Research Paper

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

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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

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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.

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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.* 2011). 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.

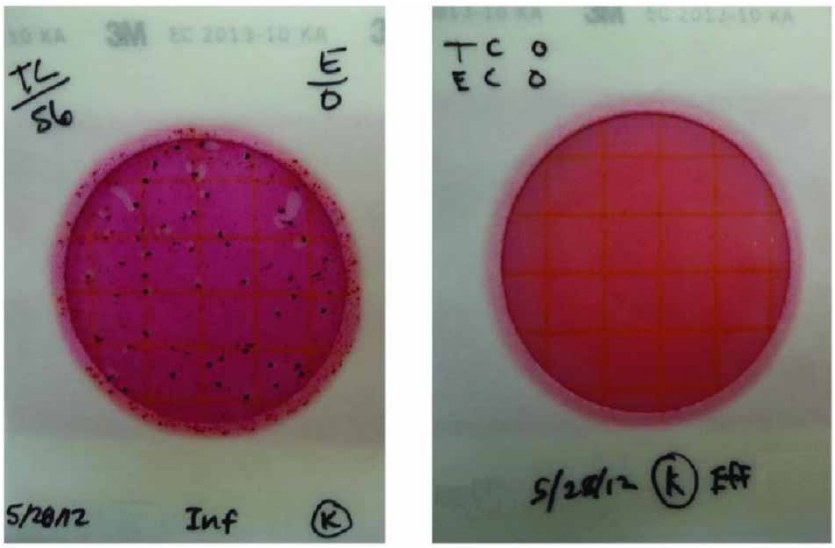

Figure 1 | Bacteria testing results from before treatment in the biosand filter (left) and after treatment (right). *Note*: This figure was originally published in Matthew *et al.* (2017).

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, EI 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.

Table 1 | Sample characteristics ($N = 93$)

Variables	%
Gender	
Female	96.8
Male	3.2
Age	
30 or below	25.8
31–40	38.7
41–50	20.4
50+	15.1
Number of children under 18	
No children	14.0
1–2 children	37.6
3 or more children	38.7
Missing	9.7
Town/area	
Chichoy	8.6
Las Guardenias	23.7
EI Hato	6.5
Monjón	5.4
Pacaco	9.7
Paya	16.1
San Juan	6.5
Socorro	23.7

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

Figure 2 | Surveyed communities are located within the red circle. Please refer to the online version of this paper to see this figure in colour: http://dx.doi.10.2166/washdev.2020.147.

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

Table 2 | Measures of key variables

Variables	Measure	Definition	Report type
Water filter use	Three items related to the respondent's filter use and their assurance	Whether the respondents use their filters How sure they were they used filters (very sure, sure, a little unsure, or very unsure) Whether the filters showed signs of regular use	Self-reported Observer
Knowledge of and supports for hygiene practices	Six items that focus on education on hygiene practices and possessing a container helped sustain the consumption (and maintenance) of filtered water	Whether they received education information on hygiene Whether they have a container with a cover to store filtered water Water containers cleaning cycle (daily/weekly/every few days/when I remember) Who reminded them to use the filter Usage purpose Main source of drinking water	Self-reported
Health beliefs	Three items related to the respondent's belief of filter use and their feelings of not using the water filters	Whether they think drinking water from the filter helps them stay healthy Whether they believed drinking unfiltered water made them sick Reasons for not using the water filters with multiple choices of feeling tired, feeling sad, feeling overwhelmed, and worried about other things in life	Self-reported
Technological factors	Two items related to filter problems and caring of technical or maintenance issues	Whether they had experienced a problem with their water filters (multiple choices: bad smell, bad taste, broken leaks/cracks, diminished water flow, or insect infestation) Whether anyone had come to their homes to answer questions on use, maintenance, and problems with filters	Self-reported

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.

Table 3 | Water filter use ($N = 93$)

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

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 (χ^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 (χ^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%) (χ^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 (χ^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 (χ^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%) (χ^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 (χ^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

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?					6.633	0.036
Yes	65.6%	77.6%	53.8%	50.0%		
No	34.4%	22.4%	46.2%	50.0%		
Do you have a container to store filtered water?					5.251	0.072
Yes	96.8%	100.0%	96.2%	88.9%		
No	3.2%	0.0%	3.8%	11.1%		
How often do you clean your water containers per week?					23.033	0.001
Every day	52.2%	62.5%	34.6%	50.0%		
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?					18.308	<0.001
Outsiders	33.3%	14.3%	61.5%	44.4%		
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? (multiple choices)						
Tap/sink (yes)	80.6%	85.7%	76.9%	72.2%	1.856	0.395
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

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) (χ^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.

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

Table 5 | Health beliefs by the category of filter users

	All sample ($N = 93$)	Regular users ($N = 49$)	Irregular users ($N = 26$)	Nonusers ($N = 18$)	Chi-square	p-value
Do you think drinking water from the filter helps you stay healthy?					1.504	0.472
Yes	95.6%	95.9%	92.0%	100.0%		
No	4.4%	4.1%	8.0%	0.0%		
Do you believe that drinking water from the tap, well, or river will make you sick?					1.835	0.399
Yes	97.8%	95.9%	100.0%	100.0%		
No	2.2%	4.1%	0.0%	0.0%		
Reasons for not using the filter (multiple choices)						
Feeling tired (yes, %)	24.4%	20.9%	25.0%	33.3%	6.981	0.137
Feeling sad (yes, %)	5.2%	2.3%	15.8%	0.0%	5.871	0.053
Feeling overwhelmed (yes, %)	16.9%	11.6%	21.1%	26.7%	2.105	0.349
Worried about other things in life (yes, %)	3.9%	2.3%	5.3%	6.9%	0.686	0.710

Table 6 | Technological factors by the category of filter users

	All sample ($N = 93$)	Regular users ($N = 49$)	Irregular users ($N = 26$)	Nonusers ($N = 18$)	Chi-square	p-value
Filter problems (multiple choices)						
Bad smell (yes, %)	51.7%	45.8%	58.3%	58.8%	1.430	0.489
Bad taste (yes, %)	49.4%	41.7%	50.0%	70.6%	4.205	0.122
Broken (yes, %)	28.1%	29.2%	29.2%	23.5%	0.216	0.897
Backed up/no flow of water (yes, %)	40.4%	31.3%	45.8%	58.8%	4.358	0.113
Infested with pests/insects (yes, %)	18.0%	10.4%	20.8%	35.3%	5.451	0.066
No problem (%)	33.7%	41.7%	33.3%	11.8%	5.025	0.081
Does anyone come to your home to answer questions on use, maintenance, and problems with filters?					7.214	0.027
Yes	94.6%	98.0%	84.6%	100.0%		
No	5.4%	2.00%	15.40%	0.00%		

not statistically significant, except with respect to pests. Regular users were less likely to report pests/insects than irregular or nonusers (χ^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 (χ^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 (χ^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 (χ^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.

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