An Evaluation of User Adherence and Perceptions of Ceramic Water Filters in Response to the 2015 Malawi Flood

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Introduction

In January 2015, the southern districts of Malawi and surrounding countries were struck by heavy rains resulting in severe flooding. During the course of the floods, over 200,000 people displaced and 176 were killed. As a result, people relocated to a number of relief camps on higher ground, including the Osyiana relief camp, located in the Nsanje District in Malawi. At the height of the flooding, more than 3000 people were living in the camp. As a result, there was an increased concern about potential disease outbreaks, such as cholera, associated with relief camps and people living such in close proximity to one another. Additionally, a lack of access to clean water often introduces gastrointestinal pathogens into the body, such as *Salmonella, Campylobacter,* norovirus, and pathogenic *Escherichia coli* (*E. coli*), resulting in diarrheal illness [1]. Improvements in drinking water quality, coupled with improved sanitation and hygiene systems, will mitigate the incidence of diarrheal diseases associated with these gastrointestinal pathogens [2].

Figure 1. An example of what the ceramic piece of a used ceramic water filter looks like. *Source:* Personal photograph

Ceramic water filters, as shown in *Figure 1*, were one household water treatment (HWT) option made available to the Osyiana relief camp. At the height of the flooding, 451 filters were distributed at no cost to those living in the Osiyana camp. The particular brand distributed is called the "Tulip Water Filter", and is capable of removing over 99% of bacteria, turbidity, and protozoa in water [3]. The system uses a ceramic filter to clean water by filtering out dirt and bacteria through small pores in ceramic material impregnated with silver [3]. These filters typically are sold in Malawi for approximately MK9000, or $19.78 USD. However, this portable point-of-use (POU) technology is ideal for households in emergency and in low-income settings, as each filter can clean up to 7000 liters of water before needing to be replaced [3].

Figure 2 & 3. The Tulip Water Filter Siphon was analyzed for user adherence in the field.
Source: Basic Water Needs website; Personal photograph

As a result of drinking treated water being considered a "non-event", the benefits of filtered water are often overlooked [4]. Additionally, certain perceptions of POU treatments within a community may be bias depending on user adherence. Limited data is available explaining why certain users may chose not to uptake certain HWT technologies, and how it is impacted by perceptions of these options. By examining social, cognitive, demographic, and economic factors, this study also aims to gain insight into user attitudes and behaviors toward Tulip Water Filters compared to other types of POU treatments**.** These findings will then be used to implement new strategies to improve rates of filter use, with the ultimate goal of reducing the incidence of diarrheal disease in post-emergency settings.

Objective

To conduct a 4 month follow up study on user compliance and perceptions of the Tulip Water Filter among households in the Osiyana relief camp in response to the floods that occurred earlier this year.

Specific Aims

1. To measure the overall uptake and usage of the Tulip Filters among households in Osyiana, Malawi.
2. To assess user perceptions among household water treatment (HWT) options available to households in the Osiyana community.

Methodology

The cross-sectional study examined 101 households still living in the main Osiyana camp that had received the Tulip Filter Siphon in February as a result of the flood. After receiving informed consent from the head of the household, enumerators conducted household surveys using Open Data Kit (ODK) software. All household surveys were translated into Chichewa. All households located within the main Osiyana camp were surveyed, with the exception of those who were never home when they were visited. All surveys were conducted in June 2015 during the dry season, when diarrheal rates are typically lower than the rainy season. Surveys included questions on household demographics, household assets, water sources, HWT use and preferences, use of Tulip Filter, water knowledge, and diarrheal incidence.

For the purposes of this study, high *"adherence*" or *"uptake"* is defined as the participant reporting use the filter at least once a week, and observing evidence that the filter has been used recently.

Upon arrival to the study site, it was reported that in April 2015, an NGO removed the borehole that the majority of the community used and installed a solar pump in its place. The solar pump extracted water from the ground into a tank with chlorine tablets. This water is then supplied to the community through two communal taps located near the tank. Two weeks into this study, the same NGO who installed the solar pump installed a borehole further into the community. As a result, the study was adjusted to account for these unanticipated developments within the community.

The survey was piloted, but after one week of data collection, questions were added to better meet the objective. Biases may have been introduced as a result of families having preconceived ideas regarding the reason for our visit and purpose of our study.

All household survey data was entered in Microsoft Excel and analyzed using Excel and SAS 9.4 software. Data was analyzed using the Fischer's exact test at the 5% significance level.

Results

All 101 household participants reported receiving their filters in February when an organization initially distributed them. On average, there were 6 members per household, and 4 children per household. Seventy-one interviewees worked on a local farm, 15 worked for a local business or sold firewood, and 13 were unemployed. When participants were asked about owning a toilet, bicycle, radio, mobile phone, and solar panel, 40% reported owning a toilet, 15% reported owning a bicycle, 10% reported owning a mobile phone, 4% reported owning a radio, and no one reported owing a solar panel, while 49% reported owning none of the above. There was no statistical difference between those who practiced high adherence with the Tulip Filter, with the exception of the percentage of people owning a toilet (p=0.04). There was also a statistical difference between the head of the household and the uptake level. *Table 1* details the demographics of the study population.

	Households with High Filter Adherence (N=39)	**Households with Low Filter Adherence (N=62)**	**P-value* (p<0.05)**
Demographics of participant			
Gender			
Female	29 (74.4%)	50 (80.6%)	NS
Age Quartile			NS
18-23	10 (25.6%)	15 (24.2%)	NS
24-30	10 (25.6%)	9 (14.5%)	NS
31-40	9 (23.1%)	18 (29.0%)	NS
41-67	8 (20.5%)	9 (14.5%)	NS
Did not know age	2 (5.1%)	11 (17.7%)	-
Profession			
Farmworker	25 (64.1%)	46 (74.2%)	NS
Local business (incl. selling firewood)	7 (17.0%)	8 (12.9%)	NS
Unemployed	7 (17.0%)	6 (9.7%)	NS
Craftsman	0 (0.0%)	1 (1.6%)	NS
Student	0 (0.0%)	1 (1.6%)	NS
Mean number of years of education	4.5	3.9	-
Characteristics of the household			
Head of household by gender			
Female	5 (12.8%)	13 (21.0%)	0.01
Male	34 (87.2%)	49 (79.0%)	
Mean number of people per household	5.85	5.82	-
Mean number of children per household	3.90	4.03	-
Presence of animal near compound	101 (100%)	101 (100%)	NS
Economic wealth by item ownership			
None of the items listed	23 (59.0%)	26 (41.9%)	NS
Toilet	10 (25.6%)	30 (48.3%)	0.04
Bicycle	5 (12.8%)	10 (16.1%)	NS
Mobile phone	3 (7.7%)	7 (11.3%)	NS
Radio	2 (5.1%)	2 (3.2%)	NS
Solar panel	0 (0.0%)	0 (0.0%)	NS

Table 1. Demographics of household by adherence level. *NS= not significant

Of the 101 participants, 98% of households reported still owning their Tulip Filters, with one household reporting that their filter was stolen in April 2015, and one household reported selling their filter in May 2015. Only 2 participants reported never using their Tulip Filters.

As previously stated, for the purposes of this study high "*adherence*" or *"uptake"* is defined as the participant reporting use the filter at least once a week, and observing evidence that the filter has been used recently. "*Recent use*" is defined as a filter with evidence of being used recently (i.e. wet ceramic filter, water inside tubing, etc.), or as the filter in use when we arrived to the household. However, there is still a possible bias with these results, as some households likely began using their filters as a result of us surveying the community. Of the participants that indicated they have stopped using their filters (n=52), 62% said it was because they started using the community's chlorinated water, 8% reported that they just did not want to use it anymore, 6% reported that an NGO told them to stop, 4% reported that it was because their filter broke, and 15% listed other reasons.

	Self-Reported High Filter Adherence (N=65)	**Self-Reported Low Filter Adherence** (N=36)
Observed recent use of filter	39 (60.0%)	5 (13.9%)
Observed not recent use of filter	26 (40.0%)	31 (86.1%)

Table 2. Self-reported versus observed recent use of the ceramic water filter by household.

Of the 65 participants that reported using their filters at least once a week, we found evidence that this is true for 60% (n=39) of the households. *Table 2* shows a full breakdown of the reported versus observed use for the filter.

	Households with High Filter Adherence (N=39)	**Households with Low Filter Adherence** (N=62)	**P-value* (p<0.05)**
Main source of drinking water			
Public tap w/ chlorine	23 (59.0%)	52 (83.9%)	0.02
Unprotected dug well	8 (20.5%)	4 (6.5%)	0.03
Surface water	3 (7.7%)	4 (6.5%)	NS
Borehole	4 (10.3%)	3 (4.8%)	NS
Secondary source of drinking water			
Public tap	15 (38.4%)	9 (14.5%)	0.008
Unprotected dug well	5 (12.8%)	5 (8.1%)	NS
Surface water	15 (38.4%)	19 (30.6%)	NS
Borehole	2 (5.1%)	22 (35.4%)	0.0005
Only drinks from primary source	2 (5.1%)	7 (11.3%)	NS
Frequency that primary source of drinking water runs out			
Everyday	19 (48.7%)	36 (58.0%)	NS
Multiple times a week	5 (12.8%)	18 (29.0%)	NS
Once a month	1 (2.6%)	0 (0.0%)	NS
Never	14 (35.9%)	8 (12.9%)	0.005

Table 3. Drinking water source per household. Secondary source of drinking water is where households retrieve their drinking water if the primary source does not have water when they need it. *NS= not significant

Overall, there was a significant difference between uptake and the number of households that used chlorinated public tap water. At the 5% significance level, of the households who drank water from the public tap with chlorinated water as their primary source of drinking water, those with low adherence were more likely to drink from the tap (p=0.02). Similarly, at the 5%

significance level, those households whose primary source of drinking water was an unprotected dug well were more likely to have a high filter adherence level (p=0.03).

Because the there was a significant difference between household uptake levels and the primary source of drinking water, there was also a significant difference between households who used the public tap as their secondary source of drinking water and adherence level (p=0.008). Details of primary and secondary drinking water sources are listed in *Table 3*.

Both households with high and low filter adherence had similar exposures to the various methods for treating drinking water. While an overwhelming percentage of households reported the ceramic filter as their favorite method for treating water, those that reported chlorine as their favorite method were more likely to have low filter uptake (p=0.02). These results are shown in *Table 4*.

	Households with High Filter Adherence (N=39)	**Households with Low Filter Adherence** (N=62)	**P-value* (p<0.05)**
Methods tried for cleaning water			
Chlorine**	39 (100.0%)	62 (100.0%)	NS
Ceramic filter (Tulip Filter)	39 (100.0%)	60 (96.8%)	NS
WaterGuard	21 (53.8%)	38 (61.3%)	NS
Boiling	3 (7.7%)	12 (19.4%)	NS
Straining	12 (30.8%)	21 (33.9%)	NS
Favorite method for cleaning water			
Ceramic filter (Tulip Filter)	36 (92.3%)	52 (83.9%)	NS
Chlorine**	2 (5.1%)	9 (14.5%)	0.02
WaterGuard	1 (2.6%)	1 (1.6%)	NS
Boiling	0 (0.0%)	0 (0.0%)	NS
Straining	0 (0.0%)	0 (0.0%)	NS

Table 4. List of water treatment options community has used and favorite method. *NS= not significant **Chlorine method at the community level, not household

In general, there was no statistical difference between households' perceptions about what makes water unsafe to drink, and whether they consider their water safe to drink, as illustrated in *Table 5*. Both households with high and low adherence for using their filter had similar perceptions about what, in general, makes water unsafe to drink. The majority of households for both adherence levels believed that their household drinking water was safe to consume (94.9% of those with high adherence, 90.3% for those with low adherence).

However, there is evidence of an association about why households perceive their water to be safe for consumption. Of the households who reported that their water was safe to consume because their water is chlorinated, there was a significantly higher likelihood that these households had low filter adherence (p=0.02). The opposite held true for households that reported that their water was safe to consume because they filtered their water. These households were significantly more likely to have high filter adherence (p=0.04). This discrepancy may help explain why certain households use the filter consistently, and others do not.

	Households with High Filter Adherence (N=39)	Households with Low Filter Adherence (N=62)	P-value* (p<0.05)
Perceptions about What Generally Makes Water Unsafe to Drink			
Dirt	28 (71.8%)	55 (88.7%)	NS
Bacteria	19 (48.7%)	19 (30.6%)	NS
Worms	1 (2.6%)	1 (1.6%)	NS
Smell	1 (2.6%)	1 (1.6%)	NS
Other	2 (5.1%)	5 (8.1%)	-
Missing	1 (2.6%)	0 (0.0%)	-
Perceptions about Whether the Household's Water Is Safe to Drink			
Yes	37 (94.9%)	56 (90.3%)	NS
No	2 (5.1%)	5 (8.1%)	NS
Do not know	0 (0.0%)	1 (1.6%)	-
Perceptions about Why the Household's Water is Safe to Drink			
Because the water is chlorinated**	19 (48.7%)	45 (72.6%)	0.02
Because I filter my water	13 (33.3%)	9 (14.5%)	0.04
Because the water is covered (i.e. Underground vs. surface water)	0 (0.0%)	3 (4.8%)	NS
Because the community told me it was	1 (2.6%)	3 (4.8%)	NS
Because the water looks clean to drink	1 (2.6%)	0 (0.0%)	NS
Other	3 (7.7%)	3 (4.8%)	-

Table 5. Perceptions of drinking safe water per household. *NS= Not significant **Chlorine method at the community level, not household

While there was no statistical difference between households with high and low adherence, there was a slight difference in the percentage in uptake levels when examining whether the filters were still properly functioning. Of those households with high uptake, 97.4% reported that their filters were functional. However, enumerator observations showed that only 76.9% of filters were functioning properly. Similarly, of those households with low uptake, 88.7% reported that their filters were properly functioning; however, only 66.7% of these households had functioning filters. Overall, there was a relatively high rate of broken filters (22%) given that it has only been 4 months since filter distribution. Percentages of reported versus observed functioning filters are listed in *Table 6.*

	Households with High Filter Adherence (N=39)	Households with Low Filter Adherence (N=62)	P-value* (p<0.05)
Current condition of Tulip Filter			
Reported condition of filter			
Working	38 (97.4%)	55 (88.7%)	NS
Broken	1 (2.6%)	2 (3.2%)	
I do not know	0 (0.0%)	5 (8.1%)	-
Observed condition of filter			
Working	30 (76.9%)	42 (67.7%)	NS
Broken	7 (17.9%)	15 (24.2%)	
Did not observe	2 (5.1%)	5 (8.1%)	-

Table 6. Reported and observed condition of the Tulip Filter. *NS= not significant

Overall, there was also no statistical difference between those with high and low adherence when describing why the filter is used in the household, as detailed in *Table 7*. However, there does appear to be recognition, by both households with high adherence and low adherence, that whenever they use the filter, it is to "make the water safer to drink" (48.7% & 46.8%, respectively).

There was also no difference between uptake levels when comparing the advantages and disadvantages of using the ceramic filter (*Table 7)*. However, the community as a whole appeared to like the filter. The top 3 advantages reported for using the filter included that it "cleans the water" (72%), "makes the water look better" (45%), and makes water "smell good" (25%). The main complaint against the filter was that it works "too slowly" (11%).

Participants generally found the filters easy to operate, with only 2 out of 101 reporting that the filter was difficult to use. This is likely due to the fact that 91% of participants reported receiving training on how to correctly use the filter by the organization (87%), the community (11%), or a friend (2%).

	Households with High Filter Adherence (N=39)	**Households with Low Filter Adherence** (N=62)	**P-value* (p<0.05)**
Why the filter is used in the household			
It makes the water safer to drink	19 (48.7%)	29 (46.8%)	NS
It prevents disease	17 (43.6%)	26 (41.9%)	NS
It makes the water look cleaner	11 (28.2%)	18 (29.0%)	NS
The filter was free	1 (2.6%)	1 (1.6%)	NS
Someone told me to	0 (0.0%)	1 (1.6%)	NS
Never used filter	0 (0.0%)	2 (3.2%)	NS
Household perceptions of filter use			
Advantages of Filter Use			
Cleans the water	28 (71.8%)	44 (71.0%)	NS
Water looks better to drink	17 (43.6%)	28 (45.2%)	NS
Smells good	11 (28.2%)	14 (22.8%)	NS
Makes water taste better	2 (5.1%)	5 (8.1%)	NS
Easy to use	2 (5.1%)	5 (8.1%)	NS
Reliable	2 (5.1%)	2 (3.2%)	NS
Other	0 (0.0%)	4 (6.5%)	-
N/A	0 (0.0%)	2 (3.2%)	-
Disadvantages of Filter Use			
Filters too slowly	3 (7.7%)	8 (12.9%)	NS
Difficult to use	0 (0.0%)	1 (1.6%)	NS
Breaks easily	0 (0.0%)	1 (1.6%)	NS
"There is nothing that I don't like about the filter"	36 (92.3%)	50 (80.6%)	NS
N/A	0 (0.0%)	2 (3.2%)	-

Table 7. Perceptions of why ceramic filter is used, and the advantages and disadvantages for using the filter. *NS= not significant

Prior to being relocated to the Osiyana camp and using any water treatment options, the majority of the community (73%) reported frequent diarrhea episodes for at least one member of the household (*Table 9)*. There was no statistical difference between households in the community with high and low ceramic filter uptake levels, providing a suitable baseline for comparison. However, self-reported frequency of diarrheal episodes for a member of the household, currently, showed no statistical difference between uptake levels and diarrhea frequency.

It is important to note that we were unable to fully separate out the effects of each water treatment option on households' diarrheal reduction as participants have not all tried every method, and many HWT options were introduced at similar times. Therefore, we are unable to make any conclusive statements regarding diarrheal episodes and filter adherence. However, almost every household reported being in better health as a result of beginning to use their filters. Additionally, of those who answered "yes" to whether participants notice a difference in their health when drinking from other treatment options versus the filter (n=46), 91% reported that the filter made them feel healthiest.

	Households with High Filter Adherence (N=39)	**Households with Low Filter Adherence (N=62)**	**P-value* (p<0.05)**
Frequency of diarrheal episodes before any water treatment			
Frequently	30 (76.9%)	43 (69.3%)	NS
Occasionally	1 (2.6%)	2 (3.2%)	NS
Rarely	0 (0.0%)	2 (3.2%)	NS
Never	8 (20.5%)	14 (22.5%)	NS
I do not know	0 (0.0%)	0 (0.0%)	-
No Response	0 (0.0%)	1	-

Table 9. Self- reported frequency of diarrhea for a member of the household prior to using any water treatment options. *NS= Not significant

	Households w/ frequent diarrhea before water treatment AND high filter adherence (N=30)	**Households w/ frequent diarrhea before water treatment AND low filter adherence (N=43)**	**P-value* (p<0.05)**
Frequency of current diarrheal episodes for a member of the household, given that they suffered from frequent diarrhea prior to using any water treatment methods			
Frequently	1 (3.3%)	2 (4.7%)	NS
Occasionally	4 (13.3%)	4 (9.3%)	NS
Rarely	3 (10.0%)	4 (9.3%)	NS
Never	22 (73.3%)	31 (72.1%)	NS
I do not know	0 (0.0%)	2 (4.7%)	-

Table 10. The self-reported frequency of a member of the household having diarrhea currently of those who self-reported frequent diarrhea prior to using any water treatment. *NS= Not significant

Less than 50% of the community had received education about the importance of drinking clean water, regardless of the level of uptake. Furthermore, just over 50% of the study population reported being concerned about drinking treated water. Comparatively, over 85% of households reported that the community as a whole encourages them to drink treated water. This disconnect between education and community encouragement may be explained by the influx of NGOs into the Osiyana camp after the floods. While the community may not quite understand why they should be concerned about drinking treated water, they know it is important because of outside organizations encouraging them to do so. Additional details on the community's education and beliefs on the importance of drinking treated water are located on *Table 8.*

	Households with High Filter Adherence (N=39)	Households with Low Filter Adherence (N=62)	P-value* (p<0.05)
Previously received education on water safety			
Yes	19 (48.7%)	30 (48.4%)	NS
No	20 (51.3%)	31 (50.0%)	
Missing	0 (0.0%)	1 (1.6%)	-
Does community encourage you to drink clean water?			
Yes	32 (82.1%)	56 (90.3%)	NS
No	7 (17.9%)	4 (6.5%)	
I do not know	0 (0.0%)	1 (1.6%)	-
Missing	0 (0.0%)	1 (1.6%)	-
Are you concerned about drinking clean water?			
Yes	21 (53.8%)	32 (51.6%)	NS
No	18 (46.1%)	29 (46.8%)	
Missing	0 (0.0%)	1 (1.6%)	-

Table 8. Community education and beliefs on the importance of drinking clean water. *NS= not significant.

Discussion

Overall, there was little difference between filter adherence levels in regards to the perceptions of water cleanliness, advantages to using the Tulip Filter, education about drinking treated water, or health outcomes. Due to the nature of humanitarian work in emergency settings, this does not come as a surprise.

During the floods, several NGOs and local organizations offered various point-of-use (POU) water treatment options for those who relocated. As a result, confusion and mixed messages resulted in the community trying many methods (74% of household have tried 3 or more methods for treating water).

While the local hospital recommended straining and boiling, several other organizations provided PUR flocculant-disinfectant or WaterGuard, in addition to the Tulip Filter. Additionally, in April 2015 an NGO removed the community's sole borehole and installed a solar pump, complete with four taps, and water storage tank in its place (*Figure 4)*. This storage tank has five Aquatab chlorine tablets placed in it to chlorinate the water. The tabs are replaced by the community once a month.

Figure 4. Solar water pump and storage tank installed by an NGO and used by the majority of the community. *Source:* Personal photograph

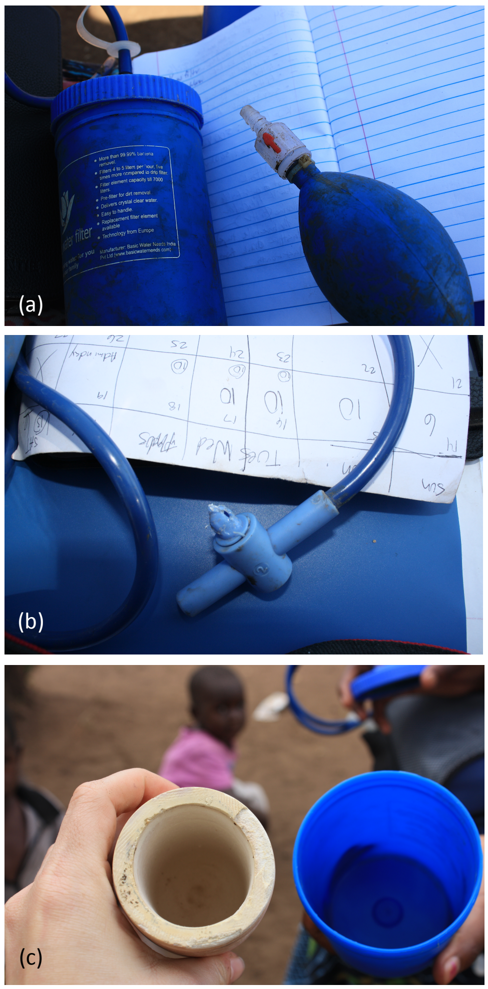
Because the ceramic filter is a POU technology and the chlorinated water being a communal source of treated water, direct comparisons cannot be made between these two water treatment options. This is likely a major confounding factor in this study. Furthermore, while a large proportion of the community reported the Tulip Filter being their favorite water treatment method, low levels of adherence point to a possible response bias resulting from participants' preconceived ideas about why they were surveyed. Future studies investigating the effectiveness of these water treatment options may better examine the relationship between adherence and effectiveness of the treatment options.

Overall, male-headed households were more likely to have high adherence than female-headed households. While it is unclear why this is the case, one possible explanation is that more men than women attended the Tulip Filter trainings in February. Because women are typically the ones who collect water, future trainings should focus more on their education on how to use the filter and the health benefits associated with drinking treated water.

When examining the community's primary sources of drinking water, the chlorinated public tap was the primary source of drinking water for 75% of the community. Of those who used the public tap as their primary source of drinking water, households were significantly more likely to have low ceramic filter adherence. This is likely the result of the community believing that the chlorine in the water is enough to make their water safe to drink. Evidence of this is shown in *Table 5,* where there is a significant difference between perceptions about why one's water is safe to drink and level of filter uptake. Households who answered that chlorine was the reason why their water was safe to drink were more likely to have lower filter adherence.

Households primarily collecting water from unprotected dug wells were twice as likely to have high filter adherence as those who had low filter adherence. This may result from the perception that water that looks "dirty" is not safe to drink. Additionally, households who reported using their ceramic filter as the reason why their water was safe to drink were more likely to have high adherence.

Therefore, these associations may explain why certain households have lower adherence in the community. While overall adherence to the Tulip Filter remains low, these findings suggest that if distributed to communities where there is no treated water source, adherence to these ceramic filters will likely be higher.



Figures 5a, 5b, & 5c. Common problems found to hinder filter use. *Source:* Personal photograph

While not showing a significant difference between household uptake levels and why participants use the ceramic filter, the fact that 48% of households reported using the filter because "it makes water safer to drink" shows that the community understand the importance of drinking treated water. Additionally, common advantages listed for using the filter include that it "cleans the water", "makes the water look better", and that it makes the water "smell good". The water "smelling good" is likely in comparison to the smell of the chlorinated water. The only major complaint against the Tulip Filter was that it filtered the water too slowly. Together, these findings further support the notion that, if distributed to communities with no other source of treated water, uptake of these ceramic filters will likely be high.

While showing no significant difference between the level of uptake and the condition of the filter, it is still important to note that there were slight differences between the percentage working Tulip Filters and level of adherence. It is also important to note that there were a fairly large percentage of respondent with misunderstandings about what they considered a working filter, compared to a broken filter.

Common problems with the filters included damaged tubing (*Figure 5a*), broken nozzles (*Figure 5b*), and the ceramic filter being disconnected from the rest of the siphon (*Figure 5c*). The ceramic filter can easily be reattached with locally available superglue. While the tubing, nozzle, and other pieces can easily be replaced, these parts are not currently available to the community. Furthermore, the cost of a Tulip Filter Siphon is currently MK9000, or $19.78 USD. Based on the low socioeconomic status of these households, these filters do not appear to be the best sustainable water treatment option in this community. In order to be a viable option, these filters would need to be heavily subsidized by a local NGO, and replacement parts be made available for the community.

The overall health impacts of the Tulip Filter are not currently apparent. While the majority of households reported better health as a result of using their filters, overall low adherence and high rates of not functional filters make it difficult to determine. Additionally, because we are unable to separate out the effects of each water treatment option on households' diarrheal reduction, we are unable to make any conclusive statements regarding diarrheal episodes and filter adherence. However, it is promising that, in general, there has been a significant reduction in reported diarrheal episodes for households since relocating to the Osiyana camp. This is likely the result of various water treatment options that have been introduced into the community. This may encourage community members to continue using these treatments, or even increase use of such technologies in other communities, as households begin to notice a difference in their health.

Lastly, based on the survey results there appears to be a gap in knowledge as to why drinking clean water is important. This was illustrated in *Table 8*, where the community did not appear to have received much education on the importance of drinking treated water, nor was the community overwhelmingly concerned about doing so. This lack of concern can significantly hinder efforts to improve water treatment uptake. However, over 85% of respondents reported that the community encouraged them to drink treated water. This is likely the result of the numerous NGOs arriving in the Osiyana camp after the floods. While the community may not quite understand why they should drink treated water, they know it is important because these organizations are encouraging them to do so. Consequently, more emphasis should be placed on NGOs not only distributing these technologies to communities and showing people how to use them, but educational programs should be put in place to help communities understand why they should be concerned. These programs would likely increase HWTS uptake as people's knowledge expands.

One limitation in this study was a failure to ask what the filter is used for. While it was initially assumed to be for drinking purposes, we discovered during data collection that women use the filter for other purposes as well. For example, four women we spoke with admitted to using the filter for cleaning their water for cooking purposes.

Conclusion

Overall, the Tulip Filter is one viable option for treating water in post-emergency situations. As a whole, the community seemed to accept the Tulip Filter as a suitable water treatment option for their households. While uptake of the filter has remained relatively low (39%), it is likely the result of many water treatment options introduced simultaneously (i.e. chlorinated public taps), rather than a rejection of the filter itself. Consequently, the utilization and perceptions of the ceramic filter were contingent on the chlorinated water from public taps. Overall preferences for the filter appear to be favorable and point to high uptake in communities where other treatment options are not available. The Tulip Filter has the potential to be a sustainable option, if replacement parts are made available for the community and significant financial assistance is provided.

Follow-up visits are essential in order to ensure continued use and proper usage of the filters. Additional studies on how filters are being used and a water quality analysis should be conducted to ensure that these filters are as effective in these households as in laboratory settings. Studies should also be conducted to tease out various water treatments' effects on diarrheal illness and determine if the Tulip Filter truly decreases the incidence of diarrhea.

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