Tropical Medicine and International Health doi:10.1111/j.1365-3156.2012.03082.x

VOLUME 17 NO 11 PP 1361–1368 NOVEMBER 2012

Factors affecting continued use of ceramic water purifiers distributed to tsunami-affected communities in Sri Lanka

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Abstract

OBJECTIVES There is little information about continued use of point-of-use technologies after disaster relief efforts. After the 2004 tsunami, the Red Cross distributed ceramic water filters in Sri Lanka. This study determined factors associated with filter disuse and evaluate the quality of household drinking water.

METHODS A cross-sectional survey of water sources and treatment, filter use and household characteristics was administered by in-person oral interview, and household water quality was tested. Multivariable logistic regression was used to model probability of filter non-use.

RESULTS At the time of survey, 24% of households (107/452) did not use filters; the most common reason given was breakage (42%). The most common household water sources were taps and wells. Wells were used by 45% of filter users and 28% of non-users. Of households with taps, 75% had source water *Escherichia coli* in the lowest World Health Organisation risk category (<1/100 ml), *vs.* only 30% of households reporting wells did. Tap households were approximately four times more likely to discontinue filter use than well households.

CONCLUSION After 2 years, 24% of households were non-users. The main factors were breakage and household water source; households with taps were more likely to stop use than households with wells. Tap water users also had higher-quality source water, suggesting that disuse is not necessarily negative and monitoring of water quality can aid decision-making about continued use. To promote continued use, disaster recovery filter distribution efforts must be joined with capacity building for long-term water monitoring, supply chains and local production.

keywords water, point-of-use, disaster, ceramic filters

Introduction

As more programmes are launched to implement point-of-use (POU) household water treatment in developing nations, there are opportunities to follow different types of programmes over time to determine what influences continued POU use. Follow-up studies to evaluate use patterns and what influences use over time can pinpoint strengths and weaknesses of implementations and improve future programs. Post-implementation evaluations so far have focused largely on programs designed to encourage adoption and long-term daily use by households for whom piped or improved water access is not in the foreseeable future (Brown *et al.* 2009; Liang *et al.* 2010). POU technologies are also being distributed after disasters (Palmer 2005a), where safe water access can be disrupted by infrastructure damage, well flooding and displacement to temporary shelter lacking water and sanitation (Clasen *et al.* 2006; Villholth *et al.* 2008).

Point-of-uses can meet immediate safe water needs after a disaster (Dunston *et al.* 2001; Mong *et al.* 2001; Doocy & Burnham 2006). But people may return home to damaged infrastructure, or the same unsafe sources they used before. Whether introducing POU treatment in this setting results in continued use and safer water is uncertain. Previous evaluations suggest that adoption and use of POUs distributed for disaster relief may differ from other implementation programs (Clasen *et al.* 2006). Although lack of safe water can be a lasting problem post-disaster, there is little information about whether people continue to use POU technologies that they received in a disaster relief effort.

From February 2007 to December 2008, the Red Cross distributed free ceramic water filters (CWFs) in Sri Lanka as part of relief programs after the December 2004 Indian Ocean tsunami. Approximately, 12 000 filters were distributed in the south-western districts of Ampara, Matara, Galle, Kalutara and Gampaha, as described previously (Casanova *et al.* 2012). This study was an independent post-implementation assessment of households that received CWFs during the program, consisting of a cross-sectional survey with water sampling and analysis. Study objectives were to determine household environmental and demographic characteristics associated with filter disuse and evaluate the quality of household drinking water.

Methods

A cross-sectional survey was administered by in-person oral interview; methods have been described in detail (Casanova *et al.* 2012). Study protocols and materials were approved by the UNC Biomedical IRB (#09-1453) and the Ethical Review Committee of the Faculty of Medicine, University of Ruhuna, Sri Lanka. Study communities were in Galle, Kalutara and Matara districts. Inclusion criteria were as follows: family or other household communal unit received a CWP through the implementation program, family or other household communal unit was still living at the same location where they received the filter and willingness to participate. Exclusion criteria were family or other household communal living unit no longer lived at the location where they received the filter, including households that were found to be resettlement villages.

Data were collected from September to December 2009. The target population was 9000 households that received filters; the target sample size was 5% (450 households). Communities were selected by random number generator. Enumerators went from door to door until a sample size of 450 was reached. Study households were visited twice. At visit, 1 informed consent was obtained and water samples were taken. At visit 2, the survey was administered and water samples were taken. Questions validated in previous studies for collecting data on household water use practices and POU use were used (Stauber *et al.* 2009). If a filter was present, the enumerator looked at the filter to determine whether it was being used. In households with filters, enumerators sampled source water and filtered water (if available). Water was also put through the filter to measure the flow rate. In households without filters, water used for drinking was sampled.

A total of 523 households were approached and gave informed consent, and 452 households completed both survey and water sampling. The female in charge of the household (the primary caregiver for the children, responsible for household work and responsible for or knowledgeable about the household water management) gave informed consent and responded on behalf of the household. Surveys were administered by native Sinhala-speaking medical graduate enumerators. Data were collected on water sources, treatment practices, filter use and household and demographic variables using predominantly closed-ended questions. Responses were recorded on paper and entered into EpiInfo.

Data analyses were performed using SAS (v9.2) and GraphPad Prism 5. Multivariable logistic regression modelled filter non-use at time of survey (outcome) and water source (exposure). Covariates were assessed using backwards stepwise elimination procedure and kept in the model based on an *a priori* change of >10% in the coefficient of the exposure.

Results

Self-reported use was ascertained by asking the respondent when the last time was that they used the filter; 71% of households reported having used the filter on the day of survey or the day before, 5% within the last month and 24% more than 1 month ago. Filter use was validated by enumerator observation of the filter itself: whether there was water in the filter storage vessel or filter element and having the respondent demonstrate the filter was working by pouring water through. Water was seen in the filter in 88% of households reporting use yesterday or day before, 41% of households reporting use within the last month, and only 1% of households reporting use more than 1 month ago. The enumerator was able to observe the filter working in 98% reporting use yesterday or day before and 95% reporting use within the last month, *vs.* only 35% reporting use more than 1 month ago. Based on self-report and observation, households were classified as filter users if they reported using the filter within the last month and as filter non-users if they reported last using the filter more than 1 month ago. Using this classification, 24% of households (107/452) were filter non-users at the time of survey.

Demographics of filter user and non-user households were compared, including proxy measures of household wealth (home ownership, household possessions and cooking fuel types), and household sanitation and hygiene. There were no significant differences in these measured household characteristics between filter user and non-user households (Table 1).

Respondents were asked where they obtained water for the household; they could choose more than one option (Table 2). The most frequent response was tap inside or outside the house, or both. Water from piped systems in this area is largely treated surface (river) water. Wells (mostly shallow hand-dug) were also common. About 5%

of households reported using surface water sources. There was no statistically significant relationship between filter use/non-use and surface water ($P = 0.58$). Significantly, more filter user households (45%) reported water from shallow hand-dug wells as a household water source than non-user households (28%) ($P = 0.0016$).

A number of households reported having both taps and wells, although it is not clear whether they have taps attached to private wells or are connected to piped water while also having a private well (Table 3). There was a significant difference between the numbers of filter users and non-users reporting both a tap inside and a well ($P = 0.008$). There was also a significant difference between the numbers of filter users and non-users reporting both a tap outside and a well ($P = 0.05$).

Households were asked if they used any methods of water treatment (Table 4). Ceramic filters, boiling and having tap water that was already treated were the most frequent responses; other methods were rare. While 66%

Table 1 Household demographics and sanitation and hygiene

	Filter users (n = 345)		Filter non-users (n = 107)	
	n	%	*n*	%
Own the home	316	92	101	94
Home has electricity	327	95	99	93
Electricity 24 hrs/day	330	96	100	93
HHs in lowest wealth quintile	56	16	20	19
Child under 5 in HH	90	26	29	27
Cooking method				
Electricity	3	1	2	2
Gas	32	9	15	14
Firewood	308	89	90	84
Sanitation and hygiene				
Shared latrine	7	2	3	3
Private latrine	143	41	38	36
Shared toilet with sewer	5	1	3	3
Private toilet with sewer	190	55	63	59
Soap in home	326	94	102	95
HW inside home	269	78	83	78
HW outside home	75	22	24	22
HW with faucet or tap	211	61	76	71
HW with bucket	76	22	21	20
HW with other device	58	17	10	9

Table 3 Frequency of multiple water sources in households

	Filter users (n = 345)		Filter non-users (n = 107)	
	n	%	*n*	%
Tap inside, no well	58	17	31	29
Tap inside, well*	14	4	7	7
Tap outside, no well	62	18	26	24
Tap outside, well*	14	4	5	5
Tap inside and outside, no well	34	10	16	15
Tap inside and outside, well	10	3	4	4
Well (any type), no tap	150	43	17	16

*Statistically significant difference.

Table 2 Household water sources by filter use status (n = 452)

	Filter users (n = 345)		Filter non-users (n = 107)	
	n	%	*n*	%
Tap inside the house*	72	21	38	36
Tap outside the house*	76	22	31	29
Tap inside and outside*	44	13	20	19
Shallow (hand-dug) well, lined*	156	45	30	28
Shallow (hand-dug) well unlined*	16	5	0	0
Deep (drilled) well	26	8	5	5
Lake or pond	16	5	0	0
River, stream, or canal	0	0	3	3
Rainwater	5	1	2	2
Purchased water	0	0	0	0
Other	3	1	0	0

*Statistically significant difference ($P < 0.05$).

Table 4 Treatment methods comparison of filter users vs. non-users (n = 452)

	Filter users (n = 345)		Filter non-users (n = 107)	
	n	%	*n*	%
Boiling	113	33	40	37
Chlorination with bleach	7	2	0	0
Other chemical	0	0	0	0
Ceramic water filter	345	100	0	0
Biosand filter	0	0	0	0
Other sand/granular medium filter	0	0	0	0
Letting water 'settle' in container	4	1	1	1
Coagulation	0	0	0	0
Tap water is already treated*	85	25	71	66
Do not treat water*	1	0	16	15
Other treatment	1	0	1	1

*Statistically significant difference.

of non-users reported that their tap water was already treated, only 25% of filter users did ($P < 0.0001$). Filter users and non-users reported boiling water in roughly equal proportions (33% of users and 37% of non-users). There was no significant relationship between filter use/non-use and boiling ($P = 0.41$), or between boiling and reporting tap water was already treated ($P = 0.46$).

Non-user households appeared less likely to use any form of water treatment. In response to the question 'How often do you treat your water?' with choices of 'always', 'sometimes' and 'never', only 22% of non-users reported that they 'always' treated their water; 59% of non-users reported that they 'never' treated their water and 19% reported 'sometimes'. In contrast, 64% of filter users reported that they 'always' treated their water. There was a significant difference in the reported frequency of treating water ('always', 'sometimes' or 'never') between households that reported boiling and households that did not ($P < 0.0001$). Of 63 non-user households that reported 'never' treating water, 60 reported that they did not boil water, suggesting that households do consider boiling a form of treatment. The results do not indicate that households that were not using the filter were substituting other forms of treatment. Of the non-user households that treated water, 32 of 41 reported that they used treated water for drinking only; this was similar to what was reported by user households. Other uses of treated water were rare.

Initial use of the filter was high; 97% (104/107) of households that were non-users at the time of survey reported that they used the filter after receiving it. Time in use for filters was estimated based on distribution date (for users) or distribution date and user recall of the date use was stopped (for non-users) (Figure 1). Of 92 non-user households for which the respondent could estimate the date they stopped using the filter, 13% used the filter for <3 months, 14% between 3 and 6 months, 51% between 6 months and 1 year and 23% between 1 and 2 years.

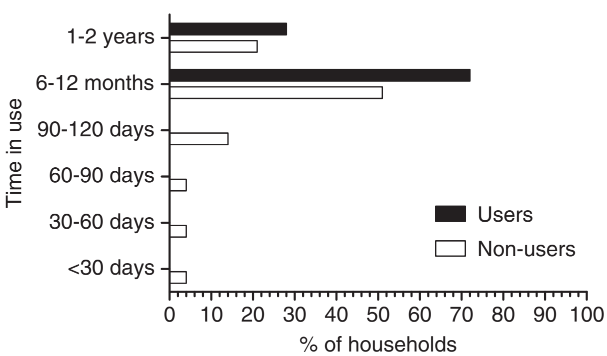

Figure 1 Ceramic filter time in use ($n = 421$).

Non-user households were asked about reasons for stopping use. For a multi-option question about why they stopped using the filter, the most frequently selected reason was breakage (42%) (Figure 2). Only 5% of non-user households selected 'found a better or more trusted source of water'. Although these households indicated that the new source was tap water, the small number choosing this option suggests there was not much post-distribution change to better or more trusted alternative water sources. Only 12 non-user households reported that they tried to get a new filter at some point. Most non-users who reported that their filter broke and they had not replaced it indicated that they could not find a new filter or did not want one (Figure 3).

Escherichia coli in source water from in user and non-user households was compared (Figure 4). In both user and non-user households, there was significantly more *E. coli* in source water from households with wells than households with taps ($P < 0.0001$). More non-users reported taps as the household water source than users, while wells were more common among filter users. Most households reporting taps had high-quality source water; 75% had source water in the lowest World Health Organisation (WHO) risk category for *E. coli* (<1/100 ml). In households reporting taps as the main water source, there was a significant difference in source water *E. coli* between users (mean 0.27 $\log_{10}$ MPN/100 ml) and non-users (mean 0.084 $\log_{10}$ MPN/100 ml) ($P = 0.006$). Only about 30% of households reporting wells as the household water source had source water in the lowest WHO risk category for *E. coli*. In well households, there was no significant difference in source water *E. coli* levels between filter user and non-user households ($P = 0.40$).

Several demographic and environmental variables were examined for associations with filter non-use at time of follow-up using stratified analysis and a Mantel–Haenzel (MH) test for homogeneity of effect. Because >40% of non-users reported filter breakage, bivariate analyses were conducted with and without households that reported breakage (Figure 5). Based on bivariate analyses, a logistic regression model with filter non-use at time of survey as the outcome of interest and household water source (tap, well or tap and well) as the main exposure was constructed, with well water as the referent group. Potential covariates were assessed for confounding during model formulation, and a backwards stepwise elimination process was used based on *a priori* 10% change in effect criterion. Variables for water perceived as dirty, water perceived as not safe, household was told to treat water, members of the household always drink treated water and time in use in

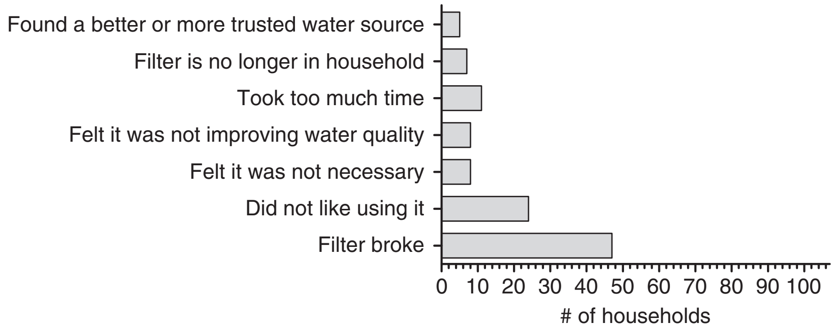

Figure 2 Reasons for stopping filter use (n = 107).

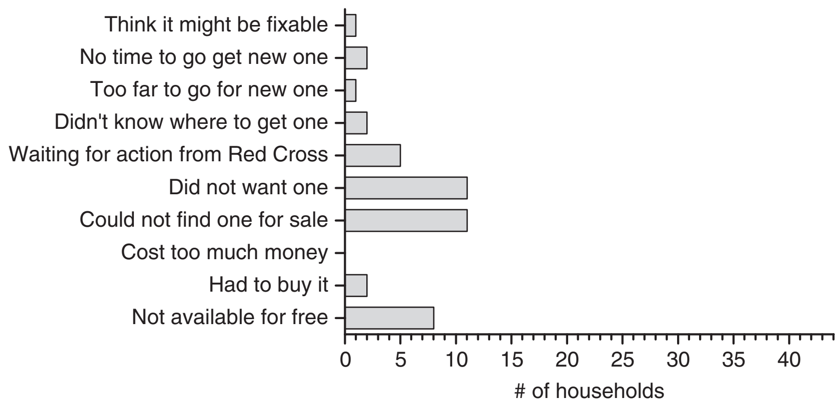

Figure 3 Reasons for not obtaining replacement filter in non-user households reporting filter breakage (n = 47).

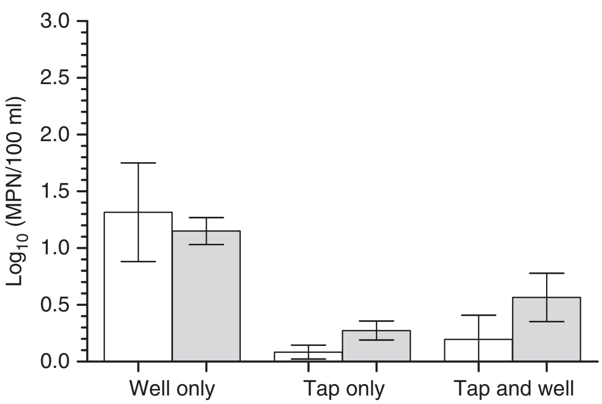

Figure 4 *Escherichia coli* in households source water in filter user and non-user households (white = non-users, grey = filter users; bars = 95% CI).

6-month blocks were included in the model. Odds ratios for filter disuse are shown in Table 5. Households that reported taps (inside or outside) as their household water source were approximately four times more likely to discontinue filter use than households that reported well water, even when households whose filters broke were excluded from the analysis. Households that reported both a tap and well as the main water source were also four to five times more likely to likely to discontinue filter use than households that reported only well water as their household water source.

Discussion

Two years after a ceramic filter distribution to tsunami-affected communities, 24% of households were non-users (not used the filter within the past month). Most were initial users who discontinued. The main factors influencing discontinuation were filter breakage and household water source; households with tap water were more likely to discontinue use than households with well water.

The most common water sources were taps or wells; some reported both. There was a significant relationship between non-use and household water source, having *E. coli* in water, perceiving water as dirty, perceiving water as unsafe, reporting treating water because they were told to and reporting that members of the household always drank treated water. Households reporting taps as the main water source were more likely to discontinue filter use than households reporting well water. This may continue a

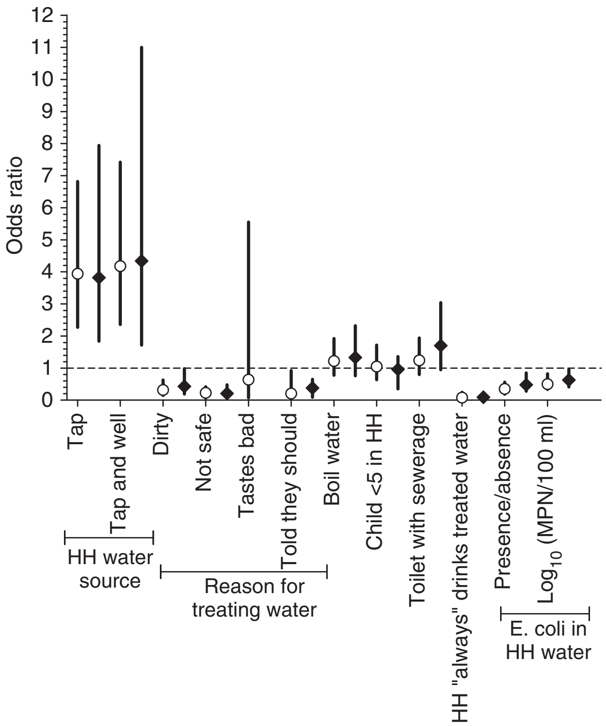

Figure 5 Bivariate associations between household variables and filter disuse (circles = households with broken filters included; diamonds = households with broken filters excluded; bars = 95% CI).

Table 5 Odds ratios from logistic regression models of the relationship between filter disuse and household water source

	OR	95% CI
Breakage included (n = 446)		
Well (referent group)	1	–
Tap	4.5	2.1–9.3
Tap and well	4.8	1.7–13.5
Breakage excluded (n = 400)		
Well (referent group)	1	–
Tap	3.9	1.6–9.3
Tap and well	5.3	1.7–17.1

trend: 6 months post-tsunami, the Red Cross distributed filters to households in a southern coastal area (they were not part of this study). In a follow-up evaluation, having well water was a significant predictor of continued filter use (Palmer & Shirlaw 2005b). Households with wells may perceive their water as poor quality and in need of treatment, but no significant differences were found between tap and well water in turbidity, a visual indicator of water quality. Although taps increased the odds of disuse, tap source water also had fewer *E. coli* and was more likely to fall into the WHO lowest risk category for drinking water than well water. In disaster recovery, where households may transition to better quality sources over time, discontinuing POU use may not be a negative outcome if the sources available are of good microbiological quality.

The results differ from CWF post-implementation studies in Cambodia, where wells were associated with disuse (Brown & Sobsey 2007). In Cambodia, wells are mainly deep groundwater and the alternative is often highly contaminated surface water. In Sri Lanka, shallow hand-dug wells are the most common wells, and well water had more *E. coli* than tap water. The two settings may demonstrate similar trends, with access to the drinking water source perceived as safer (taps in Sri Lanka, deep wells in Cambodia) associated with filter disuse.

Filtering was more common among user households than any form of treatment was among non-user households. Households that discontinue filter use do not appear to be appreciably substituting other treatment methods. Boiling, the most common method of POU treatment worldwide (Clasen *et al.* 2008), is common in the study population (37% of non-users). Households do not seem to substitute boiling for other treatment; roughly equal proportions of filter and non-filter households boiled, regardless of water source. Boiling appears to be a common practice alongside POU treatment or piped water access; this echoes findings that one-third of Cambodian filter users boiled their water (Brown & Sobsey 2010).

Of households that could recall when they stopped use, more than 50% had used it for longer than 1 year. Breakage was the most frequently cited reason, usually during cleaning and from being knocked over. Few households reported replacing, fixing or purchasing parts for the filter. Responses suggest this is owing to lack of availability rather than unwillingness to purchase; most respondents indicated willingness to pay for a new filter. Continued use could be higher if replacements were available; households reported wanting a replacement, but not knowing where to obtain one. Many unused filters were still present in the household, representing potential opportunities for repair.

At survey, filters had been in use from 6 months to longer than 2 years. In a study of a ceramic candle filter disaster response in the Dominican Republic, 16 months later 88% of households still had filters, but only 48% were working. As in this study, breakage was a major factor (candle filters have smaller, thinner filter elements) (Clasen & Boisson 2006). A post-implementation assessment of ceramic filter distribution programs in Cambodia observed a rate of decline in usage of approximately 2% per month, largely due to breakage. The odds of continued use decreased by about 44% every 6 months (Brown *et al.* 2009). The data from this survey compare favourably, with a 25% decline in use over 1–2 years.

There are still few data on whether post-disaster distribution of POUs facilitates long-term adoption. Immediate post-tsunami assessments suggest that people resettling were more likely to adopt filters than people who received them while living in temporary emergency shelter (Palmer 2005a; Palmer & Shirlaw 2005b). Targeting populations for POU distribution as they resettle after a disaster may fill a need for safe water, but may not result in habitual long-term use. This population demonstrated disuse over time, associated with water sources and perceptions of drinking water. It has been observed that 'although the circumstances and raised risk perceptions which result from a natural disaster may be sufficient to trigger initial or short-term behaviour change, these do not seem to be sustained and people may no longer feel the need to treat their water if there are not any visual or sensory cues to suggest that it is unsafe or unpalatable' (Clasen *et al.* 2006). In this study, responses and turbidity analysis did not suggest visual cues influenced user perception of water quality or filter use. This is not necessarily negative; disuse was associated with water sources that were of better quality, although households did not have this information in their decision-making about filter use. The trends were towards filter use with poorer quality water and non-use with better quality water, but not because households have access to water quality information. Following implementation programs with water quality monitoring and information to households may aid their decision-making about POU use, ensuring that households most at risk continue to use treatment.

The study was subject to several limitations. Questions about source water were not designed to determine whether households with both well and tap water had separate sources or taps connected to wells. Responses were self-reported. Filter time in use was based on user recall; there is no way to verify when exactly use was stopped. It was also a cross-sectional survey, meaning that certain useful types of longitudinal data could not be collected, such as the rate of decline in use over time.

This study provides some of the first evidence about long-term use of ceramic pot filters distributed as part of disaster recovery efforts. Recovery campaigns may present opportunities to facilitate adoption of CWFs among users who are not connected to piped water supplies as part of rebuilding. Users of CWFs in tsunami-affected Sri Lankan communities were satisfied with their filters and perceived their water as needing treatment. Those using well water, which was of poorer quality than tap water, are potentially a population of long-term CWF users. Although tap water users were more likely to discontinue filter use, they also had higher-quality source water, so in this particular context, disuse is not necessarily negative. It does suggest that in follow-up of filter implementations continued monitoring of household water quality is important.

The local manufacturing capacity to keep these communities supplied with filters needs to be created and maintained, ideally with monitoring to help households decide if continued filter use is an optimal use of household resources. The useful life of a filter depends partly on frequency of cleaning (which thins the walls) and clogging of deep pores that slows flow rate. As seen in other settings, breakage is crucial. Although a filter could theoretically last years, replacement every 1–2 years has been suggested (Brown & Sobsey 2007). If filters are distributed in a one-off model, households that were satisfied with filters may give up if replacements are not available. In the absence of a local market in POU technologies, or robust organisations that provide POUs, there may be few options once a filter breaks. The lessons from this study about the need for continued monitoring and continued replacement supply chains are universal, applicable to many countries and many disaster situations. Disaster recovery filter distributions must be joined with long-term commitment to building capacity for water monitoring, supply chains and local production capacity to ensure long-term safe water.

Acknowledgements

The authors thank study participants from Galle, Matara and Kalutara, Sri Lanka. Without their time and patience, this study would not have been possible. We thank our interviewers and laboratory staff. We are grateful to the American and Sri Lankan Red Cross for financial support and use of their facilities. Thanks to Douglas Wait and the UNC Environmental Microbiology laboratory for assistance establishing lab capacity in Sri Lanka, and Dr. Christine Stauber for assistance with survey and database design.

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