Water treatment in rural Guatemala: factors associated with the use of biosand water filters

Chi-Fang Wu, Lissette M. Piedra, Lenore E. Matthew, Emily C. Rhodes and Thanh H. Nguyen

ABSTRACT

Point-of-use water filters are a means to provide clean water vital to the health of people in developing countries. The factors that influence the adoption of this technology include hygiene knowledge, health beliefs related to the use of new technology, and technical issues with using the filter (e.g., water taste and breakage). This study examines how people in Mayan communities in rural Guatemala perceived biosand filters they had received and what factors related to their filter use. Based on the survey and interviewer observations, approximately 53% were regular filter users, 28% were irregular filter users, and 19.4% were non-filter users. The observational data revealed that actual filter use is lower than self-reported use, reflecting complexities in the adoption of technology. One such complexity can be seen in the connection between health beliefs and behavior. The belief that believing drinking filtered water is salubrious does not necessarily coincide with filter use, but education and hygienic practices correlated with regular filter use. Furthermore, regular users typically depend on family members for a daily reminder to use the filter, suggesting that education should foster peer support as well as imparting knowledge.

Key words | biosand filter, Guatemala, point of use, regular filter users, water filters, water treatment

INTRODUCTION

The World Health Organization (2019) has prioritized access to clean drinking water as a way to prevent serious health problems in developing countries (Montgomery & Elimelech 2007). Biosand filters stand out among point-of-use (POU) water treatment technologies as effective, inexpensive, and easy to use (Sobsey et al. 2008; Stauber et al. 2012). However, some challenges threaten the consistent use of such filters and other water treatment technologies (Brown et al. 2009; Casanova et al. 2012; Inauen et al. 2013). Beyond unclean drinking water, unsuccessful efforts to promote water treatment technologies in impoverished communities can lead to a general distrust of high-tech solutions and misgivings about local leaders who supported the intervention (Rohloff et al. 2011). This paper uses survey and observational data to explore how Mayans in rural Guatemala perceived biosand filters they received and what factors coincided with consistent use.

WATER FILTER PROJECT IN GUATEMALA

The Guatemalan non-governmental organization Wuqu’ Kawoq (WK) provides health and educational services in several rural Mayan communities. Since 2012, they have...
collaborated with Engineers Without Borders (EWB) at the University of Illinois Urbana-Champaign (UIUC) to design an in-home potable water system for remote regions of Guatemala that would use local materials (Bradley et al. 2014). Over several years, EWB helped WK build, install, and maintain biosand filters that were placed in every home in targeted communities. However, when EWB observed uneven patterns of use, they invited faculty from the UIUC School of Social Work to investigate why.

EWB and WK team members had observed a few features that influence the regular use of the filters, which we used as a starting point in our literature review. We found that their observations aligned with three insights acknowledged in the literature. First, social norms around good hygienic practices and social pressures to enact those behaviors can also influence filter use (Do et al. 2014; Williams et al. 2015). Second, people benefit from having information on how the use of water technologies can improve their health (Ojomo et al. 2015; Williams et al. 2015; Clasen & Boisson 2016). Third, people like things to work; they are unlikely to use filters that are cumbersome, prone to breakage, or that suffer from design flaws (De Ver Dye et al. 2011; Tobias & Berg 2011). The following sections explore these insights.

LITERATURE REVIEW

Hygienic practices and social supports

When organizations that provide POU technology provide instruction on the importance of good hygiene and the health benefits of using filters, recipients are more likely to use the technology (Ojomo et al. 2015; Clasen & Boisson 2016). Ongoing contact with community health educators also supports the use of water treatment products (Wood et al. 2012; Williams et al. 2015). In an earlier study, we documented how the WK community workers helped the social work and engineering team recognize that people were suspicious of water testing procedures the engineers used to ascertain that the filters were working properly. To address this, EWB created a visual display with before and after pictures showing water with and without pathogens (see Figure 1; Matthew et al. 2017).

Social reinforcement of health norms influences water filter use. Health perceptions and social context promote the use of household water treatment technologies (Brown et al. 2009; Freeman et al. 2012; Wood et al. 2012; Francis et al. 2015). Wood et al. (2012) found that social support from relatives, friends, neighbors, healthcare workers, spouses, and children promoted the use of water treatment.

Figure 1 | Bacteria testing results from before treatment in the biosand filter (left) and after treatment (right). Note: This figure was originally published in Matthew et al. (2017).
Francis et al. (2015) found that support from male members of the household increased the use of high-throughput membrane filters. Freeman et al. (2012) found that women in rural India who participated in a self-help group increased their use of mineral-based water filters. These findings underscore the importance of household and community members in promoting water filter use.

Health beliefs

Attribution theory posits that beliefs influence actions when people believe that an outcome (e.g., consuming clean water) is worthwhile and that they can implement behaviors that will produce that result (e.g., use a biofilter daily), these beliefs influence their actions (Weiner 1985). Some studies illuminate this connection. Inauen et al. (2013) found that among a sample of Bangladeshis, lower scores of self-efficacy and commitment to collect safe water correlated with the lower use of available filters, including biosand filters. Similarly, in Chad, perceived self-efficacy predicted the adoption of water treatment technology, including biosand filters (Lilje et al. 2015). In rural southern India, researchers found belief that water filters produced health benefits promoted the use of available high-throughput membrane filters over time (Francis et al. 2015).

Workable technologies

Ease of use and perception play a key role as people in developing countries adopt new technologies (Tobias & Berg 2011; Casanova et al. 2012; Wheeler & Agha 2013; Ojomo et al. 2015). For example, in a study involving biosand filters in Vietnam, Tobias & Berg (2011) found low use among people who perceived them as inflexible and difficult to maintain. Conversely, a perceptible improvement in the quality of the water increases the use of filters. Ojomo et al. (2015) found that villagers in Tanzania used biosand filters because they clarified turbid water. In a study of a community filter in rural Ethiopia, Huber & Mosler (2013) found that improved taste promoted use. EWB and WK had observed that showing people before and after pictures of pathogen removal in filtered water seemed to boost use (Matthew et al. 2017; Piedra et al. 2020).

Maintenance issues, especially difficulty in securing replacement parts, contribute to disuse and even total abandonment of the water treatment technology (Brown et al. 2009; De Ver Dye et al. 2011). Brown et al. (2009) found this pattern with users of ceramic filters in rural Cambodia. De Ver Dye et al. (2011) found that slow water flow and breakage discouraged use among rural Kenyan users of carbon water filters. Problems other than the monetary cost of repairs seem to affect use more. While Wood et al. (2012) found that free maintenance promoted the sustained use of a chlorine-based technology in Malawi, other investigators addressing varying types of technology have found that people willing to pay for clean water are more likely to continue using the technology – if they know where to obtain replacement filters (Brown et al. 2009; Clasen & Boisson 2016).

The source of the water, which varies in the WK-served area, also affects use. A study in Ghana found that whereas 69% who got their water from dugouts continued the use of ceramic filters, the percentages were 55%, 52%, and 33% for those who rely on rain, dug wells, and public standpipes, respectively (Clopeck 2009). In Bangladesh, well-users were less likely to use their biosand filters than users of piped water or deep tube wells (Inauen et al. 2013). Similarly, in Chad, 95% of those who get their water from a well do not use any of the widely available, varying types of water filters (Lilje et al. 2015).

In summary, the literature converges with our field observations; our survey gathered data on these factors. We sought to examine how hygiene practices and social supports, health beliefs, and workable technologies might influence the regular use of filters.

METHODS

Survey construction

The survey construction process was iterative and collaborative between the UIUC team and the WK, including the discussion of linguistic and cultural issues. The survey was written in English, translated into Spanish, and then modified according to WK staff recommendations. We then
piloted the survey in five households that had received filters, which led to the clarification of unclear questions and the elimination of awkward phrasing. After all the changes were incorporated, the survey was translated back into English (Brislin 1970). The final survey included 53 questions over five domains: (1) knowledge of and supports for hygienic practices, (2) filter use and water consumption, (3) filter maintenance, (4) water filter implementation, and (5) filter providers.

Sample and procedures

Three WK community health workers administered the water use survey during home visits between March and August 2014. The participants were heads of households, 18 years or older, who had received a filter from WK, who were home at the time of the visit (we did not document how many were unavailable). This created a convenience sample of 93 indigenous Mayan households (see Table 1 for the sample characteristics). Since most community members have low levels of literacy, WK workers read an oral script introducing the study and asked the identified heads of household if they wanted to participate, indicating they had no obligation, could stop at any time during the survey’s administration, and could skip any question they liked. All agreed to participate. Participants, as well as the WK workers, live in Socorro, Paya, San Juan, Las Guardenias, Pacoco, El Hato, or Chichoy (see Figure 2 for the locations of these communities). All WK workers are native Spanish speakers, and all questions and disclosures were given in Spanish.

Questions were read aloud, and participants responded aloud. Each survey was assigned a number; no identifying information was collected. The institutional review boards of UIUC and WK approved the study.

Measures

Table 2 shows measures of key variables.

Water filter use

Interviewers asked whether the respondents use their filters and asked those who said ‘yes’ how sure they were they used filters ‘all the time’ (very sure, sure, a little unsure, or very unsure). Because preliminary fieldwork suggested that reports of usage might not be reliable (Matthew et al. 2017; Piedra et al. 2020), the interviewers examined the filters for signs of use (e.g., a clean filter with damp filtration sand indicates frequent and consistent use).

We defined ‘regular filter users’ as those who reported using the filters, answered ‘very sure’ or ‘sure’, and had a filter that showed signs of frequent use. ‘Irregular filter users’ did not meet at least one of these criteria. ‘Non-filter users’ (1) self-reported that they did not use their filters and/or (2) had filters that appeared unused.

Knowledge of and supports for hygiene practices

Answers to six questions measured knowledge of and supports for hygiene practices: (1) receiving education information on
hygiene, (2) having a container with a cover to store filtered water, (3) participants’ container cleaning cycle (daily/weekly/every few days/when I remember), (4) who reminded them to use the filter, (5) what they used filtered water for, and (6) household’s main source of drinking water.

Health beliefs

Three questions measured health beliefs: (1) does drinking filtered water help you stay healthy (1 = yes, 0 = no); (2) does drinking unfiltered water made you sick; (3) reasons for not using the filters – feeling tired, feeling sad, feeling overwhelmed, and feeling worried about other things in life.

Technical factors

Respondents were asked if they had experienced a problem with their water filters (multiple choices: bad smell, bad
taste, broken leaks/cracks, diminished water flow, insect infestation; yes = 1 for each, 0 otherwise). Based on this, the respondents were coded as having had a problem or never had a problem. The second question concerned whether anyone had come to their homes to answer questions on use, maintenance, and problems with filters.

**Data analysis**

Descriptive statistics (frequency distributions and means) were used to assess the use of water filters and to understand perceptions of and barriers to the adoption of the filters. Bivariate analyses (chi-square test) were conducted to examine what factors vary by the category of filter users.

**RESULTS**

**Water filter use**

As expected, we found inconsistencies between self-reports and the observational data, as shown in Table 3. Over 82.8% (N = 77) said they used their filters all the time, while only 3.2% said they never used their filters. However, observational data showed that only 62.4% (N = 58) of the respondents used filters consistently. Regular, irregular, and non-filter users represented 52.7% (N = 49), 28.0% (N = 26), and 19.4% (N = 18) of the 93 participants, respectively. Three people reported nonuse but an additional 15 had filters that appeared unused. Among irregular users, 17 were classified as such because they did not meet our criteria for consistent use.
Eighty-three respondents (89.2%) indicated that their filters were installed between 2008 and 2013, generally between 2009 and 2012.

Factors associated with water filter use

Knowledge of hygienic and support for practices

Table 4 illustrates the results of the chi-square tests that compared the hygiene knowledge and support for the use of filtered water for each user type (six questions). Overall, 34.4% of the study sample said that they did not receive training on hygienic water practices. More than three quarters (77.6%) of regular users reported having received this education but only 53.8% of irregular users and 50.0% of nonusers did ($\chi^2 [1, N = 93] = 6.63, p = 0.036$).

All regular users had a container to store filtered water, while 96.2% ($N = 25$) of irregular users and 88.9% ($N = 16$) of nonusers had one ($\chi^2 [1, N = 93] = 5.25, p = 0.072$). Although these differences are marginally significant, they are worth reporting because all participating households received a container when WK installed their filters.

Consistent access to clean water requires maintaining the filter. As expected, regular filter users were more likely to clean their containers daily (62.5%) than irregular users (34.6%) and nonusers (50%) ($\chi^2 [1, N = 93] = 23.03, p = 0.001$). Half of irregular users reported cleaning their containers only when they remembered.

Most regular users relied on family members (85.7%) for a daily reminder to use the filter, while a minority of irregular users (38.5%) relied on family instead of outsiders such as social workers or healthcare workers ($\chi^2 [1, N = 93] = 18.31, p < 0.001$). These results align with our field observations as to the importance of family members in the sustained use of filters (Piedra et al. 2020).

Among regular users, 89.8% used filtered water for cooking, compared to 68% of irregular users ($\chi^2 [1, N = 93] = 5.96, p = 0.051$). Regular users were also more likely to use filtered water (55.1%) for handwashing than irregular users (20.0%) and nonusers (38.9%) ($\chi^2 [1, N = 93] = 8.47, p = 0.015$).

Finally, access to a convenient water source makes a difference. No significant pattern emerged among the majority who obtained their water from a tap/sink source. However, as the water became more inconvenient, we found an opposite pattern. Those who obtained their water from a river source (28.0% of participants) included half of the nonusers, 26.9% of irregular users, and 20.4% of regular users ($\chi^2 [1, N = 93] = 5.74, p = 0.57$). The 66.7% of participants used a groundwater/well source included 83.3% of nonusers, 69.2% of irregular users, and 59.2% of regular users.

Beliefs and emotions

As shown in Table 5, health beliefs did not differ significantly among the categories of users; nearly all agreed

| Variables | % |
|-----------|---|
| Filter use (self-reported) | |
| Yes | 96.8 |
| No | 3.2 |
| How sure they were used filters? (self-reported) | |
| Very unsure | 2.2 |
| A little unsure | 1.1 |
| Sure | 6.5 |
| Very sure | 82.8 |
| Missing | 7.6 |
| Does the filter look like it is being used constantly? (interviewer observed) | |
| Yes | 37.6 |
| No | 62.4 |
| Water filter users | |
| Regular users | 52.7 |
| Irregular users | 28.0 |
| Nonusers | 19.4 |
| Year filter installed | |
| 2008 | 7.5 |
| 2009 | 24.7 |
| 2010 | 12.9 |
| 2011 | 20.4 |
| 2012 | 20.4 |
| 2013 | 3.3 |
| Missing | 10.8 |
that drinking filtered water helps them stay healthy and drinking water from other sources could make them sick. However, irregular users were more likely to reference sadness (15.8%) than regular users (2.3%) or nonusers (0) ($\chi^2 [1, N = 93] = 5.87, p = 0.053$). Nonusers were more likely to express fatigue (33.3%) and feeling overwhelmed (26.7%) than irregular and regular users. However, we found no statistical difference in negative emotion reported by the use level.

### Table 4 | Knowledge and support for hygienic practices by the category of filter users

|                                      | All ($N = 93$) | Regular users ($N = 49$) | Irregular users ($N = 26$) | Nonusers ($N = 18$) | Chi-square | p-value |
|--------------------------------------|----------------|--------------------------|----------------------------|---------------------|------------|---------|
| Is your family receiving education on hygiene? | Yes 65.6% | 77.6% | 53.8% | 50.0% | 6.633 | 0.036 |
|                                      | No 34.4%   | 22.4% | 46.2% | 50.0% |            |         |
| Do you have a container to store filtered water? | Yes 96.8% | 100.0% | 96.2% | 88.9% | 5.251 | 0.072 |
|                                      | No 3.2%    | 0.0%  | 3.8%  | 11.1% |            |         |
| How often do you clean your water containers per week? | Every day 52.2% | 62.5% | 34.6% | 50.0% | 23.033 | 0.001 |
|                                      | Every week 16.3% | 16.7% | 7.7%  | 27.8% |            |         |
|                                      | Every few days 9.8% | 14.6% | 7.7%  | 0.0%  |            |         |
|                                      | When I remember 21.7% | 6.3%  | 50.0% | 22.2% |            |         |
| Who makes sure your family uses the filter every day? | Outsiders 33.3% | 14.3% | 61.5% | 44.4% | 18.308 | <0.001 |
|                                      | Family members 66.7% | 85.7% | 38.5% | 55.6% |            |         |
| What do you use the filtered water for? | Drinking (yes) 98.9% | 100.0% | 100.0% | 94.4% | 4.156 | 0.125 |
|                                      | Cooking (yes) 80.4% | 89.8% | 68.0% | 72.2% | 5.956 | 0.051 |
|                                      | Washing hands (yes) 42.4% | 55.1% | 20.0% | 38.9% | 8.465 | 0.015 |
|                                      | Washing utensils (yes) 23.9% | 28.6% | 12.0% | 27.8% | 2.682 | 0.262 |
| What is the main source of drinking water for members of your household? | Tap/sink (yes) 80.6% | 85.7% | 76.9% | 72.2% | 1.856 | 0.395 |
| (multiple choices)                    | River water (yes) 28.0% | 20.4% | 26.9% | 50.0% | 5.743 | 0.057 |
|                                      | Surface water (yes) 5.4% | 8.2%  | 3.8%  | 0.0%  | 1.890 | 0.389 |
|                                      | Ground water/well (yes) 66.7% | 59.2% | 69.2% | 83.3% | 3.562 | 0.169 |
|                                      | Rainwater (yes) 15.1% | 14.3% | 15.4% | 16.7% | 0.061 | 0.970 |

### Technical factors

Table 6 indicates that the majority experienced several problems related to their filters, including leaks/cracks, diminished water flow, and pest infestation. They also described problems with filtered water (a foul odor and/or poor taste). Some participants indicated more than one problem. Irregular users experienced slightly more problems than regular users, although these differences were
not statistically significant, except with respect to pests. Regular users were less likely to report pests/insects than irregular or nonusers ($\chi^2 [1, N = 93] = 5.45, p = 0.066$, marginally statistically significant). Regular users were more likely to report no filter problems than irregular users and nonusers ($\chi^2 [1, N = 93] = 5.03, p = 0.081$, marginally statistically significant). The lack of variance may reflect EWB and WK’s follow-up; most reported that someone had come to their home to answer questions. More regular users and nonusers reported having had someone come to their home than irregular users ($\chi^2 [1, N = 93] = 7.21, p = 0.027$).

We further examined the association between experiencing multiple problems identified with the filters and disuse.
Results from the chi-square analysis indicate that experiencing multiple problems is marginally significantly related to disuse ($\chi^2 [1, N = 93] = 7.78, p = 0.09$). Specifically, 13 out of 18 nonusers reported experiencing multiple problems.

**DISCUSSION**

When used consistently, biofilters promote health through the consumption of clean water, and current technologies are not expensive. However, achieving consistent use may not be straightforward. In our study, 53% were regular filter users, 28% were irregular filter users, and 19.4% were non-filter users. We sought to understand what distinguished biosand filter recipients who used their filter consistently from those who used it irregularly or not at all. Although the majority of participants self-identified as regular users, observational data revealed that actual filter use is lower than self-reported use, reflecting complexities in the adoption of technology.

One such complexity can be seen in the connection between health beliefs and behavior. While most respondents agreed that drinking filtered water is salubrious, holding this belief did not necessarily coincide with filter use. This result is unsurprising given past research on the discrepancies between beliefs and actions (Tversky & Kahneman 1974; Kahneman 2003, 2011; Lilje et al. 2015). Having the right health beliefs may be necessary but insufficient for consistent and correct use; people may need additional support before new behaviors become habits (Duhigg 2012; Clear 2018). For example, participants receiving education on the benefits of proper hygiene were more likely to use their filter consistently. Formal instruction helps people initiate the correct behaviors. Other aids that facilitated regular use included a follow-up home visit by a team member to answer questions on operating the filter. Our study suggests that educational programs promote the uptake of water treatment technology by demystifying operational processes and clarifying expectations (Wood et al. 2012; Williams et al. 2015).

Community and family members can also reinforce filter use. Regular users in our study depend on family members for a daily reminder to use the filter, while irregular users relied more on outsiders such as social workers or healthcare workers. These findings align with other studies, showing that peer and family support encourages filter use (Freeman et al. 2012; Francis et al. 2015). They also support our field observations identifying the importance of family members in sustained filter use and the fact that the consistency of use seems to be connected to the formation of identity as a filter user, reinforced within a broad network of like-minded people, ideally family members through daily interactions (Piedra et al. 2020). This confirmation suggests that educational approaches need to do more than inform. Implementation strategies that create identity and encourage peer support may prove more effective than those that solely depend on external instruction.

Nonetheless, our findings suggest that the information gained through existing educational programs may be pivotal. Regular users in our study were more likely than irregular and nonusers to use filtered water for cooking and handwashing. They were also more likely to clean their filter frequently and use a designated container to store filtered water than those with more erratic use patterns. These behaviors align with information in outreach education efforts. They also support previous studies showing concern with hygiene correlates with the regular filter use (Ojomo et al. 2015; Clasen & Boisson 2016).

This study has several limitations. First, due to the limitations of our sample, our findings are not generalizable. Second, our cross-sectional design means we only know what the participants reported and WK workers observed at a specific point in time. Usage likely varies over time because environmental pressures affect filter maintenance. In addition, the relatively small sample size constrained our use of bivariate analyses and did not allow us to control for other variables that might have an impact on use.

Our measures of health beliefs and emotions were subjective as well. We cannot disentangle the role of emotions and use. Irregular users may be particularly isolated from supportive others, reacting to a debilitating mental health condition (e.g., major depression), or experiencing an acute crisis that undermined the formation of new habits related to filter use. More research should examine how psychological support might affect water filter usage.

Finally, while we relied on self-report data from the surveys and observational data from the community workers, neither source allowed us to consider social contexts and
relationships that may shape people’s experiences with the water technology and influence their use. Moreover, because the organization that provided the filters administered the survey, results may be biased. Given cultural norms of politeness, participants and workers may have motives to please each other and satisfy the host organization.

CONCLUSION

Our findings provide some insights that might help inform future efforts to promote the use of water treatment technologies. We show the importance of recognizing distinctions between different categories of users. Whenever possible, subjective measures should be coupled with objective data, as we did in distinguishing regular-, irregular-, and non-filter users. The intersections of these types with other factors have practical implications for future projects like the one studied here.

Our findings suggest that educational efforts need to move beyond the mere transmittal of knowledge, person by person. Rather, such efforts should foster the formation of community groups that will reinforce learned behaviors through supportive norms shared by their members, contributing to the health of all.

ACKNOWLEDGEMENTS

This study received financial support from the University of Illinois at Urbana-Champaign Campus Research Board Grant, awarded to Chi-Fang Wu, Lissette M. Piedra and Thanh H. Nguyen. Moreover, Dr. Nguyen received support from the National Science Foundation International Research Experience for Students (NSF-IRES # 1559530).

REFERENCES

Bradley, I., Straub, A., Maraccini, P., Markazi, S. & Nguyen, T. H. 2011 Iron oxide amended biosand filters for virus removal. *Water Research* 45 (15), 4501–4510. https://doi.org/10.1016/j.watres.2011.05.045.

Brislin, R. W. 1970 Back-translation for cross-cultural research. *Journal of Cross-Cultural Psychology* 1 (5), 185–216. https://doi.org/10.1177/1559104570000100301.

Brown, J., Proum, S. & Sobsey, M. D. 2009 Sustained use of a household-scale water filtration device in rural Cambodia. *Journal of Water and Health* 7 (3), 404–412. https://doi.org/10.2166/wh.2009.085.

Casanova, L. M., Walters, A., Naghawatte, A. & Sobsey, M. D. 2012 Factors affecting continued use of ceramic water purifiers distributed to tsunami-affected communities in Sri Lanka. *Tropical Medicine & International Health* 17 (11), 1361–1368. https://doi.org/10.1111/j.1365-3156.2012.03082.x.

Clasen, T. & Boisson, S. 2016 Assessing the health impact of water quality interventions in low-income settings: concerns associated with blinded trials and the need for objective outcomes. *Environmental Health Perspectives* 124 (7), 886–889. https://doi.org/10.1289/ehp.1510532.

Clear, J. 2018 *Atomic Habits: An Easy & Proven Way to Build Good Habits & Break Bad Ones*. Penguin Random House, New York.

Clopeck, K. L. 2009 *Monitoring and Evaluation of Household Water Treatment and Safe Storage Technologies: The Sustained Use of the KOSIM Ceramic Water Filter in Northern Region Ghana*. Master’s Thesis, Retrieved from MIT Libraries. http://dspace.mit.edu/handle/1721.1/51653?.

De Ver Dye, T., Apondi, R., Lugada, E., Kahn, J. G., Sandiford-Day, M. A. & DasBanerjee, T. 2011 A qualitative assessment of beliefs, attitudes, and behaviors related to diarrhea and water filtration in rural Kenya. *American Journal of Public Health* 101 (8), 1515–1520. https://doi.org/10.2105/AJPH.2011.300127.

Do, M., Kincaid, D. L. & Figueroa, M. E. 2014 Impacts of four communication programs on HIV testing behavior in South Africa. *AIDS Care* 26 (9), 1109–1117. https://doi.org/10.1080/09540121.2014.901487.

Duhigg, C. 2012 *The Power of Habit: Why We Do What We Do in Life and Business*. Random House, New York.

Francis, M. R., Nagarajan, G., Sarkar, R., Mohan, V. R., Kang, G. & Balraj, V. 2015 Perception of drinking water safety and factors influencing acceptance and sustainability of a water quality intervention in rural southern India. *BMC Public Health* 15 (1), 731. https://doi.org/10.1186/s12889-015-19740.

Freeman, M. C., Trinies, V., Boisson, S., Mak, G. & Clasen, T. 2012 Promoting household water treatment through women’s self help groups in rural India: assessing impact on drinking water quality and equity. *PLoS One* 7 (9), e44068. https://doi.org/10.1371/journal.pone.0044068.

Huber, A. C. & Mosler, H.-J. 2013 Determining behavioral factors for interventions to increase safe water consumption: a cross-sectional field study in rural Ethiopia. *International Journal of Environmental Health Research* 23 (2), 96–107. https://doi.org/10.1080/09603123.2012.699032.
Inauen, J., Hossain, M. M., Johnston, R. B. & Mosler, H.-J. 2013 Acceptance and use of eight arsenic-safe drinking water options in Bangladesh. *PLoS One* 8 (1), e53640. https://doi.org/10.1371/journal.pone.0053640.

Kahneman, D. 2003 A perspective on judgment and choice: mapping bounded rationality. *American Psychologist* 58 (9), 697–720. http://doi.org/10.1037/0003-066X.58.9.697.

Kahneman, D. 2011 *Thinking, Fast and Slow*. Macmillan, New York, NY.

Lilje, J., Kessely, H. & Mosler, H.-J. 2015 Factors determining water treatment behavior for the prevention of cholera in Chad. *The American Journal of Tropical Medicine and Hygiene* 95 (1), 57–65. https://doi.org/10.4269/ajtmh.14-0613.

Matthew, L. E., Piedra, L. M., Wu, C.-F., Kramer Díaz, A., Wang, H., Straub, A. P. & Nguyen, T. H. 2017 Social work and engineering: lessons from a water filtration project in Guatemala. *International Social Work* 60 (6), 1578–1590. https://doi.org/10.1177/0020872816655869.

Montgomery, M. A. & Elimelech, M. 2007 *Water and sanitation in developing countries: including health in the equation*. *Environmental Science & Technology* 41 (1), 17–24. https://doi.org/10.1021/es072435t.

Ojomo, E., Elliott, M., Goodyear, L., Forson, M. & Bartram, J. 2015 Sustainability and scale-up of household water treatment and safe storage practices: enablers and barriers to effective implementation. *International Journal of Hygiene and Environmental Health* 218 (8), 704–713. https://doi.org/10.1016/j.ijheh.2015.03.002.

Piedra, L. M., Matthew, L. E. & Wu, C. 2020 Participant responses to a water treatment intervention in rural Guatemala. *Qualitative Social Work* 1–18. http://doi.org/10.1177/1473325020906251.

Rohloff, P., Díaz, A. & Dasgupta, S. 2011 Beyond development: a critical appraisal of the emergence of small health care nongovernmental organizations in rural Guatemala. *Human Organization* 70 (4), 427–437. https://doi.org/10.17750/humo.70.4.qb16gr1p6x6x032q.

Sobsey, M. D., Stauber, C. E., Casanova, L. M., Brown, J. M. & Elliott, M. A. 2008 Point of use household drinking water filtration: a practical, effective solution for providing sustained access to safe drinking water in the developing world. *Environmental Science & Technology* 42 (12), 4261–4267. https://doi.org/10.1021/es702746n.

Stauber, C. E., Printy, E. R., McCarty, F. A., Liang, K. R. & Sobsey, M. D. 2012 Cluster randomized controlled trial of the plastic biosand water filter in Cambodia. *Environmental Science & Technology* 46 (2), 722–728. https://doi.org/10.1021/es203114q.

Tobias, R. & Berg, M. 2011 Sustainable use of arsenic-removing sand filters in Vietnam: psychological and social factors. *Environmental Science & Technology* 45 (8), 3260–3267. https://doi.org/10.1021/es102076x.

Tversky, A. & Kahneman, D. 1974 Judgment under uncertainty: heuristics and biases. *Science* 185 (4157), 1124–1131. https://doi.org/10.1126/science.185.4157.1124.

Weiner, B. 1985 An attributional theory of achievement motivation and emotion. *Psychological Review* 92 (4), 548–573. https://doi.org/10.1037/0033-295X.92.4.548.

Wheeler, J. & Agha, S. 2015 Use of Certeza point-of-use water treatment product in Mozambique. *Journal of Water, Sanitation and Hygiene for Development* 3 (3), 341–348. https://doi.org/10.2166/washdev.2013.198.

Williams, H. A., Gaines, J., Patrick, M., Berendes, D., Fitter, D. & Handzel, T. 2015 Perceptions of health communication, water treatment and sanitation in Artibonite department, Haiti, March–April 2012. *PLoS One* 10 (11). https://doi.org/10.1371/journal.pone.0142778.

Wood, S., Foster, J. & Kols, A. 2012 Understanding why women adopt and sustain home water treatment: insights from the Malawi antenatal care program. *Social Science & Medicine* 75 (4), 634–642. https://doi.org/10.1016/j.socscimed.2011.09.018.

World Health Organization 2019 Drinking-water. Available from: https://www.who.int/news-room/fact-sheets/detail/drinking-water (accessed 14 August 2019).

First received 26 November 2019; accepted in revised form 9 March 2020. Available online 15 April 2020