply

This domain refers to the processes used to bring the product to the consumer. Factors under this domain include effective supply chain, sustainable financing, and competition between technologies. Effective supply chain, which included continuous availability of spare parts and local manufacturing, was identified 22 times and was one of the ten most identified factors. The IF for this domain was 30.

User guidance on HWTS products

Factors related to this domain were identified 24 times. This domain refers to the ability of individuals/households to carry out technical activities related to HWTS practices. These include ability of individuals to effectively use products and technologies, behavior change activities, and household follow-up activities to ensure households effectively use products and technologies. Training individuals on how to use products and technologies was identified by 12 individuals and was one of the ten identified factors.

Discussion

Empirical support for domains: Evidence from literature and interviews

Each of the domains identified during the interviews is relevant to sustaining and scaling up HWTS practices as each one is relevant to some aspect of continuously getting the product to the consumer and/or increasing the customer base. Additionally, each domain includes at least one of the top ten identified factors. The relative importance of each is, however, dependent on the technology/practice being promoted, the community in which it is promoted, and the goal of the organization promoting the practice. Evidence from literature and interviewee responses for each of the domains is presented below.

User preferences

Although efforts to increase demand for HWTS often focus on microbial treatment efficacy of products and on health benefits, promoting HWTS based on health and treatment efficiency is unlikely to generate sustainable demand as consumers often select an HWTS option based on the convenience of the practice and design appeal of the product rather than the efficacy (Wellin, 1955; Figueroa and Kincaid, 2010; Center for Communication Programs, 2008; Albert et al., 2010; Luoto et al., 2011). Albert et al. (2010) note that HWTS "product dissemination at scale to the poor will not occur until we better understand the preferences, choices, and aspirations of the at-risk populations." Interviewees in this study contributed examples from their own projects that were consistent with evidence in the literature. Interestingly, user preferences ranged from technology-related preferences to cultural drivers. Preferences highlighted during the interviews included examples related to: aesthetic product design and treated water, technological design of product, social status achieved from product ownership, and cultural and religious beliefs.

Aesthetic aspects of both HWTS hardware and the water produced were frequently mentioned as important drivers of adoption. For example, an interviewee from an NGO in Ghana reported that through their safe storage programs, it had been observed that containers are purchased based on the color even though they are not

[1] This domain does not include ability to pay for products and technologies as that factor is part of "resource availability" domain.

always used to store water. In short, they are bought for their aesthetic looks (Interviewee no. 1). In Tanzania, biosand filters were desirable to the population because they clarify turbid water, a common problem with water sources in these areas (Interviewee no. 2). These preferences vary by culture and context; for example, many interviewees noted that the smell and taste of chlorine was unacceptable in some cultures, leading to a lack of demand by these populations (Interviewees nos. 3–7). The significance of aesthetics is unsurprising as products not only achieve the technical goal for which they were designed but also carry a personal meaning for users (generally influenced by culture) and communicate the identity of the users (generally influenced by individual tastes) (Gotzsch et al., 2006).

Convenience of operation and contribution to social status were also mentioned. For example, in Tanzania, an interviewee (no. 2) noted that WaterGuard tablets are more popular than liquid WaterGuard because of the ease of using the tablets. The tablets are pre-measured for a specific volume of water whereas liquid WaterGuard™ needs to be measured prior to being added to water. In Morogoro, a city in Tanzania, owning biosand filters in some rural regions was viewed as socially advantageous; as a result, demand for biofilters increased in these places (Interviewee no. 8). Ensuring that HWTS products are seen as aspirational has previously been identified as important in generating demand (PATH, 2009; Lee and Kotler, 2011).

To ensure sustained demand, it is therefore important that user preferences – whether technological, social, or economic – are adequately addressed. A similar conclusion was reached by Clasen (2008), who identified a "focus on users" as one of ten factors that warrant priority when considering scaling up HWTS. To "focus on users" one has to figure out what they want, need, and will use, and then deliver it. It is important to note that individuals have varying preferences and as a result, product variety is important. Product choice increases the likelihood of HWTS practices being employed as people have the option to choose the product or technology that suits their needs.

Integration and collaboration

Partnerships are important for the successful adoption of the safe water program and essential in ensuring the in-country sustainability of a product or practice (POUZN Project, 2007). Interviewees and the published literature cite diverse types of partnerships, including those with governments, NGOs, community members and integration into health programs, as essential to the sustainability and scalability of HWTS interventions.

Interviewees cited partnerships with community leaders and other change agents, like teachers and health workers, as being vital to ensuring diffusion of the promotion messages as well as sustainability of the practice. In rural areas, partnerships with community chiefs are sometimes vital to changing behavior of community members. One example of this was given by an interviewee in Ghana who stated that, due to hierarchical structure of several communities in which the organization implements programs, the heads of the community needed to be consulted before the promoted HWTS product is accepted (Interviewee no. 11). Partnering with community members helps ensure that after implementing organizations leave, there are still individuals present to continue the message. Implementing organizations partner with leaders because they are well-respected and community members follow their lead (Interviewees no. 7 and no. 8).

Many other types of partnerships have also been cited as useful to effectively promoting HWTS practices. Partnerships with trusted spokespersons are important to product adoption and can improve rural penetration (POUZN Project, 2007). In Tanzania, an interviewee reported that through their organization's partnership with local charity organizations, there is greater reach to rural populations located in areas that are hard to access through failed road networks and other factors (Interviewee no. 6). This partnership has improved scale-up as a result. Certain organization types also bring particular expertise to the mix when partnerships are formed. For example, government-led and NGO-led HWTS programs can benefit from the marketing expertise of private sector firms. Public-Private Partnerships (PPPs) can be important in incentivizing the private sector to make greater investments in HWTS programs. In Kenya, the private sector is strongly encouraged by the government to get involved and submit proposals for HWTS partnership directly to the Ministry of Public Health and Sanitation (MoPHS) with importation waivers granted to manufacturers of proven technologies (WHO and UNICEF, 2011b).

In addition to partnerships, interviewees noted that integrating HWTS programs into other WaSH and health-related programs is beneficial for sustaining and scaling-up HWTS practices. Interviewees noted that through integration, resources are maximized and are able to go farther than standalone projects. In a report put together by a number of organizations including Action Against Hunger, Action for Global Health, End Water Poverty, PATH, Tearfund, and WaterAid, it is stated that integrated approaches can be cost-effective for donors and more closely reflect and respond to determinants of disease (WaterAid, 2011). Integration is also an effective way of reaching specific populations of interest that can be useful in further promoting HWTS practices. In collaboration with UNICEF, CDC and PSI, the government of Malawi's Ministry of Health piloted a hygiene promotion program targeting mothers that attend ante-natal care (ANC) clinics. The initiative focused on key hygiene improvement interventions including treatment and safe storage of water at the household level and bottles of WaterGuard™ along with a water storage bucket were distributed to pregnant women. An increase in the number of women who had heard about WaterGuard™, treated their water correctly with WaterGuard™, and stored their drinking water correctly was observed a year later during follow-up (Sheth et al., 2010). A second follow-up survey conducted three years after the baseline survey, showed that WaterGuard use and purchase, as well as confirmed residual chlorine rates were higher than during the baseline survey period (Loharikar et al., 2013).

Standards, certification, and regulations

With numerous HWTS products and technologies available, it is important that consistent standards for quality and performance be established. According to Lantagne (2009), the consistency and quality of commercial bleach products available in developing countries is inadequate for use. In addition to potential health benefits not being realized, this inconsistency can produce skepticism about the efficacy of HWTS practices which in turn can negatively influence sustained use. Numerous benefits of mandatory and voluntary certification standards at varying scales (industry, national, and international) were reported during the interviews and in the literature. In response to this need for and the agreed upon benefits of consistent quality, stakeholders have started employing standards for HWTS products and technologies (Interviewee no. 11).

Government standards and regulations can ensure that only effective products are marketed in a country and, ideally, that these standards are enforced. Testing regimes in wealthy countries have long been used to certify water treatment devices. However, these may not be effective or appropriate for developing country markets for reasons including expense and regulatory capacity. In the absence of government involvement, voluntary standards set by

manufacturers and implementing organizations can provide some of the same benefits. Filter manufacturers in Ghana and Tanzania note that standards are useful and do not pose a challenge for the manufacturing process. Instead, the standards help ensure that quality products are being produced consistently (Interviewees nos. 9–13). There is no evidence in the published literature for the benefits of voluntary HWTS standards but according to ITC (2010), between 2002 and 2007, growth rates of markets associated with sustainability claims such as organic products labelled products have doubled those of their counterparts. Some of the potential benefits include increased trust of consumers and consistent quality of product; standards, however, generally increase costs for manufacturers (ITC, 2010). Possible social desirability bias in the interviewee responses should be noted here as none of the costs or challenges of standardization were mentioned. Interviewees likely assumed that their responses would be favored if there was complete agreement with standardization. Although standards contribute to quality of products, certification informs the public that the products are of good quality. This can help increase confidence in products which maximizes the likelihood of adoption and sustained use (ITC, 2010). Additionally, Wessells et al. (2001) note that consumer organizations in many countries argue that customers have a right to know about the safety of purchased products. Products that have the "stamp of approval" from governments are viewed as being safer and more effective than products without this stamp (Interviewees no. 14 and no. 15). In Tanzania, the Tanzania Bureau of Standards (TBS) logo on products reportedly increases the trust of users (Interviewee no. 15).

In addition to government involvement through establishing standards and granting certification, governments can implement other policies that facilitate sustainability and scale-up of HWTS practices. EAWAG's Department of Water and Sanitation in Developing Countries (SANDEC) has found that scaling up is more likely where governments take greater ownership of the program because it typically yields more stable funding than most NGO-led programs (EAWAG SANDEC, 2002). Government involvement also takes advantage of existing resources, capacity, credibility and authority (Clasen, 2008). Along with the personnel of the government, the permanency of the government in the country makes having a government body in favor of HWTS key to consistent use of HWTS. The presence of policies specifically tailored to HWTS can help maximize the impact of efforts to promote and implement different HWTS practices. In Ghana, once HWTS is incorporated into District Plans by district authorities, these authorities can receive funding from national government to carry out HWTS activities (Interviewee no. 16).

The advantages of having clear policies are many and accrue to different actors involved in HWTS and fosters partnerships between actors. In Ghana and Tanzania, interviewees (no. 15, no. 17, no. 18) noted that, through national strategies and action plans, partnerships had been promoted and there was greater coordination of ongoing activities. Evidence of the formation of these partnerships can be seen in national strategies of several countries including Ghana. One of the guiding principles in the Ghanaian national HWTS strategy is forming partnerships that leverage both private and public sector resources (MLGRD Ghana, 2014). Effective implementation of policies related to HWTS requires that responsibilities towards HWTS are housed in an agency and clear roles of this agency and any supporting agencies are defined. For example, one interviewee (no. 15) noted that during implementation of an HWTS program, his organization reached out to, and received support from, a national ministry; however, the program was undermined when another ministry asserted leadership of HWTS affairs and that the program needed to end.

Market strategies

Most early leaders of the global HWTS community came from the non-profit sector, disaster relief, government, the UN system, and academic departments of engineering and microbiology. Therefore, it should not be surprising that knowledge of market-based strategies for HWTS in developing countries lags behind other areas. The focus on market-based strategies within the HWTS community has increased over time as efficient mechanisms to sustain and scale-up HWTS practices have been investigated.

Robust market strategies depend upon effective analysis of a market. This comprises: (1) carefully choosing and understanding consumers; (2) developing products that are acceptable to consumers; (3) pricing products to be affordable and to recover costs; (4) ensuring effective supply chains; and (5) effectively promoting products to create demand (Borden, 1964). Items 1, 2, 3 and 5 have been described above; effective supply chain for HWTS and competition between technologies are discussed below.

The presence of an effective supply chain for a particular HWTS product or technology is dependent on several factors including: availability of raw materials for manufacture, availability of skilled human resources for manufacture, minimal import barriers and favorable import regulations (for foreign products), availability of wholesalers and retailers, and dependable transportation systems. For many HWTS technologies or products, there is a need for frequent purchase (e.g. chlorination tablets) or periodic replacement of parts, (e.g. ceramic filters) so ensuring that a supply chain is available is crucial to the sustainability of practicing HWTS. The high rate of breakage of ceramic filters noted in Cambodia (approximately 2% per month) suggests that sustainability of ceramic filter interventions is highly dependent on the availability of replacement parts and access to, and awareness of, a distribution point (Brown et al., 2007). The consumer's ability to adopt and sustain a promoted behavior depends on the existence and availability of products and technologies, and it is vital to not only consider the availability of supplies, but also the proximity of consumers to the distributors (Cogswell and Jensen, 2008). An interviewee, a distributor of chemical disinfectants, noted that although there was great demand for the product, occasionally products were not available and as a result sustainability was compromised. Many populations in need of safe water reside in remote locations; as a result developing an effective supply chain can be challenging. Using local materials can ease this challenge (Interviewee no. 10). Therefore, HWTS technologies that can be manufactured locally have an implicit advantage for sustainability and scale-up (Sobsey et al., 2008; Taylor et al., 2009; Christopher, 2000). However, quality of products always needs to be guaranteed regardless of manufacturing location.

In addition to product availability, two other important aspects of the supply chain are import regulations and tariffs. With regard to the importing of products or spare parts, many study participants noted that a challenge was getting the products quickly when needed. To address import delays, a large stockpile of HWTS product had to be secured in anticipation of future in-country demand (Interviewees no. 19, no. 9, no. 11, no. 12, and no. 20). The presence of high tariffs also plays a role in affecting the supply chain because high tariffs increase the price at which products can be sold to retailers which in turn, increases the price retailers can sell product to consumers (Interviewee no. 21).

Some aspects of competition between technologies were identified by six interviewees as a barrier, specifically the "bad-mouthing" or otherwise undermining of competing products and practices. While diversity of HWTS options was mentioned as enhancing overall HWTS use (see User preferences discussion), competition was not identified by interviewees as an enabler to

the sustainability or scalability of an individual HWTS intervention. However, fair competition has the potential to benefit consumers. Rangan and Sinha (2011) noted that due to competition between Hindustan Lever and Tata Swach, costs for filters were reduced to increase consumer base.

Resource availability

The lack of resources in developing country markets has presented a persistent challenge to HWTS scale and sustainability. Both the literature and interviewees cite numerous cases in which limited human and economic resources produce barriers to the success of HWTS. As an example, Clasen (2009) notes that programs using pot-style filters have had limited success in achieving coverage for numerous reasons, one of which is a lack of technical expertise in the development of the technology.

Creative and inexpensive ways to leverage the human capital of the community at low cost have been reported. Community leaders, religious leaders and other prominent individuals may be willing to contribute to HWTS promotion efforts without formal compensation; involving prominent individuals in HWTS promotion at little to no cost may be possible and has been shown to be effective (Figueroa and Kincaid, 2010; POUZN Project, 2007). In some settings, this type of approach should be considered to address broader aspects of HWTS programs than just promotion. Interviewees (no. 2, no. 5, and no. 22) supported this and noted that through engaging churches and other local organizations, larger populations – particularly populations in hard to reach areas – were reached. Additionally, technical, marketing and other experts may be willing to volunteer their time for an HWTS project, if it is seen as a good cause or, for local experts, if it can provide connections and social capital within the community (Interviewee no. 20).

Economic resources are a persistent challenge in the communities most in need of HWTS. The most frequently identified barrier to HWTS uptake by interviewees was product cost. The clearest way for HWTS programs to become sustainable is for households to demand and be able to afford the product. However, diverse financing mechanisms have been necessary to ensure affordability of products. Some examples include free distribution (in which case organizations and partners determine ways for this to be done sustainably), provision of subsidies (e.g. need-based subsidies provided by the government), and provision of microfinance loans. One of the factors identified by Population Services International (PSI) as crucial to initiating a Safe Water System project is identifying appropriate target group(s) with both: high incidence of waterborne diseases and sufficient resources to regularly purchase the product (POUZN Project, 2007). Many populations in need of HWTS products simply do not have the resources to purchase HWTS technology or products. One way in which products have been provided to these populations is by demanding "sweat equity", i.e. consumers assist in the manufacture, transport and installation of technologies which reduces or eliminates any cash contribution that may have been required (Clasen, 2008). For populations that cannot afford HWTS products, this approach may prove more effective because research has shown that providing goods for free can undermine sustainability as a result of a lack of buy in or investment by users (Blanton et al., 2014). In Tanzania, an international NGO found that when biosand filters were given for free, they were not used; they report that use increased after they began selling the filters (Interviewee no. 8).

User guidance on HWTS products

Training is vital to ensure individuals adopt the practice correctly. This is true regardless of whether implementers view a particular HWTS technology or product as easy or intuitive to use. Numerous examples of incorrect use of technologies have been reported. Examples for solar disinfection (SODIS) include: users have been observed exposing bottles to the sun in an area that becomes shaded after a few hours, exposing the wrong side of the bottle to the sun, not closing bottles tightly, and partially filling bottles which could reduce UV-A radiation as a result of air bubbles (EAWAG SANDEC, 2002). Incorrectly using a technology or product could reduce or eliminate the health benefits of adopting water treatment at the household level, possibly decreasing demand for HWTS as skepticism on the efficacy of water quality interventions increases (Clasen, 2008).

Training on how to use HWTS products and technologies is viewed as important to ensure consistent use of the product or technology. Users may believe products are ineffective if they continue to get sick, even if the reason they are getting sick is incorrect use (Interviewee no. 10). For most HWTS products and technologies, leaflets or pamphlets are provided along with the products and technologies during sale and distribution that inform users on how to use the products or technologies and also clean and maintain them, where necessary. The effectiveness of these pamphlets for ensuring correct use is not well understood. An interviewee in rural Tanzania noted that recurrent training on how to use the different HWTS products and technologies was also found to be necessary, as user behavior lapsed over time. The interviewee provided no evidence of this knowledge lapse and there may be a number of reasons why knowledge lapse occurred including ineffective training initially and evaluation of skills of different consumers over time; however, programs like the Potter's for Peace (PFP) filter program in Nicaragua are beginning to implement follow-up training activities to improve knowledge about training and maximize effective practices (Lantagne et al., 2006). Apart from training on how to use water treatment products and technologies, training on safe storage is also vital. Interviewee no. 10 noted that water quality in storage containers could be just as unsafe as or even more unsafe than water from unimproved sources because of poor storage practices. Although no evidence was provided to support this finding in the specific case on which Interviewee no. 10 was reporting, this observation is consistent with the literature. Wright et al. (2004), through a systematic meta-analysis of 57 studies, found that the bacteriological quality of drinking water declines significantly after collection and this decline is sometimes partially explained by poor storage. Bain et al. (2014) also found that stored water contamination was more likely than contamination at the source. These findings illustrate the need for training in correct storage practices.

Diffusion of innovation theory and the six domains

Diffusion of Innovations (DOI) theory was popularized by Everett Rogers and seeks to explain how new ideas and technologies are taken up by a population as well as the reason for the uptake and the rate at which they spread. This theory has been used in various sectors to understand effective ways to motivate adoption of technologies and is one of the most popular theories used for explaining diffusion of products and technologies (Murphrey and Dooley, 2000; Dooley, 1999; Al-Jabri and Sohail, 2012). Other adoption theories include: (1) extension theory – focuses heavily on communication as the main mode for increasing adoption and does not provide a framework for studying adoption; (2) bounded rationality – developed by Herbert Simon in 1957 and focuses largely on the goals of the individuals and their available resources and how these play a role in decision-making; (3) theory of reasoned action – addresses the internal determinants of individual behaviors in different situations about different practices; and (4) consumer behavior theory – uses the needs of the producers as the starting point for evaluating the advantages

Table 3
Using DOI theory to assess defined domains for sustainability and scale-up of HWTS practices.

Elements of diffusion	Element categories identified by Rogers (2003)	Domains that support DOI element categories[a,b]
The innovation	I. Relative advantage of HWTS in comparison with no HWTS or inadequate HWTS practices II. Compatibility with needs, existing values and past experiences of households III. Complexity of use of HWTS product or technology IV. Ability to be tried before investment Observability of results of HWTS practices	**User preferences** - Social status achieved from employing HWTS practices[I] - Aspirational products; easy to incorporate into normal routine[II] - Ease of use of HWTS practice[III] - Visual proof of water treatment or, potentially, improved health[V] **Resource availability** - Consumable HWTS technologies versus those with large initial capital investment[IV]
Communication channels	Interpersonal channels/face-to-face (effective in persuading individuals to adopt)	**Integration and collaboration** - Partnerships with change agents, local NGOs, community leaders, etc.[I]
Time	I. Innovation-decision process i. First knowledge of HWTS practice/product ii. Attitude formation about the HWTS practice/product iii. Decision to adopt or reject of HWTS practice/product iv. Implementation and use of HWTS product v. Confirmation of the decision to adopt or reject HWTS practice/product	**Integration and collaboration** - Partnerships with leaders to promote practice/product[I-i] - Involving change agents[I-ii,I-iii] **Standards, certification, and regulations** - Certification to boost population confidence in product[I-ii] **User preferences** - Practice/product compatibility with users[I-ii,I-iii] - Social status strengthened[I-v] **Market Strategies** - Clear supply chain–consistent availability of products in the market[I-iv] **Resource availability** - Upfront cost and continued cost of practice/product[I-iv] **User training** - Correct and consistent use to see visual changes, if any, and to realize health benefits[I-v]
The social system	I. Effects of formal and informal relationships II. Relevance of change agents in diffusion III. Influence of cultural norms on diffusion	**Standards, certification, and regulations** - Partnerships with the government[I] **Integration and collaboration** - Partnerships with community leaders, teachers, health workers, etc.[II] **User preferences** - Religious and traditional beliefs about water treatment and/or water treatment products[III]

[a] More detail about these domains can be seen in the discussion section. This table highlights some key factors of each of the domains that relate to DoI elements.
[b] Superscripted letters and roman numerals refer to factors directly related to the "Element categories identified by Rogers (2003)" column on the same row.

and disadvantages of an innovation and assumes that prospective adopters actively search for information (Botha and Atkins, 2005). DOI theory is used to assess the six domains identified in this paper because it is comprehensively assesses the adoption process. It is appropriate for assessing HWTS adoption because it incorporates the technological aspects of the innovation as well as the social conditions necessary for adoption.

According to DoI theory, there are four main elements in the diffusion of an innovation: the innovation itself, communication channels, time, and the social system. Table 3 illustrates how the six domains identified in this paper are supported by DoI theory and how the six domains relate to the four main elements in the diffusion of an innovation.

In considering HWTS as an innovation, it is important to note that the target population needs to contemplate both the different HWTS practices possible and the numerous products available to carry out these practices. As a result, there are two boundaries to cross for adoption to take place. To illustrate this, a fictional example is presented. In a community with a turbid water source in which HWTS practices are promoted, a household may opt for filtration rather than chlorination because filtration has the relative advantage of reducing turbidity over chlorination, SODIS, and boiling. Filtration is also relatively simple to practice. After opting for filtration, the household then needs to decide between biosand filtration and ceramic filtration and consider the degree to which turbidity reduction can be observed. Therefore, for HWTS, there is a need for a double diffusion for adoption to occur. It is important to consider both the practice and the product being promoted to sustain and scale-up HWTS practices.

All domains matter

In a study to determine enablers and barriers to uptake and sustained use of improved cookstoves, Rehfuess et al. (2014) identified and defined seven domains, each of which was populated with multiple factors identified in the study. They concluded that "all domains matter and jointly influence" uptake and sustained use. Based on the discussion of each domain for sustaining and scaling up HWTS practices above, a similar conclusion can be made here. Interviewees comprised individuals from dozens of countries, diverse organizations, and various settings and despite this, at least one of the ten most identified factors fit into each of these domains, illustrating the significance of each. Prioritizing domains is beyond the scope of this study; however, the diverse cultures, beliefs, rules, resources, and preferences that define individual behaviors make prioritizing domains extremely difficult, and likely unhelpful. Additionally, Rehfuess et al. (2014) note that "broadly speaking, the evidence suggests that policies and programs must consider all factors" and that to prioritize, a suitable evidence base and knowledge of the relevant context is required. It is, therefore, important to consider all domains when implementing HWTS programs.

Study limitations

Interview and survey responses could not be independently verified. This is one limitation of studies that use self-reported data. Confirmation bias in this study could have led to interviewees attributing positive or negative outcomes to specific factors that

may or may not have been the main influence. Additionally, social desirability bias could potentially have led to reluctance of interviewees to report on failed HWTS programs in which they were involved. The study could also have benefited from increased access to under-represented categories of interviewees, particularly manufacturers. Fieldwork was carried out in countries with similar socio-economic characteristics and the study could have benefited from in-depth analysis of countries with diverse socio-economic characteristics.

Conclusion

This study used interviews, focus groups and online questionnaires with experienced HWTS practitioners and identified 47 enablers and barriers to HWTS sustainability and scale-up. The enablers and barriers were grouped into 23 factors and categorized into six domains. Collectively, all six domains consider individuals (target households and communities), organizations (implementing organizations, governments, etc.) and the formal and informal rules that guide individuals and organizations. Additionally, the domains identified in this study cover the major aspects of moving products from development to the consumers and are supported by Diffusion of Innovation theory. Due to the comprehensive nature of the domains, it is important that each domain is considered for all programs that aim to sustain and scale-up HWTS practices.

This study showcases the importance of collaboration between different organizations regardless of the HWTS practice and product promoted. Strong collaborations can lead to sharing lessons learned, thereby, improving the likelihood of effectively promoting HWTS and subsequently enabling sustainability and scale-up of HWTS practices.

The results from this study were used to develop three tools that that can guide organizations in implementing effective HWTS programs. One enables rapid assessment of the feasibility of employing a product in a community, based on supply chain present. Another enables the assessment of the household and community conditions prior to program implementation to guide organizations in the planning and implementation processes of HWTS programs. The third enables assessment of the readiness of the national governments – in terms of government efforts and policies – to sustain and scale-up HWTS practices. These tools are yet to be piloted but can be made available to interested parties[2].

Future research can dig deeper to better understand the extent to which each of these domains play a role under different contexts. Additionally, research can look into ways to assess each of these domains. Piloting the tools developed during the study may facilitate some of this research in addition to validating the tools.

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[2] Contact the corresponding author for access.

References

Albert, J., Luoto, J., Levine, D., 2010. End-user preferences for and performance of competing POU water treatment technologies among the rural poor of Kenya. Environ. Sci. Technol. 44 (12), 4426–4432.

Al-Jabri, I.M., Sohail, S.M., 2012. Mobile banking adoption: application of diffusion of innovation theory. J. Electron. Comm. Res. 13 (4), 379–391.

Bain, R.E.S., Gundry, S.W., Wright, J.A., Yang, H., Pedley, S., Bartram, J.K., 2012. Accounting for water quality in monitoring access to safe drinking-water as part of the millennium development goals: lessons from five countries. Bull. World Health Organ, 228–235.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., Bartram, J., 2014. Fecal contamination of drinking-water in low- and middle-income countries: a systematic review and meta-analysis. PLoS Med. 90 (3), http://dx.doi.org/10.1371/journal.pmed.1001644.

Blanton, E.M., Chankova, S., Ganesan, R., Elliott, T., Dargan, T., Goodyear, L.L., 2014. Microfinance partnerships to improve access to durable water filters: results from six pilots in India and Cambodia. J. Water Sanit. Hyg. Dev. 4 (4), 699–708.

Boisson, Sophie, Stevenson, M., Shapiro, L., Kumar, V., Singh, L.P., Ward, D., Clasen, T., 2013. Effect of household-based drinking water chlorination on diarrhoea among children under five in Orissa, India: a double-blind randomised placebo-controlled trial. PLoS Med., http://dx.doi.org/10.1371/journal.pmed.1001497.

Borden, N.H., 1964. The concept of the marketing mix. In: Schwartz, G. (Ed.), Science in Marketing. Wiley, New York, NY, pp. 7–12.

Botha, N., Kris, A., 2005. An assessment of five different theoretical frameworks to study the uptake of innovations. In: Conference Proceedings, Nelson, New Zealand: New Zealand Agricultural and Resource Economics Society Inc. Conference.

Brown, J., Clasen, T., 2012. High adherence is necessary to realize health gains from water quality interventions. PLoS ONE, http://dx.doi.org/10.1371/journal.pone.0036735.

Brown, J., Sobsey, M., Proum, S., 2007. Improving Household Drinking Water Quality: Use of Ceramic Water Filters in Cambodia. WSP, Washington, DC.

Brown, J., Proum, S., Sobsey, M.D., 2009. Sustained use of a household-scale(SK) water filtration device in rural Cambodia. J. Water Health, 404–412.

Center for Communication Programs, 2008. Experiences in Haiti, Ethiopia, and Pakistan: Lessons for Future Water Treatment Programs. Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD.

Christopher, M., 2000. The agile supply chain: competing in volatile markets. Ind. Mark. Manage. 29 (1), 37–44.

Clasen, T., Schmidt, W.P., Rabie, T., Roberts, I., Cairncross, S., 2007. Interventions to improve water quality for preventing diarrhoea: systematic review and meta-analysis. Br. Med. J., http://dx.doi.org/10.1136/bmj.39118.489931.BE.

Clasen, T.F., 2009. Scaling Up Household Water Treatment Among Low Income Populations. WHO, Geneva.

Clasen, T.F., 2008. Scaling Up Household Water Treatment: Looking Back, Seeing Forward. World Health organization, Geneva.

Cogswell, L., Jensen, L., 2008. Guidelines for Assessing the Enabling Environment Conditions for Large Scale, Effective and Sustainable Handwashing with Soap Projects. WSP, Washington, DC.

Dooley, K.E., 1999. Towards a holistic model for the diffusion of educational technologies: an integrative review of educational innovation studies. Educ. Tech. Soc. 2 (4), 35–45.

EAWAG SANDEC, 2002. Solar water disinfection: a guide for the application of sodis. In: SANDEC Report No 06/02. EAWAG SANDEC, Duebendorf, Switzerland.

Enger, K.S., Nelson, K.L., Rose, J.B., Eisenberg, J.N.S., 2013. The joint effects of efficacy and compliance: a study of household water treatment effectiveness against childhood diarrhea. Water Res. 47 (3), 1181–1190.

Elsanousi, S., Abdelrahman, S., Elshiekh, I., Elhadi, M., Mohamadani, A., Habour, A., ElAmin, S.E., ElNoury, A., Ahmed, E.A., Hunter, P.R., 2009. A study of the use and impacts of LifeStraw in a settlement camp in southern Gezira. Sudan. J. Water Health 7 (3), 478–483.

Figueroa, M.E., Kincaid, L.D., 2010. Social, Cultural and Behavioral Correlates of Household Water Treatment and Safe Storage. Center Publication HCI 2010-1: Health Communication Insights, Johns Hopkins Bloomberg School of Public Health, Center for Communication Programs, Baltimore, MD.

Gotzsch, J., Chanaron, J.J., Birchall, D., 2006. Product development with a focus on attractive product expression: an analysis of case studies. Int. J. Prod. Dev. 3 (3/4), 467.

Hunter, P.R., 2009. Household water treatment in developing countries: comparing different intervention types using meta-regression. Environ. Sci. Technol. 43 (23), 8991–8997.

Hutton, G., Haller, L., 2004. Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. WHO, Geneva.

ITC, 2010. Voluntary standards in developing countries: the potential of voluntary standards and their role in international trade. Int Trade Forum Mag. (3), ⟨http://www.tradeforum.org/Voluntary-Standards-in-Developing-Countries-The-Potential-of-Voluntary-Standards-and-their-Role-in-International-Trade/⟩.

Lantagne, D., 2009. Viability of commercially available bleach for water treatment in developing countries. Am J Public Health 99 (11), 1975–1978.

Lantagne, D.S., Quick, R., Mintz, E.D., 2006. Household Water Treatment and Safe Storage Options in Developing Countries: A Review of Current Implementation Practices. US Centers for Disease Control and Prevention.

Lee, N., Kotler, P., 2011. Product: creating a product platform. In: Lee, N., Kotler, P. (Eds.), Social Marketing: Influencing Behaviors for Good. SAGE, California, pp. 257–262.

Loharikar, A., Russo, E., Sheth, A., Menon, M., Kudzala, A., Tauzie, B., Masuku, H.D., Ayers, T., Hoekstra, R.M., Quick, R., 2013. Long-term impact of integration of household water treatment and hygiene promotion(SK) with antenatal services on maternal water treatment and hygiene practices in Malawi. Am. J. Trop. Med. Hyg. 88 (2), 267–274.

Luoto, J., Najinin, N., Mahmud, M., Albert, J., Islam, M., Luby, S., Levine, D.I., 2011. What point-of-use water treatment products do consumers use? Evidence from a randomized controlled trial among the urban poor in Bangladesh. PLoS ONE, http://dx.doi.org/10.1371/journal.pone.0026132.

MLGRD Ghana, 2014. National Strategy for Household Water Treatment and Safe Storage in Ghana. Ministry of Local Government and Rural Development, Republic of Ghana.

Monse, B., Benzian, H., Naliponguit, E., Belizario, V., Schratz, A., van Palenstein Helderman, Wim, 2013. The fit for school health outcome study – a longitudinal survey to assess health impacts of an integrated school health programme in the Philippines. Biomed Cent. Public Health, http://dx.doi.org/10.1186/1471-2458-13-256.

Murphrey, T.P., Dooley, K.E., 2000. Perceived strengths, weaknesses, opportunities, and threats impacting the diffusion of distance education technologies in a college of agriculture and life sciences. J. Agric. Educ. 41 (4), 39–50.

Ojomo, E., Elliott, M., Forson, M., Bartram, J., 2014. Implementing household water treatment interventions: actors and factors for success. In: Proceedings of the 37th WEDC International Conference, Hanoi, Vietnam.

Onda, K., LoBuglio, J., Bartram, J., 2012. Global access to safe water: accounting for water quality and the resulting impact on MDG progress. Int. J. Environ. Res. Public Health 9 (3), 880–894.

PATH, 2009. PATH's Safe Water Project in Vietnam. Household Water Treatment and Storage: Findings from a Qualitative Consumer Research Study. PATH, Seattle, WA.

POUZN Project, 2007. Best practices in social marketing safe water solution for household water treatment: lessons learned from population services international field programs. In: The Social Marketing Plus for Diarrheal Disease Control: Point-of-Use Water Disinfection and Zinc Treatment (POUZN) Project. Abt Associates Inc., Bethesda, MD.

Prüss-Üstün, A., Bartram, J., Clasen, T., Colford, J.J., Cumming, O., Curtis, V., Cairncross, S., 2014. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. Trop. Med. Int. Health 19 (8), 894–905.

Rangan, K.V., Sinha, M., 2011. Hindustan Unilever's 'Pureit' Water Purifier. Harvard Business School, Harvard (9-511-067).

Rehfuess, E.A., Puzzolo, E., Stanistreet, D., Pope, D., Bruce, N.G., 2014. Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review. Environ. Health Perspect. 122 (2), 120–130.

Rogers, E.M., 2003. Diffusion of Innovations. Free Press, New York, NY.

Sheth, A.N., Russo, E.T., Menon, M., Wannemuehler, K., Weinger, M., Kudzala, A.C., Tauzie, B., Masuku, H.D., Msowoya, T.E., Quick, R., 2010. Impact of the integration of water treatment and handwashing incentives with antenatal services on hygiene practices of pregnant women in Malawi. Am. J. Trop. Med. Hyg. 83 (6), 1315–1321.

Sobsey, M.D., Stauber, E.C., Casanova, L.M., Brown, J.M., Elliott, M.M., 2008. Point of use household drinking water filtration: a practical, effective solution for providing sustained access to safe drinking water in the developing world. Environ. Sci. Technol. 42 (12), 4261–4267.

Sobsey, M.D., 2002. Managing Water in the Home: Accelerating Health Gains from Improved Water Supply. World Health Organization, Geneva.

Taylor, J., Bate, R., Putze, E., Tren, R., 2009. The push for local production, costs and benefits – a case study of Uganda's Quality Chemicals. In: Policy Paper, Africa Fighting Malaria.

WaterAid, 2011. Join up, scale up: How integration can defeat disease and poverty. In: ACF International, Action for Global Health, End Water Poverty. PATH, Tearfund and WaterAid.

Wellin, E., 1955. Water boiling in a Peruvian town. In: Paul, B.D. (Ed.), Health, Culture and Community. Russel Sage Foundation, New York, NY.

Wessells, C.R., Cochrane, K., Deere, C., Wallis, P., Willmann, R., 2001. Product Certification and Ecolabelling for Fisheries Sustainability. Food and Agricultural Organization, Rome.

WHO, UNICEF, 2011a. Drinking Water: Equity, Safety and Sustainability. WHO, UNICEF, New York, NY.

WHO, UNICEF, 2011b. National Household Water Treatment and Safe Storage Strategies and Integrated Household Environmental Health Interventions. WHO/UNICEF International Network on Household Water Treatment and Safe Storage in Collaboration with the Water Institute at UNC, Entebbe, Uganda.

WHO, UNICEF, 2014. Progress on Drinking Water and Sanitation: 2014 Update. World Health Organization and UNICEF, Geneva, Switzerland.

World Bank, 2011. Household Cookstoves, Environment, Health and Climate Change: A New Look at an Old Problem. World Bank, Washington, DC.

Wright, J., Gundry, S., Conroy, R., 2004. Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. Trop. Med. Int. Health 9 (1), 106–117.