Validation Study Report: Evaluating New Evidence-Based FRC Targets at Mtendeli, Tanzania

Consultancy Report

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Executive Summary

MSF OCA launched a validation study to evaluate the household water safety effectiveness of the new evidence-based FRC targets for centralized chlorination in emergencies at a new field site, the Mtendeli refugee camp in Tanzania. The new targets specify what FRC (free residual chlorine) levels should be at tapstands depending on site temperature and sanitary conditions, and are based on field evidence from refugee camps in South Sudan, Jordan, and Rwanda. At Mtendeli, temperatures were moderate (25-30°C) and ambient sanitary conditions were poor, similar to the previous case study site of Kigeme, Rwanda, so the 0.6-0.8 mg/L FRC target developed from the Kigeme case study was also adopted at Mtendeli. Primary data collection for the validation study consisted of documenting FRC in a unique parcel of water first from the point of distribution (tapstand) and then again at the point of consumption (households after ~18 and ~24 hours of storage and use). We analyzed the paired FRC data to determine the proportion of household water samples passing the designated water safety threshold of 0.2 mg/L FRC when tapstand FRC is within different target ranges. Overall, we found that the new 0.6-0.8 mg/L FRC target at tapstands provided an adequate degree of household water safety at ~24 hours post-distribution (71% of samples passing the water safety threshold) and outperformed the current 0.2-0.5 mg/L guideline target (40% passing only). At ~18 hours post-distribution, we found that the current 0.2-0.5 mg/L guideline target at tapstands provided an adequate degree of household water safety (81% passing), so tapstand FRC levels need not be increased if only ~18 hours of water safety is sought. While we set out to obtain a total of 180 samples with follow-up at 24 hours post-distribution, constraints on field data collection due to the handover of the Mtendeli project, as well as households in some areas of the camp having fewer water storage containers obliging them to collect water at more frequent intervals, meant that we ultimately
collected 156 samples with follow-up split between ~18 and ~24 hours post-distribution, which somewhat limits the strength of these conclusions. Finally, with the data we collected on water quality and water-handling practices at Mtendeli, we developed linear regression models to explore factors driving chlorine decay. We found strong evidence that container type and opacity strongly influenced the extent of chlorine decay such that jerrycans were protective of the safe water chain compared to buckets, and opaque containers had significantly less chlorine decay than translucent containers. Therefore, opaque jerrycans may be considered the preferred option for NFI kits distributed during emergencies. In addition, we found a weak but inconsistent protective effect for container cleanliness, and no evidence for the protective effect of container covering or method of drawing. This does not mean that these hygienic water-handling practices are not in fact protective, just that confirmatory evidence was not found in this study. Overall, the validation study confirms that the new evidence-based FRC targets were effective for ensuring household water safety at a new field site.
1 Introduction

The emergency water treatment guidelines used by MSF and other humanitarian agencies (UNHCR, Sphere Project, etc.) stipulate what free residual chlorine (FRC) levels should be at camp water distribution points in order to protect against microbiological contamination and assure water safety. These guidelines are framed as universal treatment rules that are applicable to any field site:

- 0.2 - 0.5 mg/L, under normal conditions;
- 0.5 - 1.0 mg/L, if pH or turbidity are elevated (> 8 and 20 NTU); and
- 0.8 - 1.0 mg/L, during outbreaks of waterborne disease.

The problem, however, is that these guidelines are based on no evidence from humanitarian field settings. Instead they derive from the WHO Guidelines for Drinking-Water Quality, which are based on conventions for municipal piped water systems in stable settings—a context that is fundamentally dissimilar to refugee/IDP camps.

Multiple anecdotal reports suggest these guidelines may fail to ensure water safety in emergency settings, and recent systematic studies also point to their ineffectiveness. During the 2012-2013 refugee crisis in Maban County, South Sudan, household water quality monitoring in three refugee camps revealed that 40% to 58% of households that collected water from chlorinated tapstand sources had no detectable chlorine protection in their stored water (1). Moreover, environmental viral assays that were conducted in the wake of a major hepatitis E outbreak in the Maban County camps found human adenoviruses—an indicator of human faecal contamination—in stored household water (2). These findings demonstrate that even when current FRC guidelines are implemented, it may not mean water is safe where people are consuming it in the refugee/IDP camp setting.
In response to this problem, MSF OCA launched operational research in South Sudan to investigate the decay of chlorine in refugee camp water supplies, with the aim of developing new evidence-based FRC guidance that is proven to ensure water safety in refugee/IDP camp settings (3). In collaboration with UNHCR and the University of California, Berkeley, in 2014-2015, we expanded the research to refugee camps in diverse environmental and climatic settings around the world including Jordan and Rwanda. While clearly not exhaustive, these three sites are representative of some of the regions in which we face major displacement crises today.

Based on our microbiological water quality findings (4), as well as conventions stated in the literature (5), we defined the desired level of water safety as 0.2 mg/L when the last cup of water is consumed, assumed as 24 hours post-distribution. We found the current FRC guideline of 0.2–0.5 mg/L could only ensure household water safety in settings were temperature was moderate (20–30°C) and ambient sanitary conditions were good. Where ambient sanitary conditions were poor and/or temperature hot (>30°C), the current guideline provided insufficient protection. In such settings, FRC needs to be increased in order to ensure household water safety (4):

<table>
<thead>
<tr>
<th>Site Conditions</th>
<th>FRC Target Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature</strong></td>
<td><strong>WASH conditions</strong></td>
</tr>
<tr>
<td>Hot (&gt;30°C)</td>
<td>Poor</td>
</tr>
<tr>
<td>Hot (&gt;30°C)</td>
<td>Good</td>
</tr>
<tr>
<td>Moderate (20–30°C)</td>
<td>Good</td>
</tr>
<tr>
<td>Moderate (20–30°C)</td>
<td>Poor</td>
</tr>
</tbody>
</table>

*“WASH Conditions” are a proxy for ambient sanitary conditions and include overall environmental, domestic, and personal hygiene. If multiple WASH standards are not met (water quantity, water access, sanitation coverage, etc.), WASH conditions are classified as “poor”. If most or all WASH standards are met or exceeded, they are “good”.*
We propose that these **new evidence-based FRC targets** be adopted into practice and replace the current non-evidence-based guidelines in order to improve household water safety in refugee/IDP camp settings. To validate the new FRC targets and facilitate uptake, MSF OCA has proposed they be implemented and evaluated at a new field site: the Mtendeli refugee camp in Tanzania. This report presents the findings of the validation study at Mtendeli.

2  Methodology

The hypotheses we set out to evaluate in this validation study are as follows:

<table>
<thead>
<tr>
<th>The evidence-based FRC target for the specific temperature and ambient sanitary conditions at Mtendeli:</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Provides an adequate degree of household water safety, and</td>
</tr>
<tr>
<td>ii. Outperforms the current guideline range of 0.2–0.5 mg/L.</td>
</tr>
</tbody>
</table>

The study therefore entailed the following key tasks:

1. Identify the appropriate FRC target for Mtendeli from the new evidence-based FRC targets based on site temperature and ambient sanitary conditions.

2. Adjust chlorination in the Mtendeli water system to achieve the desired FRC target. (As it turned out, the water supply at Mtendeli was already being chlorinated at a higher level than that recommended in current guidelines, so FRC levels were already within the desired range and no further adjustment was necessary. This made Mtendeli an ideal “natural experiment” to evaluate the effectiveness of the new evidence-based FRC targets.)

3. Primary data collection to document the change in FRC in a unique parcel of water going from the point of distribution (i.e., directly from tapstands) to the point of
consumption (i.e., from storage containers after several hours of household storage and use). (We were primarily interested in evaluating water safety at 24 hours post-distribution, however time and HR constraints in the field meant that we had to collect follow-up data for about half of our samples at 18 hours post-distribution. This limitation is discussed further below.)

4. Analyse data by plotting household FRC as a function of tapstand FRC (on the principle that higher tapstand FRC should result in a higher household FRC in the paired data). From this we determine the proportion of samples passing the minimum threshold for household water safety (0.2 mg/L) versus those not passing for different ranges of tapstand FRC in order to evaluate our hypotheses.

2.1 Site background and determination of appropriate FRC target

The Mtendeli refugee camp in Tanzania hosts a population of 20,000+ Burundian refugees. Through summer 2016, MSF carried out water chlorination, supply, and monitoring activities at the camp in collaboration with Tanganyika Christian Refugee Services (TCRS). MSF handed over responsibility for these functions to TCRS in September 2016. Primary data collection for this validation study was conducted at the camp from September 5th to 14th, 2016.

The first step in the validation study was to determine the appropriate FRC target to apply at Mtendeli from the new evidence-based FRC targets table in Section 1 (Introduction) based on site temperature and sanitary conditions. With respect to temperature, MSF field staff at the time of study inception estimated midday temperatures at Mtendeli to be in the range of 25 to 30°C. This range is further corroborated by historical climate data from the nearby city of Kibondo, which indicated a daytime high of 27.3°C for the month of August (6). Therefore, with average mid-afternoon temperature apparently in the range of 20 to 30°C, we classify temperature at
Mtendeli as “moderate”. Overall, temperature conditions at Mtendeli resemble those at the Kigeme camp in Rwanda, both of which are classified as having a tropical savannah climate (Aw) under the Köppen-Geiger climate classification system (6).

With respect to ambient sanitary conditions, we consider the “WASH conditions” category in the new FRC targets table in Section 1 (Introduction). This category is a proxy for ambient sanitary conditions including overall environmental, domestic, and personal hygiene, and is assessed by the degree to which key WASH standards for water supply and sanitation are achieved (or not). Data on per capita water consumption come from a number of sources. Bulk water delivery figures from MSF WASH monitoring in Week 30 (the latest available data at the time of study inception) indicate a per capita water consumption of 21.5 L/p/d (7). On the other hand, MSF epidemiological surveillance indicates 15.9 L/p/d. While the former likely does not account for system losses, the latter may be subject to underreporting, so the true consumption figure likely lies between the two. Therefore, the MSF minimum standard of 15-20 L/p/d (for chronic emergencies and stabilized situations) is in all probability being achieved at Mtendeli (8). Similarly, the number of persons per operational water point (tap) was 152 in Week 30 (7), which met the MSF guideline of 1 tap for 200-250 persons (but not the UNHCR standard of 125 persons per tap). Latrine coverage at Mtendeli was not monitored by TCRS, however, MSF field staff estimate coverage to be in the range of 25 to 30 people per latrine, which does not meet the MSF standard (for chronic emergencies and stabilized situations) of 1 latrine for 20 users, 1 latrine for 4 household cluster, or preferably, family latrines. Therefore, on the balance of these features, we classify WASH conditions at Mtendeli as “poor”. Visual inspection of the field site (Figure 1) provides additional corroboration that ambient sanitary conditions at Mtendeli were
more similar to the Maban County (South Sudan) and Kigeme (Rwanda) camps rather than the Azraq (Jordan) camp.

Figure 1 | Images of the Mtendeli field site indicate that ambient sanitary conditions are poor and resemble conditions at the Maban County (South Sudan) and Kigeme (Rwanda) camps rather than the Azraq (Jordan) camp.

Therefore, because Mtendeli temperature is “moderate” and WASH conditions are “poor”, we recommend FRC be set to 0.6-0.8 mg/L at camp tapstands, as per the new FRC guidance table in Section 1 (Introduction). According to the case study at Kigeme, Rwanda which had similar site conditions to Mtendeli, delivering FRC at the tapstand in this range should ensure 0.2 mg/L at 24 hours post-distribution (4).

We mentioned at the start of this section that the recommended FRC target is already being implemented at Mtendeli. MSF maintained a water quality monitoring ODK database covering the four-month period from February to May 2016 (9), which reported an average tapstand FRC of 0.60 mg/L (range: 0.1-3.0 mg/L) and an average household FRC of 0.36 mg/L (range: 0-3.0
mg/L). These data suggest that the recommended FRC target of 0.6–0.8 mg/L is effective at delivering household water safety. There are however two key limitations with the ODK dataset that keep us from using these data to concretely evaluate our two hypotheses:

- The length of post-distribution time in the ODK dataset is not precisely known (it is indicated broadly as water taken “today”, “yesterday”, and “before yesterday”); and
- Samples are not paired so cannot link tapstand FRC to household FRC.

Therefore, while the ODK dataset is useful for demonstrating that the recommended FRC target is being implemented at Mtendeli and no further adjustment of chlorination levels is necessary, it cannot positively demonstrate the degree of household water safety achieved by different tapstand FRC targets. The validation study improves upon the ODK dataset with respect to these gaps allowing us to evaluate the hypotheses laid out at the beginning of this section.

2.2 Study materials

The following materials are required for the validation study:

- Palintest Chlorometer (or equivalent) with DPD1 and DPD 3 tablets
- Hanna Instruments Temperature/pH/EC Probe (or equivalent)
- Multiple copies of Data Form (Appendix C: Data Form)
- 1 copy of Recruitment Script (Appendix D: Recruitment Script)
- Multiple copies of Consent Form (Appendix E: Consent Form)
- Clipboards, pens, and permanent markers

2.3 Primary data collection

Primary data collection was based on the principle of testing the same parcel of water twice, first from the tapstand and then at the household after several hours of storage and use, in order to
obtain paired data representing the overall chlorine decay between point of distribution and consumption. The procedures and instruments utilized in primary data collection are included in the appendices:

- Appendix B: Data Collection Procedure
- Appendix C: Data Form
- Appendix D: Recruitment Script
- Appendix E: Consent Form

One minor procedural change was required with respect to the temperature data collection. Because we were not able to obtain two temperature probes in the field, the research team adapted by obtaining temperature data from a nearby weather station at Gasanda, 1 km away from Mtendeli (they took readings on a daily basis just after midday). This is a minor deviation from the procedure as designed and has no effect on data quality.

2.4 Sampling strategy

2.4.1 Sample size

To determine the optimal number of samples to collect for this validation study, we had to balance between how representative the data were with the burden of field data collection. Following the method described in Appendix A: Background on Sample Size Determination), we determined that collecting 180 samples would be ideal. However, because of time and human resources constraints related to the handover of the Mtendeli project in September, we were able to collect only 156 unique samples ultimately.
2.4.2 Follow-up timing

We wanted to assess household water safety at 24 hours post-distribution, however, this turned out to not be possible in newer areas of the camp where households had fewer water storage receptacles. This obliged them to use and collect water at more regular intervals such that ~18 hours was the maximum water age we could obtain in these areas. The overall distribution of follow-up sampling ranged from 16 up to 26 hours post-distribution, with about 55% (84 samples) in the range of ~18 hours (including data from 16 to 20 hours) and another 40% (58 samples) in the range of ~24 hours (including data from 22 to 26 hours) (Figure 2).

![Post-Distribution Times](image)

**Figure 2** | Household water samples collected had a post-distribution age ranging from 16 to 26 hours.

This split meant that the overall sample size for evaluating water safety at 24 hours post-distribution was reduced by about half, weakening the degree of confidence we are able to place in findings, but also enabling us to assess water safety at 18 hours post-distribution as well. The two cases of ~18 and ~24 hours are uniquely relevant to two different water system arrangements.
common in displacement camps. In camps where the water supply is turned on just once a day, 24 hours of FRC protection is necessary as water will be stored and used for a whole day before new water becomes available. In camps where the water supply is turned on twice daily (usually morning and late afternoon), just 18 hours of FRC protection is needed as this represents the maximum time between collecting water in the late afternoon and when it becomes available again the next morning (although 24 hours of FRC protection would provide a great margin of safety in case any water is not refilled immediately).

2.4.3 Spatial coverage

According to camp WASH monitoring data, there were 56 usable water points functioning as of Week 30 at Mtendeli (7). Therefore, each functioning tapstand must be tested three times in order to arrive at the optimal 180 samples. A systematic sampling strategy was therefore proposed at study inception:

1. Begin sampling at the lowest numbered functioning tapstand (i.e., TS1).
2. Once the above sample is complete, proceed to the next functioning tapstand in the sequence (i.e., TS2). If that tapstand is not operating, proceed to the next tapstand in sequence (i.e., TS3) until a functioning tapstand is found for sampling to continue.
3. Once all functioning tapstands have been sampled, begin again at the lowest numbered tapstand.
4. Repeat until 180 total samples are obtained.

In this way, all functioning tapstands across the camp are systematically sampled, making the data representative of the camp as a whole. In addition, water-catchers should be approached randomly at tapstands for participation in the study, which will ensure that water-handling behavioural data is also representative of prevailing practices at the camp.
Ultimately, we collected 156 unique samples from 53 tapstands functioning at the time of the study, such that each tapstand was sampled on three separate occasions. As sampling evenly covered all tapstands in the camp, the water quality data is representative of Mtendeli camp as a whole.

3 Results and Discussion

3.1 Water quality

At Mtendeli we found FRC levels at tapstands to average 0.70 mg/L (range: 0.04-1.27 mg/L). A histogram presenting the distribution of tapstand FRC is given in Figure 3.

![Distribution of Tapstand FRC at Mtendeli Camp](image)

**Figure 3** Histogram of tapstand FRC at Mtendeli indicates that desired FRC target range is being achieved. Tapstand FRC centred on the recommended range of 0.6-0.8 mg/L, with approximately 45% of samples within this range, and the rest normally distributed around it. This indicates that our recommendation was already being implemented at Mtendeli. The dispersion of the data,
including a few near zero events, however indicates that control of chlorination at Mtendeli might still be improved upon. Additionally, because we have some data in the 0.2-0.5 mg/L range, we can use these (albeit limited) data to evaluate the level of household water safety achieved by the current guideline range as well.

In addition to FRC, we also documented TRC (total residual chlorine) in order to assess whether there was a significant combined residual component in the Mtendeli water supply. Overall, we found the mean TRC to be 0.77 mg/L (range: 0.07-1.72 mg/L) suggesting there is a small combined component (<0.10 mg/L with respect to mean), which is in line with what we expect for a groundwater source with limited organics content.

Our primary water quality parameter of interest however was household FRC. At Mtendeli, we found it to be on average 0.39 mg/L (range: 0.0-1.12 mg/L), which broadly supports the hypothesis that the desired level of household water safety (0.2 mg/L at the point of consumption) was being achieved. However, as per Figure 2, the follow-up time for these samples ranged from 16 to 26 hours, so we need to clarify this aspect and its relation to household FRC. Overall, we found mean household FRC at ~18 hours post-distribution to be 0.44 mg/L, while mean household FRC at ~24 hours post-distribution was 0.34 mg/L, with the difference being statistically significant (p<0.05). Conversely, there was not a statistically significant difference in initial tapstand FRC between the ~18 and ~24 hour post-distribution datasets (p>>0.05), so the difference in household FRC is attributable to the post-distribution time elapsed rather than the initial tapstand FRC being different. Histograms of household FRC distribution at ~18 and ~24 hours post-distribution are presented in Figure 4.
Figure 4 | Household FRC varies depending on the length of time elapsed post-distribution.

From Figure 4, we observe that there is a greater proportion of near zero events at ~24 hours post-distribution than at ~18 hours, so we suspect that water is less safe at 24 hours. We evaluate this more closely in the next section.

3.2 Evaluation of household water safety effectiveness

By plotting household FRC (at point of consumption) as a function of tapstand FRC (at point of distribution) and assessing the proportion of samples passing the water safety threshold (0.2 mg/L at the point of consumption), we can evaluate whether the new FRC target recommendation for Mtendeli of 0.6-0.8 mg/L: i) provides an adequate degree of household
water safety; and ii) outperforms the current guideline range of 0.2–0.5 mg/L (or not). We evaluate these hypotheses for both ~18 and ~24 hours post-distribution. Household water safety plots for ~18 hours and ~24 hours post-distribution are presented respectively in Figure 5 and Figure 6.

**Figure 5** Empirical check of household water safety at ~18 hours post-distribution. The recommended FRC target range is indicated by the green vertical lines.
Empirical check of household water safety at ~24 hours post-distribution. The recommended FRC target range is indicated by the green vertical lines.

Table 1 below counts the relative proportion of samples that pass or fail to pass the 0.2 mg/L household water safety threshold when tapstand FRC is delivered at various ranges.

<table>
<thead>
<tr>
<th>Tapstand FRC</th>
<th>~18 hours post-distribution</th>
<th>~24 hours post-distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pass</td>
<td>Fail</td>
</tr>
<tr>
<td>0.2 - 0.5 mg/L</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>0.6 - 0.8 mg/L</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>0.8 - 1.0 mg/L</td>
<td>17</td>
<td>1</td>
</tr>
</tbody>
</table>

The first of two hypotheses we set out to evaluate in this validation study was whether the recommended 0.6-0.8mg/L FRC target for Mtendeli provides an adequate degree of household water safety. To do this, we have to first define what we mean by an “adequate degree”. For this
we turn to the foundational studies conducted in South Sudan, Rwanda, and Jordan from which the new evidence-based FRC targets were developed. In these studies, we found that when tapstand FRC was in the current 0.2-0.5 mg/L guideline range, the proportion of household samples passing the 0.2 mg/L water safety threshold at follow-up was between 15% and 50%, whereas when tapstand FRC was in the range of the new 0.6-0.8 mg/L recommended target, the pass rate was between 70% and 100% (Table 2). Therefore, we define an “adequate degree” of household water safety to be at least 70% of household water samples passing the 0.2 mg/L FRC threshold at follow-up. We observe in Table 1 that the recommended 0.6-0.8 mg/L FRC target for Mtendeli provides an adequate degree of household water safety at 24 hours post-distribution (71% of samples passing).

**Table 2 | Household water safety effectiveness of current guideline and new evidence-based FRC targets.**

<table>
<thead>
<tr>
<th>Site</th>
<th>Time Post-Distribution</th>
<th>Current Range FRC Target</th>
<th>Proportion Passing</th>
<th>Recommended Range FRC Target</th>
<th>Proportion Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>South Sudan, 2013</strong></td>
<td>7 to 9 hrs</td>
<td>0.2 – 0.5 mg/L</td>
<td>15%</td>
<td>1.1 – 1.3 mg/L</td>
<td>72%</td>
</tr>
<tr>
<td><strong>Jordan, Summer 2014</strong></td>
<td>18 to 26 hrs</td>
<td>0.2 – 0.5 mg/L</td>
<td>No data</td>
<td>0.8 – 1.3 mg/L</td>
<td>71%</td>
</tr>
<tr>
<td><strong>Jordan, Winter 2015</strong></td>
<td>18 to 26 hrs</td>
<td>0.2 – 0.5 mg/L</td>
<td>100%</td>
<td>0.4 – 0.5 mg/L</td>
<td>100%</td>
</tr>
<tr>
<td><strong>Rwanda, 2015</strong></td>
<td>18 to 26 hrs</td>
<td>0.2 – 0.5 mg/L</td>
<td>50%</td>
<td>0.6 – 0.8 mg/L</td>
<td>85%</td>
</tr>
</tbody>
</table>

The second of the two hypotheses was whether the recommended 0.6-0.8 mg/L FRC target outperforms the current 0.2-0.5 mg/L FRC guideline target at Mtendeli. Whereas the recommended 0.6-0.8 mg/L target yielded a 71% pass rate at 24 hours post-distribution, the current guideline 0.2-0.5 mg/L target offers inadequate protection with only 40% passing (Table 1). Therefore the recommended 0.6-0.8 mg/L target outperforms the current 0.2-0.5 mg/L guideline target for household water safety effectiveness at 24 hours post-distribution.
With respect to household water safety effectiveness at ~18 hours post-distribution, from Table 1 we observe that the current 0.2-0.5 mg/L guideline range provides an adequate degree of water safety (81% passing), so FRC levels need not be increased if just ~18 hours of water safety assurance is required.

Furthermore, we note that by increasing tapstand FRC up to 0.8-1.0 mg/L, the degree of household water safety pass rate achieved can approach 100%. Increasing FRC however comes with the risk of driving up taste and/or odour-driven rejection concerns, so the incremental degree of protection may or may not be worth the increased chance of rejection.

Finally, we should note that there were only 55 and 41 samples respectively with follow-up at ~18 and ~24 hours post-distribution, which is unfortunately fewer than the number of samples we had hoped to collect (for the reasons described in section 2.4.2). This means that the degree of confidence we have in our conclusions is somewhat limited compared to what we had hoped.

### 3.3 Factors associated with chlorine decay

We also developed linear regression models in order to identify water-handling factors associated with chlorine decay. The models we developed included the following independent variables:

- Initial FRC at the tapstand;
- Length of time elapsed post-distribution;
- Air temperature;
- Whether the water storage container was stored indoors or outdoors;
- Whether the water was transferred between containers;
- Whether the water mixed or replaced with another water;
- How much water was used in the household;
• Water container type;
• Water container opacity;
• Water storage covering;
• Water container cleanliness; and
• Method of drawing water.

The variables were progressively added to the model in order to elucidate possible interactions; outcomes are presented in Table 3 below.
### Table 3 | Factors associated with post-distribution chlorine decay at Mtendeli.

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
<th>Model 7</th>
<th>Model 8</th>
<th>Model 9</th>
<th>Model 10</th>
<th>Model 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial FRC level</td>
<td>0.400***</td>
<td>0.377***</td>
<td>0.364***</td>
<td>0.364***</td>
<td>0.396***</td>
<td>0.309**</td>
<td>0.314**</td>
<td>0.307**</td>
<td>0.307**</td>
<td>0.280**</td>
<td>0.272*</td>
</tr>
<tr>
<td>Time elapsed post-distribution</td>
<td>0.016*</td>
<td>0.016*</td>
<td>0.016*</td>
<td>0.016*</td>
<td>0.011</td>
<td>0.011</td>
<td>0.011</td>
<td>0.011</td>
<td>0.012</td>
<td>0.012</td>
<td>0.013</td>
</tr>
<tr>
<td>Air temperature</td>
<td>0.064</td>
<td>0.062</td>
<td>0.063</td>
<td>0.063</td>
<td>0.062</td>
<td>0.085**</td>
<td>0.081**</td>
<td>0.080**</td>
<td>0.079**</td>
<td>0.080**</td>
<td>0.073**</td>
</tr>
<tr>
<td>Container stored outside</td>
<td>0.145</td>
<td>0.137</td>
<td>0.137</td>
<td>0.104</td>
<td>0.084</td>
<td>0.09</td>
<td>0.093</td>
<td>0.095</td>
<td>0.089</td>
<td>0.089</td>
<td>0.058</td>
</tr>
<tr>
<td>Water is in same container (not transferred)</td>
<td>-0.08</td>
<td>-0.079</td>
<td>-0.05</td>
<td>-0.029</td>
<td>-0.045</td>
<td>-0.045</td>
<td>-0.045</td>
<td>-0.046</td>
<td>-0.046</td>
<td>-0.046</td>
<td></td>
</tr>
<tr>
<td>Water is the same as original (not mixed)</td>
<td>-0.001</td>
<td>-0.031</td>
<td>-0.044</td>
<td>-0.056</td>
<td>-0.056</td>
<td>-0.054</td>
<td>-0.062</td>
<td>-0.062</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water not consumed (container fullness)</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container type (jerrycan vs. bucket)</td>
<td>-0.167***</td>
<td>-0.154***</td>
<td>-0.277***</td>
<td>-0.277***</td>
<td>-0.271***</td>
<td>-0.271***</td>
<td>-0.271***</td>
<td>-0.271***</td>
<td></td>
<td></td>
<td>-0.18</td>
</tr>
<tr>
<td>Container opacity (translucent vs. opaque)</td>
<td>0.144*</td>
<td>0.144*</td>
<td>0.138</td>
<td>0.140*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container covering (covered vs. uncovered)</td>
<td>-0.008</td>
<td>0.006</td>
<td>0.015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container cleanliness (clean vs. unclean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.072*</td>
<td>-0.069</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method of Drawing (pouring vs. dipping)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.112</td>
</tr>
<tr>
<td>R² Adjusted</td>
<td>0.195</td>
<td>0.195</td>
<td>0.204</td>
<td>0.199</td>
<td>0.276</td>
<td>0.3750</td>
<td>0.371</td>
<td>0.381</td>
<td>0.377</td>
<td>0.392</td>
<td>0.391</td>
</tr>
<tr>
<td>N</td>
<td>155</td>
<td>151</td>
<td>151</td>
<td>151</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>149</td>
<td>147</td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001
Overall, the $R^2$-adjusted values indicate that the variables included explain about 40% of the total variability in the data. Other unknown and/or undocumented factors account for the remaining variability in the data. Next, we proceed through each of the variables and evaluate its association with chlorine decay.

- **Initial FRC at the tapstand** showed a very strong (large $\beta$ coefficient) positive association with chlorine decay that was consistently statistically significant. Chlorine decay is known to be a non-linear phenomenon such that higher initial FRC will result in greater absolute decay, so this is as expected.

- **Length of time elapsed post-distribution** showed a weak positive association with chlorine decay. We expected that this variable might have a positive association with chlorine decay given the skewing evident in Figure 4. However, it was only statistically significant up to the point that container type was introduced, suggesting a possible interaction in which container type may better explain chlorine decay in the household better than the sheer length of time it is stored in the household.

- **Air temperature** had a moderate positive association with chlorine decay. Generally speaking, we expect higher temperatures will increase the rate of chlorine decay by virtue of temperature-driven reaction kinetics. We found this variable to be statistically significant once container type was controlled for, suggesting a possible interaction in which the effect of air temperature is modified depending on the type of container in which water is stored.

- **Whether the water storage container was stored indoors or outdoors** produced no statistically significant effect.
• **Whether the water was transferred between containers** produced no statistically significant effect.

• **Whether the water mixed or replaced with another water** produced no statistically significant effect.

• **How much water was used in the household (container fullness)** had a very weak negative association with chlorine decay (the less water was consumed, the less decay there was) but it was strongly significant across all models. This is as expected because people consuming water means there are more opportunities for contamination to occur.

• **Water container type** showed a strong effect that was consistently statistically significant, indicating that jerrycans are protective compared to buckets. From the values for coefficient β, it appears that jerrycans can preserve between 0.15 mg/L and 0.28 mg/L FRC over the course of household storage and use compared to buckets, and this is a significant protective effect. This finding has operational implications for procurement and NFI distribution as it indicates that jerrycans are preferable to buckets for preserving the safe water chain. Interestingly, the effect is statistically significant at the p<0.001 level until container cleanliness is introduced into the model, suggesting that container type and cleanliness are confounded.

• **Water container opacity** had a strong effect that was statistically significant in most cases. The values for coefficient β indicate that opaque containers may face 0.14 mg/L less FRC decay than translucent containers. This variable is statistically significant in most cases with the exception of when container cleanliness is introduced into the model suggesting a potential interaction. This finding that translucent containers engender greater chlorine decay than opaque containers has operational implications for
procurement and NFI distribution. Overall, it appears that opaque jerrycans may be a good option for preserving the safe water chain.

- **Water container covering** produced no statistically significant effect.

- **Water container cleanliness** demonstrated a weak protective effect that was inconsistently significant. It did appear to have an interaction with container type so its effect may be confounded with other factors.

- **Method of drawing water** produced no statistically significant effect.

Overall, the most important findings were that water container type and opacity strongly influenced the extent of chlorine decay suggesting that jerrycans (compared to buckets) and opaque containers are strongly protective of the safe water chain. Further in-field research to confirm this effect and procurement decisions should follow. Additionally, we found a weak but inconsistent protective effect for container cleanliness, but no evidence on the protective effect of container covering and method of drawing.

4 Conclusions

The validation study carried out at the Mtendeli refugee camp in Tanzania confirms that the new evidence-based FRC targets provide an adequate degree of household water safety at 24 hours post-distribution and outperform the current guideline target of 0.2-0.5 mg/L at the new field site. Temperature and ambient sanitary conditions at Mtendeli were similar to the case study at Kigeme, Rwanda such that we adopted the 0.6-0.8 mg/L target recommendation. The validation study confirms that the new evidence-based FRC targets should be implemented in the field and used to replace the current non-evidence-based guidelines. Moreover, further studies in new settings with variable temperature and sanitary conditions will provide additional opportunities to evaluate and expand the new evidence-based FRC targets.
The data collection and analysis methodology used in this study have also been compiled into a “how-to manual” that field staff can use to improve water quality monitoring and optimize water safety as part of routine camp WASH activities. Finally, linear regression models developed with the Mtendeli data provide strong evidence that opaque containers and jerrycans (compared to buckets) reduce FRC decay and are protective of the safe water chain. Additional research to systematically evaluate this protective effect through field experiments may be pursued, but the evidence generated here and in previous study iterations is strong enough that changes to procurement and NFI kit composition may be considered at this point.
5 References

7. MSF. Mtendeli WASH Monitoring Indicators Wk 30 (Spreadsheet). Amsterdam: Medecins Sans Frontieres; 2016.
14. iSixSigma. How to Determine Sample Size, Determining Sample Size.
Appendices
Appendix A: Background on Sample Size Determination

Previous studies looking at water quality changes between source and point of consumption in development settings have had between 50 to 150 samples (10–12), so for the initial study in South Sudan we aimed for 200 samples and ultimately collected 220 unique samples divided between three camps. For the next study at the Azraq refugee camp in Jordan during summer 2014, we aimed for a similar number of samples, ultimately collecting 199. For the 2015 study at Azraq, we now had the benefit of an earlier dataset from the same site, which we could examine to more accurately determine the required sample size. To do this, we examined how variance in the FRC data in the 2014 dataset stabilized as we increased the number of samples upwards to a total of 199. We found that variance stabilized at the same level as for 199 samples at just 120 samples. Therefore, we aimed to collect 120 unique samples during the 2015 study at Azraq. For the final iteration at Kigeme, Rwanda, we aimed for a similar number and ultimately collected 134 unique samples.

These previous studies can help us to determine the number of samples required for the validation study at Mtendeli. Of the three previous studies in South Sudan, Jordan, and Rwanda, we use the Rwanda 2015 dataset, as it most closely resembles temperature and sanitary conditions at Mtendeli. In addition, we also have the benefit of an existing ODK water quality database from Mtendeli from February-March 2016 (9), which we can use to test how similar the Mtendeli and Kigeme datasets are. Table 4 summarizes tapstand and household FRC data from both camps.

<table>
<thead>
<tr>
<th>Camp</th>
<th>Test Location</th>
<th># Obs</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kigeme</td>
<td>Tapstand</td>
<td>134</td>
<td>0.65</td>
<td>0.19</td>
<td>0.23</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>Household</td>
<td>118</td>
<td>0.37</td>
<td>0.23</td>
<td>0.01</td>
<td>1.06</td>
</tr>
</tbody>
</table>
In Table 4, there are similarities with respect to mean and variance for both tapstand and household FRC at the two camps: we suspect the two populations may be statistically equivalent. To assess whether there is a statistically significant difference or not between the two camp datasets we use the *Student’s t-test*. One of the assumptions of the t-test is that data should be normally distributed, so we test tapstand and household FRC data at Mtendeli and Kigeme for normality using the *Shapiro-Wilks* test (Table 5).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>W</th>
<th>V</th>
<th>z</th>
<th>Prob&gt;</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapstand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kigeme</td>
<td>134</td>
<td>0.98564</td>
<td>1.518</td>
<td>0.940</td>
<td>0.17353</td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kigeme</td>
<td>118</td>
<td>0.96062</td>
<td>3.736</td>
<td>2.950</td>
<td>0.00159</td>
<td></td>
</tr>
<tr>
<td>Tapstand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mtendeli</td>
<td>827</td>
<td>0.67272</td>
<td>173.645</td>
<td>12.671</td>
<td>0.00000</td>
<td></td>
</tr>
<tr>
<td>Household</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mtendeli</td>
<td>234</td>
<td>0.70599</td>
<td>50.313</td>
<td>9.087</td>
<td>0.00000</td>
<td></td>
</tr>
</tbody>
</table>

The Shapiro-Wilks outputs indicate that only tapstand FRC at Kigeme is normally distributed at the 95% significance level, whereas tapstand FRC at Mtendeli as well as household FRC in both camps is non-normal (examining the histograms of these data suggest this as well). Fortunately however, the t-test is robust with respect to the normality assumption and works even when this condition is not strictly met (13). Therefore, we can proceed with the t-test comparing the two camp datasets (Table 6).
Table 6 | Two-sample t test with unequal variances for tapstand FRC levels at Mtendeli and Kigeme.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>Std. Dev.</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mtendeli</td>
<td>827</td>
<td>.6041113</td>
<td>.0088022</td>
<td>.2531306</td>
<td>.5868339 .6213886</td>
</tr>
<tr>
<td>Kigeme</td>
<td>134</td>
<td>.6458209</td>
<td>.0162039</td>
<td>.1875737</td>
<td>.6137702 .6778716</td>
</tr>
<tr>
<td>combined</td>
<td>961</td>
<td>.6099272</td>
<td>.0079157</td>
<td>.2453868</td>
<td>.5943931 .6254613</td>
</tr>
</tbody>
</table>

| diff | -.0417096 | .0184403 | -.0780519 | -.0053673 |

diff = mean(TapFRC_Mt) - mean(TapFRC_Ki)  
t = -2.2619  
Ho: diff = 0  
Satterthwaite's degrees of freedom = 219.989

Ha: diff < 0  
Pr(T < t) = 0.0123

Ha: diff != 0  
Pr(|T| > |t|) = 0.0247

Ha: diff > 0  
Pr(T > t) = 0.9877

From Table 6, we see there is a statistically significant difference between tapstand FRC at Mtendeli and Kigeme (p < 0.05). Table 7 presents t-test outputs for household FRC data.

Table 7 | Two-sample t test with unequal variances with household FRC data for Mtendeli and Kigeme.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Err.</th>
<th>Std. Dev.</th>
<th>[95% Conf. Interval]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mtendeli</td>
<td>234</td>
<td>.3641026</td>
<td>.0170224</td>
<td>.2603931</td>
<td>.330565 .3976401</td>
</tr>
<tr>
<td>Kigeme</td>
<td>118</td>
<td>.3709322</td>
<td>.0213766</td>
<td>.2322097</td>
<td>.3285969 .4132675</td>
</tr>
<tr>
<td>combined</td>
<td>352</td>
<td>.3663921</td>
<td>.0133776</td>
<td>.2509862</td>
<td>.3400817 .3927024</td>
</tr>
</tbody>
</table>

| diff | -.0068296 | .0273262 | -.0606386 | .0469794 |

diff = mean(HHFRC_Mt) - mean(HHFRC_Ki)  
t = -0.2499
With household FRC data, we find there is not a statistically significant difference between the Mtendeli and Kigeme datasets ($p >> 0.05$). This supports the possibility that household FRC at the two camps may be part of the same population, and justifies the use of the Kigeme dataset to estimate sample size for Mtendeli as well.

Selecting the appropriate sample size involves the interplay of several factors including how precise we want our final estimates to be, the practicality and cost of collecting data, and the inherent variability of the population. Our approach here is to optimize for both estimation precision and cost/practicality by determining the maximum sample size beyond which the return in greater precision with additional samples begins to diminish. To calculate sample size, $n$, we use formula (1), which is a statistical relationship linking how closely the sample (i.e., Mtendeli) approximates the population (i.e., Kigeme). Specifically, the relationship in formula (1) calculates how many samples, $n$, are required to arrive at a sample mean, $\bar{x}$, that is within a designated margin of error, $E$, from the population mean, $\mu$, at a specified level of significance, $\alpha$ (14). Since the mean is an essential measure of the central tendency of a dataset, it is useful feature to assess how well a sample approximates a population.

$$n = \left( \frac{Z\alpha/2 \cdot \sigma}{E} \right)^2 \quad (1)$$

Where:
• $z_{\alpha/2}$ is the critical value, the positive $z$-value that is the vertical boundary for the area of $\alpha/2$, in the right tail of the standard normal distribution, and is 1.96 when $\alpha = 0.05$ (at the 95% confidence level);

• $\sigma$ is the population standard deviation, taken as the Kigeme estimate, 0.23, from Table 4;

• $E$ is the margin of error, the maximum difference between the observed sample mean $\bar{x}$ and the true value of the population mean $\mu$.

We vary the margin of error, $E$, in formula (1) in order to generate a range of possible sample sizes, $n$ (Table 8).

Table 8 | Sample size required to arrive at a sample mean which approximates the population mean with a variable margin of error.

<table>
<thead>
<tr>
<th>Acceptable Margin of Error, E</th>
<th>Sample Size Required, n</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>21</td>
</tr>
<tr>
<td>0.05</td>
<td>83</td>
</tr>
<tr>
<td>0.04</td>
<td>130</td>
</tr>
<tr>
<td>0.03</td>
<td>231</td>
</tr>
<tr>
<td>0.02</td>
<td>518</td>
</tr>
<tr>
<td>0.01</td>
<td>2072</td>
</tr>
</tbody>
</table>

Because household FRC data are usually in the range of 0.01 to 0.10, we want to minimize the margin of error without taking on an excessive number of samples. Reducing the margin of error on the sample mean to 0.01, which is the same as the lower detection limit of the Palintest chlorometer, would optimize precision but the number of samples required is high ($n = 2072$). Conversely, we could minimize the sample size to $n = 21$, but the margin of error would be excessive ($E = 0.10$ mg/L when the lower end of the range of FRC is 0.01 mg/L). Therefore, in order to optimize sample size for precision and practicality, we seek the maximum sample size beyond which the return in greater precision with additional samples begins to diminish. This is
the most efficient amount of data to collect to support our analytical goals. Therefore, we plot the data from Table 8 in Figure 7, and identify the inflection point as the optimal sample size.

Figure 7 | Diminishing returns on margin of error as sample size increases.

We see in Figure 7 the inflection point appears to lie between the third \( (n = 130, E = 0.04) \) and fourth data point \( (n = 231, E = 0.03) \). We therefore interpolate between these two points and recommend that approximately 180 samples be collected at Mtendeli. This sample size optimizes representativeness while minimizing the burden of data collection in the field.
Appendix B: Data Collection Procedure

First Part: Tapstand Water Quality

1. Begin at selected tapstand.

2. Fill in Surveyor, Date, and Sample Number fields on the top of the Data Form.

3. Tapstand Location: Fill in fields as appropriate to define location of tapstand.

4. Wait for water-collector to arrive, explain study using Recruitment Script, and complete Consent Form.

5. Sampling Event #1: Direct from Tap at Tapstand.
   a. Record Time.
   b. Measure and record Ambient Air Temperature.
   c. Rinse out chlorine test vial three times with water directly from the tapstand. Collect sample of water from tapstand into test vial. Measure and record FRC and TRC following procedure given in Palintest manual.

6. Ask water-collector to fill container as they normally would.

   a. Once the water-collector has finished filling their container, mark the container with the Sample Number using permanent marker.
   b. Record the Container Type and Colour on form.
   c. Record the container’s Opacity. To do this, imagine if there was an object floating on the water inside the container. If you could not see this object floating on the water inside the container, then the container is opaque (mark “Y”). If you could see this object floating on the water inside the container, consider this as not opaque (mark “N”).
d. Record whether the container is **Covered**. If the container is completely sealed such that nothing can get in, then consider the container to be *covered* (mark “Y”). If there is any gap or hole in the cover such that external material can fall into the container, then consider the container to be *uncovered* (mark “N”).

e. Record whether the container is **Clean**. If the inside surface of the container is completely clean with no visible dirt, marks, or algae, consider the container to be *clean* (mark “Y”). If there is any visible algae, dirt, or marks on the inside surface of the container, consider the container to be *unclean* (mark “N”).

8. **Household Location.** Ask the water-collector where their household is located in the camp. Complete fields as needed to locate household. If you cannot find this household on your own for follow-up sampling the next day, accompany the water-collector to their household to make a visual ID so you can return on your own later.

9. Explain to the water-collector that you will return to check the water quality again after several hours. During this time they should continue to use the water as they normally would. If the water is almost finished, ask them to leave a little bit (e.g., one cup) in the same container so that you can test it when you return for follow-up. If they need to use the container and have to re-fill it, ask them to tell you they have re-filled it and do not collect water quality data at follow-up.

*End of first part. Proceed to next tapstand to start new sample from Step #1.*

*Additional temperature measurement:*
*Each day around midday, measure and record ambient air temperature.*
Second Part: Follow-up Household Water Quality

10. After the designated amount of time has elapsed (24 hours), return to the household from the first part of sampling.

   a. Ask water-collector to show you the container from the first part of sampling. Confirm it is the same container by checking for the sample number you had marked on it at the beginning. Ask the water-collector if it contains the same water from the first part of sampling when you were both at the tapstand, or if it has been re-filled or mixed with other water since that time.
      i. If it is the same container and the same water, mark “Y” in the Same Container and Same Water fields and proceed to Step #11b.
      ii. If it is the same water but has been transferred to a different container, mark “N” in the Same Container field and “Y” in Same Water field and proceed with Step #11b.
      iii. If the container has been re-filled or mixed with new water (i.e., it is not the same water), mark “N” in the Same Water field. Do not proceed to Step #11b and conclude sample.
   b. Record How Full is Container as a percentage (e.g., 100% for completely full, 50% for half full, 10% if just a little bit of water left, etc.).
   c. Ask the water-collector to demonstrate their Method of Drawing Water and record this on the form.
   d. Record the Container Type and Colour on form. If it is the same container as before, just copy down the same fields from earlier.
e. Record the container’s **Opacity**. To do this, imagine if there was an object floating on the water inside the container. If you could not see this object floating on the water inside the container, then the container is *opaque* (mark “Y”). If you could see this object floating on the water inside the container, consider this as *not opaque* (mark “N”). If it is the same container as before, just copy down the same fields from earlier.

f. Record whether the container is **Covered**. If the container is completely sealed such that nothing can get in, then consider the container to be *covered* (mark “Y”). If there is any gap or hole in the cover such that external material can fall into the container, then consider the container to be *uncovered* (mark “N”). If it is the same container as before, just copy down the same fields from earlier.

g. Record whether the container is **Clean**. If the inside surface of the container is completely clean with no visible dirt, marks, or algae, consider the container to be *clean* (mark “Y”). If there is any visible algae, dirt, or marks on the inside surface of the container, consider the container to be *unclean* (mark “N”). If it is the same container as before, just copy down the same fields from earlier.

h. Observe yourself and also ask the water-collector where the water container was primarily stored. Record whether the container was **Stored in Direct Sunlight** for most of the duration of household storage and usage after it was collected from the tapstand.

12. **Sampling Event #2: Follow-up from container in household.**

   a. Record the **Date** and **Time** of the follow-up visit

   b. Measure and record **Ambient Air Temperature**.
c. Rinse out chlorine test vial three times with water directly from storage container.

Collect sample of water from container into test vial. Measure and record FRC and TRC.

13. Thank water-collector for their participation and conclude sample.

*End of second part. Proceed to next household to complete follow-up for another sample.*
Appendix C: Data Form

The original data form is given below and included as a separate Excel document and pdf attachment. Slight modifications to this form were made over the course of fieldwork at Mtendeli, which are also included below.
Appendix D: Recruitment Script

1. Hello, my name is _____________. I am working with researchers from MSF.
2. We are doing a research study about water supplies in refugee camps.
3. We would like to ask you some questions about how you handle the water you will collect here and then take back to your home.
4. We would also like to test your water twice, first here at the tapstand and then again later at your home. We will return to your home after 24 hours to test again. Each time we will take a cup of water from your container to do the testing, so in total we will take two cups of water.
5. This will not take longer than a half hour of your time, all together.
6. This research will help us make the water supply safer for you and your family in this camp and in other refugee camps around the world. Are you interested in participating?

If [NO]: Thank the participant for their consideration and approach another individual.

If [YES]: Provide participant with a consent form and begin data collection.
Appendix E: Consent Form

CONSENT TO PARTICIPATE IN RESEARCH

Safe Water for Refugees

Introduction
We are researchers working with Médecins Sans Frontières. We are planning to conduct a research study. We would like to invite you to take part in this study. We are inviting you to participate in this study because we would like to see how you h

Purpose
The purpose of this research study is to learn how water quality changes between where you collect it and where you drink it in the refugee camp.

Procedures
If you agree to be in this study, you will be asked to do the following:

- You will be asked some questions about how you collect, transport, store, and use water. This will be done at the tapstand and in your home. Your responses to the questions will be recorded on a form and electronically. This should take about half an hour of your time in total.

- Please continue to collect and use water as you normally do. We will observe and record these practices. We will collect 2 cups of water for water quality analysis here at your home.

Study time
We request a total of 1/2 hour of your time.

Study location
All study procedures will take place at the camp water distribution point (tap-stand) or at your home.
Benefits
We hope this study will help us to make the water supply in this refugee camp safer and better protect your own and your family's health. This information will also help us to improve the quality of water supply in all refugee camps around the world.

Risks/Discomforts
- We will observe and record the cleanliness of your water storage containers. We will state that it is clean, unclean, or dirty. This may be an uncomfortable thing to talk about for you. You are free to decline to answer any questions you don't want to, or to stop the survey at any time if you don’t want to continue.
- Breach of confidentiality: As with all research, there is a chance that confidentiality could be compromised. This means that the information could be seen by others who are not involved in the research. We are taking precautions to minimize this risk.
- The study may entail increasing the chlorine level in the camp water supply up to a maximum of 1 mg/L. This is within the normal range of practice in refugee camps. This chlorine level may have slight taste or odour but represents no health risk because it is far below the World Health Organization maximum allowable chlorine concentration in drinking water of 5 mg/L.

Confidentiality
Your study data will be handled as confidentially as possible. If results of this study are published or presented, individual names and other personally identifiable information will not be used. To minimize the risks to confidentiality, we will do the following:
- We will only ask you for your name and house number so we can return for a follow-up visit. After the follow-up visits, we will remove the name and house number on the data collection form so there will be no personal identifiers. Therefore by the end of the day, all of the data will be anonymous. We will not maintain a link between your identity and the research data.
- Your research records, including data collection forms will be stored in a locked cabinet with MSF, accessible only to researchers. The data will also be stored on the computer of the researcher in an anonymous manner.
• Only the researchers will have access to your study records.

Future Use of Study Data
The paper data collection forms will be retained for 2 years and then destroyed. The electronic data will be maintained for possible use in future research by MSF. We will retain this data indefinitely after the study is over. The same measures described above will be taken to protect confidentiality of this study data.

Compensation/Payment
You will not be paid for your participation in this study.

Costs
You will not be charged for any of the study activities.

Rights
Participation in research is completely voluntary.
You have the right to say no to participating or leave the study at any point without any problem or loss of benefits to which you are otherwise entitled.

Questions
If you have any questions or concerns about this study, you may contact Syed Imran Ali at +1-416-434-0192 or ali.s.imran@gmail.com or Jean-Francois Fesselet Jeff.FESSELET@amsterdam.msf.org.

Consent
You have been given a copy of this consent form to keep if you agree to participate in this research.