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A Systematic Review of the Evidence for the Sustainability of Household Water Treatment Interventions

Background

Despite appreciable efforts and commitments over recent decades to increase access to safe drinking water, a large portion of the world population still relies on unsafe sources of drinking water. Poor water quality, along with inadequate sanitation and hygiene, is a principal cause of the diarrheal diseases that result in millions of preventable deaths each year, primarily among children under five years of age. The World Health Organization recently endorsed household water treatment (HWT) based on growing evidence of HWT's ability to improve microbial water quality, effectiveness at reducing diarrheal disease, cost-effectiveness, and rapid application and acceptance. However, the sustainability of HWT remains a major issue, bringing into question whether sufficient evidence exists to support scaling-up of promotion efforts of HWT. We undertook a review to assess the quantity and quality of evidence for the sustainability of HWT interventions based on published evaluations.

Methods

Search Methods

We searched the Medline database using the PubMed online interface with the following phrase: *(Household OR Point-of-use) AND (Water OR Water Supply) AND (Treatment OR Purification OR Disinfection).* Relevant titles were selected from the search results. From these studies, the abstracts were then screened and, if selected, classified as either: **HWT intervention trials of one year or longer of duration** or **Post-implementation evaluations of HWT interventions.** Abstracts not selected included: intervention trials of less than one year of duration; non-HWT interventions; hospital-based interventions; water quality improvement field and laboratory efficacy trials; studies on cost effectiveness; commentaries; review articles; and studies looking at predictive factors of uptake of household water treatment.

Methodological Quality Assessment

We evaluated 6 indicators of study methodological quality based on recommendations described by Blum and Feachem (1983) and Fewtrell and Colford (2004):

1) **Include an adequate control/comparison group** – *An external and comparable control sample is described.*
2) **Adequate study size** – *A sample size calculation is reported, there is discussion of the statistical power of the analysis, or for post-implementation studies all recipients were included.*
3) **Multiple communities or groups** – *Study design includes either multiple communities for comparison or describes the use of within community controls.*
4) **Control of possible confounders** – *Randomization is the ideal method for controlling confounding. Measured confounders can be controlled for in analysis.*
5) **Objective measure of compliance** – *Design includes an objective measure of usage or practice of treatment behavior.*
6) **Consideration of seasonality in analysis** – *Design allows for seasonal effects or their implications are discussed.*

We assigned 1 point for each of these methodological quality indicators if we determined that a sufficient effort to address the issue was reported and no point if the approach was not reported or considered insufficient. For the score, the points were totaled for each study and divided by 6. Frequency tables of the reported quality issues were prepared.

Sustainability

Information was extracted on the age of intervention, considered time in years since the start of intervention through the completion of the study, and the level of usage, as either reported, confirmed, or both. The measurement of confirmed usage depended on the study and usually consisted of self-reported treating of water by respondents plus confirmation through an objective observation or measurement.We extracted information reported on 7 sustainability criteria based on those described by Sobsey et al. (2008) and Lantagne et al. (2009):

1) Effectiveness (microbiological, physical)
2) Water quantity produced
3) Local water quality/range of water quality treated
4) Ease of operation/time to treat
5) Cost
6) Supply chain requirements and durability
7) Consumer preference (taste and appearance; perceived effectiveness; cultural acceptability)

Figures 1a-e – Confirmed HWT usage and age of intervention (disaggregated usage values from interventions with multiple types of HWT). Circle width corresponds to relative methodological score: a) boiling (n=1), b) chlorination (n=8), c) filtration (n=5), d) flocculant-disinfectant (n=5), and e) solar disinfection (n=2).

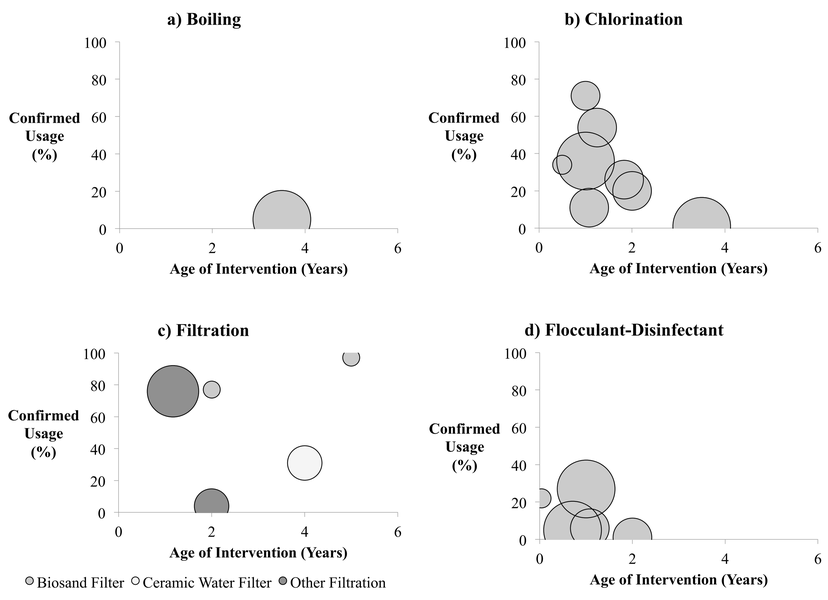

Table 2 – Treatment usage and ages of intervention of selected HWT intervention and post-implementation studies (N=20).

Authors	Year	Country	HWT	Type of Study	Reported Usage (%)	Confirmed Usage (%)	Age of Intervention (years)
Duke et al.	2006	Haiti	Biosand Filter	Post-implementation	--	97	5.00
Fiore et al.	2010	Nicaragua	Biosand Filter	Post-implementation	--	77	2.00
Ngai et al.	2007	Nepal	Biosand Filter	Post-implementation	83	--	1.00
Ram et al.	2007	USA	Boiling	Post-implementation	42	--	0.00
Brown et al.	2009	Cambodia	Ceramic Water Filter	Post-implementation	--	31	4.00
Boisson et al.	2010	D.R. Congo	Ultra-filtration	Intervention	--	76	1.17
Gupta et al.	2008	Bangladesh	Filtration + Pasteurization	Post-implementation	21	4	2.00
Colindres et al.	2007	Haiti	Flocculant-disinfectant	Post-implementation	92	22	0.04
Luby et al.	2008	Guatemala	Flocculant-disinfectant	Post-implementation	--	5	0.71
Harris et al.	2009	Kenya	Chlorination	Intervention	(80-95)	26 (80-92)	1.83
Makutsa et al.	2001	Kenya	Chlorination	Post-implementation	--	34	0.50
Parker et al.	2006	Kenya	Chlorination	Post-implementation	--	71	1.00
Ram et al.	2007	Madagascar	Chlorination	Post-implementation	73	54	1.25
Stockman et al.	2007	Malawi	Chlorination	Post-implementation	12	--	2.50
Conroy et al.	2001	Kenya	SODIS	Intervention	96	--	1.50
Mausezahl et al.	2009	Bolivia	SODIS	Intervention	80	32	1.25
Arnold et al.	2009	Guatemala	Boiling, SODIS, Chlorination, Any	Post-implementation	20, 13, 5, 33	5, 4, 1, 9	3.50
Blanton et al.	2010	Kenya	Flocculant-disinfectant, Chlorination (Any)	Intervention	15, 23	6, 11 (18)	1.08
Freeman et al.	2009	Kenya	Flocculant-disinfectant, Chlorination, Any	Post-implementation	--	1, 20, 20	2.00
Reller et al.	2003	Guatemala	Flocculant-disinfectant, Chlorination	Intervention	--	27*, 36*	1.00

*Disinfectant alone (not plus vessel)

Table 2 – Methodological considerations met by intervention and post-implementation studies of HWT.

		Intervention (N=6)		Post-implementation (N=14)	
	Methodological Considerations Met	n	%	n	%
1	Include an adequate control/comparison group	6	100	2	14
2	Adequate study size	4	67	7	50
3	Multiple communities or groups	6	100	12	86
4	Control of possible confounders	4	67	7	50
5	Include an objective measure of compliance	5	83	11	79
6	Consider seasonality in analysis	4	67	5	36

Results

Literature Search

- 1,419 titles obtained from search on October 30, 2010.
- 162 (11.4%) relevant titles selected.
- 26 (16.0%) abstracts selected.
- 6 articles excluded upon review for not reporting any measure of usage of the intervention.
- 20 articles were included in the final review (Table 1).

Studies Reviewed

- All articles published in the past 12 years.
- Reviewed 14 post-implementation evaluations and 6 intervention trials of one year or longer.
- Selected studies represented 12 countries: Kenya (30%) and Guatemala (15%) the most commonly studied.
- Chlorination was the most represented HWT intervention (25%), followed by combined interventions (20%) involving either: chlorination and flocculant-disinfectant; or boiling, solar disinfection, and chlorination.

Study Quality

- The majority of intervention studies were considered of high quality based on our limited criteria, randomizing to control possible confounders (4/6, 67%), selecting a control group (6/6, 100%), and providing information on power calculation (4/6, 67%) (Table 2).
- Of 14 post-implementation studies reviewed, 12 (86%) lacked an adequate control and comparison group. The effect of seasonality on water management practices was infrequently addressed with the study design (5/14, 36%).

Sustainability

- We still lack quality evidence of a sustained, long-term change in practices as a result of HWT interventions (Figures 1a-e).
- Only one study confirmed practice of boiling and found that the usage was low 6 months after a promotion activity.
- Chlorination interventions represented the majority of the HWT interventions reviewed and demonstrated varying levels of methodological quality and usage with measures at 1 year of intervention age ranging from 11 to 71%.
- Chlorine was generally reported to be widely available. The cost involved still remained a barrier for some intended users, but for others the lower relative cost was a reason to choose this intervention over others. The proportion of users who found the taste and smell disagreeable was often reported in studies but appeared low in general.
- Measured flocculant-disinfectant usage was generally low (<30%), even for younger interventions. Cost and lack of availability were reported as barriers to the use of flocculant-disinfectant. In an emergency situation, users reported that it was easy to use, but under everyday conditions it was reported as burdensome.
- Studies of filtration interventions found some of the higher rates of usage even for older interventions. Authors reported that filters were generally viewed as effective, but, despite ease of use and improved water quality, the time involved was a reason for disuse and that high initial cost might be a barrier. The poor durability of all types of filters was reported along with supply chain difficulties.
- The published evidence for biosand filters indicates high usage, even 5 years after the intervention, but suffers from poorer methodological quality than the other forms of filtration. Recontamination of drinking water after treatment was also reported as a problem.
- The two high quality studies on SODIS interventions observed low levels of confirmed usage but discussed few of the sustainability criteria. Compliance in Bolivia was related to seasonality and cultivation, where despite moderate rates of use, no substantive reduction in diarrhea rates was found.

Discussion

- We found limited evidence of a sustained uptake and usage of HWT interventions.
- While some studies did find evidence of confirmed usage at the time of the study, few studies examined interventions older than one year.
- Results from studies that found high levels of confirmed usage after one year must be considered alongside their methodological quality.

Our review is limited to literature published in English and recorded in the Medline database. Other reviewers reached similar conclusions regarding the sustainability of HWT interventions based on reviews that included gray literature, but they either did not include the quality of the reviewed studies as a factor influencing the evidence itself or considered health impact instead of usage as the outcome of interest (Clasen 2009, Waddington 2009). By evaluating each of the reviewed studies against accepted criteria of methodological quality, this review contributes to the discussion regarding the role of HWT for the sustainable provision of safe drinking water.

There also exists debate in the literature about the evaluation and ranking of HWT options. Based on this review, we conclude that further studies are still needed to explore the acceptability and effectiveness of different HWT interventions (particularly new technologies such as the biosand filter for arsenic removal), under different geographic, cultural, economic, and logistical circumstances. As new research is undertaken, we would recommend that a minimum number of sustainability criteria, such as the 7 included here, be reported by all studies for the purposes of identifying which technologies are best suited to different conditions and users. Furthermore, standard approaches and indicators, particularly for confirming usage (of boiling, for example), should be developed for the comparable evaluation of HWT implementation in order to ensure the collection of quality evidence and develop effective means to increase the sustainability of HWT interventions.