Project Report

Assessing the Implementation of Selected Household Water Treatment and Safe Storage (HWTS) Methods in Emergency Settings

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Disclosure of Interest. The authors completed this work as employees of the London School of Hygiene and Tropical Medicine (LSHTM). LSHTM has been engaged by manufacturers and distributors of household water treatment and safe storage (HWTS) products, including Procter & Gamble Company, PSI, Medentech Ltd., Unilever Ltd., Miox Corporation, and Vestergaard-Frandsen SA, to provide research and consulting services in connection with the development and testing of these products, and in the implementation and evaluation of programs and initiatives involving their sale, distribution, or use.

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Cover Photos (clockwise from top left): A woman in Turkana, Kenya who received PuR and Aquatabs after a flooding event; an enumerator in West Sumatra, Indonesia collecting a water quality sample for microbiological analysis; a boy in Jajarkot, Nepal with Aquatabs, Piyush liquid chlorine, and medicine distributed during a cholera epidemic; and, an enumerator in Leogane, Haiti testing free chlorine residual in a household after the earthquake. Photos taken by Daniele Lantagne.

EXECUTIVE SUMMARY

We were commissioned by UNICEF and Oxfam to undertake this study to address two overarching questions: 1) What role, if any, should household water treatment and safe storage (HWTS) play in emergency response (in other words, is HWTS a necessary, effective, and suitable intervention for protecting people affected by emergencies compared to other possible interventions)?; and, 2) What are the factors, if any, associated with feasible, and potentially sustained, implementation of HWTS in response to emergencies (e.g., type of emergency, characteristics of setting and affected population, capacity of responders, types of interventions, nature of programmatic support)? We focused particularly on evaluating HWTS interventions implemented in the acute emergency context, within eight weeks of emergency onset.

To answer these questions, we investigated HWTS implementations in four acute emergency contexts between August 2009 and March 2010, including: 1) a cholera outbreak in Jajarkot, Nepal; 2) an earthquake in West Sumatra, Indonesia; 3) a flooding event during a cholera epidemic in Turkana, Kenya; and, 4) an earthquake that caused significant internal displacement in Haiti. These emergencies represented a diverse range of emergency situations, geographical settings, affected population size, and HWTS implementation strategy. In each emergency we conducted the following activities: 1) spatial analysis; 2) household surveys; 3) water quality testing; 4) qualitative interviews with water, sanitation, and hygiene (WASH) responders and logistical staff; and, 5) data collection to characterize response costs.

We used microbiological improvement of household water quality as our main indicator of HWTS intervention effectiveness. While we are ultimately interested in the health impact of HWTS interventions, assessing health outcomes directly is not possible in the acute emergency context where rapid assessment is vital and diarrheal disease rates are variable. The potential for health benefits can be reasonably inferred if: 1) the intervention reached the target population at risk of waterborne disease due to reliance on unsafe water (coverage); 2) that population used the HWTS intervention (use); and, 3) as a result of such use, household drinking water met WHO guideline values for microbiological water quality. Using an HWTS option to improve household microbiological water quality from above WHO guidelines values before treatment to below WHO guidelines value after treatment is defined in this report as "effective use".

Overall, we conducted 1,521 household surveys in the four emergencies. Large variations were seen in the following household characteristics: female respondent education, percent of female head of households who can read, displacement after emergency, percent of households with covered stored drinking water, reported diarrhea, access to improved water sources pre-emergency, reason for considering water safe, perceived post-emergency health risks, and pre-emergency HWTS option knowledge. A statistically significant increase in access to improved water sources after emergency onset was noted in two of the emergencies.

The HWTS options distributed within the acute emergency contexts were predominantly: 1) chlorine-based (liquid or tablets such as Aquatabs); and, 2) available in country before the emergency. Filters were distributed only in Haiti, and at relatively small scale. The only option imported after the emergency that was able to be distributed within the acute emergency timeframe were Aquatabs flown into Haiti.

Confirmed use of chlorine-based options, as measured by free chlorine residual, ranged from <1% of the targeted population in Indonesia, where there was significant taste and smell objections and low perceived disease risk, to 89.5% in Haiti, where targeted rural households used mostly unimproved water sources and received education from community health workers hired by an NGO with pre-emergency experience promoting HWTS in Haiti.

Effective use of HWTS options varied significantly between implementation strategies in the emergencies. Overall, 18.5% of recipients had free chlorine residual in their drinking water in Nepal, where microbiological sampling was not able to be completed. In Indonesia, even though the distributed chlorine options were not used, 88.1% of the surveyed population reported boiling. Overall, 21.1% of the surveyed population improved the quality of their stored household water using boiling to meet WHO guideline values for *E. coli*. In Kenya, after a non-food item (NFI) distribution with a single training on Aquatabs and PuR, 7.6% of targeted households were using Aquatabs or PuR to improve the quality of their stored household water to meet WHO guideline values for *E. coli*. In Haiti, effective use of Aquatabs ranged from 13.0% in NFI-type distributions in spontaneous settlements to 67.5% in rural areas with community health worker promotion. Ceramic and biosand filter effective use were relatively low, at 10.0% and 8.4%, respectively. This was due to ceramic filters being distributed to households with untreated water that already met WHO guideline values and incorrect installation of biosand filters.

The HWTS distribution projects with the highest rates of effective use shared three key properties: 1) they targeted households with contaminated water, such as those using unimproved sources; 2) they provided an HWTS option that effectively treated the water; and, 3) they provided the option to a population familiar with that option before the emergency, willing to use it, and trained in its use with the necessary supplies provided. When these factors came together a high effective use rate was seen. When one factor was missing – such as when untreated household water was not contaminated in the otherwise effective ceramic filter distribution in Haiti, when the biosand filters were ineffective at removing microbes due to incorrect installation in Haiti, or the population was not willing to use chlorine-based options distributed in Indonesia – effective use dropped substantially to less than 10%.

Based on our investigations, we identified 10 key factors for feasible implementations of HWTS programs in the acute emergency context, and make the following 10 recommendations:

1) HWTS options should be distributed in emergencies with waterborne disease risk. In those emergencies where the likelihood of waterborne disease is low, resources should be allocated to more pressing priorities such as food, shelter, security, or other needs particular to the emergency.
2) Responders should develop a strategy to target the appropriate population, such as those without access to more traditional water supply interventions, before distribution of HWTS options.
3) HWTS programs should be targeted to households actually drinking contaminated water, such as those drinking from unimproved sources.
4) Responders should develop HWTS programs that build on the population's pre-existing knowledge of HWTS options and on pre-emergency HWTS programs.
5) Responders should distribute safe storage containers as part of the acute emergency response if the local container is not appropriate for the HWTS option distributed.

6) Responders should: a) pre-position appropriate HWTS options in emergency-prone areas; and, b) identify local organizations that can distribute and train on the options immediately after emergency onset.
7) Rather than accept a supplier-driven HWTS option decision tree, responders should include HWTS options within a comprehensive WASH strategy that evolves throughout the emergency based on assessments of the local conditions and knowledge of community water knowledge, attitudes, and practices.
8) Training is crucial for the correct use of all HWTS options. Responders should provide the appropriate level of training to recipients. At minimum a single training for 'simple' options (such as chlorine-based options or ceramic filters), and multiple trainings for 'complex' options (such as PuR or biosand filters) should be provided. Also, only simple options should be distributed in the acute emergency context. Complex options can be distributed after the emergency stabilizes and there is higher capacity for training and follow-up.
9) New, unverified, or unknown HWTS options should not be introduced into an acute emergency context without extensive piloting, follow-up, training, and evaluation.
10) It is highly recommended that the WASH Cluster align on a uniform chlorine dose in each emergency context, and select one tablet size that is appropriate for the water quality, storage container size, and taste and smell acceptability within the specific emergency.

Recommendations for organizations interesting in implementing HWTS in the acute emergency context are thus summarized in eight steps. **Prepare.** Before emergencies occur, complete a comprehensive emergency preparedness program, including training of staff, development of Water, Sanitation, and Hygiene (WASH) Cluster teams, and pre-positioning of appropriate HWTS options. **Strategize.** After emergency onset, develop an integrated WASH response strategy (that includes HWTS if appropriate) based on a rapid assessment that investigates: 1) the impact of the emergency on the health of the affected population; 2) the water quality situation; and, 3) the WASH knowledge, attitudes, and practices of the affected population. **Select.** Select HWTS options that are appropriate for the water quality, logistical, and cultural conditions of the particular emergency context. **Provide.** Provide the affected population with: 1) enough HWTS option for the emergency duration; 2) a HWTS option appropriate for the existing storage container(s) or an appropriate storage container; 3) specialized equipment needed to use the option; and, 4) the materials for recipients to maintain durable options. **Train.** Train the recipients appropriately, including follow-up trainings for complex options. **Be realistic.** Understand that NFI-kit distribution will likely lead to low uptake of HWTS options in the acute emergency context, which does not necessarily mean the intervention is not valuable or not cost-effective. **Evaluate.** Conduct evaluations using simple and robust metrics to assess program efficacy, and share these results with the wider community. **Link.** The most successful emergency HWTS programs were in areas with successful development HWTS programs before the emergency. By supporting and linking to pre-existing HWTS programs, effective use of HWTS in the emergency can be increased.

There is little evidence on the uptake, correct use, and effective use of any health product in the acute emergency situation. Our results show than HWTS can be effective in the acute emergency context, and provide insights for maximizing efficacy. HWTS has advantages compared to other options in terms of being rapidly deployable, fast to distribute, and proven to improve the quality of stored household water. However, HWTS has large drawbacks as well, most especially placing the responsibility for water treatment at the individual household rather than the centralized level. With appropriate preparation and implementation strategies, HWTS options can be one appropriate tool for providing safe water in the acute emergency context.

CONTENTS

List of Figures[1]

1: Unless otherwise noted, photographs were taken by Daniele Lantagne

List of Tables

ACRONYMS

AT	Aquatabs
BSF	Biosand Filter
CDC	US Centers for Disease Control and Prevention
CHW	Community Health Worker
CI	Confidence Interval
CMR	Crude Mortality Rate
CWH	Clean Water for Haiti
DSI	Deep Springs International
FCR	Free Chlorine Residual
FR	Female Respondent
GON	Government of Nepal
GOW	Gift of Water
HH	Household
HOH	Head of Household
HRC	Haiti Response Coalition
HWTS	Household Water Treatment and Safe Storage
IDP	Internally Displaced Person
INGO	International Non-governmental Organization
KRCS	Kenya Red Cross Society
LSHTM	London School of Hygiene and Tropical Medicine
NFI	Non-food Item
NEWAH	Nepal Water and Health
NRCS	Nepal Red Cross Society
NGO	Non-governmental Organization
OR	Odds Ratio
P&G	Procter & Gamble Company
PFP	Potters for Peace
PPS	Population Proportionate to Size
PSI	Population Services International
RtD	Relief-to-Development Continuum
SES	Socio-economic Status
SODIS	Solar Disinfection
SWS	CDC Safe Water System
USAID	United States Agency for International Development
UNICEF	United Nations Children's Fund
VDC	Village Development Committee
WASH	Water, Sanitation, and Hygiene
WATSAN	Water and Sanitation
WFP	World Food Program
WHO	World Health Organization
WTU	Water Treatment Unit

Please note that in this report, the acronym HWTS has replaced PoUWT (point-of-use water treatment) at the request of UNICEF.

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1 INTRODUCTION

Unsafe drinking water, inadequate sanitation facilities, and poor hygiene cause four billion cases of diarrhea each year, resulting in 1.8 million deaths mainly among children under 5 years of age (Boschi-Pinto, 2008). A growing body of evidence from the development context shows that treating water at the household level improves the microbiological quality of household water and reduces the burden of diarrheal disease in users (Clasen, 2007). Based on this evidence, the World Health Organization (WHO) promotes household water treatment and safe storage (HWTS) as a means of achieving the health gains of safe drinking water for the 884 million who lack access to improved water supplies and the millions more drinking microbiologically unsafe water (WHO, 2005b; UNICEF/WHO, 2008).

Safe drinking water is also an immediate priority in emergencies. While outbreaks of waterborne disease after emergencies are not inevitable, experience has shown that the burden of diarrheal disease can increase, especially in connection with flooding events or population displacement (Noji, 2005).

When normal supplies of drinking water are interrupted or compromised, emergency-affected populations have long been encouraged by responders to boil or chemically disinfect their drinking water to ensure its microbiological integrity. However, the effectiveness of these interventions in the acute emergency context has not been rigorously evaluated. More recently, HWTS options that have been shown effective in the development context – such as chlorination, flocculant/disinfectant powders, solar disinfection, ceramic filtration, and biosand filtration – have been recommended for use in emergencies by manufacturers, promoters, and implementers. However, before this work it was unknown: 1) whether these interventions are more, less, or as effective in the emergency context as in the development context; and, 2) where HWTS options might be advantageous compared to standard water supply provision emergency responses, such as the provision of tanker truck water.

This study evolved from the research needs of UNICEF and Oxfam and research gaps identified in previous work conducted by the authors (Lantagne, 2009b). These research gaps are summarized in Section 2. The overarching research questions this study aimed to answer were:

1) What role, if any, should HWTS play in emergency response? In other words, is HWTS a necessary, effective, and suitable intervention for protecting people affected by emergencies compared to other possible interventions?
2) What are the factors, if any, associated with feasible, and potentially sustained, implementation of HWTS in response to emergencies (e.g., type of emergency, characteristics of setting and affected population, capacity of responders, types of interventions, nature of programmatic support)?

To answer these questions, we evaluated HWTS responses during four acute emergencies (within eight weeks of emergency onset) between August 2009 and March 2010. The tools used to answer the research questions, including situational and spatial analysis, household surveys, water quality testing, qualitative interviews, and collecting cost data, are described in Section 3. Results from the four emergencies investigated are described in Annexes appended to the end of this report, and summarized in Section 4. The overall discussion of results is presented in Section 5, and recommendations and conclusions are presented in Section 6.

2 CONTEXT

2.1 Background

Environmental health interventions to reduce diarrheal disease in the development context fall into four general categories: 1) improved water supply; 2) household water treatment and safe storage; 3) handwashing promotion; and, 4) sanitation provision. Each of these interventions has been shown to reduce diarrheal disease in developing countries (Esrey, 1985; Esrey, 1991; Fewtrell, 2005). Five HWTS options – chlorination, flocculant/disinfectant powder, solar disinfection, ceramic filtration, and biosand filtration – have been shown to reduce diarrheal disease in users by improving and maintaining the microbiological safety of the water during transport, storage, and use in the home in developing countries (Clasen, 2007; Stauber, 2009). A sixth, boiling, is widely used but not verified to reduce diarrheal disease. Feasible HWTS programs select a high-quality culturally appropriate option, distribute the products reliably, and work with trusted local community educators to encourage healthy practices (Lantagne, 2008b).

There has been significant debate in the research community about the efficacy of water, sanitation, and hygiene (WASH) interventions in preventing diarrhea. Systematic reviews have reported varying levels of diarrheal disease reductions associated with each of the four main categories of WASH interventions – water supply, water treatment, sanitation, and hygiene. (Esrey, 1991; Fewtrell, 2005; Clasen, 2007; Cairncross, 2010). Some researchers have noted that HWTS may not be as effective as initially thought due to the bias in self-reported diarrheal disease data and the lack of evidence on the sustained impact of HWTS interventions (Hunter, 2009; Schmidt, 2009). Clasen argued that studies of HWTS interventions have shown objective evidence of health outcomes, that previous blinded studies present methodological problems, and that bias is unlikely to account for the full health impact reported in field trials (Clasen, 2009). Ultimately, the potential for HWTS to prevent diarrheal disease depends largely on the extent to which drinking water represents a significant pathway for the transmission of diarrheagenic agents and other factors affecting the target population that further studies are necessary to determine.

The research on HWTS referenced above has mostly occurred in the development, and not the emergency, context. However, "humanitarian aid, which aims to mitigate the effects of crises on vulnerable populations, is not the same as development assistance, which aims to alleviate the root causes of poverty and vulnerability" (Lippuner, 2005). Humanitarian principles are well-defined and rooted in international law, while "developmentalist interventions" "tend to be underpinned by less clearly articulated" principles (Maxwell, 1999). The differences in implementing organization principles can have significant impact on HWTS projects. An organization whose goal is to provide safe water for the duration of the emergency only might select a different HWTS option than one whose goal is to ensure sustainable access to a cost-recovery product. An emergency organization providing safe water to the people most in need may have different priorities than a development organization working with the local government to reach the most people with an intervention. An emergency organization must make option selection and implementation decisions more quickly than a development organization. There are also health differences between the emergency and development contexts. Emergencies can have a higher crude mortality rate (CMR) (Toole, 1990) and a higher likelihood of disease outbreaks due to population migration (Watson, 2007). In addition, emergencies have a higher level of funding (de Ville de Goyet, 2000) and tend to have more competing priorities for staff time (CARE, Undated). All of these factor impact which HWTS option is selected and most appropriate for the context.

All of these factors also raise questions about the generalizability of HWTS results from development settings into emergency settings. Some factors, such as a higher disease burden, would potentially increase the effectiveness of HWTS in the emergency as compared to the development setting. Other factors, such as less staff time to train users on the HWTS option due to competing priorities, would potentially decrease the effectiveness of HWTS options in the emergency context.

We propose that HWTS interventions would be most effective in emergencies with increased diarrheal disease risk. Contrary to popular opinion, diarrheal disease does not increase after all emergencies. For the purpose of this report, emergencies will be categorized as: '*natural disasters*', '*complex emergencies*', and '*outbreaks*'. *Natural disasters* are "catastrophic events with atmospheric, geologic, and hydrologic origins" that include "earthquakes, volcanic eruptions, landslides, tsunamis, floods, and drought" (Watson, 2007). A '*complex emergency'* is defined by the UN as "a humanitarian crisis in a country, region or society where there is total or considerable breakdown of authority resulting from internal or external conflict and which requires an international response that goes beyond the mandate or capacity of any single agency and/or the ongoing United Nations country program" (IASC, 1994). "A *disease outbreak* is the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season. An outbreak may occur in a restricted geographical area, or may extend over several countries. It may last for a few days or weeks, or for several years" (WHO, 2008).

Although many myths surround the increased risk due to outbreaks in post-natural disaster situations, the reality is that deaths associated with natural disasters are predominantly blunt trauma, crush-related injuries, or drowning, and victims are triaged and treated primarily by local survivors before the arrival of international aid (de Ville de Goyet, 2000; Watson, 2007). The two situations in which natural disasters have been shown to lead to increased diarrheal disease burden are: 1) flooding events; and, 2) when the disaster leads to large-scale population displacement (Noji, 1997).

HWTS, as an intervention that reduces the diarrheal disease burden, could thus potentially be an effective intervention: 1) in response to emergencies with increased risk of diarrheal disease, including flooding events or natural disasters that lead to displacement (Noji, 1997); 2) in some complex emergency settings when relief cannot progress to development and WASH infrastructure can not be developed; and, 3) in response to outbreaks caused by untreated drinking water, especially cholera outbreaks, which are currently increasing in severity and quantity throughout Africa (Gaffga, 2007). The health consequences of emergencies and population displacement, together with the projected increase in scope of emergencies (UNISDR, 2006) and funding for emergency response (DI, 2006), shows there is a strong need to understand the existing and potential role for WASH interventions (including HWTS) in emergencies. A working model of the potential role for interventions to decrease diarrheal disease in emergencies was developed based on this data and is presented in Figure 1.

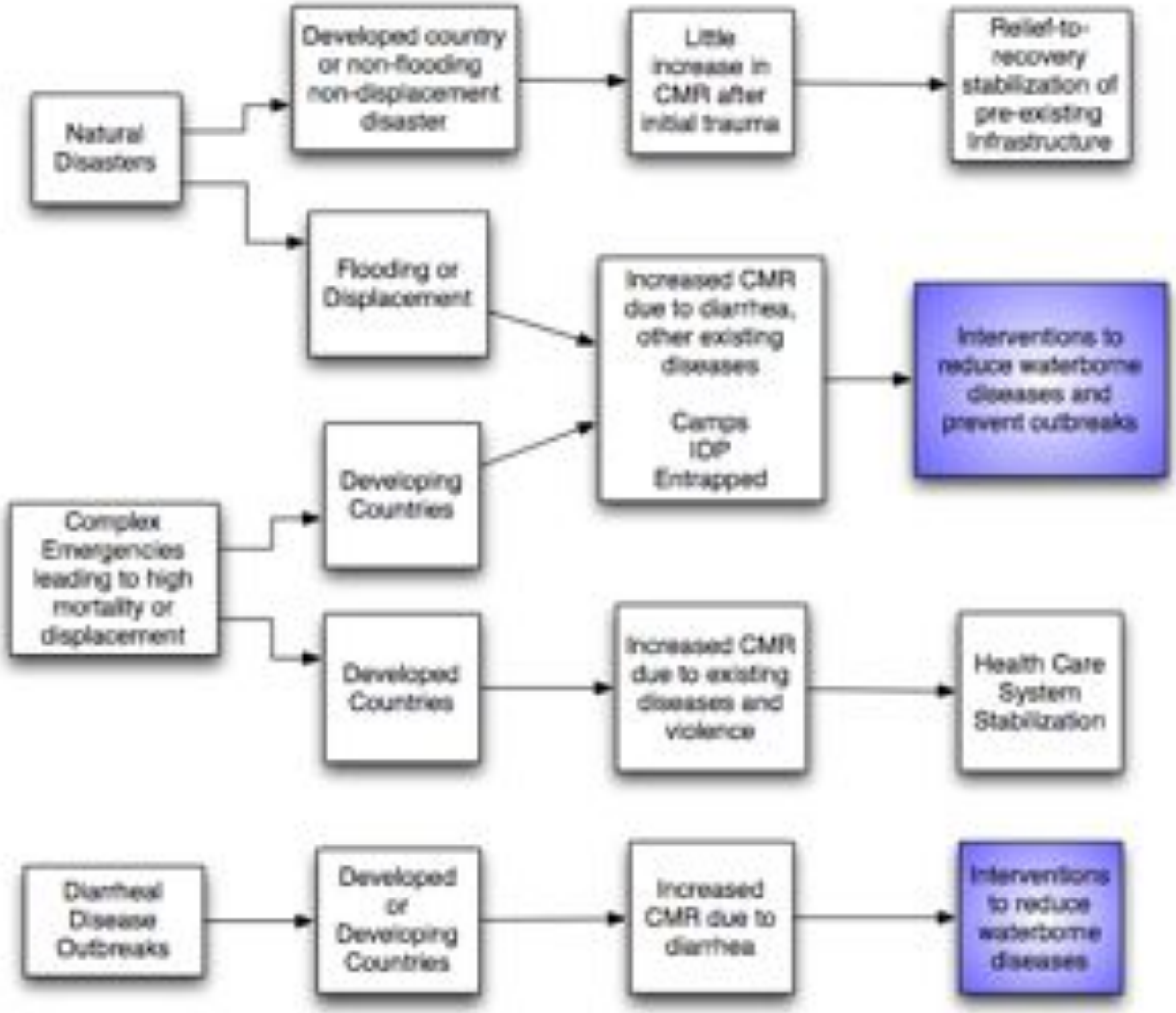


Figure 1: Emergencies where interventions to prevent diarrhea are indicated

2.2 Prior research

Before initiating the research summarized herein, the authors completed a literature review and implementer survey to document the current evidence base for, and use of, HWTS in the emergency context (Lantagne, 2009b). This work was supported by the Centers for Disease Control and Prevention (CDC) and the United States Agency for International Development (USAID). In this section, this review is summarized. For the full report, the reader is referred to (Lantagne, 2009b).

2.2.1 Literature review

We undertook a comprehensive literature review to identify papers, project evaluations, and other literature on HWTS use in emergencies. Literature was identified through five mechanisms: 1) searching the authors' personal databases; 2) conducting database searches on MedLine and PubMed; 3) requesting reports from survey respondents; 4) sending targeted emails to individuals identified as researchers in underrepresented areas requesting grey literature; and, 5) soliciting materials from conferences and meetings.

A total of 28 journal articles, project evaluations, and manuals were identified describing HWTS interventions in emergencies (Lantagne, 2009b). By HWTS method, this includes 9 (32.1%) on the Procter & Gamble flocculant/disinfection product PuR, 7 (25.0%) on sodium hypochlorite (the CDC Safe Water System (SWS)), 4 (14.3%) on ceramic filtration, 3 (10.7%) on boiling and safe storage promotion, 3 (10.7%) specifically on HWTS in the 2004 Asian Tsunami, 1 (3.6%) on solar disinfection, and 1 (3.6%) on a commercial filter. As can be seen, research on the commercial product PuR dominates the evidence base, and although chlorine tablet distribution is common in emergencies, and solar disinfection and biosand filtration are common development HWTS interventions, no evaluations were identified using these options. However, some data is available on chlorine tablet distribution as two studies exploring PuR also collected data on chlorine tablets.

This literature provides some evidence HWTS is effective in non-acute emergency settings. PuR use was shown to reduce diarrheal disease in one long-term refugee camp (Doocy, 2006), and PuR and Aquatabs were both shown to improve microbiological quality of household water in cyclones (Johnston, 2008; Hoque, Undated). Sodium hypochlorite use improved microbiological quality of water after the tsunami (Gupta, 2007) and during a complex emergency (Ritter, 2007). Ceramic filters have been shown to improve microbiological quality of water during and after flooding (Palmer, 2005; Clasen, 2006). However, almost all evidence showing HWTS effectiveness was collected in stable emergency situations in many ways similar to development circumstances, where organizations had the capacity to conduct trainings and ongoing follow-up with recipients. No research documented HWTS effectiveness in acute emergencies, or in situations where training and follow-up is infeasible.

Health impact and microbiological reduction are gold standards for measuring HWTS impact, however, these metrics can be difficult to access in emergencies. Some projects were able to gather valuable impact metrics, such as chlorine residual in household water and quantitative information on use and acceptance. Other metrics collected, such as non-controlled self-reported diarrheal disease data or knowledge of methods to reduce diarrhea, were of less value. We recommend that appropriate metrics to assess HWTS impact (such as uptake measurements or chlorine residual presence as opposed to diarrheal disease reduction), considering what is realistic to collect in emergencies rather than the perceived need to obtain health outcomes, should be utilized in future evaluations.

Training is key for HWTS uptake in, and continued use after, emergencies. High usage of PuR in emergencies was associated with a training session and additional follow-up education (Doocy, 2006; Handzel, 2006; UNICEF, 2007; Johnston, 2008; Hoque, Undated). Sodium hypochlorite use in emergencies was seen in 3-20% of household waters (Dunston, 2001; Gupta, 2007), although higher long-term uptake levels (76.7% in Haiti) were documented when families had yearly follow-up education (Ritter, 2007). In one study, 26.3% of ceramic filter users were using the filter correctly 16 months after one initial training (Clasen, 2006). One study documenting lack of microbiological improvement in boiled water in Indonesia indicated not all users boiled correctly, and additional training was recommended (Gupta, 2007). A direct comparison of these percentages should be avoided, as some studies sampled the entire community population and others only households receiving the intervention. Overall, however, no study identified in the literature review documented greater than 20% uptake when HWTS options were distributed and used within the acute emergency context.

Although cost may not factor significantly in emergency response programs, cost-recovery is critical if continued access to HWTS in the post-emergency stage is desired. Average product costs – not including transportation, distribution, or marketing – of PuR (treats 10 Liters), Aquatabs (20 Liters), and sodium hypochlorite bottles (1000 Liters) are 0.035, 0.015, and 0.33 USD, respectively. Willingness to pay estimates (for PuR, Aquatabs, and ceramic filter replacement parts) were less than product cost except for sodium hypochlorite bottles (Dunston, 2001; Mong, 2001; Handzel, 2006; Colindres, 2007; Ritter, 2007; UNICEF, 2007; Johnston, 2008; Hoque, Undated).

Each HWTS option has benefits and drawbacks, and thus, situations where they are most appropriately implemented. In emergencies, ceramic filters appeared to be a more appropriate intervention after the acute emergency has passed, when householders are moving from transitional to permanent situations. Locally-made or locally-available products with low cost, such as sodium hypochlorite or chlorine tablets, may be more appropriate for a relief-to-development model where continued access to the products is desired. PuR may be most appropriate in populations using highly turbid water, where follow-up training can be conducted. Boiling may be particularly appropriate among populations already familiar with it, or entrapped populations when they have the materials to practice the method. Safe storage is an important complement to any HWTS method, especially those that do not provide for residual protection against re-contamination. We did not recommend using new products in an emergency unless product efficacy and user acceptability had previously been assessed in field trials.

Lastly, the review documents that chlorine dosage significantly affects chlorination projects in emergencies, and appropriate dosage regimes should be developed. Some emergency organizations recommend a high dosage at 5 mg/L, which is unnecessary in any waters that can effectively be treated with chlorine, and will likely exceed the taste acceptability threshold (Lantagne, 2008a). In addition, another recommended dosage of 0.5 mg/L 30 minutes after treatment will likely not maintain sufficient residual during household storage of water (Lantagne, 2008a). We recommended a dosage of 2 mg/L for clear water (and double that for turbid) if this does not exceed the local taste threshold.

2.2.2 Survey results

We collected data from implementers with experience using HWTS in emergencies using a Word Form survey distributed via email. The survey was designed with a mixture of attribute, belief, and knowledge questions in order to gain information on the survey respondents, their perspectives on HWTS in emergencies, and their experience with HWTS in emergencies. We used language that was simple, concise, non-leading, and unbiased. The survey began with a set of open-ended questions about HWTS in emergencies, and continued with one page of specific, forced-choice questions about individual projects, using one or more HWTS options, in emergencies. There was space to specify information for up to four individual projects within each survey. Based on the survey design, data is presented: 1) by respondent, with answers to general open-ended questions; 2) by project, with project specific information; and, 3) by projects where only one HWTS option was implemented. Because many of the forced-choice questions were based on project, which could have had one or more HWTS option promoted, valuable information to allow for comparison between the HWTS options was gained from the project responses that included only one HWTS option. Respondents were requested to complete the survey on their personal computer, and email back the response. The survey was approved by the London School of Hygiene and Tropical Medicine (LSHTM) Ethics Committee.

The 40 survey respondents described 75 projects representing a diverse geographic coverage across Africa, Asia, and the Americas (Lantagne, 2009b). Sixty-four (85%) projects were implemented in emergencies identified as having high diarrheal disease risk (such as flooding events and outbreaks). The majority of the projects (68%) began in the acute emergency stage, when the risk of outbreak is highest. Projects generally targeted persons at higher risk of disease and with less access to improved water supplies, such as those living in rural areas, small communities, and the internally displaced. Overall, the projects targeted areas with unimproved water supplies (57% of supplies), and the specific HWTS option used in single-option projects was mostly appropriate for the local water sources. However, PuR was targeted 32% of the time to improved sources. In addition, chlorine tablets were targeted 72% of the time to improved sources. Because improved sources are often of lower turbidity and chlorine demand, this provides another indication the higher dose tablet of 5 mg/L is unnecessary.

Technical assistance on HWTS implementation in emergency response was primarily found locally (50.6% from within the respondents organization and 29% from other local contacts) or from within the respondents' organization internationally (30% of projects). This result highlighted that technical assistance should be available locally and specifically targeted for each implementing organization. Although 89% of respondents noted that they had assessed their project in some manner, few of these assessments were independent or made available for review. Thus, the implementers' perception of success cannot be matched with quantitative data showing project feasibility, and knowledge gained from these evaluations cannot be collated and shared as lessons learned.

There is evidence that HWTS projects in emergencies are growing at an exponential rate, as the 66 projects described by respondents started between 1999-2007, and exhibited an exponential growth rate (R^2=0.92), but this may be the result of systematic or reporting bias. Implementers found it difficult to respond to many logistical questions, and thus the amount of water treated in respondents' projects could not be calculated.

Product issues (such as availability and knowledge) dominated the HWTS option selection process as opposed to user reasons such as preference or choice, and product factors were considered the easiest factors in implementing HWTS. Concurrently, user acceptance and user training were identified as the most difficult factors in implementation, and should be considered more fully in project planning. The easiest and most difficult factors in implementation varies between HWTS options, indicating implementation strategies should be specialized for each HWTS option.

2.2.3 Lessons learned and research indicated

In development settings, HWTS options have been convincingly shown to improve the microbiological quality of household water and reduce diarrheal disease in users. There is comparatively little rigorous evidence of HWTS in emergency settings. However, from the literature review and user surveys, we determined that: 1) HWTS can be an effective water treatment intervention in non-acute (more developmentalist) emergencies; 2) current HWTS projects generally tend to correctly target emergencies with high diarrheal disease risk; 3) considering user preference in HWTS option selection facilitates implementation; 4) training is crucial to uptake of HWTS in emergencies; 5) adequate product stocks are necessary for emergency response; 6) difficulties in obtaining local product registration hinder projects; 7) users should have all materials necessary to use the HWTS options; and, 8) chlorine dosage should be considered in light of user acceptability.

In addition, we found that: 1) there is little literature on effectiveness of HWTS in acute emergencies; 2) introducing an new/unverified/untested HWTS option in an emergency may not be effective; 3) some HWTS options may be more appropriate in particular emergencies than others, as HWTS option selection is highly context specific; 4) HWTS should be one strategy among many to improve safe water access in emergencies; and, 5) the relevance of sustainable access to the products should be considered in project planning.

One main result from these investigations is that additional research on HWTS in emergencies is needed. HWTS use appears to be increasing in emergency response, despite the fact that most documented feasible HWTS in emergency projects have been implemented at relatively small-scale with significant follow-up, rather like developmentalist HWTS projects. There is little documented evidence of HWTS efficacy in larger-scale, acute emergency contexts. Of particular concern is the low uptake rate in acute emergencies of all HWTS options. No study conducted in the acute emergency documented greater than 20% uptake, and one study documenting uptake increased the longer the time after the emergency a filter was received (Palmer, 2005). Research is needed to understand determinants of adoption of HWTS in emergencies, and work to encourage adoption among a higher percentage of the targeted population.

Based on the information collected in the literature review and implementer survey, we recommended further research on HWTS in emergencies, including: 1) conducting HWTS project evaluations in large-scale immediate-onset acute emergency contexts, using appropriate metrics for program efficacy; 2) evaluating all HWTS options, including standard interventions not supported by a commercial enterprise, and understanding the benefits, drawbacks, and appropriateness for each HWTS option within specific types and stages of emergencies; 3) evaluating all HWTS options used in a single emergency response, not just one option, and understanding the relative trade-offs between options in terms of cost, acceptability, ease-of-use, and health impacts; 4) understanding the behavioral determinants of adoption for HWTS in emergencies, such as potential pre-exposure to the HWTS options, and developing training materials and strategies specifically targeted at these determinants; 5) comparing HWTS options to other options to reduce diarrheal disease in emergencies, and understanding the potential role for HWTS as part of a larger WASH strategy in emergencies at various emergency stages; 6) documenting how organizations select HWTS options – because they are simply available, or because of an option selection framework – and developing appropriate option selection frameworks; and, 7) understanding whether emergency use of HWTS stimulates long-term uptake of available, affordable HWTS options in the post-emergency situation.

Based on the investigations conducted and described herein, the authors worked in conjunction with the Sphere Project to develop guidelines for organizations interested in using HWTS in emergencies. These guidelines will be included in the new Sphere revision. They state: 1) that HWTS can be used as an option when centralized treatment is not possible; 2) the options that have been shown to reduce diarrhea and improve microbiological water quality; 3) that the most appropriate HWTS option for any given context depends on existing water and sanitation conditions, water quality, cultural acceptability, implementation feasibility, availability of option, and local conditions; 4) that successful emergency household level water treatment implementations should include the selection of culturally acceptable options, provision of adequate material product, and appropriate training to the beneficiary recipients; 5) that introducing an untested/non-verified/new water treatment option in an emergency should be avoided; 6) that in areas with anticipated risk, pre-placement of HWTS options should be considered to facilitate a quick response; and, 7) the use of locally-available products should be prioritized if continued use in the post-emergency phase is desired. A committee of experts developed and vetted a decision tree for HWTS options, which will also be included in the Sphere Revision.

3 RESEARCH METHODS

The research plan for this project evolved from the needs of both UNICEF and Oxfam and the research gaps summarized in the previous section. Based on the initial proposal developed by the authors, UNICEF, Oxfam, and LSHTM staff worked cooperatively to realign the proposal with the reality of conducting research in the acute emergency context and develop a protocol with two main research questions and five sub-questions. The initial proposal and final protocol are both available from the authors. All changes relative to the initial proposal were made and agreed on by all three organizations based on the capacity to support the field researcher and additional staff in the field.

The objective of this study was to systematically observe and capture data from a number of first phase rapid onset emergencies relating to implementing agencies' distribution/education techniques and overall user performance with a number of HWTS technologies. The overarching research questions this study aimed to answer were:

1) What role, if any, should HWTS play in emergency response? In other words, is HWTS a necessary, effective, and suitable intervention for protecting people affected by emergencies compared to other possible interventions?
2) What are the factors, if any, associated with feasible, and potentially sustained, implementation of HWTS in response to emergencies (e.g., type of emergency, characteristics of setting and affected population, capacity of responders, types of interventions, nature of programmatic support)?

The sub-questions for the study included:

1) What is the coverage of the interventions?
2) To what extent are the various HWTS options used correctly by the target population?
3) Does the use of the HWTS options provide effective protection against waterborne disease (as measured by improvements in microbiological water quality)?
4) Which options are more robust or resistant to sub-optimal use as compared to the development context?
5) How does the deployment of the various HWTS options compare in terms of resource allocations, including staff time and costs?

This report also examines: a) global availability and time required to reach the target population; b) time for demonstration and training; c) requirements for personnel, transportation and other resources to achieve effective coverage; d) synergies with other emergency response activities (e.g. distribution of supplies, hygiene promotion); and, e) cost of implementing various HWTS methods (hardware and programmatic cost) including cost per person covered.

The site selection criteria were mutually agreed upon by LSHTM and the study sponsors to help ensure that we could collect data addressing these research questions and sub-questions. These included: 1) the emergency occurred in a high-diarrheal disease risk emergency such as a flood, outbreak, or displacement event; 2) multiple HWTS options were distributed; 3) water supply options were installed as part of the emergency response as well; 4) the affected population has various levels of training and exposure to HWTS options; and, 5) the study was logistically feasible.

Because we did not know the specific context before arrival, we were prepared to conduct a wide variety of investigatory methods, depending on what was appropriate and feasible within each emergency. To answer these research questions, our protocol included five tools: 1) situation and spatial analysis; 2) household surveys; 3) water quality testing; 4) qualitative interview with WASH responders and logistical staff; and, 5) collection of data to characterize response costs. We used water quality characteristics (physical and level of microbiological contamination) as the main health proxy indicator (as health outcomes are not possible to measure in the context of an acute emergency where rapid assessment is vital and diarrhea rates are variable). In Table 1, the relationship between research tool and sub-question is shown, and each tool is described in more detail in the following sections. This research protocol was approved by the LSHTM Ethics Committee.

Table 1: Relationship between research tool and sub-question

Research Tool	Research Sub-Question Informed
Situational and spatial analysis	2, 4, 5
Household surveys	1, 2, 3, 4
Water quality testing	1, 3, 4
Qualitative interviews with WASH responders and logistical staff	5
Collection of data to characterize response cost	5

During the study period, the authors and sponsors of this study were in continuous contact to identify and discuss the deployment potential of new emergencies as they occurred and evolved. Collaboratively, we collected information from respondents on the ground within and external to our organizations to determine if an emergency met the deployment criteria. Deployment occurred after: 1) the organizations on the ground confirmed the emergency met the inclusion criteria; 2) a host organization for the study was identified; and, 3) LSHTM, UNICEF, and Oxfam staff all approved the inclusion of the particular emergency in the study.

3.1 Situational and spatial analysis

Upon arrival in each emergency, the first task was to determine the scope of the HWTS response. Both before and after arrival, we met with and/or emailed with WASH Cluster (a coordination group of WASH responders in the emergency convened by UNICEF under the mandate of the Emergency Relief Coordinator) representatives, implementing non-governmental organizations (NGOs), HWTS providers, emergency responders, and HWTS manufacturers to determine: 1) what HWTS options were available in country; 2) which products had actually been distributed to households; and, 3) which households had received the products. We mapped the location and size of the affected and HWTS recipient populations in order to develop an appropriate random household survey methodology. Depending on the size of the affected population and distribution of the HWTS options, we either selected a random sample of the affected population, or a random sample of HWTS recipients. The rationale for the specific sampling methodology for each emergency is described in the emergency-specific annexes.

Depending on the emergency, GPS coordinates were collected at the project, community, or household level. Coordinates were measured using a Garmin eTrex Legend (Olathe, KS, USA) by the field researcher or enumerators trained by the field researcher. Coordinates were entered into Microsoft Excel (Redmond, WA, USA), converted using EarthPoint (www.earthpoint.us) software, imported into Google Earth (Mountain View, CA, USA), and cleaned. Existing open-access Google Earth data layers were downloaded to assist in map development.

3.2 Household surveys

Before onset of any of the emergencies, we designed a survey template that could be adapted to various emergency circumstances. Once the emergency was selected for the study, the field researcher modified the template for the specific emergency and HWTS options distributed. The surveys consisted of: 1) questions about respondent and household characteristics, effect of the emergency, assets, diarrhea prevalence, and water knowledge and source before and after the emergency; 2) questions about the use of, preferences for, and knowledge of each HWTS option received; and, 3) questions about, water quality testing of, and collection of, current treated and untreated stored household drinking water. On average, there were about 30 questions on household characteristics, 10-20 questions per HWTS option received, and 10-15 questions on current household water. Each survey took 20-30 minutes to administer per household.

Survey tools were first translated into the appropriate local language, and then back-translated by the enumerators or another person fluent in the local language. They were printed before arrival at the emergency location due to anticipated lack of capacity to print and copy surveys within the emergency. Survey training and pre-testing occurred during one to two days of enumerator training in each emergency. Surveys were reviewed in the field, and any changes were hand-edited into the survey forms by the enumerators. All survey data was entered into Microsoft Excel (Redmond, WA, USA) by the field researcher, cleaned, and analyzed using Stata 10.1 (College Station, TX, USA).

3.3 Water quality testing

Microbiological water quality was the primary outcome variable in the study for whether the use of HWTS options was effective in providing protection against diarrheal disease. The goal of the water quality testing was to document if there was an improvement in microbiological water quality among treated water as compared to non-treated water from the same source and household. A secondary outcome variable for chlorine-based HWTS options was chlorine residual levels in household treated water. We also measured turbidity in treated and untreated water samples because reductions in turbidity have been associated with increased user acceptance of HWTS options and improved microbiological outcomes (Crump, 2004). All water quality data was entered into Microsoft Excel (Redmond, WA, USA) by the field researcher, cleaned, and analyzed using Excel and Stata 10.1 (College Station, TX, USA).

3.3.1 Microbiological indicators

Enumerators were trained by the field researcher to collect a treated water sample (if available) and an untreated water sample (from the same source if treated water was available) aseptically from each surveyed household. Samples were collected in sterile WhirlPak™ bags with sodium thiosulfate to inactivate any chlorine residual present, and stored on ice in a cooler for analysis. Each evening after surveys were completed, the field researcher conducted the microbiological testing using Millipore (Billerica, MA, USA) portable filtration stand laboratory equipment. Samples were diluted appropriately with sterile buffered water, filtered aseptically through a 45-micron filter, placed in a plastic petri-dish with a media soaked pad, and incubated in a portable incubator for 24 hours at the appropriate temperature.

Negative controls were included each day and 10% of samples were duplicated. For the first two emergencies, mFC media to measure fecal (thermotolerant) coliforms (incubated at 44.5°C) was used. However, this was replaced with mColiBlue24 media to test for total coliform and *E. coli* (incubated at 35-37°C) during the last two emergencies due to the higher resistance of mColiBlue24 to deviations in incubation temperature in resource limited environments (PATH, 2007). One deviation from Standard Methods is holding time before the sample was fully filtered was extended from 8 to 12 hours in some environments due to travel logistics (APHA/AWWA/WEF, 1998). We do not anticipate this to have significant impact on our results.

3.3.1.1 Effective use metric

In this study, we introduce the concept of "effective use". Effective use is our metric to identify the portion of the target population that actually benefits from the intervention. For this purpose, householders must not only be users, but: 1) must be vulnerable (by relying on contaminated sources of drinking water; and, 2) must be using the HWTS option in a manner that reduces the microbiological contamination of that water. In this study, "effective use" is the percent of households reporting use (and with treated and untreated water samples available at the household at the time of the unannounced survey visit) multiplied by the percent who had contaminated drinking water before treatment and uncontaminated water after treatment. The contamination/uncontamination levels were calculated two ways: 1) if the untreated water had greater than 1 CFU/100 mL of *E. coli* before treatment and less than 1 after (i.e., the strict WHO definition of safe water); and, 2) the same calculation, but using the "low-risk" guideline value of <10 CFU/100 mL as the breakpoint (WHO, 1993). To compute the percentage of the targeted population with access to improved drinking water due to the intervention we multiply the percent of the targeted population that reported using the option by the percent of the targeted population with effective use for each of the HWTS options.

$$\begin{aligned}\text{Effective use (\%)} &= \text{\% reporting use at unannounced visit (n = recipients)} \\ &\quad \times \text{\% with improved water (n = treated/untreated pairs available)}\end{aligned}$$

3.3.2 Free chlorine residual

Enumerators were trained by the field researcher to test free chlorine residual (FCR) using a Hach ColorWheel (Loveland, CO, USA) test kit. FCR was tested at all households reporting water treated with a chlorine-based HWTS option or stored tanker truck water at the time of the household survey. Results, in the range of 0.0-3.5 mg/L, were recorded on the survey data sheet.

3.3.2.1 Chlorine Dosing

Before continuing, a note on chlorine dosage regime differences between fixed-dosed HWTS options and WHO guidelines for FCR in drinking water is needed. The commercially available chlorine-based HWTS options – PuR, Aquatabs, and most sodium hypochlorite products – are all based on a fixed chlorine dosage to ensure adequate water treatment for a range of water sources. The chlorine dosage of PuR sachets is 2.0 mg/L for all waters, because the ferrous sulphate removes the organic material that causes chlorine demand. A 2.0 mg/L PuR dosage has been found to be adequate to maintain chlorine residual in 30 representative water sources in western Kenya of turbidity ranging from 0.3-1724 NTU, with an average of 331.9 NTU (Crump, 2004). The dosage of chlorine tablets (such as Aquatabs) is, generally, 2.0 mg/L for clear water (1 tab) and 4.0 mg/L for turbid water (2 tabs), although some tablets and emergency organizations dose differently to ensure a specific residual (Bastable, 2008), and many organizations use a higher dose of 5 mg/L in emergencies (Edmondson, 2008). Although 5 mg/L does not exceed the WHO standard for chlorine residual in drinking water, it does exceed the taste acceptability threshold seen in both African and Asia taste-testing results and recommended by WHO (WHO, 2004; Lantagne, 2008a). The standardized dosage for sodium hypochlorite products is 1.875 mg/L for clear water (0-10 NTU) and 3.75 mg/L for turbid water (10-100 NTU). This dosage was found to maintain adequate chlorine residual levels (greater than or equal to 0.2 mg/L and less than 2.0 mg/L for 24 hours after treatment) in 86.6% of 82 clear water samples and 91.7% of 12 turbid water samples tested from representative sources in 13 developing countries (Lantagne, 2008a). Treating water with turbidity greater than 100 NTU directly with sodium hypochlorite was not recommended. Although these fixed dosages lead to chlorine residuals that exceed the recommended WHO chlorine residual for infrastructure treated water at the point of delivery of 0.2-0.5 mg/L, these dosage regimes has been specifically approved as "consistent with the Third Edition of the [WHO] Guidelines [for drinking-water quality]" for household water treatment purposes, where it is assumed water will be stored for a period of time at the household level (Bartram, 2005).

At the user level, correct use of PuR, Aquatabs, and liquid sodium hypochlorite will be indicated by a FCR of 0.2-2.0 mg/L at least 30 minutes after treatment because these products dose at 2.0 mg/L. Thus, throughout this section, 0.2-2.0 mg/L will be used as the appropriate FCR, as opposed to the 0.2-0.5 mg/L recommended by WHO for infrastructure treated waters. A limitation of using the 0.2-2.0 mg/L range is that it does not account for time since treatment – it is possible water treated with a chlorine-based product fewer than 24 hours ago that is at the bottom of this range could become contaminated before the time of 24 hours after treatment.

In contrast to the commercially available chlorine-based options used in development contexts, in emergency contexts emergency organizations generally recommend determining the chlorine demand of each water source in each emergency empirically. This is accomplishing by first creating a '*mother solution'* of 1% chlorine solution using calcium hypochlorite powder or commercially-available bleach, and then adding different amounts of this solution to water with the goal of obtaining a FCR of 0.4 to 0.5 mg/l 30 minutes after chlorine addition. According to the WHO, this "can be determined using a special test kit. If this is not available, a slight smell of chlorine is a crude indicator" (WHO, 2005a).

This difference in chlorine dosing between the development and emergency contexts significantly affects chlorination projects in emergencies, for if the taste is unacceptable, householders will not use the product (POUZN, 2007). Development organizations are generally wary of the mother solution model because accurately making quality-controlled, known concentration mother solution in the field is difficult. Powder and particularly bleaches (Lantagne, 2009a) are not always the concentrations advertised and testing individual sources can lead to large variability in dosage regimes. In addition, while 0.5 mg/L is an adequate residual for treating water distributed by infrastructure systems, it is not adequate for maintaining chlorine residual to protect against recontamination while storing water in the home (Lantagne, 2008a). Emergency organizations are often wary of the commercially available fixed chlorine dosages of 2 mg/L because it is seen as a high dose that may be objectionable to users, although conversely a 5 mg/L tablet is often distributed in emergencies. A discussion on appropriate chlorine dosage often occurs in emergencies, and alignment and agreement on the appropriate dosage for each context is needed.

3.3.3 Turbidity

Turbidity was measured with a LaMotte 2020 turbidimeter (Chestertown, MD, USA) by the field researcher, the enumerators, or an employee specifically hired to test turbidity. Turbidity was tested on a daily basis after surveys and microbiological testing were completed. We used water remaining in the WhirlPak™ bags after microbiological testing for the testing. All samples were analyzed within 24 hours of collection. The meter was calibrated weekly with non-expired stock calibration solutions by the field researcher.

3.4 Qualitative interviews

The goals of the qualitative interviews with WASH responders and logistical staff were to: 1) understand their perceptions on the feasibility, failures, and utility of WASH and HWTS interventions in emergencies in general and in this particular emergency; and, 2) gain specific data on ease, cost, and timing of deployment of HWTS. All staff with known expertise in WASH working on WASH projects in each emergency were eligible for interviewing. Interviews were recorded and transcribed. Interviews were conducted in accordance with an interview guide developed by the field researcher.

The categories of questions asked to WASH responders were:

- How is a typical/best/worst WASH and HWTS response in emergencies managed?
- How was this HWTS response managed?
- What are the benefits and drawbacks of this HWTS response as compared to typical/best/worst?
- How have you found the user training and response for HWTS options?
- What suggestions/ideas do you have for future WASH/HWTS projects?

The categories asked to logistical staff were:

- How have the logistics of the WASH response been organized?
- How much has the WASH response cost?
- What have been the staffing requirements of the WASH response?

3.5 Collection of data to characterize response cost

In addition to the above methods, we also emailed and discussed costing of the emergency response with as many responders as were willing and able to participate. These communications gave us valuable information on the costs of HWTS and WASH interventions before and during the emergency.

3.6 Protocol summary

Overall, this open-ended protocol design allowed us the flexibility to respond within the acute emergency context and obtain as much information as possible within the time and logistical constraints of the emergencies investigated.

4 RESULTS

Between August 2009 and March 2010, the authors investigated four emergencies: 1) a cholera outbreak in Jajarkot, Nepal; 2) an earthquake in West Sumatra, Indonesia; 3) a flooding event during a cholera epidemic in Turkana, Kenya; and, 4) an earthquake that caused significant displacement in Haiti (Table 2). In this section, we present our results. We begin with a review of the characteristics of the four emergencies investigated, characteristics of the surveyed population, and qualitative interview results. We then continue with a summary of the results for the four emergencies by the five sub-research questions, including: 1) coverage; 2) use; 3) effective use; 4) resistance to sub-optimal use; and, 5) costs. Additional detail on each of the emergencies investigated are available in annexes appended to this report.

4.1 Characteristics of emergencies investigated

In Table 2, we provide an overview of the characteristics in the four emergencies. As can be seen, three of the four emergencies (Nepal, Kenya, and Haiti) had high diarrheal disease risk, as defined in Figure 1. The fourth emergency, Indonesia, had low diarrheal disease risk, as it was an earthquake with low displacement. The settings of the emergencies ranged from extremely rural (Kenya, Nepal), to urban (Indonesia), to a mix of urban to rural mountainous (Haiti). There was a large range in the number of households affected by each emergency – from 5,592 households in Kenya to over 600,000 households in Haiti.

The responders who implemented HWTS options in the acute emergency context ranged from local non-governmental organizations (NGOs) working in the area on development strategies before the emergency (Nepal Water for Health (NEWAH) in Nepal, local NGOs in Haiti) to newly arrived national and international NGOs responding only to the emergency (Kenya Red Cross Society in Kenya, CARE and Rotary in Indonesia, one new response NGO in Haiti) (Table 2). In one emergency (Nepal) the local NGO targeted the entire population of two affected districts within the larger emergency affected area; in two emergencies (Indonesia and Haiti) NGOs targeted multiple small pockets of families within the larger affected area; and, in Kenya the entire emergency affected population was targeted with HWTS options. The HWTS options distributed were almost all chlorine tablets or liquid, although some filters were distributed in Haiti and PuR sachets were distributed in Kenya. All HWTS options distributed in the acute emergency context were pre-positioned or available in country before the emergency, with the exception of Aquatabs in Haiti, which were imported by a local NGO working in Haiti on liquid chlorine distribution before the earthquake. The financial support for these particular HWTS projects was in the tens of thousands of USD and/or was leveraged on other programmatic activities.

The only emergency where the population has potential long-term access to HWTS after the emergency was Haiti. Numerous social-marketed, marketed, and freely distributed HWTS options were available to the affected population after the acute emergency. The only program that considered providing long-term access to the products post-emergency during program planning was the Deep Springs International (DSI) Aquatabs/liquid chlorine program in Haiti. As additional emergencies have occurred in the post-earthquake context in Haiti (cholera, political violence, and hurricane) many organizations continue to promote HWTS as a safe drinking water strategy. In the other three emergencies there was no continued access to the HWTS options: 1) in Nepal the region was too remote (three days walking from the nearest air-strip) to be reached with the socially-marketed and freely distributed HWTS options available in country; 2) in Indonesia although there are HWTS options on the market the population prefers, and completes, boiling of water; and, 3) in the area of Turkana, Kenya where the emergency was the region is too remote to be reached by the UNICEF/PuR project promoting PuR or other socially marketed products. The ongoing strategies for safe water supply in these contexts are: 1) to develop access to water supply, sanitation, and hygiene with the local NGO NEWAH in Nepal; 2) to continue drinking improved water supplies and boiling in Indonesia; and, 3) in Kenya to continue development of improved water supplies under a World Vision program.

Table 2: Overview of four emergencies investigated

	Nepal	Indonesia	Kenya	Haiti
Date investigated	July 31-August 22, 2009	November 1-22, 2009	January 20-February 5, 2010	February 14-March 13, 2010
Emergency type	Cholera	Earthquake	Flooding / cholera	Displacement / earthquake
Diarrheal disease risk	High	Low	High	High
Setting	Extreme rural, mountains	Urban, peri-urban	Extreme rural desert	Urban to mountainous
Affected population	140,000 homes	181,665 homes	5,592 homes in 4 communities	600,000 homes
Population targeted with HWTS	1,565 homes (in 2 sub-districts)	1,578 homes	5,592 homes in 4 communities	4,618 homes
Responders	Local NGOs there before the emergency	NGOs arrived after the emergency	Kenya Red Cross Society (NGO arrived after emergency)	Local NGOs there before the emergency and one new NGO
HWTS intervention types	Liquid chlorine Aquatabs	Liquid chlorine Chlorine tablets	Aquatabs PuR	Aquatabs Liquid chlorine Ceramic filters Biosand filters
HWTS options in country before emergency	All (pre-positioned for anticipated flooding)	All (available in local market)	All (pre-positioned for anticipated flooding)	All (available from local NGOs already using HWTS) except Aquatabs (flown in)
Programmatic support	10,000 USD plus products	Unknown, part of other programming	37,750 USD for 2 week program	Unknown
Sustainability	None – products not available	Boiling preferred by population, other products available	None – products not available	Potential for long-term uptake as products are available locally
Ongoing development strategy	Water supply, sanitation, and hygiene	Unneeded, boiling	Water supply provision	Not currently defined, HWTS in ongoing emergencies

4.2 Characteristics of households/respondents

A total of 1,521 household surveys were completed in the four emergencies (Table 3). The majority of survey respondents were female in all cases. A lower percentage of female respondents was seen in Nepal due to the perceived inappropriateness of male enumerators interviewing female respondents, although in this case the female head of household was often present and contributing to the interview.

Large differences in household/respondent characteristics were seen in these four emergencies. Female respondent education ranged from an average of 0.3 years of education in Kenya to 7.1 in Haiti. The percent of female head of households who can read ranged from 7.9% in Kenya to 82.8% in Indonesia (note this question was not asked in Nepal). The percent of households that did not move after the emergency ranged from 29.3% who stayed in their original homes in Haiti to 99.3% in Nepal. The percent of households with covered stored drinking water ranged from 63.8% in Nepal (where a variety of containers are used for household storage) to greater than 97% in Kenya and Haiti (where jerrycans and buckets with lids were ubiquitous). Please note that in Indonesia this survey question was asked inconsistently and thus not analyzable. Reported diarrhea rates ranged from 5.4% in Nepal to 44.3% in Haiti in children, and from 6.0% in Nepal to 17.7% in Haiti in adults.

Large differences were also seen in water treatment practices between the four emergencies, including access to improved water sources after the emergency (from 57.3% in rural Nepal to 78.6% in Kenya) and water within 30 minutes of household (from 18.2% of households in desert Kenya to 100% of households in peri-urban/urban Indonesia). Interestingly, and perhaps contrary to perceived wisdom, in two emergencies (Indonesia and Kenya) there was an increased use of improved sources after the emergency as compared to reported use of improved sources before the emergency. The majority of respondents felt their water was safe to drink in all emergencies (range 65.5% in Haiti to 96.3% in Indonesia) although the reasons for this varied. In three emergencies the majority of respondents reported water was safe because it was clear (75.4-93.3%), but in Haiti only 3.5% reported water was safe because it was clear. The main reason detailed for why water was safe in Haiti was because it was "treated". Please note that in this report, tanker truck and bottled water were considered "improved". This is a deviation from the standard WHO definition, but one we feel is appropriate – as these supplies are not considered improved because they are not always treated or are sustainable, but in the acute emergency context treatment is common and sustainability is not a consideration.

The top three health problems self-identified (unprompted) by survey respondents also varied across the four emergencies. In the Nepal cholera epidemic, the top problems listed were hospital too far away, water, and garbage. In the Indonesian earthquake, the top problems listed were cough, flu, and fever. In the Turkana flooding and cholera situation, malaria, fever, and food shortage were the top problems listed. Lastly, food shortage, diarrhea, and stress were the top self-reported problems listed in the Haiti earthquake. The percent of respondents self-reporting water as a health problem after the emergency ranged from 0% in Indonesia to 44% in Haiti, and the percent self-reporting diarrhea ranged from 8.6% in Kenya to 19.0% in Haiti.

There was a large difference in the percent of the population reporting pre-emergency knowledge of HWTS options – with only 5.2% reporting knowing at least one option in Nepal (majority boiling) to 98.8-100% in Kenya and Indonesia (also majority boiling) to 88.7% in Haiti (majority Aquatabs). In all cases, the percent of the targeted population that received at least one HWTS option from an NGO in the acute emergency context was over 80%.

Additionally, even though boiling was not promoted by an NGO, 88.1% of the total Indonesian surveyed population reported boiling.

Overall, these data indicate that the four emergencies selected and investigated represent a large range of respondent/household characteristics, water practices, health perceptions, and HWTS knowledge. These differences are valuable in comparing the four case study emergencies and to demonstrate external validity of the findings. All of these differences may impact the uptake and use of HWTS by the populations. In subsequent sections we will investigate correlations between use of HWTS and household/respondent characteristics.

Table 3: Summary of survey result statistics

	Nepal	Indonesia	Kenya	Haiti
Surveyed households	400	270	409	442
Average (min-max) respondent age (years)	34.4 (11-80)	44.7 (15-92)	38.1 (16-72)	38.2 (7-78)
% female respondents	51.0	81.5	89.2	60.5
Average (min-max) female respondent school (years)	1.3 (0-12)	5.8 (0-17)	0.3 (0-12)	7.1 (0-20)
% female head of households who can read	(not asked)	82.8	7.9	70.8
% who live in the same place as before emergency	99.3	39.0	65.0	29.3
% of respondents reporting damage to home	(not asked)	99.6	98.5	80.7
% with covered stored household water	63.8	(not asked)	97.8	98.7
% reporting child diarrhea in last 24 hours	5.4	40.9	17.4	44.3
% reporting adult diarrhea in last 24 hours	6.0	14.0	9.7	14.7
% improved sources (actual)	57.3	63.3	78.6	71.8
% of respondents with water source within 30 minutes	89.5	100	18.2	93.7
Increased use of actual improved sources after emergency	No	Yes ($p=0.018$)	Yes ($p<0.001$)	No
% who feel water is safe to drink	82.0	96.3	76.5	65.5
% who feel water is safe to drink because it is clear	83.2	93.3	75.4	3.5
Top three self-identified health problems after the emergency	Hospital too far, Water, Garbage	Cough Flu Fever	Malaria Fever Food shortage	Food shortage, Diarrhea, Stress
% self-reporting water as a health problem after emergency	24.2	0	6.4	44.0
% self-reporting diarrhea as health problem after emergency	16.4	13.3	8.6	19.0
% knowing at least one HWTS option before emergency	5.2 (4.3% boiling)	100 (100% boiling)	98.8 (92.9% boiling)	88.7 (72.9% Aquatabs)
% targeted population receiving at least one HWTS option	97.0	84.3 (CARE) 88.1 (boil)	89.5	96.2

4.3 Qualitative interview results

We conducted a total of 13 qualitative interviews. We interviewed four national and local level WASH responders in Nepal and three national and local level WASH responders in Indonesia. We were unable to interview responders in Kenya, as staff was no longer available. In Haiti, due to logistical and transportation constraints, we were able to conduct a recorded qualitative interview with one responder, an email interview with another, and verbal informal conversations with an additional four responders.

In Nepal, the four qualitative interviews reflected: 1) the importance of a coordinated WASH sustainable long-term development intervention including water supply, sanitation, and hygiene to prevent future outbreaks; 2) the role of HWTS chlorination options in providing easy-to-use, fast to distribute, short-term emergency response; 3) the drawbacks of chlorination options, including taste, dosing for a specific container size, and thinking tablets are medicine; 4) the drawbacks of boiling in terms of taste; 5) the lack of investigation of non-HWTS options that might be of utility in the emergency (e.g. rainwater harvesting); 6) the difficulty of changing behavior in mountainous rural environments; 7) the limitations of a donor-driven supply chain; 8) the importance of preparedness (both on the donor and local NGO level) to reach the entire affected population; and, 9) the high demand for the products as they were perceived by the population as a life-saving intervention.

In Indonesia, the three qualitative interviews reflected that there was intense pressure for NGOs to respond in this particular emergency for monetary/political reasons due to 2009 being a dry emergency year, reflected honestly both in the NGO response and the fact we researched this emergency as part of this study. Thus, the WASH response was based on business-as-usual practices instead of planning the most appropriate response through integrated and coordinated assessments incorporating local knowledge and practices. Examples respondents noted of inappropriate response included: 1) intense pressure from companies to use products that were not appropriate in this context, including the chlorination options distributed that were, overall, not appropriate in this context due to lack of user taste and smell acceptability; 2) lack of promotion of boiling even though organizations knew this was the local preferred option; and, 3) there might have been a role for HWTS in the urban areas, but organizations assumed they were needed in rural areas, and thus did not distribute in urban areas. Lastly, respondents stated that training is needed to ensure HWTS option use and pre-preparedness is critical to both respond, and coordinate the response.

In qualitative interviews in Haiti, respondents implementing programs highlighted that products distributed in the first week after the earthquake, before establishment of tanker truck water distributions, were critical in providing safe water, although once tanker truck distribution was established they felt these distributions were of less utility. They expect greater utility of HWTS option in future once tanker truck water distribution is phased out. One HWTS manufacturer respondent highlighted "the most difficult task has been to find organizations to distribute and manage programs" highlighting the difficulty of on-the-ground distribution in this context. Another respondent implementing programs eloquently expressed that the first critical step was to locate populations where HWTS was appropriate, and then implement programs. Lastly, another respondent stated providing Aquatabs to all people allows them control to treat their own water.

4.4 Coverage

The first sub-question this study aimed to answer was: What is the coverage of the interventions? Ideally, coverage would be the percent of affected population with unsafe water supplies that received sufficient supplies of the HWTS option to meet the drinking water needs of all household members for the duration of the emergency. However, this definition is difficult to measure accurately as the percent of the affected population needing water treatment and the duration of the emergency are unknowns. For the purpose of this report we will define and discuss coverage in three ways, depending on what information was available in each emergency: 1) the percent of the targeted population that received at least one HWTS option; 2) the percent of the affected population that received at least one HWTS option; and, 3) the number of days of water treatment received by households. In the following paragraphs, these data are presented for each of the four emergencies investigated. Additional data on the number of days of water treatment received by households is also presented in the next section on HWTS use.

In Nepal, a total of 140,000 households were affected by cholera (Table 2). Upon our arrival at the emergency, we realized that the majority of the HWTS response were scattered and small distributions of chlorine products (Aquatabs, two local liquid chlorine products) by local NGOs with support from UNICEF. However, one local NGO, NEWAH, targeted all the households within two sub-districts (1,565 households) with rolling distributions of all three chlorine products, household visits, and community training by staff hired specifically to promote HWTS for two months with 10,000 USD in other donor funding. Overall, there was almost complete coverage of HWTS distribution, as 97.0% of households visited had at least one HWTS option in the household at the time of the unannounced survey in these two sub-districts. However, these results are not representative of the entire emergency area. Since these households received various of the three products multiple times, and could return to request more product at any time, it was not possible to precisely determine the number of days of product the household received, but based on survey results of products already received, 36.3 days is a conservative estimate.

In Indonesia, two programs distributed HWTS options: 1) a CARE project which targeted complete coverage in specific at-risk communities with liquid chlorine (5,000 households total); and, 2) a Rotary project distributing ShelterBox kits (which included chlorine tablets) to 624 households selected by Rotary volunteers. Overall, HWTS reached 3.1% of the 181,665 families who were affected by the earthquake. In the community selected for survey to assess the CARE response (954 households), 84.3% had received liquid chlorine. All ShelterBox surveyed households had received tablets, as the criteria for being surveyed was presence of a ShelterBox tent outside the home. The number of days of water treatment intended to be provided for liquid chlorine was 68, and for tablets in the ShelterBox 288. This was confirmed in the survey with an average of 73 for liquid chlorine, and 288 for ShelterBox recipients. Thus, coverage in this emergency depended on whether the household was targeted by CARE or Rotary.

In Kenya, Kenya Red Cross Society (KRCS) considered 5,592 households in four communities affected by the cholera/flooding emergency and 3,102 were targeted with HWTS option distribution. As it was not known at the time of the survey which households KRCS considered targeted, we simply surveyed randomly within all households in the affected population, and found 89.5% had received at least one of the two HWTS options – Aquatabs and PuR – that were distributed in non-food item (NFI) kits. An average of 110 days of water treatment were intended to have been provided using PuR and Aquatabs in the NFI kits, and the verified average received by households that received products was 97.6 days of treatment. This distribution led to almost complete coverage with HWTS options of the cholera/flooding affected population.

In Haiti, six projects were confirmed to be distributing HWTS options within the acute emergency context, reaching 4,618 (0.8%) of the 600,000 households affected. The distribution of products was not random, and in this emergency we only sampled households who were confirmed to receive products. As a consequence, a percent of the target population reached with HWTS options could not be calculated. The six projects included four chlorine distributions and two filter distributions: 1) 2,880 Aquatabs and safe storage buckets in rural Leogane with community health worker (CHW) training by the local NGO DSI; 2) an unknown number of Aquatabs in spontaneous settlements in Port-au-Prince by an international NGO; 3) 70 Klorfasil granulated chlorine bottles for 350 families in spontaneous settlements in Port-au-Prince by a local NGO; 4) liquid chlorine ("Gadyen Dlo") in one rural community (and three additional communities) in areas previous reached with a different filter (total 800 families) by DSI; 5) 350 ceramic filters distributed in Jacmel by a local Dominican Republic NGO; and, 6) 238 biosand filters distributed through a priests' network in Port-au-Prince by a local Haitian NGO. The average number of days of treatment intended to be provided was 102 for chlorine options, and indefinite (until the filter broke or needed repair) for filters. The actual water treatment provided by each of the chlorine programs was not able to be calculated, as households received chlorine products more than once on a rolling basis as needed. The actual coverage as a percentage of need varied – as in some communities targeted (such as in rural Leogane reached with the Aquatabs/bucket project or the Gadyen Dlo distributions) a higher percentage of the population was reached, but in the dispersed distributions (such as the biosand filters) it is not possible to calculate this number.

As might be expected, high coverage was attained in smaller emergencies or in targeted areas of larger emergencies within the acute emergency context. Despite reported knowledge of boiling in Nepal, Indonesia, and Kenya, the only emergency where this knowledge translated into practice was in Indonesia, where 88.1% of the population reported boiling, even in the absence of active promotion of boiling after the emergency.

Table 4: Summary of coverage statistics

	Nepal	Indonesia	Kenya	Haiti
Total affected population (households)	140,000	181,665	5,592	600,000
Targeted population (households)	1,565	5000 (CARE) 624 (SB)	3,102	4,618
% total population received at least one HWTS option	--	3.1	89.5	0.8
% target population received at least one HWTS option	97.0	84.3 (CARE)		--
Number of days of water treatment intended to be provided (actual distribution to households in next section)	Rolling, for 2 months	68-288	110	102-Indefinite
Estimated number of household days of HWTS option provided	36.3 (conservative)	73-288	97.6	---
Actual coverage as a percentage of need	Almost complete in 2 sub-districts, low elsewhere	Various, depending on program	Almost complete	Various, depending on program
Percent reporting boiling on day of unannounced survey visit	0.0	88.1	0.2	0.0

4.5 Use

The second sub-question this study aimed to answer was: To what extent are the various HWTS options used and used correctly by the target population? To address this question, we investigated the training households received, their knowledge of product use, whether they self-reported "ever using" the option, "currently using" the option, "having treated water" at the time of the unannounced survey visit, and if their water had the correct FCR level. Our cross-sectional methodology did not now allow us to investigate consistent use, which in the development context is considered an essential aspect of use to achieve optimal protection. We did investigate rate of use of the water treatment products, which is a more appropriate metric for short-term emergency projects not intended to achieve sustained use. Our results are summarized in Table 5, and discussed below.

4.5.1 Results

There was a large range in the recipients' pre-emergency knowledge of the HWTS options distributed in the post-emergency situation. In Nepal, between 0.5-1.0% of the households knew about the chlorine options distributed before the emergency, in Indonesia 18.9% knew of the chlorine options, and in Kenya 10% knew of Aquatabs and 1.2% knew of PuR. In contrast, there was a higher reported knowledge rate in Haiti at 72.9% reporting pre-emergency knowledge of Aquatabs, 11.1% the liquid chlorine, none reported Klorfasil, and 2.0% reported any filter.

The majority of households in all contexts reported receiving at least some training. Greater than 90% of households reported receiving group trainings on the HWTS option(s) distributed in Nepal, Indonesia (except for ShelterBox tablets who received no training), and Kenya. Less than 5% reported household visit trainings in all three emergencies. In Haiti, there was a mix of group and household trainings. The average Aquatabs group and household visit training rates were 55.2 and 26.4%, respectively, in the different programs. No rural DSI households reported receiving no training, 7.7% of urban DSI households reported receiving no training, and 8.4-20.8% of spontaneous settlement households reported receiving no training on Aquatabs. In the Gadyen Dlo, Klorfasil, ceramic filter, and biosand filter programs 16.3-38.1% reported household trainings, and 30.8-83.7% reported group trainings. All Gadyen Dlo, ceramic filter, and biosand filter households reported receiving at least some training, but 11.5% of Klorfasil households reported receiving no training.

In Nepal, 53.0% of households knew the fully correct treatment for Aquatabs (volume, tablets, time) and 44.9% for Piyush (drops, volume, time). Due to a problem with the survey question, this metric could not be calculated for WaterGuard (lines, volume, time). If the metric is modified to "adequate use" which includes incorrect uses that do not impact water treatment efficacy (such as too much time for Aquatabs) these numbers increase to 78.6% and 52.8% for Aquatabs and Piyush, respectively. In Indonesia, with higher background knowledge and group trainings, 13.4% of respondents knew the correct treatment method for Air Rahmat, and 15.5% knew adequate treatment. This lower correct use knowledge despite higher background knowledge is attributed to both NFI-type training and lack of interest in the products by the users. Only 1.4% of respondents knew the correct and adequate treatment for the ShelterBox tablets, which were labeled in written English directions on the box only. In Kenya, with group trainings and lower background knowledge, 89.9% knew fully correct treatment for Aquatabs, and 92.0% knew adequate treatment. For the more complicated PuR product with five treatment steps and only group training, only 2.3% of respondents knew correct and adequate treatment. In Haiti, fully correct Aquatabs knowledge was lowest in HRC spontaneous settlements (53.1%) and highest in DSI rural areas (81.7%), although adequate treatment had less variation at an average of 83.4%.

Of households that received the HWTS option options (all of which were chlorine-based) in Nepal, 9.9%, 47.2%, and 36.2% reported treated water in the household on the day of the visit using that option, 24.0-51.6% of reported users had free chlorine residual between 0.2-2.0 mg/L, and over half of self-reported users had free chlorine residual greater than 0.2 mg/L. The differential between reported treatment and free chlorine residual presence could be due to a combination of courtesy bias in the survey, incorrect water treatment, and/or water chemistry. These results should not be used to infer household preference of one product over another, as households each received different options on a rolling basis and the main reason for Aquatabs disuse was that the product was finished – so many households finished the Aquatabs, returned for more treatment supplies, received liquid chlorine, and subsequently began using that option. In Indonesia, 6.2% of households reported Air Rahmat-treated water and 1.4% Shelterbox-tablet treated water on the day of the unannounced survey visit. Fifty percent of households reporting Air Rahmat treated water had correct free chlorine residual, although it should be noted it did not appear that some of the families were using that water for drinking. No household had Shelterbox-treated water available. In Kenya, 15.4% and 9.2% of households reported treated water with Aquatabs and PuR, respectively, and over half had correct and adequate free chlorine residual. In Haiti, 21.7% of HRC spontaneous settlement, 93.3% of rural DSI, and 78.5% of urban DSI recipients reported treatment with Aquatabs. Correct free chlorine residual was greater than 60% of reported treaters in all programs, and adequate treatment was as high as 95.9% in rural DSI users. A total of 72.1% and 52.9% of ceramic and biosand filter recipients, respectively, reported using the filter on the day of the unannounced survey visit.

The percentages in the above paragraph are presented by respondents with reported treated water on the day of the unannounced survey visit. If the denominator for these percentages is adjusted to the recipient population (instead of the reported users within the recipient population), 11.7% of the targeted population in Kenya, 18.5% in Nepal, and between 16.6% (in spontaneous settlements) and 89.5% (in rural areas with CHW support) in Haiti had adequate (≥0.2 mg/L) free chlorine residual in their drinking water from the distributed HWTS options. In addition, 88.1% of the survey population in Indonesia reported boiling, and 72.1% and 52.9% of ceramic and biosand filter recipients in Haiti, respectively, reported treated water on the day of the unannounced survey visit.

The main reported reason for use of the products was that they prevent disease in the cholera-affected Nepal emergency, and that they clean water in the remaining three earthquake and flooding/cholera emergencies of Indonesia, Kenya, and Haiti. The main reported reasons for product non-use included the consumable Aquatabs were "finished" in Nepal, Kenya, and Haiti; the water is clear in Indonesia and so treatment is believed to be not needed; the taste/smell and using another product for the liquid products in Nepal; the ceramic filter had broken in Haiti; and, there was no water to use in the biosand filters in Haiti. Please note that some of the non-use reasons were very small sample sizes, and the data should be interpreted with caution (see annexes).

We conducted univariate analysis to investigate correlations between indicators of use (free chlorine residual presence, *E. coli* reduction, reported treatment) and household/respondent characteristics. We found in Nepal that knowing any HWTS option before the emergency, covering household drinking water, and receiving group training were correlated with reported treatment, and female respondent attending any school and knowing an option before the emergency were associated with free chlorine residual presence. In Indonesia, people were more likely to report boiling if the female respondent attended school, if the home had moved since the emergency, and if the household used an improved source (possibly because reported boilers were more likely to seek protected sources). In Kenya, no correlations were found with outcomes. In Haiti, for the whole dataset, households were more likely to report treatment if they had not moved since the earthquake, used an unprotected source, and believed their drinking water was safe (possibly because that had treated it). Within the DSI only dataset, households were more likely to have free chlorine residual if they used a unprotected source and were of lower socio-economic status.

Although these associations are not adjusted for other covariates, they do provide insight into the populations that reported use of the HWTS options. It appears that population characteristics associated with HWTS use include: 1) where female respondents attend school; 2) those who seek to protect stored drinking water (such as covered storage container, using an improved sources); 3) those who have knowledge indicators (knowing HWTS before emergency, training); and, 4) those considering themselves at risk (unimproved sources, lower socio-economic status).

Table 5: Summary of correct use statistics

	Nepal			Indonesia		Kenya		Haiti				
HWTS option	Aquatabs	WG	Piyush	AirRahmat	ShelterBox	Aquatabs	PuR	Aquatabs	Gadyen Dlo	Klorfasil	Ceramic	Biosand
# households targeted in program investigated	1,565			954	624	5,592		Unknown, 2,880 (DSI)	230	350	350	238
% knew product before emergency	0.5	1.0	0.5	18.9		10.0	1.2	72.9	11.1	--	2.0	
% received household training	3.8	0	0.6	0	--	3.3	2.3	26.4	38.1	34.6	16.3	35.3
% received group training	94.6	100	98.9	95.9	--	96.1	96.9	55.2	57.1	30.8	83.7	54.9
% know fully correct treatment (n=recipients)	53.0	--	44.9	13.4	1.4	89.9	2.3	53.1-81.7	76.9-100	--	--	--
% know adequate treatment (n=recipients)	78.6	--	52.8	15.5	1.4	92.0	2.3	79.0-83.7	100	--	--	--
% reporting treated water in house today (n=recipients)	9.9	47.2	36.2	6.2	1.4	15.4	9.2	21.7-93.3	69.2-71.4	50.0	72.1	52.9
% with correct FCR (n=reported treatment)	51.6	24.0	41.5	50	--	52.1	63.6	61.1-86.7	80	66.7	--	--
% with adequate FCR (n=reported treatment)	87.1	56.0	50.1	50	--	62.5	63.6	68.5-95.9	100	66.7	--	--
Main reason for use (n=recipients)	Prevents disease			Cleans water	--	Cleans water		Cleans water				
Main reason for disuse (n=recipients)	Product finished	Taste / smell	Using other	Water clear	--	Product finished		Product finished			Broken	No water
% reporting treated water in house today (n=total pop for all but Haiti (recipients))	8.3	6.3	15.8	Not enough use to calculate		12.7	5.9	21.7-93.3	69.2-71.4	50.0	72.1	52.9
% with adequate FCR (n=as above)	6.8	3.5	8.3			7.9	3.7	16.6-89.5	85.7	33.5	--	--
Overall treated water in emergency (n=targeted population)	18.5% with FCR			88.1% report boiling		11.7% with FCR		Between 16.6-89.5% of recipients in programs have FCR in chlorine-based programs.				
Variables significant in some way in univariate analysis	Female respondent attended school, knew HWTS option before, covered storage container, group training			Female respondent attended school, home moved since emergency, use improved source				Live in the same place, use unimproved sources, believe drinking water is safe, lower socio-economic status (SES)				

4.6 Effective use

The third sub-question this study aimed to answer was: Does the use of the HWTS options provide effective protection against waterborne disease, as measured by reductions in fecal pathogens in drinking water? In the results cited above, we report only whether the affected population was reached by a potentially effective HWTS option and whether the household used the option. However, this does address whether the water was contaminated before treatment and actually needed to be treated, or whether the treatment resulted in a reduction of waterborne infectious agents. In the following sections, we analyze the water quality data for each of the four emergencies investigated, and compare that to the correct use data to determine if respondents were drinking higher quality water after using the HWTS option(s).

We then calculate a percentage of the targeted population with "effective use". Effective use is our attempt to identify the portion of the target population that actually benefits from the intervention. For this purpose, householders must not only be users, but: 1) must be vulnerable (be relying on contaminated sources of drinking water); and, 2) must be using the HWTS method in a manner that reduces the microbiological contamination of that water. The contamination/uncontamination levels were calculated two ways: 1) if the untreated water had greater than 1 CFU/100 mL of *E. coli* before treatment and less than 1 after (i.e., the strict WHO definition of safe water); and, 2) the same calculation, but using the "low-risk" guideline value of <10 CFU/100 mL as the breakpoint (WHO, 1993). To compute the percentage of the targeted population with access to improved drinking water due to the intervention ("effective use") we multiply the percent of the targeted population that reported using the option by the percent of the targeted population with improved household microbiological water quality for each of the HWTS options. We then calculated a cost per household with effectively treated water in the emergency, as presented in Table 6.

Before presenting the microbiological and cost results, we would like to present turbidity results. Turbidity is an important water quality indicator, as higher turbidity levels can interfere with the microbiological effectiveness of chlorine products. The turbidity of household untreated water samples in these acute emergency contexts was relatively low. Turbidity was greater than 10 NTU in 1.1%, 0.8%, 20.7%, and 3.3% of untreated household water samples in Nepal, Indonesia, Kenya, and Haiti, respectively. Turbidity was greater than 100 NTU in 0%, 0%, 2.5%, and 0% of untreated household water samples in Nepal, Indonesia, Kenya, and Haiti, respectively. The majority of the 10-100 NTU samples in Kenya came from borehole and river sources in the desert.

In Nepal, 18.5% of households had free chlorine residual at the time of the unannounced survey visit. It was not possible to complete microbiological testing in Nepal, and thus the 18.5% number is continued as the indicator of effective use. The cost per household (for 60 days of use) reached with free chlorine residual is thus 58.23 USD, as 290 of 1,565 households targeted households were calculated to have free chlorine residual at a cost of 16,886 USD for the program. This is about 1 USD/household/day for effectively treated water.

In Indonesia, there was not enough use of the distributed products (Air Rahmat and ShelterBox tablets) to calculate an effective use percentage. However, there was high reported boiling (88.1%), and treated and untreated boiling water samples were collected. Overall, 24.6% and 33.3% of tested untreated water samples from reported boilers had <1 and <10 CFU/100 mL of fecal coliforms, and 23.9% of tested households reporting boiling reduced their household water contamination from above 1 to <1 CFU/100 mL and 31.2% reduced their household water contamination from above 10 to <10 CFU/100 mL. By multiplying the percent of households who reported treatment by the effective use percentage, a final percentage of 21.1% of households surveyed reduced their household water contamination from above 1 to <1 CFU/100 mL and 27.5% of households surveyed reduced their household water contamination from above 10 to <10 CFU/100 mL. The was no cost to NGOs for this treatment, as it was background water treatment.

In Kenya, 46.5% and 22.2% of tested Aquatabs and PuR reported treatment households had household untreated water with <1 CFU/100 mL, and 53.5% and 38.9% of tested Aquatabs and PuR reported treatment households had <10 CFU/100 mL in household untreated water. For Aquatabs, 41.9% and 34.9% of tested household reduced their stored water contamination from greater than 1 and 10 CFU/100 mL to less than 1 and 10 CFU/100 mL. For PuR, the equivalent numbers are both 38.9%. Thus, the targeted population effective use rate is 5.3% and 4.4% for Aquatabs at the 1 and 10 CFU/100 mL stratifications, and 2.3% and 2.3% for PuR treated waters at the same stratifications. In total, 7.6% of households targeted treated their water from >1 to <1 CFU/100 mL, and 6.7% treated their water from >10 to <10 CFU/100 mL.

The total number of targeted households with water treated with PuR and Aquatabs from above 1 CFU/100 mL to below 1 CFU/mL is thus 425 (calculated by multiplying the number of households in the four communities by the percent with effectively treated water), and at a total program cost of 37,500 USD, this is 88.23 USD per household. The equivalent number for above 10 CFU/100 mL to below 10 CFU/100 mL is 375 households reached, at a cost of 100 USD per household. These costs are for an average 97.6 days of treatment, or, again, about 1 USD/household/day.

Access to safe drinking water in Haiti varied by program, with between 7.7-55.2% of households tested having untreated stored water with less than 1 CFU/100 mL, and 21.1%-76.0% with less than 10 CFU/100 mL. The highest percentage of untreated water that was already clean was seen in the ceramic filter recipients. The percent of samples effectively treated at the breakpoint of 1 CFU/100 mL ranged from 15.8% (biosand filters) to 72.4% (DSI Aquatabs/safe storage program), and from 36.8%-56.9% at the 10 CFU/100 mL breakpoint, also with biosand filters and DSI Aquatabs. Part of the lack of effectiveness of the biosand filters could be due to incorrect installation which inhibited the development of the biologically activated layer ("schmutzdecke") and other maintenance problems. Between 8.4% (biosand filter) to 67.5% (DSI-rural) of households had effectively treated water at the 1 CFU/100 mL breakpoint, and between 10% (ceramic filter and Aquatabs in spontaneous settlements) and 53.1% had effectively treated water at the 10 CFU/100 mL breakpoint.

Overall, the DSI program reached 1,186 rural homes and 638 urban homes with water treated to the 1 CFU/100 mL breakpoint, and 933 rural homes and 502 urban homes to the 10 CFU/100 mL breakpoint. Please note that information for the Gadyen Dlo and Klorfasil programs are not presented herein due to small sample sizes (see annexes). The ceramic filter program reached 35 families with clean water, and the biosand filter program 20 to a breakpoint of 1 CFU/100 mL, and 88 to a breakpoint of 10 CFU/100 mL. There was not enough cost data obtained in this emergency to calculate cost per household with effectively treated water or cost per day per household for effectively treated water.

Table 6: Summary of microbiological effectiveness statistics

	Reported Use (recipients)	Confirmed FCR use (recipients)	Use summary	% HH water <1	% treated <1 (treaters)	% treated <1 (recipients)	% HH water <10	% treated <10 (treaters)	% treated <10 (recipients)	HH reached <1	Cost / family <1	HH reached <10	Cost / family <10
Nepal													
Aquatabs	8.3%	6.8%	18.5% with FCR	No data collected.						290 (18.5% of 1,565 households targeted) had FCR at 16,886 USD for the program, or 58.23 USD per household with FCR			
WaterGuard	6.3%	3.5%											
Piyush	15.8%	8.3%											
Indonesia													
Air Rahmat	6.2%	0.9%	Not enough use to calculate							4,331 USD			
ShelterBox	1.4%	1.4%	Not enough use to calculate							Unknown cost for 1.1% use			
Boiling	88.1%	--	88.1%	24.6%	23.9%	**21.1%**	33.3%	31.2%	**27.5%**	No cost, background water treatment			
Kenya													
Aquatabs	12.7%	7.9%	11.7% with FCR	46.5%	41.9%	**5.3%**	53.5%	34.9%	**4.4%**	425	88.23 USD	375	100 USD
PuR	5.9%	3.7%		22.2%	38.9%	**2.3%**	38.9%	38.9%	**2.3%**				
Haiti													
Aquatabs – DSI rural	93.3%	89.5%	89.5%	13.8%	72.4%	**67.5%**	36.2%	56.9%	**53.1%**	1186	Not enough date to calculate	933	Not enough date to calculate
Aquatabs – DSI urban	78.5%	53.8%	53.8%			**56.8%**			**44.7%**	638		502	
Aquatabs – Settlements	21.7%	16.6%	16.6%	7.7%	61.5%	**13.0%**	38.5%	46.2%	**10.0%**	---		---	
Ceramic filters	72.1%	--	72.1%	55.2%	40.0%	**10.0%**	76.0%	40.0%	**10.0%**	35		35	
Biosand filters	52.9%	--	52.9%	15.8%	15.8%	**8.4%**	21.1%	36.8%	**19.5%**	20		88	

4.7 Resistance to sub-optimal use

The fourth sub-question this study initially aimed to answer was: Which options are more robust or resistant to sub-optimal use in the emergency context as compared to the development context? After completing the research, we realized the following modification of this question was more appropriate with the information able to be collected and information available: What causes sub-optimal use in the emergency context? In this section, we include uses noted during the investigations and while visiting homes of the affected population. We report ways of using the products that were incorrect or that created problematic, unexpected results. We did not anticipate these results, we simply observed what was occurring in users' homes while actually using the products, and recorded them.

Overall, the main reason for sub-optimal use in the emergencies investigated herein was when recipients lacked the know-how or materials to use the HWTS options. In Nepal, two of the three chlorine-based products were distributed for specific volumes of storage containers, and families 'made do' to find containers that were appropriate sized. It is not known if families did not use the option because they did not have the container, but it can be assumed that providing an appropriate container would have made the option easier for the family to use. In a context such as this, the fact that Piyush doses per liter would seem to present an advantage. However, because Piyush also underdoses, we are not able to compare directly whether chlorine residual was better maintained in Piyush-treated waters than WaterGuard/Aquatabs treated waters. In Kenya, families did not have the materials (two buckets, stirrer, cloth) to use PuR, and simply used PuR as they would use Aquatabs – by adding one packet into a 20-Liter jerrycan and waiting 30 minutes to drink. The resultant discoloration and flocculant in the water when PuR is used in this manner can be a deterrent to use. Lastly, in Haiti, households noted sand flowing through into treated water with the biosand filter, indicating the need for training and knowledge to fix durable HWTS options. In addition, some biosand filters were installed incorrectly by technicians; with the standing water level belowthe spout so a schmutzdecke could not be maintained, decreasing microbiological effectiveness.

4.8 Costs of deployment

The fifth sub-question this study aimed to answer was: How does the deployment of the various HWTS options compare with one another in terms of resource allocations, including staff time and costs? We addressed this question by investigating factors such as: a) global availability and time required to reach the target population; b) time for demonstration and training; c) requirements for personnel, transportation and other resources to achieve effective coverage; d) synergies with other emergency response activities (e.g. distribution of supplies, hygiene promotion); and, e) cost of implementing various HWTS methods (hardware and programmatic cost) including cost per person covered. These topics are discussed in the following paragraphs. Unless otherwise indicated, all information was provided directly by the responders.

4.8.1 Global availability and time required to reach the target population

As noted previously, all HWTS options distributed in these four acute emergency contexts (except for Aquatabs distributed in Haiti imported after the emergency by a local NGO working in Haiti on HWTS before the emergency) were available in-country before emergency onset. Thus, it is not global availability that controlled distribution in the acute emergency context, but instead local availability. The time to reach the affected population varied by emergency – products reached the affected population in Indonesia and Kenya (with good roads and a functional transit system) more quickly than products reached the affected population in Nepal (where loads were carried on porter), but in all cases, products reached the affected population within three weeks of emergency onset, and in many cases more quickly.

4.8.2 Time for demonstration and training

In both Kenya and Indonesia, HWTS options were distributed as part of NFI-kit distributions. The demonstration and training times for the HWTS options were included in the group trainings that accompanied distribution, and added a marginal time to these trainings. In Nepal and Haiti, dedicated staff were hired to complete demonstration and training of HWTS options. In Nepal, this staff was NGO-staff based in the targeted communities, and paid for out of dedicated funding for HWTS promotion during the two months of the emergency. In Haiti, various strategies for demonstration and training were used. In the DSI program, a pre-existing CHW network was activated, and over 150 CHWs were paid 23 USD per month to complete training and follow-up visits at the household level. In all the other programs NGO staff that delivered or installed the HWTS option completed a single training. This included dedicated pre-emergency staff conducting trainings on biosand filter, ceramic filter, Gadyen Dlo, and Klorfasil programs, as well as newly hired staff that distributed Aquatabs and other relief items in spontaneous settlements. Overall, the only programs that spent more than one hour in a group training with the recipients were local NGO projects with NEWAH in Nepal and DSI in Haiti. These programs had a (relatively) higher percent effective use.

4.8.3 Requirements for personnel, transportation, and other resources to achieve effective coverage

In Nepal, dedicated personnel were hired by NEWAH to complete the trainings and live in the community for the period of the emergency response. The transportation resources to deliver the products to the affected area were coordinated by UNICEF (by road) and then NEWAH (by porter). In Indonesia, the staff assembling the NFI-kits coordinated the purchase, delivery, and distribution of the HWTS options. Dedicated emergency response staff deployed to the region managed the logistics of product transportation to obtain coverage. In Kenya, staff from an existing non-water KRCS project in the region was diverted for the two-week emergency response, and all associated costs were paid for from the existing flood response project funds. In Haiti, pre-existing CHW and NGO staff were redeployed to manage the response in all projects. Transportation was challenging. Small aircraft donated from the Dominican Republic landed on informal airstrips in country to transport Aquatabs for DSI from Ireland, ceramic filters from the Dominican Republic, and Klorfasil from the United States. All other equipment – including buckets for DSI, biosand filters, and liquid chorine – was available in country at the time of the earthquake. To achieve effective coverage (such as in the DSI program), significant personnel and transportation resources needed to deployed.

4.8.4 Synergies with other emergency response activities (e.g. distribution of supplies, hygiene promotion)

In Indonesia, HWTS options were distributed as part of NFI-kits, integrally linked with other emergency supplies. In Kenya, KRCS had an open-ended year long flood response project that was activated for this particular emergency, and, like Indonesia operated under an NFI-kit distribution model. In Nepal and Haiti, the options distributed were linked with development organizations operating in the region before the emergency. In Nepal, before the emergency the NGO NEWAH had been working in the sub-districts on water supply, sanitation, and hygiene programs. After the emergency, they dedicated staff to promote HWTS until the emergency ended. In Haiti, a similar situation existed. Except for the Aquatabs distributions in spontaneous settlements, all the NGOs distributing HWTS options after the emergency had been working on HWTS on the island of Hispaniola before the emergency, and simply expanded existing activities into affected areas. The one NGO distributing Aquatabs in spontaneous settlements did so through a network of distributors also handing out many other donated emergency relief supplies. Although synergies with other response activities in NFI-kit distributions led to cost savings, there was a trade-off in terms of lower effective use seen in these contexts.

4.8.5 Cost of implementing various HWTS methods (hardware and programmatic cost) including cost per person covered

We aimed to investigate both the cost per person of product delivered, as well as compare the cost of HWTS to water supply development in the emergency affected area. However, cost data was difficult to collect within this acute emergency context, and so this section must begin with the caveat we were not able to collect all the data necessary to fully answer this research question.

In Nepal, the two month education intervention cost 10,000 USD, and the delivered product cost for the entire 1,565 families would have been 1,923-6,886 depending on which chlorine product was used (Aquatabs being the most expensive, WaterGuard the least). Thus the entire project cost was a maximum of 16,886 USD (or 10.79 per family). One water system for 60 households in this region generally costs 33,000 USD. Thus, the cost of this HWTS treatment project cost NEWAH about 1/3rd of a water system – or the equivalent of providing an improved water source to 20 families.

CARE included Air Rahmat in the NFI family kit, and as the Air Rahmat was a small portion of the volume within the large family kit, only the purchase and delivery costs of Air Rahmat from Jakarta to Pariaman were considered in the costing. The cost of purchasing and transporting 10,000 Air Rahmat bottles to Pariaman was 4,331 USD, or 43.31 US cents per bottle, or 86.62 US cents per household reached. Trainings on Air Rahmat were supposed to have been conducted at the family kit distributions, so there was little additive cost for that time. The cost of a ShelterBox is 490£ per box in the UK, and DHL ships the boxes to emergencies at no cost, and local Rotary Clubs in affected areas deliver the kits to recipients. We were not able to obtain information from ShelterBox on the cost of the tablets, but we estimate they represent an insignificant cost relative to the entire kit.

The total cost for the 2-week operation in Kenya, including consumables and transport and staff costs, was 37,750 USD. The consumable costs alone were: 400 KSH for 2 two jerry cans, 80 KSH for 2 soaps, 300 KSH for 100

Aquatabs, and 140 KSH for 20 PuR sachets. This totals 920 KSH, or 11.5 USD per household. For comparison, the costs of drilling a borehole in the region is between 17,000 and 21,000 USD and a community tank system costs about 6,000 USD for construction costs and 320 USD/month for maintenance. Thus, the cost of the WASH emergency response distribution was equivalent to providing two wells or about six community tank systems.

Cost data was generally unavailable within the context of the Haiti earthquake response. Equipment and supplies were flown into the emergency via volunteer small planes landing on makeshift airstrips throughout the country. Transportation and logistics costs were almost certainly high, but not amenable to accounting. DSI estimates installation of one system is 15 USD and the cost of one filter from FilterPure is about 25 USD. One NGO reported tanker truck water cost of 29 USD/1000 Liters of delivered water. Assuming that a HWTS option can produce 20 Liters of water per day, it becomes more cost-efficient to use HWTS after 25.9 days in the case of a DSI system or 43.1 days for the ceramic filter than to use tanker truck water. However, this does not account for the benefits of centrally treated water, rather than depending on each individual family to treat their own water.

As can be seen, HWTS project costs can be quite low – with per household costs of 10.79 per family in Nepal (education and HWTS options), less than 1 USD to include the Air Rahmat in the NFI-kit in Indonesia, 11.50 per family in Kenya (hygiene kit with safe storage and HWTS in NFI-kit), and unknown, but in the 25 USD range for Haiti. These numbers are not directly comparable, as some include transportation and some do not. However, scaling up HWTS projects to respond to a large emergency situation could be cost-prohibitive. In addition, as presented earlier, the cost per household reached effectively with HWTS was approximately 1 USD per day per household for Nepal and Kenya. This cost data highlights the point that HWTS can be economical and efficient when it is used in response to a targeted area or hotspot within an emergency that cannot be reached by other means or has a relatively high diarrheal disease risk. More data is needed to compare HWTS costs to other WASH intervention costs to determine how to integrate HWTS into a larger WASH strategy where they are appropriate and cost-efficient.

5 DISCUSSION

We investigated HWTS implementations in four acute emergency contexts to answer five research sub-questions and two main questions. The emergencies studied – cholera in Nepal, earthquake in Indonesia, concurrent flooding and cholera in Kenya, and earthquake with displacement in Haiti – represented a diverse range of emergency situations, geographical settings, affected population size, and implementation strategies.

In discussing the results of this report we are aware that unvalidated "perceived wisdom" is often used to make recommendations in emergency situations. By contrast, academic rigor, which aspires to proof beyond a reasonable doubt, is sometimes limiting in its ability to make recommendations to implementing organizations. In this report, which is a collaboration between emergency response organizations and an academic institution, we hope to bridge the gap between these worlds, by both promoting evidenced-based recommendations for HWTS programming in emergencies, and acknowledging a reduced standard of evidence.

In answer to our first research question, our results suggest that HWTS can be effective and suitable under some circumstances. HWTS has advantages compared to other options (such as water supply development) in terms of being rapidly deployable, fast to distribute, and shown to improve the quality of stored household water. However, HWTS has large drawbacks as well, including placing the responsibility for water treatment at the individual household rather than the centralized level; necessitating training and follow-up; the availability of appropriate materials; and, understanding and accepting that a (potentially large) portion of the target population will not use the option correctly to improve their water quality.

In answer to our second research question, our results do provide useful guidance on the factors associated with effective and appropriate implementation of HWTS in response to emergencies (e.g., type of emergency, characteristics of setting and affected population, capacity of responders, types of interventions, nature of programmatic support).

The factors identified in this research that led to feasible programs in the acute emergency context are:

1) The emergency has high waterborne disease risk.
2) The recipient population is correctly targeted.
3) The water quality in the emergency is contaminated with microbiological indicators.
4) The target population is aware of HWTS before the emergency.
5) The target population has the appropriate safe storage container for the HWTS option (and all the materials).
6) Pre-preparedness has been completed.
7) An appropriate HWTS option is selected for the emergency.
8) Adequate trainings are conducted in the appropriate language.
9) Behavior change is considered.
10) An appropriate chlorine dosage is used.

Each of these factors is discussed individually in the following paragraphs.

5.1.1 The emergency has a high waterborne disease risk

Not all emergencies present an increased risk of infectious diseases generally or waterborne diseases in particular. Research has shown that emergencies involving flooding, displacement, and outbreaks increase the risk of waterborne disease. Three of the emergencies investigated herein had high waterborne disease risk (Haiti, Nepal, and Kenya), while the fourth (Indonesia) did not. In any emergency response, it is essential to prioritize supplies and staff time. In those emergencies where the likelihood of waterborne disease is low, resources should be allocated to more pressing priorities such as food, shelter, security, or the particular emergency needs.

5.1.2 The recipient population is correctly targeted

The most successful programs targeted high-risk areas and distributed HWTS to those populations. This requires not only an assessment of exposure to unsafe drinking water, but also a decision that conventional centralized drinking water interventions will not meet the immediate or longer term need.In Turkana and Nepal, KRCS and NEWAH targeted the most-affected communities with a short-term HWTS intervention as part of a longer-term water supply project. In Haiti, DSI developed a strategy to reach rural, mountainous populations outside the reach of tanker truck distributions. Populations that appear to be more appropriate for HWTS include: rural populations using unimproved sources (as in Haiti and somewhat in Kenya), and geographically dispersed populations outside of any other distribution network (such as in Nepal). It is recommended all emergency response organizations target appropriate populations before distribution of HWTS options.

5.1.3 The water quality in the emergency is contaminated

There is a common belief that all water in the emergency context is highly contaminated. As can be seen from the data presented in this report, this perception is wrong. A high percentage of waters stored in the home remained free of microbiological contamination – between 24.6% and 38.3%. Unimproved sources were significantly more contaminated. Turbidity was quite low (less than 5% of samples above 10 NTU) in all of the emergencies except Turkana, where 23.2% of sources were above 10 NTU. Thus, it is important to target HWTS programs to households actually drinking contaminated water. If limited sampling capacity or HWTS options are available, rough metrics associated with contaminated water, such as unimproved sources, can be used to target HWTS options most effectively.

5.1.4 The target population is aware of HWTS before the emergency

A theme noted throughout the data set was that people who knew the HWTS options before the emergency were more likely to have the desired outcomes of product use and improved water quality. The highest effective use rates were seen in the Haiti DSI and Indonesia boiling programs – both programs that existed well before the emergency. While emergencies may be a driver for behavior change, the data shows that if the population has been exposed to the option before the emergency, the barrier to effective behavior change is lowered. Emergency responders should thus develop HWTS programs that build on the population’s pre-existing knowledge and in-country pre-emergency programs.

5.1.5 The target population has the appropriate safe storage container for the HWTS option (and all the materials)

The programs with the highest effective use (Indonesia boiling and Haiti DSI Aquatabs) shared the characteristic that the population had the appropriate storage container with which to use the HWTS option. In Indonesia, families predominately stored water in 1-5 Liter thermoses or teapots after boiling on their table, prepared and stored safely for drinking. In the DSI program, a safe storage container (a modified version of the commonly used 5-gallon/20-Liter bucket, with a tap and lid) was provided to all families. In Kenya, a safe storage container (collapsible 20-Liter jerrycan) was provided as well, and even though use of the HWTS options was not high, use of the container was. In contrast to these successes, the lack of an appropriate container for dosage in Nepal led the recipients to become inventive in finding a container. While some users were able to do this, it is unclear how many people discontinued HWTS option use because it was not possible to find an appropriately sized container. In addition, the lesson of PuR in Kenya, where users used the PuR as they would Aquatabs in the collapsible containers, highlights the need to ensure the target population has access to all the products necessary to correctly use the HWTS option. It is thus recommended that organizations distribute safe storage containers (and all associated materials necessary for the product) as part of the acute emergency response if the local container is not appropriate for the HWTS option distributed.

5.1.6 Pre-preparedness is completed, including:

5.1.6.1 Emergency response coordination and prior knowledge of partners

One theme that emerged from the qualitative interviews is that pre-preparedness in terms of WASH Cluster training and organization before the emergency greatly assisted coordination of the response in the emergency. In addition, prior knowledge of local partner organizations that could distribute HWTS options in the acute emergency accelerated the delivery of products to households in the acute emergency context.

5.1.6.2 Having the products in country before the emergency

All but one HWTS option distributed in the acute emergency contexts we studied were already stocked or locally available before the emergency. The liquid chlorine and Aquatabs in Nepal were pre-positioned for anticipated floods and/or available in-country. In Indonesia, the liquid chlorine was available in country, the chlorine tablets were pre-packaged in the ShelterBox kits ready for immediate shipment, and boiling required no distribution of specialized products. The Aquatabs and PuR distributed in Turkana were stocked at the KRCS warehouse awaiting distribution for the flood response project. In Haiti the liquid chlorine, and biosand and ceramic filters were already made in country (or nearby in the Dominican Republic). The Klorfasil bottles were pre-stocked and flown from the United States in checked baggage. The Aquatabs distributed by DSI, an organization that has been working on HWTS in Haiti for three years, were flown from Ireland to the Dominican Republic via air freight, and then to Haiti on donated prop plane landing on a makeshift airstrip. This result highlights the importance of pre-preparedness, local production, and/or local knowledge in order to effectively distribute HWTS options in the acute emergency context, as there simply is not time to import and distribute HWTS options if the organization is not already established and prepared to conduct an acute emergency HWTS response. Thus, it is recommended organizations pre-position appropriate HWTS options in emergency-prone areas.

5.1.7 The appropriate HWTS option for the emergency is selected

Ultimately, it would be ideal to have an evidence-based set of conclusions on HWTS option effectiveness in the acute emergency context that acts as a reference resource for country level practitioners undertaking preparedness activities. This report provides the first data available to responders on HWTS effectiveness in the acute emergency context. We anticipate that as further evaluations are conducted, evidence-based reference resources can be developed. One point to note, however, is that numerous qualitative interview respondents and responders mentioned the push they receive from HWTS manufacturers to use a particular product in emergency response. These suggestions are often not driven by appropriateness of product in terms of water quality or recipient population needs and desires, but instead by donors and suppliers wishing to have their product be used (and purchased) in the emergency response. Rather than accept a supplier-driven product, responders should work to create comprehensive WASH strategies that evolve throughout the emergency based on assessments of the local conditions and knowledge of community water knowledge, attitudes, and practices. Overall, an appropriate HWTS option is one that is: easy-to-use, available, acceptable to the recipient population, adequately treats the water, cost-effective, and integrated into the overall WASH strategy.

5.1.8 Adequate trainings in the appropriate language are conducted

Training is crucial for the correct use of all HWTS options. Based on the results seen in these investigations, we propose HWTS options can be categorized as "simple" (needing only one training to ensure correct knowledge of use) and "complex" (needing multiple trainings to ensure correct knowledge of use).

Adequate knowledge of water treatment was greater than 50% for chlorination options (liquid and tablets) distributed with a single training in Haiti and Nepal. In the NFI-kit distributions of Kenya and Indonesia, Aquatabs adequate use knowledge was high (at 92%) in Kenya but adequate use knowledge was less than 20% in Indonesia for both liquid (distributed with NFI-training) and tablets (distributed with no training). Thus, the 2-step processes (add chlorine to volume of water, wait 30 minutes) liquid and tablet chlorine can both be considered "simple" options, and a single training should be sufficient to ensure adequate use knowledge, except in circumstances (like Indonesia) where chlorine taste resistance is high. However, adequate knowledge of PuR use was less than 10% in NFI-kit single-training distribution in Kenya. This is consistent with previous research documenting that with the complex 5-step process of using PuR, at least one follow-up training is needed with recipients to ensure correct knowledge. Thus, PuR should be considered a "complex" option.

There is a question as to whether durable options should be considered simple or complex, as they are simple 2-step processes to use (add water, filter into bucket) but there is a more complex installation and maintenance component. Based on the results seen in this investigation, we feel that ceramic filter maintenance and use provided no "complexity" barrier to the population in the acute emergency context. However, biosand filter installation and maintenance was difficult for the NGO and recipient population. We thus tentatively propose, although this needs additional evidence, that ceramic filters be considered simple, and biosand filters complex.

In all cases, the appropriate level of training should be provided to users – at minimum a single training for simple options, and multiple trainings for complex options – and training and directions should be provided in the local language and pictorially for non-literate populations. It is recommended in the acute emergency context to only distribute "simple" options, and wait for stabilization of the emergency, capacity to conduct additional training and follow-up, and permanent housing to distribute more complex options. If more complex options are known to the population before the emergency and/or extensive training can be completed with the target population, it might be possible to distribute these options as well, although follow-up should be conducted.

5.1.9 Behavior change is considered

HWTS is an intervention that requires individual behavior change. There is perceived wisdom that both emergencies provide an opportunity for rapid behavior change in water treatment practices; and that populations in the acute emergency context are too overwhelmed to change behavior. In the emergencies investigated herein, there was behavior change to ameliorate perceived risk documented, as: 1) respondents in two emergencies (Kenya and Indonesia) were more likely to use improved sources after the emergency; and, 2) respondents in Nepal quickly adopted chlorine-based products they were unfamiliar with before the emergency due to the perceived risk of cholera. Water practices and knowledge can vary significantly even within a small geographical area. For example, there was a significant difference in knowledge of the local root erut for water flocculation within even the four adjoining communities studied in Kenya.

Although documented behavior change was seen in the above cases, many qualitative interviews respondents discussed the difficulties of changing behavior in the acute emergency context and behavior change was not observed in all emergencies. In Indonesia, chlorine products were not used and, in Kenya, few used the distributed products. While it appears that prior knowledge of HWTS (or the safety of improved sources) reduces the behavior change barrier after the emergency, it requires significant training to introduce an new product to a population in an emergency, as can be seen by the education component required in the Nepal program. It is not recommended to introduce an new, unverified, unknown product into an acute emergency context without extensive follow-up, training, and evaluation.

5.1.10 An appropriate chlorine dosage is used

An appropriate chlorine dosage is one that: 1) maintains residual protection during the storage time of the water used by the population in the household storage container; and, 2) does not exceed the taste threshold of the recipient population, which varies by culture. In some cases, as in Haiti where no taste and smell resistance was seen, this balance is easy to strike. In other cases, such as in Indonesia where the target population would not use chlorine-based products, this balance was impossible to attain. Additionally, in Nepal and Kenya, 16.1-60% and 4.4% of reasons for product disuse, respectively, were taste or smell. Thus, chlorine dosage is a critical issue for uptake in the acute emergency context, and in all cases, responders should promote the lowest chlorine dose that adequately maintains FCR at the household level. The use of 5 mg/L dosage Aquatabs should be minimized except when water is highly contaminated (above 10 NTU) and there is no other option for water treatment. It has been shown that chlorine can be effective at higher turbidity ranges (10-100 NTU) at a double dose of 4 mg/L, which can be promoted for an emergency situation.

Also consistently noted in this study is that recipients did not comprehend that different tablets distributed were for different volumes. The majority of respondents simply felt one tab (of any size) was for the storage container they had. To avoid over- or under-dosing and the associated water treatment and acceptability consequences, it is highly recommended that the WASH Cluster align on a uniform dose and size of tablet for distribution that is appropriate for the water quality, storage container size, and taste and smell acceptability in the specific emergency context. The dose should be set by the WASH Cluster to not exceed 2 mg/L 30 minutes after dosing, and not fall below 0.2 mg/L in the normal household storage container for the length of time water is stored in the household.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In a previous report by the authors summarizing the current knowledge base of HWTS in emergencies, further research to address knowledge gaps in seven areas was recommended, including:

1) conducting HWTS project evaluations in large-scale immediate-onset acute emergency contexts;
2) evaluating all HWTS options, including standard interventions not supported by a commercial enterprise;
3) evaluating all HWTS options used in a single emergency response, not just one option;
4) understanding the behavioral determinants of adoption for HWTS in emergencies;
5) comparing HWTS options to other options to reduce diarrheal disease in emergencies;
6) documenting how organizations select HWTS options; and,
7) understanding whether emergency use of HWTS stimulates long-term uptake of available, affordable HWTS options in the post-emergency situation.

The investigations conducted by LSHTM under an agreement with UNICEF and Oxfam and described in this report have provided information to fill in the first six of these gaps. To address the seventh research gap, the authors have a further agreement with UNICEF to revisit two of the emergencies documented herein – Kenya and Haiti – six months after the emergency to document any follow-up use and practices around water treatment in the communities which received interventions. That follow-up report is available from the authors.

Previous research conducted in the emergency setting has documented that HWTS: 1) can be an effective water intervention; 2) current HWTS projects correctly target emergencies with high diarrheal disease risk; 3) considering user preference in HWTS option selection facilitates implementation; 4) training is crucial to uptake of HWTS in emergencies; 5) adequate product stocks are necessary for emergency response; 6) difficulties in obtaining local registration hinder projects; 7) users should have all materials necessary to use the HWTS options; and, 8) chlorine dosage should be considered in light of user acceptability. The research presented in this report confirms and expands upon theses previous findings.

We confirmed that HWTS can be an effective intervention in the acute emergency context, with high uptake and efficacy. We also found that training users in the options is crucial and the logistics of adequate product stocks and having the materials necessary to use the option are critical to HWTS use. We further documented the challenges with maintaining a chlorine dose that is both effective at maintaining chlorine residual and acceptable to the users. We documented some of the first results on Aquatabs use in the acute emergency context.

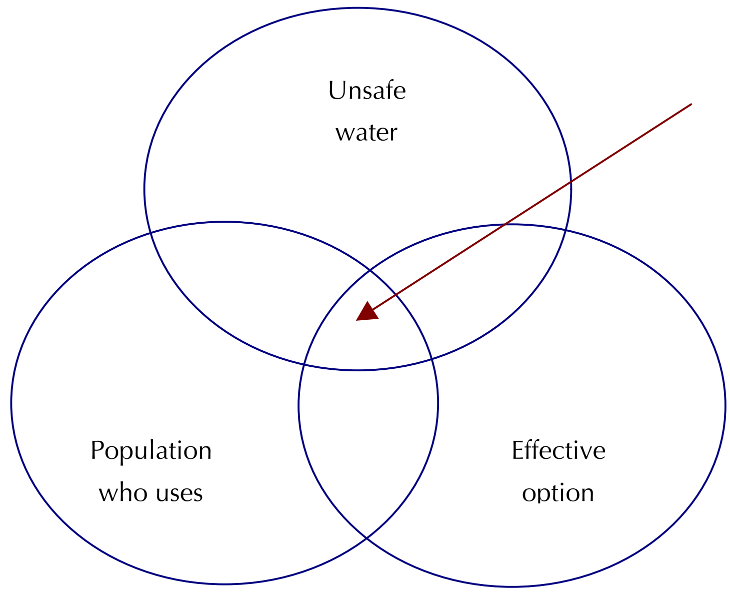
6.2 Characteristics of successful projects

The HWTS projects with the highest effective use rate seen in this study combined three factors:

1) They targeted households with contaminated water, such as those using unimproved sources;

2) They provided an effective HWTS option that effectively treated the water; and,

3) They provided this option to a population who was familiar with that product, willing to use it, and trained in its use with the necessary supplies provided.



When these factors came together, such as the DSI project targeting rural earthquake-affected households in Haiti that provided Aquatabs and a safe storage container to a population familiar with chlorine-based HWTS options, high effective use was observed. When one factor is missing – such as contaminated water in the otherwise effective ceramic filter distribution in Haiti, or an effective product in the biosand filter distribution in Haiti, or a population willing to use the products in the chlorine-based product distributions in Indonesia – effective use drops significantly.

6.3 Limitations

The main limitation of this research is the simple fact that this was case study research conducted in imperfect, but real-world conditions. Our work was limited by logistical issues such as electricity access, challenges of working in the acute emergency context, and by which emergencies occurred during the time allotted for the study. The emergencies studied herein represent a wide range of situations, from natural disasters such as earthquakes and floods to outbreaks, with rural to urban populations with previous exposure to HWTS or not, and geographically distributed across the globe. The HWTS responses incorporated a number of different strategies – from drive-by NFI-kit distribution to integration into previously existing community health worker networks. Chlorine-based options were studied most frequently, simply because chlorine-based options are more often used in the acute emergency context.

The emergency type missing in this study, however, is a large flood event in a area that floods regularly with a population that receives HWTS options during each flood event, and is thus familiar with the products. For a high quality evaluation of PuR and Aquatabs distribution to families who received training on PuR during seasonal flooding in Bangladesh, the reader is referred to two studies that document high uptake and effective use of HWTS (Hoque, Undated) (Johnston, 2008). In the first study, 83.7% of visited households were using PuR (62.8%) or Aquatabs (20.9%) correctly to treat their water to safe microbiological standards. In the second study, 72% of household had

PuR treated water, and 10% had Aquatabs treated water at the time of the unannounced survey visit (Hoque, Undated). A total of 100% of households had PuR in the house, with 72% having treated water at the time of the unannounced visit. A smaller percentage, 65% of households, had Aquatabs in the house, but only 10% had treated water at the time of the unannounced visit (Johnston, 2008). This research supports our findings that without additional training, approximately 10% of households have treated water at the time of the unannounced visit, and with training and follow-up that uptake can be significantly increased.

6.4 Further research

Further research evaluating the use of HWTS in the acute emergency context is indicated. This report is based on case studies. Studying future emergency responses will help more fully characterize and expand our knowledge base on HWTS in emergencies. It is highly recommended that future research include implementation-based case studies incorporating robust protocols and investigating all the facets of actual HWTS implementations in emergency response, including behavior change research to document which and why users adopt the products. Research aimed at showing that individual products are effective in controlled circumstances is of utility in showing product effectiveness, but not at informing responders how to make better decisions in the emergency context. Research showing that many people use a product, but that does not quantify the water quality of the population, does not provide information on risk reduction. Research promoting one HWTS intervention type over another may be of academic interest, but does not account for on-the-ground realities such as: not all HWTS options can be carried on porters a three day trek and achieve any meaningful coverage in the affected population, or shipped in small planes landing on makeshift airstrips, or purchased in large bulk orders for 20,000 affected families. Research not investigating the reality of cost implications does not provide meaningful data to responders who must weigh the hard question of whether to provide a more expensive option that has been shown to maintain FCR or reduce microbiological indicators more reliably, or a significantly less expensive option with slightly less effectiveness to a larger number of recipients.

This type of implementation-based research is not without its challenges – robust protocols and flexibility are de rigueur, and the data sets are not controlled. However, this type of research will assist implementers to improve field practice and provide safe drinking water to affected populations.

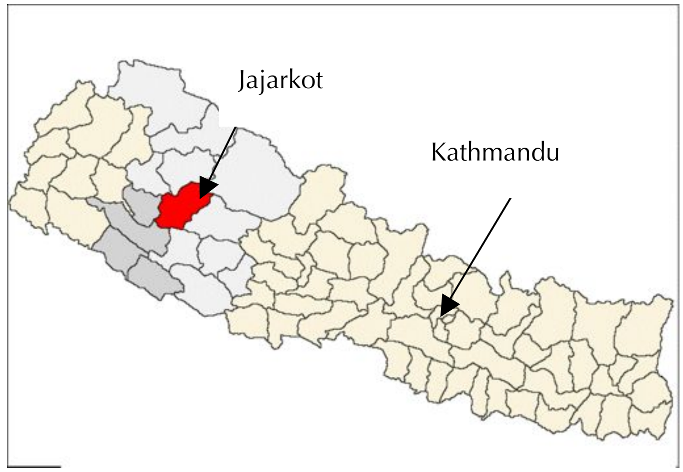
Lastly, it must be stated that there is little evidence on the uptake, correct use, and effective use of health products requiring behavior change – soap, mosquito bednets, condoms – distributed in the acute emergency context. This lack of knowledge highlights three points: 1) the difficulty of conducting research in the acute emergency context; 2) that the results presented herein should not be viewed as discouraging – as some qualitative interview responders noted outside of interviews that they would not expect higher uptake of other products in the acute situation; and, 3) further research is indicated investigating cross-product learnings, which will be conducted by the first author at Harvard.

6.5 Recommendations on implementing HWTS in emergencies

Lastly, we will end this report with a simple list of eight recommendations for responders interested in potentially implementing HWTS in the emergency context, including:

1) **Prepare.** Before emergencies occur, complete a comprehensive emergency preparedness program, including staff training, WASH Cluster team development, and pre-positioning of appropriate HWTS options.
2) **Strategize.** After emergency onset, develop an integrated WASH response strategy (that includes HWTS if appropriate) based on a rapid assessment that investigates: 1) the impact of the emergency on the health of the affected population; 2) the water quality situation; and, 3) the WASH knowledge, attitudes, and practices of the affected population.
3) **Select.** Select HWTS options that are appropriate for the water quality, logistical, and cultural conditions of the particular emergency context. Understand that some more complex and durable options may not be appropriate until recipients are established in a permanent, instead of temporary, housing.
4) **Provide.** Provide the affected population with: 1) enough HWTS option for the emergency duration; 2) an HWTS option appropriate for the existing storage container(s) or an appropriate storage container; 3) specialized equipment that are needed to use the option; and 4) the materials for recipients to maintain durable options.
5) **Train.** Train the recipients appropriately, including follow-up trainings for more complex options.
6) **Be realistic.** Understand that "NFI-kit" distribution of HWTS options will lead to a low uptake of 10% or less in the acute emergency context. This does not necessarily mean the intervention is not valuable or not cost-effective.
7) **Evaluate.** Conduct evaluations using simple and robust metrics to assess program efficacy, and share these results with the wider water, sanitation, and hygiene community.
8) **Link.** The most successful emergency HWTS programs were in areas with successful development HWTS programs before the emergency. By supporting and linking to pre-existing HWTS programs, uptake of HWTS in the emergency can be significantly increased.

7 Jajarkot, Nepal Cholera Outbreak



Jajarkot is one of 75 districts in Nepal, located in the mid-western region of Nepal 600 miles from Kathmandu. Jajarkot is in the 'hilly' region of Nepal, south of the Himalayas and north of the plains areas (Figure 2). The district covers 2,230 square kilometers. Jajarkot includes 30 Village Development Committees (VDCs), each consisting of nine wards. Jajarkot's 2001 population was 134,868 people, and the projected 2011 current population is 151,551. Jajarkot district headquarters is accessible via a Nepali government plane that lands at an airstrip in Rukum (the neighboring district to the east), followed by a 3-4 hour trek. The individual VDCs are accessible via 1-4 day treks from headquarters. No motorized transport is available, and loads are carried by porter.

Figure 2: Nepal district map (http://en.wikipedia.org/wiki/Jajarkot_District)

7.1 Description of emergency

The Epidemiology and Control Division of the Ministry of Public Health categorizes Jajarkot as one of 26 'high risk' outbreak prone districts, expecting 1-3 diarrheal disease outbreaks per year based on previous years experience (MPH, 2009). On May 4, 2009, a cholera death was reported in Jajarkot District. Subsequently, five specimen samples from infected persons were tested by the WHO, and three grew *Vibrio cholera*, confirming the advent of an epidemic (WHO, Undated). Some in the popular culture blamed the outbreak on poor-quality 'decayed' World Food Program (WFP) Food (Nepalnews.com, 2009).

In July 2009, a research team assessed the attack rate and case fatality rate in the outbreak. The team collected data from the District Hospital and one clinic, and found 12,500 cases and 128 deaths (Bhandari, 2009). Based on the projected Jajarkot population of 151,551, the attack rate was calculated to be 8.2% and case fatality rate to be 1%. Five of thirteen (38.5%) specimen samples tested positive for *Vibrio cholera* 01 biotype El Tor, serotype Ogawa. These results were released in October 2009 and were not available at the time of our field visit in August 2009.

With UNICEF district staff assistance, we were able to review Jajarkot Headquarters District Hospital records to obtain the most accurate cholera case data possible on August 7, 2009. The hospital's records, collected from all VDCs in Jajarkot, documented that in the fourteen weeks since the first death, 133 deaths had occurred. These deaths were listed by VDC, and date of death was included for 118 (88.7%) records. A mortality epi-curve was developed based on the 118 records with date of death, showing that the outbreak appeared to have peaked by the time of the field team arrival to Jajarkot (Figure 3). The last death in the curve occurred August 3, 2009. Cases were not recorded by

VDC in hospital records. As of August 20, 2009 UNICEF considered that 153 people died from presumed cholera in Jajarkot, and that the outbreak had spread to 11 neighboring districts. Jajarkot (and Rukum to the east) were the most affected districts.

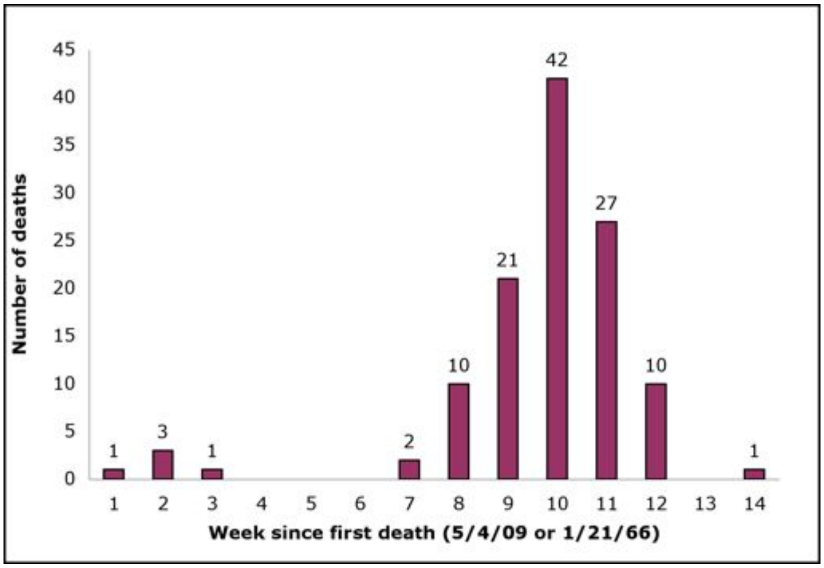


Figure 3: Jajarkot district cholera mortality (from District Hospital records)

In March 2010, the Nepali National Health Research Council released results from laboratory testing that confirmed the epidemic was caused by a combination of pathogens, and not solely by cholera bacteria. Testing found Aeromonas, Shigella, Campylobacter, VTEC and *E. coli* O157:H7 bacteria in stool samples collected from patients in Jajarkot (Republica, 2010). However, "all bacteria were combined either with Cholera or Aeromonas." The results cited that a total of 300 people in the far and mid-western districts, including Jajarkot, died in the outbreak.

7.2 Situational analysis and methods

The field researcher arrived in Kathmandu on August 2, 2009, and: 1) met with UNICEF staff to gain information on the outbreak; 2) organized local transport and logistics for Jajarkot; 3) finalized and translated the survey; and, 4) trained enumerators hired in Kathmandu before departing for Jajarkot.

The WASH Cluster was already activated. International organizations such as WHO and UNICEF, donors such as USAID and DFID, international NGOs such as CARE, Concern Worldwide, and ADRA, and local NGOs such as Environment and Public Health Organization (ENPHO) and NRCS (Nepal Red Cross Society) were all responding by providing emergency medical care and supplies and/or water, sanitation, and hygiene (WASH) supplies and training. Many of the organizations, including NRCS, ADRA, DFID, ENPHO and UNICEF, were providing HWTS options, including Aquatabs chlorine tablets, the Population Services International (PSI) locally-produced liquid chlorine solution (WaterGuard), and the ENPHO locally-produced liquid chlorine Piyush (Figure 4). Although numerous organizations were purchasing and providing Aquatabs, WaterGuard, and Piyush, there was no information in Kathmandu on where exactly the HWTS options were being distributed.

Figure 4: HWTS options (and ORS/medicines) distributed (Jajarkot, Nepal)

As of July 28, 2009, UNICEF reported having distributed 468,000 chlorine tablets (treating 5 Liters of water each), 10,000 oral rehydration salt packets, 9,000 bars of soap, and 20,000 zinc tablets for diarrhea treatemtn to the government of Nepal (GON) and responders. These stocks had been pre-positioned in Kathmandu to respond to anticipated flooding in another area of the country, and were diverted when the outbreak occurred. UNICEF planned to deliver 500,000 zinc tablets and 37,000 bottles of chlorine (which were locally-made, on order, and available at a lower cost on a per liter treated basis than tablets) in the following two months for outbreak response in Jajarkot. UNICEF directly financially supported the NRCS and DEPROSC to provide health education in Jajarkot. In addition, UNICEF provided (at no cost) the HWTS options to Nepal Water and Health (NEWAH), which had financial support from Concern Worldwide to provide training and distribution of HWTS options. UNICEF also developed a strategy for provision of HWTS options and soap to 151 VDCs in 18 districts should the outbreak spread significantly.

On August 5th, the field researcher departed for Rukum and trekked to Jajarkot Headquarters. In headquarters, information on HWTS option distribution was gathered in meetings with local DEPROSC, NRCS, NEWAH, GON, and UNICEF staff. To prevent overlap, the local WASH Cluster assigned each of the 30 VDCs in Jajarkot to one NGO for WASH response. In Figure 5, the VDCs in orange were assigned to NRCS (supported by Save the Children and UNICEF), in blue to DEPROSC (supported by UNICEF), in yellow to NEWAH (supported by Concern Worldwide), and in white/cream to two other local NGOs.

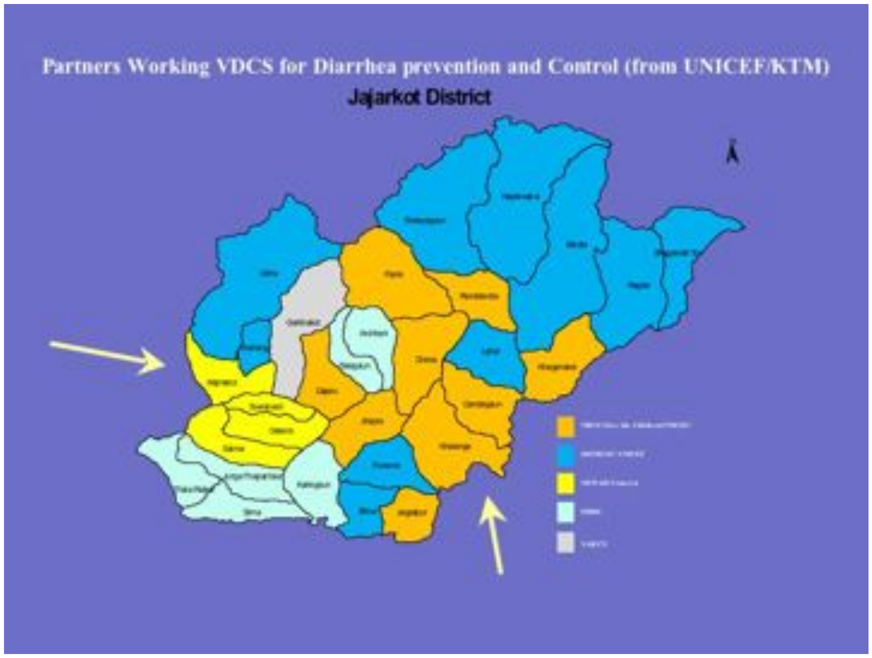


Figure 5: NGOs assigned to VDCs in Nepal (image credit Madhav Parahi of UNICEF/Nepal)

In headquarters, information on the number of Aquatabs distributed by each NGO by VDC was obtained and compared to the VDC cholera death rate and population. As can be seen in Figure 6, the distributed Aquatabs treated an average of less than 50 Liters per household in 12/30 (40%) VDCs. Sixteen VDCs had higher distribution rates (between about 50-150 Liters/household), and two had rates above 200 Liters/household.

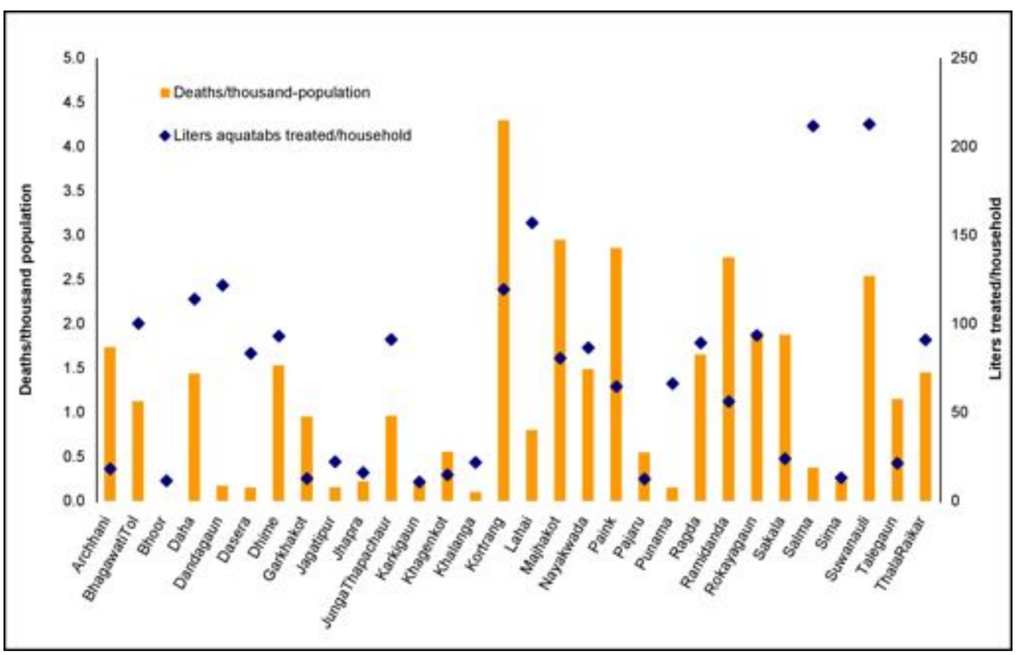


Figure 6: Cholera deaths and Aquatabs distributed by VDC (Jajarkot, Nepal)

The reason for the large difference by VDC in Liters treated per household was that many NGOs targeted Aquatabs distributions to a single area in a single day, or through health clinics. Only one NGO, NEWAH, targeted complete coverage of the population with HWTS. This was due to working in four highly cholera-affected districts (Majhakot, Dasera, Suwanauli, and Salma) and because NEWAH obtained separate funding from Concern Worldwide, specifically stating as a grant objective "distribution of Water purification materials like water guard Piyush and Aqua tab and ORS in house hold level for effected people especially poor and dalit HH"[sic] for one month with locally based staff at the VDC level (NEWAH, 2009).

We chose to work with NEWAH for this study, evaluating the responses in Suwanauli and Majhakot. These two VDCs had some of the highest cholera death rates and highest levels of HWTS distribution with Aquatabs. In addition, Suwanauli and Majhakot were accessible, with only a 2-day trek to the location and known facilities (in the NEWAH offices) where we could live and work. We chose these study location before obtaining data on WaterGuard and Piyush distributions, which were not available in Headquarters.

It must be noted that results presented in this report are not representative for the entire HWTS response in the Jajarkot cholera outbreak – they are only representative for the NEWAH response. The HWTS distribution in other VDCs was likely of such low volume of treated water per household that there was not significant benefit. Programs in the future should consider providing sufficient HWTS options per household in a large-scale outbreak, which is what UNICEF was planning should the outbreak have expanded.

7.2.1 Spatial analysis

Spatial analysis was not conducted in this response, as the region was so remote that: 1) no maps except the VDC borders (as shown in Figure 5) were available; 2) Google Earth does not have any coverage in this area; and, 3) there was no satellite service for GPS meters or cell phones to collect GPS points. We did obtain and use hand drawn maps of the ward locations in each VDC upon arrival from local NEWAH staff. However, these were sketch drawings and not sufficient for spatial analysis.

7.2.2 Methods used in investigation

In this investigation we: 1) conducted four qualitative interviews with national and local level WASH responders; 2) conducted a household survey in Suwanauli (101 households) and Majhakot (299 households); 3) conducted water quality testing; and, 4) collected cost data from NEWAH staff at the VDC level and in Kathmandu.

7.2.2.1 Household survey and water quality testing

PSI recommended Blitz Media in Kathmandu for survey translation, enumerators, and data entry. Five enumerators were trained on August 3, 2009. The enumerators translated the survey, and Blitz Media typed the survey in Nepali and back-translated. The survey consisted of a maximum of 87 questions (all products received), including 28 questions on respondent and household characteristics, effect of the emergency, assets, diarrhea prevalence, and water knowledge and source before and after the emergency; 10-12 questions on each HWTS option received; and, summary questions on current water supply/water testing. If a household received no HWTS options, 30 questions were asked. Surveys took approximately 20 minutes to administer and Blitz Media entered the survey data into

Microsoft Access (Redmond, WA, USA). Data was analyzed by the field researcher in Microsoft Excel (Redmond, WA, USA) and Stata 10.1 (College Station, TX, USA).

We completed population proportionate to size (PPS) surveys by VDC and ward sampling because we had 2001 census data by VDC and ward, hand drawn ward maps, and local knowledge of ward boundaries from the population. Within each ward, enumerators worked with the local population to draw a map of households. Households tended to be clustered in 1-3 areas within the ward, and enumerators completed the total number of surveys needed for each ward by sampling from a representative number within each sub-ward housing cluster.

Enumerators tested FCR at households reporting treated water that day using Hach ColorWheel test kits. One enumerator used a different test kit (the Lamotte test tube kit) using DPD-1 tablets and a color scale with a range of 0-5 mg/L. The field researcher tested turbidity daily using the Lamotte 2020 meter.

All the materials for 600 microbiological tests using portable membrane filtration laboratory equipment were transported to the study location by porter. At this point in the overall study, the authors had decided to use media testing for fecal (thermotolerant) coliforms, which requires incubation at 44.5°C, in order to be more in line with European emergency water quality testing procedures. Unfortunately, with no electricity and cold nights there was no way to maintain incubation at 44.5°C, and while some results were acceptable, many were of poor quality indicating inadequate incubation and overgrowth with non-temperature resistant bacteria. The images in Figure 7 show (clockwise from top left) attempting incubation on the ceramic stove, high-quality results, highly contaminated sources, and low-quality results with overgrowth of non-thermotolerant bacteria. In the last two emergencies in this study, we used mColiBlue24 media, widely used in the United States, testing for total coliform/*E. coli* indicators. This media incubates at 35-37°, and is resistant to deviations in incubation temperature often seen in locations with unreliable electricity (PATH, 2007). Thus, microbiological results were discarded are not included for this study.

Figure 7: Incubation challenges (Jajarkot, Nepal)

In the following sections, results from the qualitative interviews and survey results are described.

7.3 Qualitative interview results

A respondent from a local office of an international organization with prior experience in emergencies stated that the best WASH emergency response is multi-faceted, with “safe water supply to the people by boiling, by filtration, by chlorination”, “bleaching powder in reservoir”, “promote sanitation technique for handwashing”, and “appropriate toilet facilities”. The respondent noted, however, that “we have limitation, if emergency is in wider area; it is difficult to provide everything at the same time.” The respondent suggested one option for potential investigation for use, stating “the most feasible option in this rainy season is harvesting rainwater” but added that there were no rainwater harvesting pilot projects at this time.

The respondent noted limitations of HWTS, including: 1) lack of knowledge by target group (“Especially, the water treatment products are not used by people in village areas. They do not have such type of behavior”); 2) the expense (“The water treatment products are quite expensive and they are not feasible for them to buy and use it further. External agencies should support during emergency as we do with chemical product.”); 3) lack of sustainability (“You can provide WaterGuard and it can work for one month”); 4) difficulty in dosing with Aquatabs (“It is difficult to use by people because it need five Liters of water at a time.”); 5) low coverage (“We are unable to cover whole population. It is due to availability of products, and resources and time.” “There is limited supply to the community and only few members get it.”); and, 6) lack of pre-positioning (“We didn’t feel that there would be this type of outbreak. That’s why, some of things like pre-positioning of water treatment products. We had only few.” “If there is proper planning, we can rescue all the people on time by awaring [informing] them.”).

The respondent also noted HWTS positives, including: 1) length of time water can be treated (“Among chemical products, WaterGuard is the best option. It can help for one month.”); 2) fast response time (“There is an understanding in this emergency situation. If we have we can provide within a week in hilly or mountain region.”); and, 3) user demand (“There is high demand and positive response for the people that water treatment can save their life. That is the most important thing.”).

Another respondent from the international office of an international organization stated that the organization is “keen to push it [HWTS in emergencies] until we know it doesn’t work.” The respondent highlighted that “chlorination is the best method for immediate solution” but that “distribution of chlorine products should be done collectively with other important products” and “we have to study what is possible in this emergency situation that needs to be promoted other than chlorine”, including rainwater harvesting, which hadn’t been investigated. The respondent noted the importance of pre-preparedness, stating “we had never thought that there would be such type of disaster” and “We always get resources for response. We hardly get money for preparedness.” In addition, pre-preparedness was highlighted vis-à-vis working with local NGOs, as the respondent stated that local NGOs “through their knowledge of the community and their network from their volunteers to get far more comprehensive distribution of the products compared to some agencies.”

A respondent for a large local NGO with no prior experience in emergencies noted the “hardest work is to make people understand and change their behavior,” and the easiest behavior change mechanism is “to teach door-to-door”. This organization received products in Jajarkot from Kathmandu within 10 days. About the chlorination options specifically, the respondent observed “of course, we have not other options to supply for community people.” While, “the aware people are using boiled water … [which] is not tasty to drink”, the respondent highlighted limitations of the Aquatabs (“There is confusion to the community people. They think that these are the medicine.” and “We found that community has no proper measurement of water pot.”) and of WaterGuard (“WaterGuard is bitter and smell of Piyush is better than WaterGuard”). The respondent felt that “Affected person is using water treatment materials carefully. Who do not have affected, they generally do not care.”

Overall, the respondent stated “For sustainable, we have some points. Water source should be improved, household sanitation should be improved, and latrines should be building, in the community. These things are much necessary for the epidemic for long term.”

A respondent from a local NGO with prior experience promoting handwashing and HWTS in diarrheal disease emergencies, that also received chlorination products in this emergency, spoke eloquently about the balance between WASH and HWTS options in the development and emergency context. The respondent stated, “first of all, we have to supply pure water at any cost. It is the government responsibility to provide but in hilly regions it is not possible.” The respondent continued by noting that in the emergency period “most of the NGOs and INGOs are supporting from household level seriously” to the extent that “I think nobody is promoting non HWTS watsan” in the emergency.

In discussing the various HWTS options in the development context, the respondent mentioned “The only one option is boiled water. They can give certain amount of chlorine tablet, water bottles, and filters but the best one is boiled water.” The reason for this was that “Most of the people are poor, so, they cannot afford to buy filter, they cannot buy chlorination water and also they need more bottles. Without bottles, they cannot SODIS [solar disinfection], so, the most feasible option is boiled water because they can get fire wood, oven, and pot. There is not much cost to boil.” However, despite feeling like boiling was the only feasible options, they also felt “I think filter is the most sustainable option”, but limited by the fact the population “can’t buy it.” It was mentioned the population would accept filters because “people do not prefer chlorinated water and boiled water because its taste will be turned.” Overall, however, it was felt “in normal situation, we have to promote boiled water.”

For HWTS in the emergency context the respondent stated “If such type of emergency happens, they [the donors] will use water purification methods.” There was perceived pressure to use chlorination options as “NGOs, government, and donor agencies are providing only chlorinated water. Nobody is supplying filter.” “We have talked about filter many times. … They said they couldn’t supply it. They can only support chlorination.” Limitations of chlorination options were noted, including: 1) the difficulty of supplying the options (“Even in this emergency situation, we cannot easily supply Piyush and WaterGuard.”); 2) the limited effectiveness over time (“This chlorination tablets, other preventive measure can work for three months - this problem will again arise in future.”); and, 3) a preference for non market based solutions (“Such market linked option should be minimized.” and “Without cost, nobody provides, can you believe?”). Despite this, benefits of chlorination were also noted, including the ease of use and distribution, with the statement “most easiest method is chlorination, even its cost is high. For the quickest time, chlorination is the easiest and has quick response.” It was noted the NGO was “getting in one week” the chlorine from Kathmandu.

Overall, the respondent argued for a coordinated WASH developing strategy, stating: "In this emergency situation, most of the houses are using chlorination, either by tablets, Piyush, WaterGuard. They do not have any other options. Everybody wanted to be alive. … But it is not the final solution. It is temporary. … If you like to promote sustainable development, you need to support to build toilet construction, to use pipelined water, and to use soap. Rather they are supplying them chlorination tab."

Collectively, the four qualitative interviews reflect the following points:

- The importance of a coordinated WASH sustainable long-term developing intervention including water supply, sanitation, and hygiene to prevent future outbreaks.
- The role of HWTS chlorination options in providing easy-to-use, fast to distribute short-term emergency response.
- The drawbacks of chlorination options, including taste, dosing for a specific container size, and thinking tablets are medicine.
- The drawbacks of boiling in terms of taste.
- The lack of investigation of non-HWTS options that might be of utility in the emergency (rainwater harvesting).
- The difficulty of changing behavior in hilly environments.
- The limitations of a donor-driven supply chain.
- The importance of preparedness (both on the donor and local NGO level) to reach the entire affected population.
- The high demand for the products as they were perceived by the population as a life-saving intervention.

7.4 Survey results

Survey results are presented in Table 7 for the survey population as a whole, and stratified by VDC. The Majhakot and Suwanauli survey populations were not identical across all characteristics, and differences were quantified in dichotomous variables using the chi-squared test (p-values of <0.05 indicate a statistical significant difference between survey populations). The denominator for total percentages are noted in the row variable description. Denominators for the VDC column percentages are not presented.

Overall, one-quarter of the total Suwanauli and Majhakot populations were surveyed, with 400 surveys completed by five enumerators in all nine wards in each VDC. About half the survey respondents were women. This number must be understood by the cultural fact that enumerators were more likely to be able to interview respondents of their same gender (p=0.026). In addition, in many cases with male enumerators, the male head of household (HOH) was the 'official' respondent, but the female HOH was also involved in answering survey questions. It was not possible to hire all female enumerators due to the rural and physically challenging nature of the survey environment.

The average respondent age was just over 34. If the respondent was female, 21.1% had attended any school. The average school attendance was 6.1 years for those women who had attended, and 1.3 for the total female respondent (FR) population.

There was no measurable internal displacement, as 99.3% of families were in the same house as before the emergency. The majority of households owned their own land (83.3%), and all but one respondent owned their own home. Overall, 99.5% of families had water available within 30 minutes of their home, with 10.5% having water access at their home. About two-thirds of the survey population covered their household stored water. Adult women were responsible for collecting water in 78.3% of households, followed by adult men (8.0%), boys (7.5%) and girls (6.3%).

There was a statistically significant difference in reported cholera attack rate, with an attack rate of 3.5% in Suwanauli, compared to 1.8% in Majhakot. Both rates are much less than the 8.2% attack rate reported by Bhandari in their investigations.

Overall 97% of the population received at least one HWTS option from NEWAH, although the products distributed in each VDC varied. More people in Suwanauli received Aquatabs and/or Piyush, and more households in Majhakot received WaterGuard. This was not a deliberate distinction, but simply how NEWAH delivered products received from UNICEF at different times, with Aquatabs arriving first, followed by additional Aquatabs and the liquid chlorine solutions of Piyush and WaterGuard.

Table 7: Survey results by VDC (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Total population (households)	409	1156	1565	
Surveyed households	101	299	400	
% of households surveyed	24.7	25.9	25.6	
Wards surveyed	9	9	18	
Number (%) female respondents (n=400)	54 (53.5)	150 (50.2)	204 (51.0)	0.566
Respondent age in years (min-max) (n=400)	33.3 (11-70)	34.8 (12-80)	34.4 (11-80)	
Number (%) female respondents (FR) attend school (n=204)	10 (18.5)	33 (22.0)	43 (21.1)	0.591
If FR school, average (min-max) years school (n=43)	6.6 (1-12)	5.8 (1-11)	6.1 (1-12)	
All FR average (min-max) years school (n=204)	1.2 (0-12)	1.3 (0-11)	1.3 (0-12)	
Number (%) live is same place as before emergency (n=400)	99 (98.0)	298 (99.7)	397 (99.3)	
Number (%) own their land (n=400)	85 (84.2)	248 (82.9)	333 (83.3)	0.777
Average (min-max) amount of land owned (ropani) (n=333)	3.1 (1-16)	2.5 (1-20)	2.6 (1-20)	
Number (%) own their own home	101 (100)	298 (99.7)	399 (99.8)	0.561
Number (%) families reporting cholera (n=400)	12 (11.9)	24 (8.0)	36 (9.0)	0.242
Number (%) cases cholera reported (n=2384 people)	23 (3.6)	31 (1.8)	54 (2.3)	<0.001
Reported cholera attack rate (per 1000 people)	36	18	23	
Number (%) with water available at household (n=400)	8 (7.9)	34 (11.4)	42 (10.5)	0.328
Number (%) with water available within 30 minutes (n=400)	91 (90.1)	267 (89.3)	358 (89.5)	0.820
Number (%) with covered stored water (n=400)	65 (64.4)	190 (63.5)	255 (63.8)	0.883
Number (%) received Aquatabs (n=400)	95 (94.1)	218 (72.9)	313 (78.3)	<0.001
Number (%) received WaterGuard (n=400)	0 (0)	53 (17.7)	53 (13.3)	<0.001
Number (%) received Piyush (n=400)	67 (66.3)	107 (35.8)	174 (43.5)	<0.001
Number (%) received at least one product (n=400)	99 (98.0)	289 (96.7)	388 (97.0)	0.487

The 400 surveyed households included a total population of 2,384 people (average=5.96 people/household, min=1, max=18), including 504 children under 5 (average=1.26 children/household, min=0, max=4) (Table 8). The only statistically significant difference between VDCs in the reported diarrhea rates was that there was less reported diarrhea in all children under 5 reported in Suwanauli.

Table 8: Survey population and reported diarrhea in last 24 hours (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Total population (by household)	6.3 (2-18)	5.8 (1-14)	6.0 (1-18)	
Under 5 population (by household)	1.3 (0-4)	1.2 (0-4)	1.3 (0-4)	
% females 5 and over with diarrhea	5.4	7.0	6.5	0.432
% males 5 and over with diarrhea	7.6	4.7	5.5	0.099
% 5 and over with diarrhea	*6.5*	*5.8*	*6.0*	*0.594*
% under 5 females with diarrhea	1.5	7.3	5.6	0.095
% under 5 males with diarrhea	1.5	6.3	5.1	0.129
% under 5 with diarrhea	*1.5*	*6.8*	*5.4*	*0.025*

Survey respondents were asked about their water source three times: 1) what source they used before the emergency; 2) if there was a change in source after the emergency, what source they used now; and, 3) in the last part of survey, where the actual stored household water collected today came from. In this emergency, as can be seen in Table 9 and Figure 8, there was little difference between reported before emergency, reported after emergency, and actual at-survey water sources in households. Although there was a slight trend toward increased reported and actual use of improved sources after the emergency, these results were not statistically significant (p=0.414 and 0.595 for Suwanauli and Majhakot, respectively).

Respondents in Majhakot reported a significantly higher use of improved sources (p<0.001). This difference is attributed to the fact NEWAH has been working on water supply projects developing piped networks and improved springs in Majhakot for years, and only began working in Suwanauli during this HWTS emergency response project.

Table 9: Reported water sources before emergency, after emergency, and at time of visit (Jajarkot, Nepal)

	Suwanauli (n=101)			Majhakot (n=299)		
	Before	After	At visit	Before	After	At visit
Tubewell (number (%))			2 (2.0)			4 (1.3)
Surface water (number (%))	12 (11.9)	11 (10.9)	10 (9.9)	4 (1.3)	4 (1.3)	3 (1.0)
Spring box (number (%))	26 (25.7)	30 (29.7)	30 (29.7)	112 (37.5)	116 (38.8)	110 (36.8)
Unimproved spring (number (%))	54 (53.5)	52 (51.5)	50 (49.5)	111 (37.1)	107 (35.8)	108 (36.1)
Piped water (number (%))	9 (8.9)	8 (7.9)	9 (8.9)	72 (24.1)	72 (24.1)	74 (24.8)
% Improved (number (%))	*35 (34.7)*	*39 (38.6)*	*41 (40.6)*	*184 (61.5)*	*195 (65.2)*	*188 (62.9)*
% Unimproved (number (%))	*66 (65.3)*	*62 (61.4)*	*60 (59.4)*	*115 (31.5)*	*104 (34.8)*	*111 (37.1)*

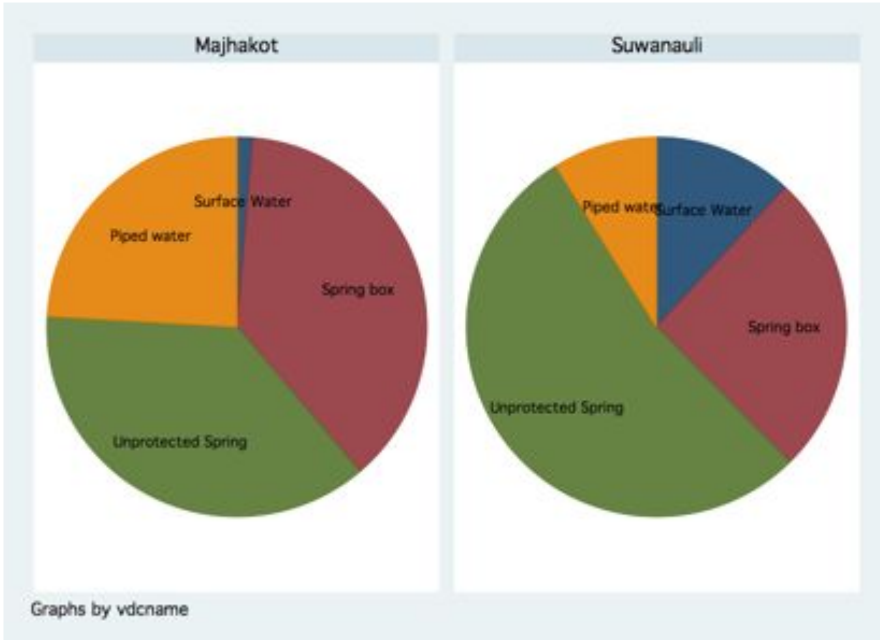


Figure 8: Before emergency reported water sources in Majhakot and Suwanauli (Jajarkot, Nepal)

Respondents were asked if they felt their water was safe to drink. The results varied by water source (Table 10), with 96.5% of households using 220 improved sources after the emergency considering their water safe as compared to 69.2% of households using 94 unimproved sources (p<0.001).

Table 10: Percent of respondents who perceive their water source as safe (Jajarkot, Nepal)

	Surface	Spring box	Unimproved spring	Piped water	All
Perceived safe (number (%))	6 (40.0)	142 (97.3)	104 (65.4)	76 (95.0)	328 (82.0)
Perceived unsafe (number (%))	8 (53.3)	3 (2.1)	44 (27.7)	1 (1.3)	56 (14.0)
Don't know (number (%))	1 (6.7)	1 (0.7)	11 (6.9)	3 (3.8)	16 (4.0)

The majority of respondents who perceived their water as safe did so because the "water looks clean" (Table 11). Respondents were more likely in Majhakot than Suwanauli to state water did not have germs as opposed to water looks clean as the reason (p=0.031). This could be because of increased education from NEWAH programs.

Table 11: Reasons respondents perceive water as safe (multiple answers possible) (Jajarkot, Nepal)

	Suwanauli	Majhakot	All
Water looks clean (number (%))	69 (94.5)	204 (80.0)	273 (83.2)
Water without germs (number (%))	2 (2.7)	26 (10.2)	28 (8.5)
Don't know (number (%))	2 (2.7)	25 (9.8)	27 (8.2)
Totals (number (%))	*73 (100)*	*255 (100)*	*328 (100)*

Similarly, the majority of respondents who perceived their water as unsafe did so because the "water looks dirty" (Table 12). Respondents were more likely in Majhakot to state water did have germs as opposed to water looks dirty as the reason than in Suwanauli, although this result was not significant, potentially due to low sample size.

Table 12: Reasons respondents perceive water as unsafe (multiple answers possible) (Jajarkot, Nepal)

	Suwanauli	Majhakot	All
Water looks dirty (number (%))	13 (46.4)	17 (60.7)	30 (53.6)
Germs in water (number (%))	12 (42.9)	6 (21.4)	18 (32.1)
Causes diarrhea (number (%))	1 (3.6)	2 (7.1)	3 (5.4)
Don't know (number (%))	2 (7.1)	3 (10.7)	5 (8.9)
Totals (number (%))	*28 (100)*	*28 (100)*	*56 (100)*

Respondents were asked what their largest health problems were since the advent of the cholera outbreak, and all self-reported answers were recorded (no answers were prompted). A total of 604 responses (1.51/household) were received (Table 13). The three largest self-identified health problems were: 1) hospital too far away (26.4% of respondents); 2) water problems; and, 3) garbage. A total of 16.4% of respondents self-identified diarrhea as a problem.

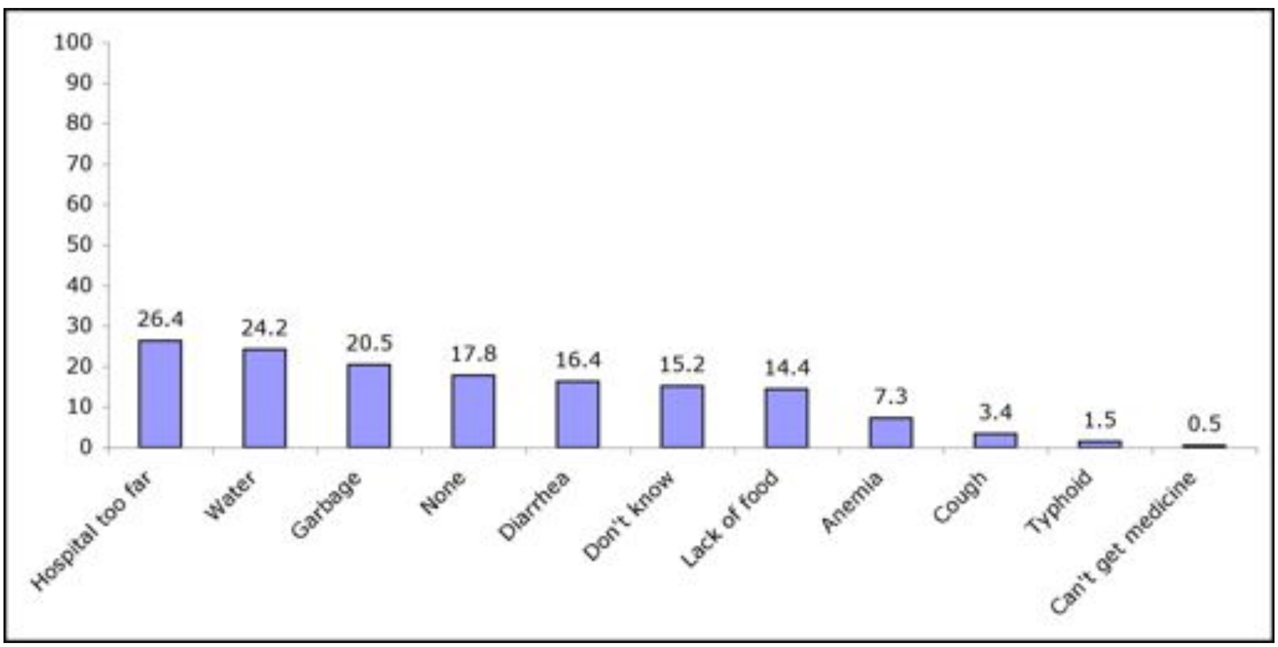


Figure 9: Percent of respondents listing health problems after the emergency (Jajarkot, Nepal)

There was low prior knowledge of HWTS in this survey population, with 94.8% of respondents stating they did not know of any option to treat their water before the emergency. Of those who did self-report an option (this question was not prompted), boiling and solar disinfection (SODIS) were the most common answers. No statistically significant differences were seen between the two VDCs. Overall, only 5.2% of respondents self-reported knowing a HWTS option before the emergency.

Table 13: HWTS options known before emergency (multiple answers possible) (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Boiling (number (%))	4 (4.0)	13 (4.3)	17 (4.3)	0.867
SODIS (number (%))	2 (2.0)	13 (4.3)	15 (3.8)	0.279
WaterGuard (number (%))	1 (1.0)	3 (1.0)	4 (1.0)	0.991
Tablet (number (%))	1 (1.0)	1 (0.3)	2 (0.5)	0.419
Piyush (number (%))	1 (1.0)	1 (0.3)	2 (0.5)	0.419
Filter (number (%))	0 (0)	1 (0.3)	1 (0.3)	0.561
None (number (%))	*96 (95.1)*	*283 (94.7)*	*379 (94.8)*	*0.876*

7.5 Coverage

UNICEF estimated that a total of 18 districts, including 151 VDCs and over 140,000 affected households (826,000 people), were affected by the cholera outbreak in mid-western Nepal. Jajarkot was the most heavily affected district, with over half of the cholera deaths reported. The projected current population within the 30 VDCs in Jajarkot is 25,428 households (151,551 people). For the purposes of coverage, we will limit our discussion to Jajarkot District in this report, as we collected no on-the-ground information from Rukum or other districts.

Overall, 330,630 tablets treating 5 Liters each (1,663,150 Liters) were reported at the VDC level to have been distributed for 24,147 households. This is equivalent to 68.9 Liters/household (3.4 tablets), or using a value of 20 Liters of high-quality water needed per household per day, to 3.4 days of safe drinking water. However, 1) HWTS distribution varied within Jajarkot, with NGOs receiving HWTS options from UNICEF and distributing them with different implementation strategies; and, 2) Aquatabs are distributed in a minimum number of 10 tablet strips, which means while the "average" might be 3.4 tablets, in reality households would have received 0, 10, 20, and so on tablets. Only NEWAH targeted population-based distribution for what they considered the time horizon of the outbreak – two months. Other NGOs completed targeted distribution in health clinics or one geographical region. As presented in Figure 6, the distributed Aquatabs treated an average of less than 50 Liters/household in 12 of 30 (40%) VDCs in Jajarkot, between 50-150 Liters/household in sixteen (53.3%) VDCs, and above 200 Liters/household in two (6.7%) VDCs. Thus, on a population basis, the coverage of HWTS in all the VDCs in Jajarkot was insignificant except in the NEWAH targeted areas.

Overall, 97% of the affected population in the NEWAH VDCs of Suwanauli and Majhakot received at least one HWTS option, indicating almost complete coverage by this metric within these VDCs (Table 14). Aquatabs, Piyush, and WaterGuard were distributed in these VDCs, and at the VDC level we were able to obtain additional data on

Piyush and WaterGuard distribution not available at the District level. There was not deliberate product selection done in the distribution – NEWAH simply distributed whichever option UNICEF had provided at the time.

Table 14: Percent of respondents who received each HWTS option (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Number (%) received Aquatabs (n=400)	95 (94.1)	218 (72.9)	313 (78.3)	<0.001
Number (%) received WaterGuard (n=400)	0 (0)	53 (17.7)	53 (13.3)	<0.001
Number (%) received Piyush (n=400)	67 (66.3)	110 (36.8)	177 (44.3)	<0.001
Number (%) received at least one product (n=400)	99 (98.0)	289 (96.7)	388 (97.0)	0.487

In addition, families could and did receive products more than once, at group trainings, household distributions, or by walking to the NEWAH office and requesting more products. Thus, respondents received a variety of combinations of chlorine based HWTS options (Table 15).

Table 15: Product combinations received by respondents (Jajarkot, Nepal)

	Suwanauli (n=101)	Majhakot (n=299)	Total (n=400)
No product	2 (2.0)	10 (3.3)	12 (3.0)
Aquatabs only	32 (31.7)	128 (42.8)	160 (40.0)
Piyush only	4 (4.0)	27 (9.0)	31 (7.8)
WaterGuard only	0 (0.0)	44 (14.7)	44 (11.0)
Aquatabs and Piyush	63 (62.4)	81 (27.1)	144 (36.0)
Aquatabs and WaterGuard	0 (0)	7 (2.3)	7 (1.8)
Piyush and WaterGuard	0 (0)	0 (0)	0 (0)
Aquatabs and Piyush and WaterGuard	0 (0)	2 (0.7)	2 (0.5)

Due to this ongoing distribution, it was not possible to calculate a Liters treated per household by HWTS option in these two VDCs, as households could not state how much product they had received over the numerous distributions. However, of the 388 households that received at least one product, 344 (88.7% of recipients, 86% of households surveyed) had product on the day of the unannounced survey visit in their home, which indicates that NEWAH was very close to meeting their target of providing HWTS to all households for 2 months of time.

We did collect self-reported HWTS option recipient data. A total of 313/400 (78.3%) survey respondents received an average of 24 Aquatabs (range 10-220) (Table 16). Twenty-four tablets is enough to treat 120 Liters of water, which provides six days of treated water to a household using 20 Liters of high-quality water per day. Overall, 17.7% of the surveyed population received one bottle of WaterGuard, with one household receiving two bottles (Table 18). One bottle is enough to treat 1,200 Liters of water, or provide 60 days of treated water to a household. The 177 recipients of Piyush reported receiving an average of 1.1 bottles per household (range 1-3) (Table 20). As one bottle treats 400 Liters, this is enough to treat 440 Liters, or provide 22 days of treated water for a family using 20 Liters of high quality water per day. This data is likely an underreport of distribution as respondents may have indicated the amount of product received only the last time they received the product, not the cumulative product received. However, the average number of days of treatment reported by the survey population was 36.3, range 0-30 days. This also provides an indication that NEWAH is meeting their target.

As can be seen, the coverage data in Nepal is complicated by the size of the emergency, the different distribution strategies of NGOs, and rolling distribution of HWTS options. What can be stated from this coverage data is that rolling distribution targeting all households in highly affected areas can lead to high coverage with distribution of HWTS options and presence of HWTS options in the household at the time of the unannounced survey visit.

7.6 Correct use

Three products – Aquatabs, Piyush, and WaterGuard – were distributed in Nepal and are discussed in the following sections.

7.6.1 Aquatabs

UNICEF provided 33 mg Aquatabs, meant for treating 5 Liters of water at a dosage of 4 mg/L. Users were instructed to add one tablet to 5 Liters and wait 30 minutes before drinking. All 211 respondents who could show us the Aquatabs they received had the 33 mg tablet (Table 16). A total of 313/400 (78.3%) survey respondents received an average of 24 Aquatabs (range 10-220). Twenty-four tablets is enough to treat 120 Liters of water, which provides six days of treated water to a household using 20 Liters of high-quality water per day.

The large majority of people received group trainings (94.6%) on how to use the tablets, with a minority (3.9%) receiving household trainings. Five respondents (1.6%) reported receiving no training. On average, 84.7% of respondents knew to add the tablet to 5 Liters of water, with ranges of 1-20 Liters reported. Overall, 58.8% of respondents knew to wait 30 minutes before drinking, with time ranges reported between 1-120 minutes. A large number of respondents (67, 21.4%) reported a 60 minute wait time before drinking, indicating they may have been taught that number in the trainings. Fully correct use knowledge (1 tablet, 5 Liters, 30 minutes) was 53.0% of Aquatabs recipients, although that number increases to 78.6% if incorrect but adequate treatment (such as waiting longer than 30 minutes and/or treating less volume of water with one Aquatab) is included.

Over 70% of respondents reported ever using Aquatabs, and 54.8% reported they are still currently using the Aquatabs. Less than half of overall respondents stated they use a 5 Liter container for water treatment with Aquatabs. Only 9.9% of respondents reported having current household water treated with Aquatabs, indicating that despite reporting current use, many did not have water available at the household level. This could be because many households stated they only made treated water for mealtimes, and drank the water only then. Another 16.3% of Aquatabs respondents reported having current household water treated with either Piyush or WaterGuard. Of the 31 respondents who reported current stored household water treated with Aquatabs, 27 (87.1%) had FCR greater than or equal to 0.2 mg/L, and 16 (51.6%) had FCR between 0.2-2.0 mg/L.

The main reason detailed for Aquatabs use was that it prevents disease, and the main reason for non-use was that the product was finished (Table 17). Overall, 100 (31.2%) respondents reported they had finished the Aquatabs. If the rates of use are recalculated using 'households with Aquatabs remaining' instead of 'Aquatabs recipients' as the denominator, usage rates rise to 19.2% in Suwanauli, 11.9% in Majhakot, and 14.6% overall. The rate of tablet use could not be calculated because recipients received tablets at multiple times.

Majhakot non-users were likely to say they discontinued use because the product was finished than Suwanauli non-users, which may explain why overall, the metrics on Aquatabs are statistically significantly better in Suwanauli as opposed to Majhakot. More recipients in Suwanauli reported correct knowledge of container volume, fully correct knowledge of Aquatab use, using a 5 liter container, stored household treated water with Aquatabs today, and had a FCR greater than or equal to 0.2 mg/L. Chlorine taste and smell concerns accounted for 19.0% of product non-use reasons.

Table 16: Aquatabs knowledge and use (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Number (%) received Aquatabs (n=400)	95 (94.1)	218 (72.9)	313 (78.3)	<0.001
Number (min-max) tablets received (n=309)	35 (10-210)	19 (10-70)	24 (10-210)	
Number (%) reporting group training received (n=312)	82 (86.3)	213 (98.2)	295 (94.6)	
Number (%) reporting household training received (n=312)	11 (11.6)	1 (0.5)	12 (3.8)	
Number (%) with correct knowledge of 5 L volume (n=313)	89 (93.7)	176 (80.7)	265 (84.7)	0.003
Number (%) with correct knowledge of 30 minute wait (n=313)	60 (63.2)	124 (56.9)	184 (58.8)	0.300
Number (%) with fully correct use knowledge (n=313)	58 (61.1)	108 (49.5)	166 (53.0)	0.061
Number (%) include incorrect, but adequate treatment (n=313)	79 (83.2)	167 (76.6)	246 (78.6)	0.194
Number (%) report ever using (n=312)	73 (77.7)	147 (67.4)	220 (70.5)	0.069
Number (%) report current use (n=313)	62 (65.3)	109 (50.0)	171 (54.6)	0.070
Number (%) report using 5 L container for treatment (n=313)	58 (61.1)	86 (39.4)	144 (46.0)	<0.001
Number (%) report Aquatabs treated water today (n=313)	15 (15.8)	16 (7.3)	31 (9.9)	0.005
Number (%) AT recipients reporting other treatment (n=313)	11 (11.6)	45 (20.6)	51 (16.3)	
Number (%) with correct FCR in AT treated water (n=31)	8 (53.3)	8 (50.0)	16 (51.6)	0.091
Number (%) with FCR ≥0.2 mg/L in AT treated water (n=31)	15 (100)	12 (75.0)	27 (87.1)	0.038
Number (%) report Aquatabs treated water today if product was not finished (n=213)	15 (19.2)	16 (11.9)	31 (14.6)	

Table 17: Reasons for use and non-use of Aquatabs (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Use because (n=171)				
Cleans water (number (%))	15 (24.2)	8 (7.3)	23 (13.5)	0.209
Prevents disease (number (%))	47 (75.8)	101 (92.7)	148 (86.5)	
Do not use because (n=137)				
Product finished (number (%))	17 (56.7)	83 (77.6)	100 (73.0)	0.048
Do not like taste or smell (number (%))	9 (30.0)	17 (15.9)	26 (19.0)	
Hard to use (number (%))	2 (6.7)	0 (0)	2 (1.5)	
Using Piyush or WaterGuard (number (%))	2 (6.7)	7 (6.5)	9 (6.6)	

7.6.2 WaterGuard

The correct usage of WaterGuard is to fill the cap to the first line for a small gagri or bucket (5-10 Liters) and to the second line for a large gagri or bucket (15-20 Liters), add that amount of chlorine to the container, wait 30 minutes, and drink. This dosage (for a 10 or 20 liter container) is 1.4 mg/L. WaterGuard is labeled in Nepali. It was only distributed in Majhakot, so data for Suwanauli are not included herein.

Overall, 17.7% of the surveyed population received one bottle of WaterGuard, with one household receiving two bottles (Table 18). One bottle is enough to treat 1,200 Liters of water, or provide 60 days of treated water to a household. All recipients received group training, and none received household training. The majority of respondents (78.8%) knew the correct wait time of 30 minutes before drinking the water, and nine of the 11 (81.8%) that did not report 30 minutes reported 60 minutes, indicating their might have been an error in the training and that adequate, if incorrect, water treatment was occurring. Two respondents did not know how long to wait. Fully correct treatment use could not be calculated as enumerators reported the answers to "how much WaterGuard do you add" differently, with some reporting lines and some milliliters. The data could not be disaggregated in cleaning. The majority of respondents indicated they had ever used (96.2%) and were currently using (94.1%) WaterGuard. The average container size used was reported at 11.1 Liters, with a large range from 2-25 Liters. Almost half of WaterGuard recipients reported current household stored water treated with WaterGuard, 24% of whom had FCR in the range of 0.2-2.0mg/L and 56% with FCR above 0.2 mg/L. The main reason for WaterGuard use was that it "prevents disease" (95.8%) and the main reason for disuse (a small sample of 3 respondents) was taste and smell (Table 19).

Table 18: WaterGuard knowledge and use (Jajarkot, Nepal)

	Majhakot
Number (%) received WaterGuard (n=299)	53 (17.7)
Number (%) received 1 bottle (n=53)	52 (98.1)
Number (%) reporting group training received (n=53)	53 (100)
Number (%) reporting household training received (n=53)	0 (0)
Number (%) with correct knowledge of 30 minute wait (n=52)	41 (78.8)
Number (%) with fully correct use knowledge (n=53)	---
Number (%) report ever using (n=52)	50 (96.2)
Number (%) report current use (n=51)	48 (94.1)
Average (min-max) container size (L) used for treatment (n=51)	11.1 (2-25, stdev 6.5)
Number (%) report WG treated water today (n=53)	25 (47.2)
Number (%) WG recipients reporting other treated today (n=53)	1 (1.9)
Number (%) with correct FCR in WG treated water (n=25)	6 (24.0)
Number (%) with FCR ≥0.2 mg/L in WG treated water (n=25)	14 (56.0)
Number (%) report WG treated water today if product was not finished (n=52)	25 (48.1)

Table 19: Reasons for use and non-use of WaterGuard (Jajarkot, Nepal)

	Majhakot
Use because (n=48):	
Cleans water (number (%))	2 (4.2)
Prevents disease (number (%))	46 (95.8)
Do not use because (n=5):	
Product finished (number (%))	1 (20)
Do not like taste or smell (number (%))	3 (60)
Hard to use (number (%))	1 (20)

7.6.3 Piyush

The correct usage of Piyush is to open the container, poke a hole in the plastic, and add three drops of Piyush per liter treated, wait 30 minutes, and drink. The 177 recipients of Piyush reported receiving an average of 1.1 bottles per household (range 1-3) (Table 20). As one bottle treats 400 Liters, this is enough to treat 440 Liters, or provide 22 days of treated water for a family using 20 Liters of high quality water per day. A total of 98.9% of respondents reported receiving group training, 0.5% receiving household training, and 1 household reporting receiving no training. Upon examination, enumerators felt 90.7% of holes made by respondents in the plastic were adequate to dispense drops. Over sixty percent of respondents knew the 3 drops/liter dosing, and just under 60% knew to wait 30 minutes before drinking. Fully correct Piyush use knowledge was 44.9%, although if incorrect but adequate treatment was included, that percentage increased to 52.8%. Overall, 74.7% of respondents reported ever using the Piyush, and 67.8% reported still using the product currently.

About one-third (36.2%) of Piyush respondents reported current household stored water treated with Piyush, 41.5% which had FCR in the range of 0.2-2.0 mg/L and 50.8% with FCR above 0.2 mg/L. The main reason Piyush use was it prevents disease (85.8%) and the main reason for disuse is that the households were using WaterGuard or Aquatabs instead (60.7%). If the rates of use are recalculated using 'households with Piyush remaining' instead of 'Piyush respondents' as the denominator, usage rates rise to 20.3% in Suwanauli, 47.6% in Majhakot, and 37.3% overall.

Overall, the metrics on Piyush are statistically significantly better in Majhakot as opposed to Suwanauli, as more respondents in Majhakot reported ever using, current use, and having treated water at the time of the unannounced visit.

Two people who did not report receiving Piyush reported using it on the day of the unannounced survey visit, and this explains the discrepancy between the denominators in "respondents of Piyush reporting use today" and "survey respondents reporting Piyush use" of 63 and 65 households.

Table 20: Piyush knowledge and use (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total	p-value
Number (%) received Piyush (n=400)	67 (66.3)	110 (36.8)	177 (44.3)	<0.001
Number (min-max) bottles received (n=176)	1.2 (1-3)	1.1 (1-3)	1.1 (1-3)	
Number (%) reporting group training received (n=176)	67 (100)	107 (98.2)	174 (98.9)	
Number (%) reported household training received (n=176)	0 (0)	1 (0.9)	1 (0.6)	
Number (%) with correct knowledge of 3 drops/liter dosing (n=177)	45 (67.2)	61 (55.5)	107 (60.5)	0.081
Number (%) with correct knowledge of 30 minute wait (n=176)	44 (65.7)	60 (55.1)	104 (59.1)	0.164
Number (%) with fully correct use knowledge (n=176)	36 (53.7)	43 (39.4)	79 (44.9)	0.064
Number (%) including incorrect, but adequate treatment (n=176)	40 (59.7)	53 (48.6)	92 (52.8)	0.153
Number (%) recipients reporting ever using (n=174)	44 (65.7)	86 (80.4)	130 (74.7)	0.030
Number (%) recipients reporting current use (n=174)	40 (59.7)	80 (72.7)	120 (67.8)	
Number (%) reporting Piyush treated water today (n=177)	13 (19.4)	50 (45.5)	63 (35.6)	0.001
Number (%) Piyush respondents reporting other treatment (n=177)	9 (13.4)	5 (4.5)	14 (7.9)	
Number (%) with correct FCR in Piyush treated water (n=65)	6 (46.2)	21 (40.4)	27 (41.5)	0.101
Number (%) FCR $\geq$0.2 mg/L in Piyush treated water (n=65)	9 (69.2)	24 (46.2)	33 (50.1)	0.137
Number (%) reporting Piyush treated water today if Piyush had not finished (n=169)	13 (20.3)	50 (47.6)	63 (37.3)	

Table 21: Reasons for use and non-use of Piyush (Jajarkot, Nepal)

	Suwanauli	Majhakot	Total
Use because (n=120)			
Cleans water (number (%))	8 (20.0)	9 (11.3)	17 (14.2)
Prevents disease (number (%))	32 (80.0)	71 (88.8)	103 (85.8)
Do not use because (n=56)			
Product finished (number (%))	3 (11.1)	5 (17.2)	8 (14.3)
Do not like taste or smell (number (%))	3 (11.1)	6 (20.7)	9 (16.1)
Hard to use (number (%))	1 (3.7)	4 (13.8)	5 (8.9)
Using Aquatabs or WaterGuard (number (%))	20 (74.1)	14 (48.3)	34 (60.7)

7.6.4 Comparative analysis

Summary statistics from the previous analysis are documented in Table 22 for comparison. As can be seen, people reported fully correct and incorrect but adequate treatment knowledge at a higher rate for Aquatabs than Piyush. Respondents were more likely to report use of WaterGuard or Piyush today compared to Aquatabs, however, this number must be understand in light of the 100 respondents who reported running out of Aquatabs, also can be seen in the percent of respondents who reported other treated water if they received Aquatabs. A correct FCR of between 0.2-2.0 mg/L was reported most often in Aquatabs, followed by Piyush and WaterGuard. Any FCR was reported more often in households reporting Aquatabs use as well.

The main reason for use of HWTS options was because it "prevents disease." The main reasons for disuse were that the product was finished in the case of Aquatabs and that the households were using another product in the case of Piyush. Taste and smell concerns accounted for 38/190 reasons for disuse (20%), and were more often noted for Aquatabs, which dosed the highest (5 mg/L as opposed to 1.4 mg/L for WaterGuard and 0.75 mg/L for Piyush).

Table 22: Summary analysis of knowledge and use of HWTS options (Jajarkot, Nepal)

	Aquatabs	WaterGuard	Piyush	p-value
Number (%) received product (n= survey population)	313 (78.3)	53 (17.7)	177 (44.3)	
Number (%) received group training (n=received)	295 (94.6)	53 (100)	174 (98.9)	
Number (%) received household training (n=received)	12 (3.8)	0 (0)	1 (0.6)	
Number (%) report knowing fully correct treatment (n=received)	166 (53.0)	--	79 (44.9)	0.032
Number (%) report incorrect, but adequate treatment (n=received)	246 (78.6)	--	92 (52.8)	<0.001
Number (%) report treated water in household today (n=received)	31 (9.9)	25 (47.2)	63 (35.6)	<0.001[1]
Number (%) report treated water with other HWTS (n=received)	51 (16.3)	1 (1.9)	14 (7.9)	
Number (%) with correct FCR (n=report treatment with option)	16 (51.6)	6 (24.0)	27 (41.5)	0.170[1]
Number (%) with FCR≥0.2 mg/L (n=report treatment with option)	27 (87.1)	14 (56.0)	33 (50.8)	0.002[1]
Number (%) reason use is cleans water (n=# reporting using)	23 (13.5)	2 (4.1)	17 (14.2)	
Number (%) reason use is prevents disease (n=# reporting using)	148 (86.5)	46 (95.8)	103 (85.8)	
Number (%) reason disuse is finished (n=# reporting nonuse)	100 (73.0)	1 (20)	8 (14.3)	
Number (%) reason disuse is taste/smell (n=# reporting nonuse)	26 (19.0)	3 (60.0)	9 (16.1)	
Number (%) reason disuse is using other (n=# reporting nonuse)	9 (6.6)		34 (60.7)	

[1] p-value calculated by summing the WaterGuard/Piyush results and comparing to Aquatabs

If respondents received more than one HWTS option, we asked which they preferred. The only option pair with sample size sufficient for analysis on this question was Aquatabs and Piyush (received by 144 respondents) (see Table 15). Of the 143 respondents who received Aquatabs and Piyush and responded to this question, 95 (66.4%) preferred Piyush, 45 (31.5%) preferred Aquatabs, and 3 (2.1%) had no preference. The reason for the preference was that Piyush tasted better (which is consistent with the lower Piyush chlorine dose of 0.75 mg/L compared to Aquatabs at 5.0 mg/L), although respondents found the Aquatabs easier to use.

Table 23: Reasons for Aquatabs or Piyush preference (Jajarkot, Nepal)

	Aquatabs (n=49)	Piyush (n=97)	p-value
Tastes better	16 (32.7)	66 (68.0)	<0.001
Easier to use	27 (55.1)	31 (32.0)	
Have used before	6 (12.2)		

These results show that there is not one clear answer as to which is the most appropriate chlorine option in this emergency – Aquatabs was easier to know how to use correctly and maintained a better FCR, but people objected to the taste more and the cost of providing Aquatabs was higher and so less were provided and people ran out. Respondents reported actually using WaterGuard and then Piyush at the highest rates, but this is confounded by the 100 households who ran out of Aquatabs. If all 100 households who reported running out of Aquatabs are added into the "use Aquatabs today" number (raising that value to 131 of the 313 respondents) the rate of use of Aquatabs rises to 41.9%, equivalent to the rate of use of WaterGuard and Piyush.

Overall, however, it is quite clear that in a survey population that had very low knowledge of chlorine based options before the emergency (2% reported knowing any chlorine option), a high rate of distribution (97% for at least one product), adequate knowledge (52.8-78.6%), and reported use (9.9-47.2) confirmed by adequate FCR (50.8-87.1 of reported users) is possible in a matter of one month. Overall 121/400 (30.3%) of targeted households reported household water treatment (including 31 Aquatabs, 25 WaterGuard, and 63 Piyush receivers and the two households reporting Piyush use who did not report receiving Piyush). Of the 121 who reported treated water, 74 (27 Aquatabs users, 14 WaterGuard users, and 33 Piyush users) had FCR above 0.2 mg/L. Thus, 61.2% (74/121) of those reporting treatment had adequate FCR, and 18.5% (74/400) of the surveyed population had adequate FCR in their drinking water due to the HWTS distribution at the time of the unannounced survey visit. Given the demand from the survey population for a product to reduce the cholera disease risk in this environment, it appears the population will use whichever product is provided, regardless of taste concerns or dosage.

7.6.5 Univariate analysis

In addition to the analysis completed on the survey results, we would like to understand the associations between characteristic of the respondent and household and whether they were more likely to have outcomes desired (the dichotomous variables of receiving any product, reporting water treatment with any product, or having FCR greater than or equal to 0.2 mg/L in drinking water). We postulate, based on the literature on HWTS use, that there might be characteristics of the population that relate to improved outcomes, such as mothers education, socio-economic status of the household, etc. The variables that might impact the outcome variables in this circumstance include whether or not (the): female responded attended school, household owns their own land or home, household used a improved water source or not, diarrhea was reported in the household or in children in the household, diarrhea was considered a health problem after the emergency, household believes drinking water is safe, household covered their storage container, household received group training or household training, household was in a ward with a NEWAH office, and the socio-economic status of the household.

Initial results from a univariate analysis, comparing whether or not the factors relate to outcomes in a statistically meaningful manner shown by a p-value of less than 0.05, shows that no factors were significant in whether the households received HWTS options (Table 24). This suggests NEWAH's distribution strategy was not biased. The significant factors in whether a household reported water treatment including prior knowledge of any HWTS before the emergency, covering the household water storage container, and receiving group training. These all indicate households with higher knowledge of safe water practices are more likely to treat water. A FRC level of greater than or equal to 0.2 mg/L was related to whether the female head of household attended school and whether the household knew any HWTS option before the emergency. These are also all 'knowledge based' variables. Odds ratios and confidence intervals are presented for significant associations for statistical completeness. As can be seen, the "received group training" association crosses over 1.0 in the confidence interval, indicating this association may not be significant.

We did not consider whether or not the individual products ran out in this analysis, because respondents could have received additional product at any time from distributions or by requesting product from the NEWAH office. We did investigate whether the data was confounded by ward (i.e. whether or not the data was clustered by households in one ward all having the same outcome variables due to social norms or social support reason) and only 8.5% of the variance in the data set for FCR was confounded by ward, which is not a significant amount.

Socio-economic status quintiles were developed using principal component analysis based on household assets (including radio, television, mobile phone, cow, goat, hen, pig, and horse ownership and owning own land and home). The quintiles were not associated with the outcome variables of receiving a product, reporting treatment, or FCR greater than or equal to 0.2 mg/L.

We will continue to develop this explanatory model further to understand associations, completing forwards and backwards elimination regression to understand the relationship between these variables and the significance of each, however further development is outside the scope of this report.

Table 24: Univariate analysis results (Jajarkot, Nepal)

Postulated potential factors related to outcomes	Received product	Reported treated	FCR ≥0.2 mg/L
Female respondent attended school	0.545	0.059	**0.041** OR: 2.41 95% CI: 1.0-5.8
Family owns land	0.119	0.509	0.892
Own home	0.860	0.510	0.634
Use improved source	0.208	0.139	0.539
Knew any option before emergency	0.628	**0.001** OR: 4.08 95% CI: 1.6-10.3	**<0.001** OR: 4.47 95% CI: 1.8-11.1
Diarrhea reported in household	0.993	0.426	0.580
Diarrhea reported in children in household	0.060	0.980	0.860
Cholera reported in household	0.269	0.140	0.232
Diarrhea health problem after emergency	0.438	0.426	0.370
Believe drinking water is safe	0.377	0.825	0.574
Covered household drinking water	0.831	**<0.001** OR: 7.46 95% CI: 3.8-14.5	0.545
Received household training	--	0.060	0.247
Received group training	--	**0.043** OR: 4.10 95% CI: 0.9-18.1	0.111
Lived in ward with NEWAH office	0.061	0.999	0.787
Socio-economic status quintiles (5x2)	0.642	0.705	0.816

7.7 Microbiological improvement

In Nepal, FCR and turbidity were the only water quality metrics tested, as the microbiological media was not robust enough for the conditions. Thus, it was not possible to assess the ambient (pre-treatment) risk presented by the drinking water supply. However, a low turbidity (<5-10 NTU) and maintenance of greater than or equal to 0.2 mg/L of free chlorine residual is generally considered to be indicative of water that is free of chlorine-susceptible pathogens (SPHERE, 2004; WHO, 2004; Lantagne, 2008a). Thus, these proxies can be used to determine whether the treated water was likely to be safe for drinking. The turbidity of the source water among the study population in Nepal was quite low. The average overall turbidity was 2.1 NTU, and only two of 190 (1.1%) samples were above the 10 NTU threshold indicating the need for a double dose of chlorine-based HWTS (Table 25, Figure 10). There was no significant difference in turbidity between improved and unimproved sources (p=0.152).

Table 25: Turbidity by source (Jajarkot, Nepal)

	Average	Min	Max	<1 NTU	1-<10	10-100	>=100
Borehole (n=3)	2.6	1.3	3.5	0 (0)	3 (100)	0 (0)	0 (0)
Piped water (n=13)	2.4	0.1	19.6	4 (30.8)	9 (69.2)	0 (0)	0 (0)
Improved spring (n=62)	1.8	0	15.4	29 (46.8)	32 (51.6)	1 (1.6)	0 (0)
Surface (n=91)	1.6	0.4	3.0	22 (24.2)	68 (74.7)	1 (1.1)	0 (0)
Unimproved spring (n=21)	1.7	0.1	5.3	6 (28.6)	15 (71.4)	0 (0)	0 (0)
Improved sources (n=86)	*1.8*	*0*	*14.5*	*35 (40.7)*	*50 (58.1)*	*1 (1.2)*	*0 (0)*
Unimproved sources (=104)	*2.4*	*0*	*19.6*	*26 (25.0)*	*77 (74.0)*	*1 (1.0)*	*0 (0)*
Total (190):	*2.1*	*0*	*19.6*	*61 (32.1)*	*127 (66.8)*	*2 (1.1)*	*0 (0)*

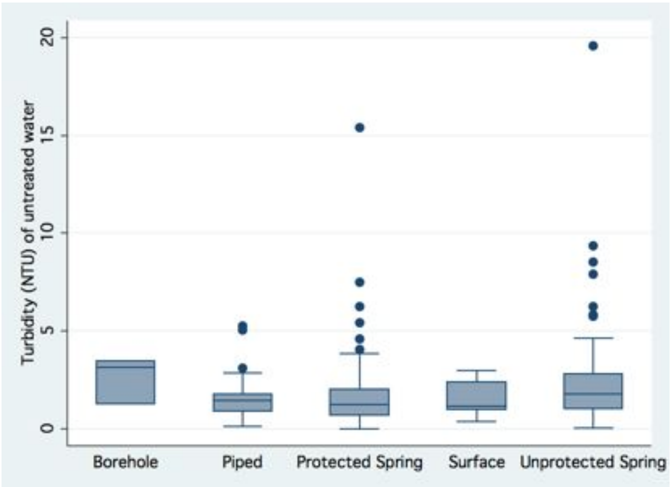


Figure 10: Turbidity by source (Jajarkot, Nepal)

FCR was maintained at a higher rate by users of Aquatabs and WaterGuard compared to Piyush. This can be expected, as the dosage of Aquatabs in this context was 5 mg/L, the dosage of Piyush was 0.75 mg/L, and the dosage of WaterGuard was 1.4 mg/L. The FCR results should be understood in light of the following realities: 1) some families that reported treated water could have been misleading, and not actually have treated their water; and, 2) many families used a variety of storage containers for their water treatment (as detailed in the next section on sub-optimal use) and dosage could have been incorrect (Figure 11, Table 26). Overall, 40.1% of treated waters were with the acceptable range for HWTS, 20.7% were high, but adequate, and 38.8% were below 0.2 mg/L, indicating that the water is no longer safe from recontamination.

In summary, only 1.1% of water sources were inappropriate for a single-dose of chlorine-based water treatment, and no water sources were inappropriate for a double-dose or higher of chlorine-based water treatment. However, 38.8% of reportedly treated household samples did not have enough FCR to protect against recontamination.

Table 26: FCR by HWTS option (Jajarkot, Nepal)

	Average	Min	Max	<0.2 mg/L	0.2-2.0 mg/L	>2.0 mg/L
Aquatabs (n=31)	1.8	0	5	4 (12.9)	16 (51.6)	11 (35.5)
Piyush (n=65)	0.5	0	3.5	32 (49.2)	27 (41.5)	6 (9.2)
WaterGuard (n=25)	1.4	0	5	11 (44.0)	6 (24.0)	8 (32.1)
Total (101):	*1.0*	*0*	*5*	*47 (38.8)*	*49 (40.1)*	*25 (20.7)*

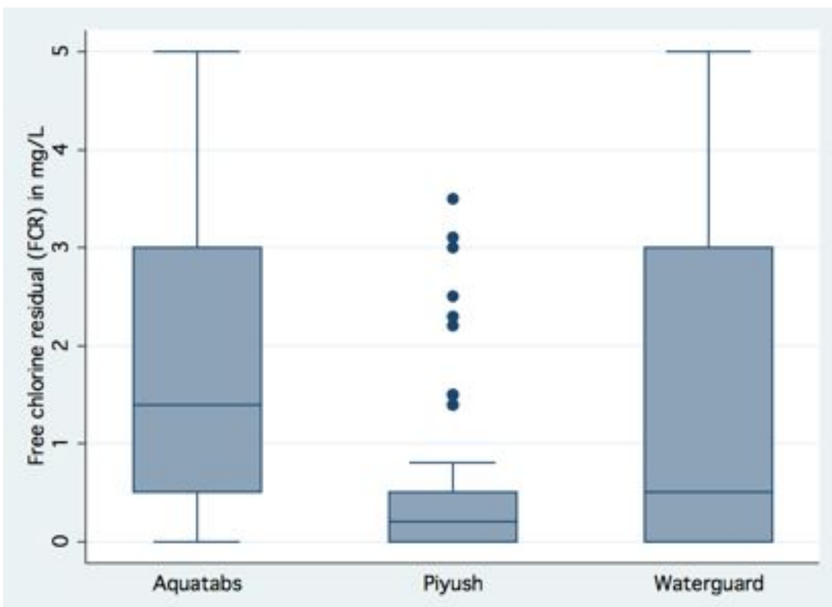


Figure 11: FCR by HWTS option (Jajarkot, Nepal)

7.8 Resistance to sub-optimal use

One theme worth noting in the Nepal data about sub-optimal use was the necessity of having a storage container appropriate for the dosing of the chlorine option, including 5-10 or 15-20 Liters for WaterGuard and 5 Liters for Aquatabs. We asked respondents that reported they had ever used the HWTS option what container they used the option with, and as can be seen a large range of container sizes was reported (Figure 12).

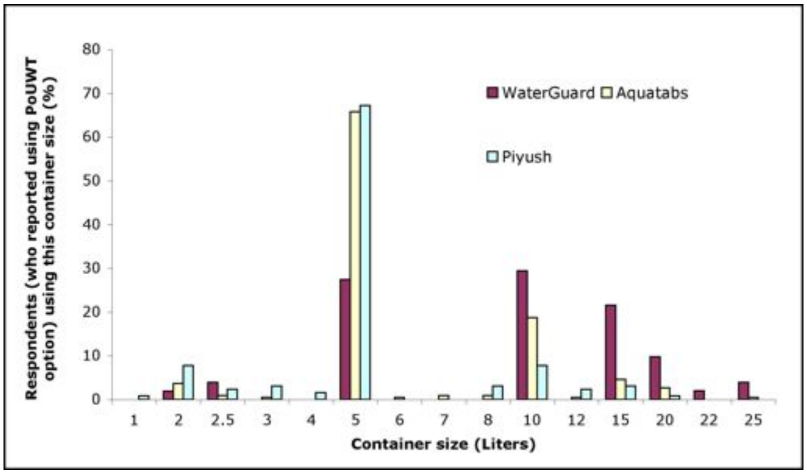


Figure 12: Storage containers reported ever used with HWTS options (Jajarkot, Nepal)

We also asked respondents who reported current water treatment today the container size they used with the option they treated the water with today. As can be seen there is less of a range, with WaterGuard use almost exclusively at higher volume containers (12 Liters and above), Aquatab use predominantly in containers that were multiples of five Liters (5, 10, 15, and 20), and Piyush use (3 drops/Liter) throughout all container sizes (Figure 13).

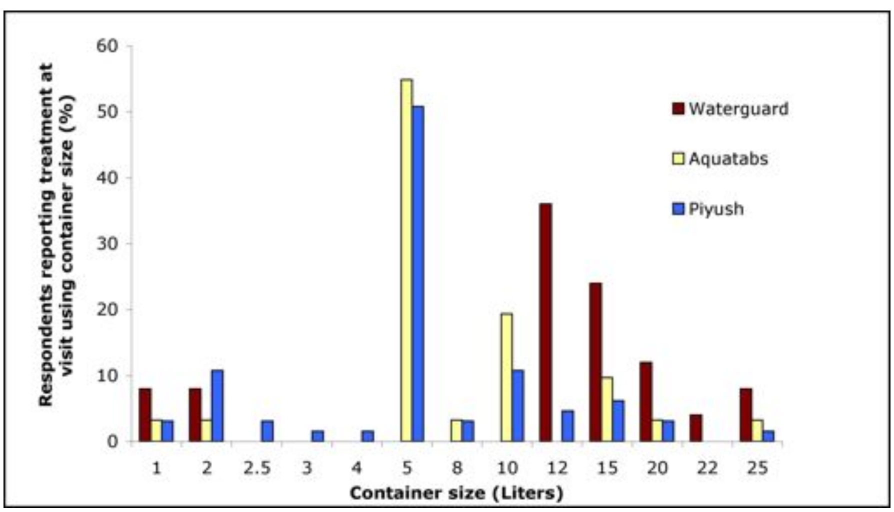


Figure 13: Storage containers used in families reporting treatment today (Jajarkot, Nepal)

Overall this data indicates that the target population found a container appropriate for the dosing regime of the option and used it, or discontinued product use. This is consistent with what was seen in the field, as people found non-standard storage containers to use when treating water with Aquatabs which required a 5 Liter container (Figure 14). There was no statistically significant difference in FCR maintenance if the appropriate container was used when treating with Aquatabs or WaterGuard, so it may be possible to overcome this issue with more clarity in instructions about the range of vessels that can be used effectively with the product. However, it appears in this emergency that providing a container (or an option that can be used with any container like Piyush) might make it easier for the family, and encourage use and uptake of all the options.

Figure 14: Non-standard 5-Liter water containers used with Aquatabs (Jajarkot, Nepal)

7.9 Cost analysis

The total cost of the education and community mobilization component for this project was 10,000 USD for two months (funded by Concern Worldwide to NEWAH). In addition, UNICEF provided the products at no cost to NEWAH, delivered to Jajarkot. UNICEF calculated that the total cost per month per household (including product and transportation costs to Jajarkot) was 169 Nepali Rupee (NR – exchange rate 76.7 NR to USD) for Aquatabs, 27.6 NR from Piyush, and 22.8 NR for WaterGuard (Table 27). These figures include a higher product cost for Aquatabs, but a higher transportation cost for WaterGuard and more uses per bottle in WaterGuard than Piyush.

Table 27: Costs of HWTS options delivered (adapted from UNICEF/Nepal) (Jajarkot, Nepal)

	Aquatabs	Piyush	WaterGuard
Cost (NR)	1.4 NR	12 NR	17 NR
Liters treated (NR)	5	400	1200
Cost/Liter treated (NR)	0.28 NR	0.03 NR	0.014 NR
Product needed month/HH (20 Liters/day)	120	1.5	0.5
Cost/HH for 1 month	168 NR	18 NR	8.5 NR
Weight of product (grams)	5 g/50 tabs	65 g/bottle	7.3 kg/25b
Weight 1 month/HH product (grams)	12 g	97.5 g	146 g
Transport (Kathmandu-Nepalganj) (10/kg)	0.12 NR	0.98 NR	1.46 NR
Transport (Nepalganj-VDC) (76/kg)	0.91 NR	7.4 NR	11.1 NR
Transport (VDC-Ward) (12/kg)	0.14 NR	1.2 NR	1.8 NR
Transport Cost per month	1.2 NR	9.6 NR	144 NR
Total Cost	*169 NR*	*27.6 NR*	*22.9 NR*

While the product cost numbers appear small, to scale this project up to the entire affected area of 151 VDCs, instead of 2, becomes potentially cost-prohibitive. Assuming 10,000 USD for two VDCs for two months (2,500 USD/VDC/month) for education, and 140,000 affected households using WaterGuard (the cheapest option) at 22.8 NR/month, the cost of a full project to provide two months of HWTS and education to the entire affected population would be: 755,000 USD for education (151 VDCs * 2,500 USD/VDC/months * 2 months) plus 83,598 USD (22.9 NR/month *140,000 affected households * 2 months = 6.384 million Nepali Rupees at 76.7 exchange rate). That total nearly 1 million US dollars (838,598 USD) for a short-term 2 month intervention project.

To compare these numbers to development projects completed by NEWAH in the same region, from 2007-2009 NEWAH received 370,000 USD to complete 12 projects to supply safe drinking water supplies and sanitation to areas in Majhakot (personal communication from NEWAH). As was seen in this data set, there were more improved water supplies in Majhakot than in Suwanauli, so this project has been of success. One water system for 60 households generally costs 33,000 USD. Thus, the cost of this HWTS treatment project cost NEWAH about 1/3rd of a water system – or the equivalent of providing an improved water sources to 20 families.

8 West Sumatra, Indonesia Earthquake

West Sumatra is one of 53 provinces in Indonesia, located on the western coast of the island of Sumatra, with a population of 4,241,000 and land area of 42,297 square kilometers (Figure 15). West Sumatra is on the 'Ring of Fire' and was affected by the 2005 Tsunami, as the province is just south of Aceh. Sumatra contains seven major cities, including the capital city of Padang, and is divided into twelve regencies.

Figure 15: Indonesian province map (from http://en.wikipedia.org/wiki/Provinces_of_Indonesia)

8.1 Description of emergency

On September 30, 2009, an earthquake measuring 7.9 on the Richter Scale struck off the western Sumatra coast. The epicenter was 45 kilometers west-northwest of Padang (UNICEF, 2009b). Second and third earthquakes, measuring 6.2 and 6.8, occurred 22 minutes and the following morning after the first earthquake, respectively. The cumulative impact of these three earthquakes left a broad swath of destruction in Padang city, Pariaman city, and Padang-Pariaman regency, with an estimated 181,665 homes severely or moderately damaged and about 745,000 people requiring assistance (Figure 16). An estimated 1,117 people were killed, and another 1,214 were severely injured (OCHA, 2009).

The piped water supplies in Padang, Pariaman, and Lubuk Basung were damaged, cutting off about 80% of the total population (OCHA, 2009). An estimate 600,000 people were reliant on water trucking until system repairs could be completed. The priorities of the WASH Cluster were to: 1) provide safe drinking water to the urban and rural affected populations through "water trucking and purification while on [sic] the same time repair the water distribution network, wells and springs"; and, 2) provide WASH services to the nine IDP camps with a combined population of 8,000 people in Agam and Pariaman.

Figure 16: West Sumatra damaged house map (provided courtesy of Oxfam/GB)

8.2 Situational analysis and methods

The field researcher arrived in Padang on November 3, 2009, and: 1) met with UNICEF staff and attended WASH Cluster meetings to gain information on the WASH response; 2) finalized and translated the survey; and, 3) met responding organizations to see who could host the research.

The WASH Cluster was activated, as, within two weeks of the earthquake, over 267 INGOs had registered to provide relief in this context. WASH Cluster meetings were conducted in Padang and in Pariaman. At the first WASH Cluster meeting in Pariaman the field researcher attended, she was introduced as staff who was there to assist NGOs with water quality testing and it was stated at the meeting that there was "no HWTS response in this emergency" as it was not appropriate. Further investigations with NGOs outside the Cluster meetings found that CARE distributed 10,000 bottles of Air Rahmat locally-manufactured liquid chlorine solution (available before the emergency, but not widely promoted in West Sumatra) in shelter kits containing two blankets, one pan, one frying pan, one gas stove, six plastic glasses, plates, and spoons, a cooking spoon, two Air Rahmat bottles, filters for coconut milk, and one jerrycan with spigots. Action Contre le Faim (ACF) also had distributed Air Rahmat bottles to about 100 families. However, when we visited the ACF distribution site, we found no one who could remember receiving Air Rahmat as many families on the distribution list had relocated, but we did find a cluster of Rotary ShelterBox tents. As the ShelterBox includes water treatment tablets, we decided to survey ShelterBox recipients. ShelterBox is an international organization that "delivers emergency shelter, warmth and dignity to people affected by disaster worldwide" by distributing a 490£ box that is purchased by a donor and provided at no cost to families in the emergency (www.ShelterBox.org) The box contains a tent, kitchen supplies, toys, tools, blankets, tarps, rope, water treatment tablets, mosquito bednets, and water containers, and 624 boxes were distributed in response to the West Sumatra earthquake.

It became obvious to the field research that despite assurances in advance of the trip about the nature of the emergency and the role of HWTS options in the response, this emergency did not actually meet the inclusion criteria for this research project – as there was little diarrheal disease risk (little displacement, flooding, or evidence of an outbreak) and there was minimal HWTS option distribution. However, this is a risk of conducting research in the acute emergency context, as it was not possible in any of the emergencies investigated to gather exact information of HWTS option distribution until arrival, and we depended on the local contacts to assist with the deployment decision-making process.

Once we had activated the study and the field researcher arrived, we determined we could learn from a non-diarrheal disease risk large-scale emergency, and widened the research scope to include researching small-scale water treatment unit (WTU) water distribution. WTUs are package treatment plants which have become more popular in recent emergencies. In this emergency, 38 water treatment units were registered by 17 NGOs. Thus, we conducted surveys with: 1) Oxfam WTU recipients at the WTU site as well as the five distribution locations for treated water; 2) CARE Air Rahmat recipients in the most affected region they distributed in that had rumors of diarrheal disease incidence (Kampung Dadok); and, 3) ShelterBox recipients. In Figure 17, clockwise from top left, images are shown of the Oxfam WTU, one Oxfam distribution site, liquid chlorine solution Air Rahmat, ShelterBox tablets, and an assembled ShelterBox tent.

Figure 17: HWTS and water supply options distributed (West Sumatra, Indonesia)

Lastly, Oxfam/GB planned to conduct an ‘improved boiling’ intervention (to teach people to boil correctly and store water safely after boiling) as part of their household hygiene training, World Vision had stocks of PuR in Indonesia based on an international agreement with Procter & Gamble and planned to distribute PuR if turbid water use was noted, and the NGO Ibu was investigating distributing filters for pre-treatment of water before boiling in areas with turbid water. It is unknown whether these programs occurred after the researcher departed the emergency.

8.2.1 Spatial analysis

We obtained ArcView data layers from the WASH Cluster Information Manager, and collected GPS points at each Oxfam tanker truck distribution location, in the region of the CARE distribution, and at ShelterBox surveyed households. As can be seen in Figure 18, the Oxfam WTU is located a considerable distance from the communities receiving tanker trucked water, Kampung Dadok is quite a rural area, and the ShelterBox's sampled were along the road.

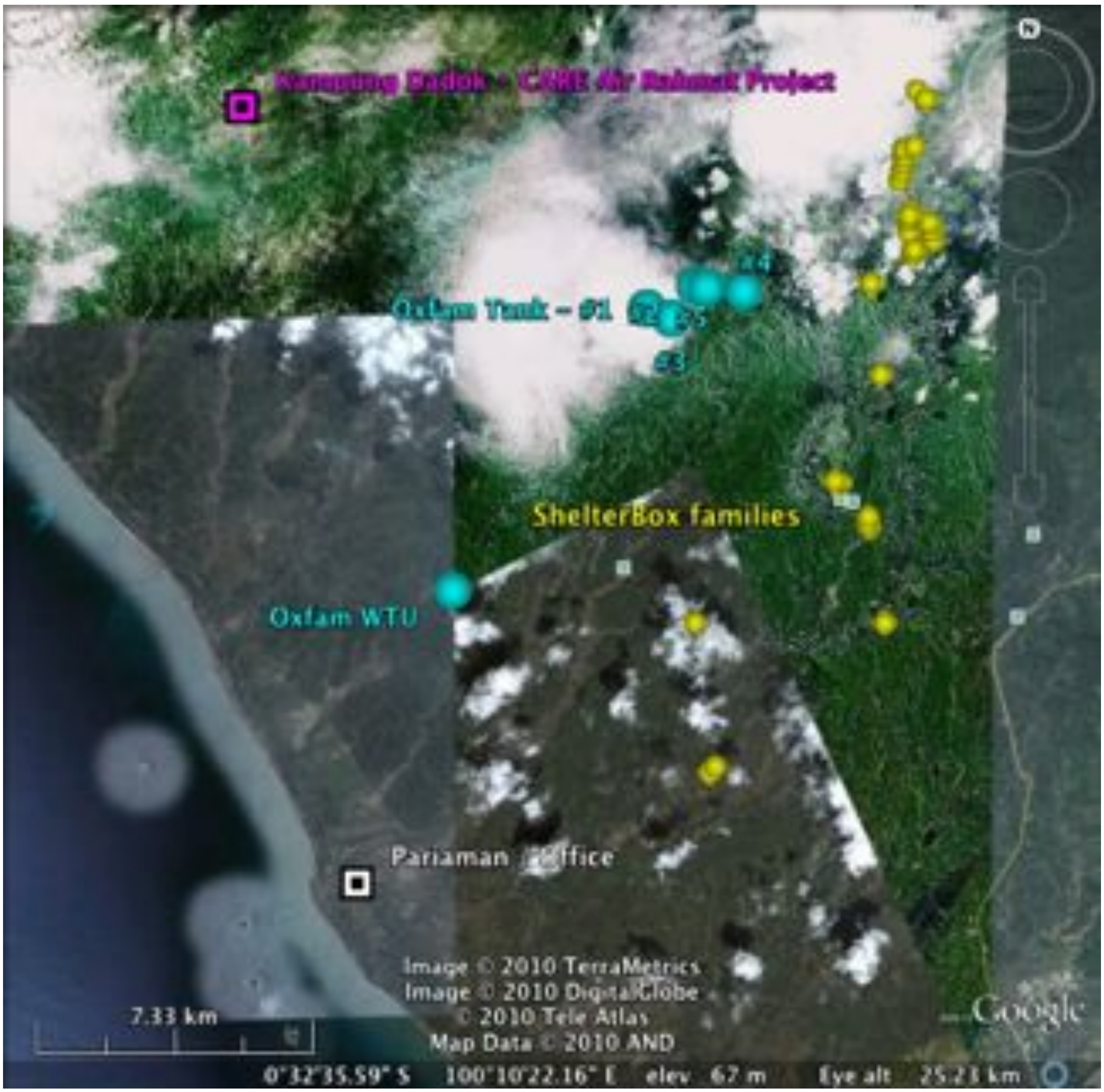


Figure 18: Map of interventions investigated (West Sumatra, Indonesia)

8.2.2 Methods used in investigation

In this investigation we: 1) conducted three qualitative interviews with national and local level WASH responders, as well one group interview with the enumerators, who were part of the affected population; 2) conducted household surveys with Oxfam tanker truck water recipients (79 households), CARE AirRahmat recipients (115), and Rotary ShelterBox recipients (76); 3) and conducted water quality testing; and, 4) collected cost data from Oxfam and CARE staff.

8.2.2.1 Household survey and water quality details

An Oxfam staff member recommended five English students and graduates from the local university in Padang to conduct the surveys. Five female enumerators were trained on November 9, 2009. The survey was translated and printed in Padang before arrival to Pariaman. The survey consisted of a maximum of 70 questions (all products received), including 28 questions on respondent and household characteristics, effect of the emergency, assets, diarrhea prevalence, and water knowledge and source before and after the emergency, 10-12 questions on each HWTS option received, and summary questions on current water supply/water testing. If a family received no HWTS options, 29 questions were asked. Two survey supplements were developed after arrival to Pariaman (for Air Rahmat and ShelterBox recipients) as we were unaware of these products at the time of survey initiation with Oxfam tankering recipient families. The supplements were translated and back-translated by the enumerators. Surveys took approximately 20 minutes to administer, the field researcher entered data on site into Microsoft Excel (Redmond, WA, USA), and data was analyzed by the field researcher in Microsoft Excel and Stata 10.1 (College Station, TX, USA).

Enumerators tested FCR at households reporting chlorine-based treated water that day or tanker truck water using Hach ColorWheel test kits. The enumerators tested turbidity nightly using the Lamotte 2020 meter.

All the materials for 600 microbiological tests using portable membrane filtration laboratory equipment were transported to the study location. Samples were completed by the field researcher each afternoon in the Oxfam office, and no deviations from Standard Methods procedures occurred. The media used in this evaluation was m-FC, testing for fecal (thermotolerant) coliforms because it had been ordered at the same time as Nepal and we knew that we would have stable electricity in this emergency, thus avoiding the incubation problems seen in Nepal.

In the following sections, results from the qualitative interviews and survey results are described.

8.3 Qualitative interview results

An international staff person assisting in response coordination who had previously responded to numerous emergencies in Indonesia noted that "in an emergency basically the thing that really makes a difference is the general approach" and that "for me everything is feasible as long as it is adapted to the needs and adapted to the country." They felt that the main WASH problems in this emergency were "because of network failure there are a huge amount of people who didn't have assess to water and they don't have another source of water" in urban areas and "they need some treatment" in rural areas that might now have unsafe water. These problems were noted in rapid assessments by the 12 organizations responding in the first week. However, the number of responding organizations increased to 267 during the response and they felt part of the motivation for their large response is that 2009 was a dry emergency season with little funding and "I would say that they go for the 5 million dollars." The respondent also noted that multiple assessments should be completed over the emergency as it evolves as in the first weeks "you don't have a choice" and you do what you can, after that the relatively new option of water purification units "may be most cost effective," but "you can not stay too long on purification units because you run out of time, of the chemicals." As for HWTS they felt "there was not [sic] choice in Aquatabs, everybody said we don't want to use them, and there is no need to use them" and instead to continue using the existing practices of "boiling water because basically everybody boils their water .. and it's important to continue this." A main concern for following emergencies is "how we ensure that people are not flying in with the things that are not appropriate" as "having thousand of, millions of Aquatabs coming in which is not necessary" and "having people coming with purification units and they only have three days to install it and go" are not of utility, especially because "too much equipment that will be left behind and not used because they don't know how to use or they don't have the chemicals for it."

They felt "it's the governments responsibility to say yes or no" to these inappropriate donations. What was "obviously" very good in this emergency "is this coordination," "because there was a core group of people, already coordinated themselves before, and who knew each other" who were really responding to the emergency with pre-preparedness, planning, and coordination, and "others just flew in." The importance of having training materials pre-prepared was highlighted.

A respondent with an international organization not distributing HWTS in this emergency who had distributed HWTS options before in other countries noted that in a good emergency response there would be an "integrated, cross-team, cross-program" intervention that occurred in response to rapid assessments and in coordination with partners. They noted poor responses are when "proposals are written and they start the response based upon what we believe [the need] was and we didn't have on-the-ground assessment" and "assumption of knowledge about what beneficiaries do or don't do" drives decision-making. In terms of HWTS, they noted that adding a "new product is the least feasible thing to do" and that "before you bring in a new intervention, you have to assess what's locally available, what's common or not" in order to develop a program. Overall, the respondent felt it "was appropriate [my NGO] didn't deliver any interventions for households," but also noted that "this was a response that was sadly hard going for us, because we went forward without a good assessment" and there "was probably no logic" in the interventions promoted, and "it's a sad lesson." This respondent also noted the pressure companies were putting on the NGOs to distribute inappropriate products, providing one of many emails they received pushing a particular product from a manufacturer:

> *We have a quantity of [HWTS option] that we would like to donate for immediate distribution to the victims of the Padang and surrounding area earthquake. My staff and I have been distributing [HWTS option] to all and any NGOs in the area willing to accept our product. If your organization would be willing to accept our donation please let me know whom to contact or how you would like them sent. As for the number of [HWTS option] we can donate I will have to check with my staff first to verify the amount of stock available for donation.*

A respondent with an international organization distributing HWTS options in this emergency, who had responded to previous emergencies in Indonesia with Air Rahmat distribution, mentioned that in West Sumatra "they don't take the habit here. They don't believe the Air Rahmat is safe to drink." and that "boiling and the kit for boiling" are the most important water safety tools to distribute in West Sumatra. They noted that "buying the Air Rahmat for the community – it is easy" but that the "community is not willing" to use it. They noted that we "demonstrate how to use the Air Rahmat and distribute leaflets to the community" but that examples as to "why they want to decontaminate" water are needed to ensure there is use of the products.

In this emergency, we also conducted an interview with the enumerators, who were all present in Padang during the earthquake, and were affected and/or displaced during the emergency. The enumerators felt that there "must be training to the people, because they do not know how to use the tablets or the chlorine" if HWTS is promoted and "I think it's better if you give training to the house, not group training because some people do not pay attention to the [group] training." They stated "we can't judge the NGOs, it's not OK to say the NGO is stupid, it's not like that. May be the NGO forgot the training, and the training is very important." However, they agreed that "providing water is better" because "West Sumatra people – they do not like chlorine taste and chlorine smell." They also listed interventions they felt were of utility, including: 1) home-building training – "we need training how to build the house like I have seen in the television" that are earthquake-proof because "it is predicted that there will be more earthquake"; 2) that people preferred products like "kitchen equipments, like tents" and small materials to "build the new house" in distribution; 3) that mental health and education were important – we are "concerned about the trauma, trauma healing, and then keep attention for education"; 4) that "Air Rahmat and the tablets is needed in Padang" [not the rural areas] … because "people in the city know how to use it and there are so many people crowded there" without water after the emergency; and, 5) that training on "how to save your life if earthquake happen" is needed. Lastly, the enumerators noted separately that there were concerns expressed by the recipient population as to whether the NGOs were working to convert the Muslim population, and whether or not the HWTS options were Halal-certified (for use by Muslims). The fact Air Rahmat was Halal-certified was expressed as a positive by the recipients.

Also of note, from the field researcher perspective, is that in this alone of any of the emergencies, a number of requests for technical assistance were received by responding organizations. The purpose of this research was to assess, and not be involved in, the response, but there clearly was a need for technical assistance on WASH and HWTS in this emergency.

Collectively, the four qualitative interviews reflect the following points:

- There was intense pressure to respond in this emergency for monetary/political reasons due to 2009 being a dry emergency year, reflected honestly both in the NGO response and the fact we researched this emergency as part of this study.
- The WASH response was not based on assessments of the greatest need, but instead based on business-as-usual practices. Assessments should have been completed throughout the stages of the emergency to plan the best response, which would have been integrated, coordinated, and incorporated local knowledge and practices.
- There was intense pressure from companies to use products that were not appropriate in this context, and while organizations knew boiling was the local preferred option, this was not promoted.
- Chlorination options were, overall, not appropriate in this context due to lack of taste and smell acceptability.
- There might have been a role for HWTS in the urban areas, but organizations assumed they were needed in rural areas, not urban.

- Training is needed to ensure HWTS option use.
- Pre-preparedness is critical to both the emergency response, and the coordination of the response.

8.4 Survey results

Survey results are presented in Table 28 for the entire survey population and by program. It is important to note that these surveys were not randomized. In the Oxfam response we conducted a convenience sample of households within a 10-minute walk of the WTU and each of five distribution points. In the CARE Air Rahmat response we conducted a random sample of the entire population of Kampung Dadok (115 of 954 (12.1%) households surveyed) by talking with village chiefs to draw household maps in the area. For the ShelterBox tablet response, we visited as many households that had ShelterBox tents outside as we could find along the road between Pariaman and Malalak (76 of 624 (12.2%) total ShelterBox's distributed).

Slightly over 80% of the survey respondents were women. In addition, in many cases when the male head of household (HOH) was the 'official' respondent (often for religious reasons), the female HOH was also involved in answering survey questions.

The average respondent age was just under 45. If the respondent was female, 85.6% had attended any school. The average school attendance was 6.7 years for those women who had attended, and 5.8 for the total female respondent population. Over 80% of female HOHs could read the newspaper.

Only one survey respondent did not report that their home was damaged in the earthquake, with 99.6% of respondents reporting damage. There was significant internal displacement, as less than 40% of respondents lived in the same place as before the emergency. However, this displacement was for the most part not into camps, but instead into temporary structures on the respondents property or into homes of friends or family. The majority of respondents (73.2%) reported receiving a kitchen kit. A higher percentage of families in the CARE distribution area, which served a rural area not along a main road, reported living in the same place as before the earthquake as inexpensive wood structures were less likely to have significant damage than poorly made concrete structures in more affluent areas. A higher percentage of CARE families also received a kitchen kit.

One hundred percent of respondents had water available within 30 minutes of their home, and 52.2% had water available at their home. Adult women were responsible for collecting water in 66.6% of households, followed by adult men (9.8%), the whole family (9.5%), boys (7.8%), and girls (6.4%). There was a discrepancy in how the enumerators reported the storage container for current household water (some reported before boiling, some after boiling) and so the percent of respondents with covered stored water cannot be calculated from the data.

Overall, 27.9% of respondents near the Oxfam distribution points and WTU reported using the Oxfam water for drinking on the day of the unannounced survey, 97 (84.3%) of families in Kampung Dadok received Air Rahmat from CARE, and, by definition, all 76 of the ShelterBox families interviewed had received the ShelterBox. Overall, 88.1% of respondents reported boiling their drinking water, with people in the rural CARE areas least likely to boil, and people in the urban areas near the road or in the Oxfam distribution area more likely to boil.

Table 28: Survey results by program (West Sumatra, Indonesia)

	CARE Air Rahmat	Oxfam Tankering	ShelterBox Tablets	Total	p-value
Total population targeted (households)	954	958	624	2536	
Surveyed households	115	79	76	270	
% of households surveyed	12.1%	8.2%	12.2%	10.6%	
Number (%) female respondents (n=270)	99 (86.1)	60 (75.9)	61 (80.3)	220 (81.5)	0.193
Respondent age in years (min-max) (n=270)	45.2 (15-90)	46.1 (18-90)	42.6 (22-92)	44.7 (15-92)	
Number (%) female respondents (FR) attend school (n=220)	83 (83.8)	53 (88.3)	53 (86.9)	189 (85.9)	0.708
If FR school, average (min-max) years school (n=189)	6.5 (1-16)	6.5 (2-17)	7.3 (1-16)	6.7 (1-17)	
All FR average (min-max) years school (n=220)	5.4 (0-16)	5.7 (0-17)	6.3 (0-16)	5.8 (0-17)	
Number (%) female HOH who can read newspaper (n=268)	90 (79.0)	68 (87.2)	64 (84.2)	222 (82.8)	0.309
Number (%) homes damaged in earthquake (n=264)	114 (99.1)	74 (100)	75 (100)	263 (99.6)	0.522
Number (%) live is same place as before earthquake (n=269)	62 (53.9)	30 (38.0)	13 (17.3)	105 (39.0)	<0.001
Number (%) receive kitchen kit (n=269)	113 (98.3)	35 (44.9)	49 (64.5)	197 (73.2)	<0.001
Number (%) with water available at household (n=270)	54 (47.0)	39 (49.4)	48 (63.2)	141 (52.2)	0.075
Number (%) with water available within 30 minutes (n=270)	115 (100)	79 (100)	76 (100)	270 (100)	
Number (%) with covered stored water	--	--	--	--	
Number (%) report using Oxfam water for drinking (n=79)	--	22 (27.9)	--	--	
Number (%) received ShelterBox tablets (n=76)	--	--	76 (100)	--	
Number (%) received Air Rahmat (n=115, n=76)	97 (84.3)	--	5 (6.6)	--	
Number (%) report boiling drinking water (n=270)	93 (80.9)	75 (94.9)	70 (92.1)	238 (88.1)	0.003

The 270 surveyed households included a total population of 1,464 people (average=5.4 people/household, min=1, max=14), including 164 children under 5 (average=0.6 children/household, min=0, max=3) (Table 29). Self-reported diarrhea rates were high, with 14.0% of adults and an extraordinary 40.9% of children under five years of age reporting diarrhea in the last 24 hours.

Table 29: Survey population and reported diarrhea in last 24 hours (West Sumatra, Indonesia)

	CARE Air Rahmat	Oxfam Tankering	ShelterBox Tablets	Total
Total population (by household)	5.5 (1-13)	5.1 (1-14)	5.7 (1-10)	5.4 (1-14)
Under 5 population (by household)	0.6 (0-3)	0.5 (0-3)	0.7 (0-2)	0.6 (0-3)
% females 5 and over with diarrhea	17.3	13.5	18.8	16.7
% males 5 and over with diarrhea	*11.5*	*8.9*	*13.7*	*11.5*
% 5 and over with diarrhea	14.5	11.1	16.0	14.0
% under 5 females with diarrhea	51.7	33.3	35.7	40.5
% under 5 males with diarrhea	36.6	37.5	52.2	41.3
% under 5 with diarrhea	*42.9*	*34.9*	*43.1*	*40.9*

Survey respondents were asked about their water source three times: 1) what source they used before the emergency; 2) if there was a change in source after the emergency, what source they used now; and, 3) in the last part of the survey, what source their actual current stored household water came from. There was no statistically significant difference in reported use of a improved source across the three programs before the emergency (p=0.090), but this difference was significant after the emergency (p=0.001), with a higher percentage of improved source use reported in Oxfam and ShelterBox targeted households than rural CARE households (Table 30 and Figure 19). A significant difference in reported use of improved sources before and after the emergency (p=0.003) was seen in the total surveyed population (with 178 reporting using improved and 92 reporting using unimproved sources compared to 144 and 126 after the emergency, respectively). This increase was not just due to reported use of Oxfam water in the Oxfam WTU respondents, but also an increase in the use of rainwater and tanked water supplies in CARE and ShelterBox recipient families, respectively. Galon water is purchased water in 20-Liter containers.

Table 30: Reported water sources before emergency and after emergency (West Sumatra, Indonesia)

	CARE (n=115)		Oxfam (n=79)		ShelterBox (n=76)	
	Before	After	Before	After	Before	After
Closed well (number (%))	2 (1.7)	3 (2.6)	8 (10.1)	8 (10.1)	7 (9.2)	6 (7.9)
Piped water (number (%))	40 (34.8)	30 (26.1)	7 (8.9)	3 (3.8)	7 (9.2)	14 (18.4)
Open well (number (%))	12 (10.4)	13 (11.3)	23 (29.1)	12 (15.2)	10 (13.2)	7 (9.2)
Rainwater (number (%))	11 (9.6)	27 (23.5)	28 (35.4)	21 (26.6)	31 (40.8)	26 (34.2)
Surface water (number (%))	50 (43.5)	41 (35.7)	12 (15.2)	8 (10.1)	19 (25.0)	11 (14.5)
Galon water (number (%))	0 (0)	1 (0.9)	1 (1.3)	2 (2.5)	2 (2.6)	4 (5.3)
Tanked water (number (%))	--	0 (0)	--	25 (31.6)	--	8 (10.5)
% Improved (number (%))	*53 (46.1)*	*61 (53.0)*	*44 (55.7)*	*59 (74.7)*	*47 (61.8)*	*58 (76.3)*
% Unimproved (number (%))	*62 (53.9)*	*54 (47.0)*	*35 (44.3)*	*20 (25.3)*	*29 (38.2)*	*18 (23.7)*

Overall, 171 respondents actually had improved source water at the time of the unannounced survey visit, very close to the reported amount (Table 31). This number is still a statistically significant increase (p=0.018) over the pre-emergency reported use of improved water sources.

Table 31: Actual water source of current stored household water (West Sumatra, Indonesia)

	CARE (n=115)	Oxfam (n=79)	ShelterBox (n=76)	Total (n=270)
Closed well (number (%))	1 (0.9)	5 (6.3)	7 (9.2)	13 (4.8)
Piped water (number (%))	28 (24.3)	2 (2.5)	12 (15.8)	42 (15.6)
Open well (number (%))	11 (9.6)	18 (22.8)	6 (7.9)	35 (13.0)
Rainwater (number (%))	29 (25.2)	23 (29.1)	30 (39.5)	82 (30.4)
Surface water (number (%))	45 (39.1)	7 (8.9)	12 (15.8)	64 (23.7)
Galon water (number (%))	1 (0.9)	2 (2.5)	3 (3.9)	6 (2.2)
Tanked water (number (%))	0 (0)	22 (27.8)	6 (7.9)	28 (10.4)
% Improved (number (%))	*59 (51.3)*	*54 (68.4)*	*58 (76.3)*	*171 (63.3)*
% Unimproved (number (%))	*56 (48.7)*	*25 (31.6)*	*18 (23.7)*	*99 (36.7)*

Figure 19: Before and after emergency reported water sources by NGO (West Sumatra, Indonesia)

A total of 260 of 270 (96.3%) of respondents considered their water safe to drink. Overwhelmingly (83.3%) respondents who perceived their water as safe did so because the "water looks clean" (Table 32). There were few reasons for thinking water was unsafe, but the reasons for this were generally related to smell and taste (Table 33).

Table 32: Reasons respondents perceive water as safe (multiple answers possible) (West Sumatra, Indonesia)

	All
Water looks clean (number (%))	251 (93.3)
Water without bacteria (number (%))	6 (2.2)
Water warm (number (%))	4 (1.5)
From earth (number (%))	2 (0.7)
From tap, everyone uses, clean, good tasting, use for long time, no choice	1 each (0.4)
Totals (number (%))	*269 (100)*

Table 33: Reasons respondents perceive water as unsafe (multiple answers possible) (West Sumatra, Indonesia)

	All
Water looks dirty (number (%))	2 (20)
Water smells bad (number (%))	4 (40)
Water tastes bad (number (%))	3 (30)
Comes from land (number (%))	1 (10)
Totals (number (%))	*10 (100)*

Respondents were asked what their largest health problems were since the earthquakes, and all self-reported answers were recorded (no answers were prompted). A total of 506 responses (1.87 per household) were received. The three largest self-identified health problems were cough (46.7% of households), flu (33.3%), and fever (30.7%). In addition to the health problems in the chart, one household each listed the following health problems: vomiting, safety, diabetes, mouth problem, appendicitis, hospital access, stroke, toothache, malaria, anemia, food shortage, and sore throat. Only 13.3% self-reported diarrhea as a health problem.

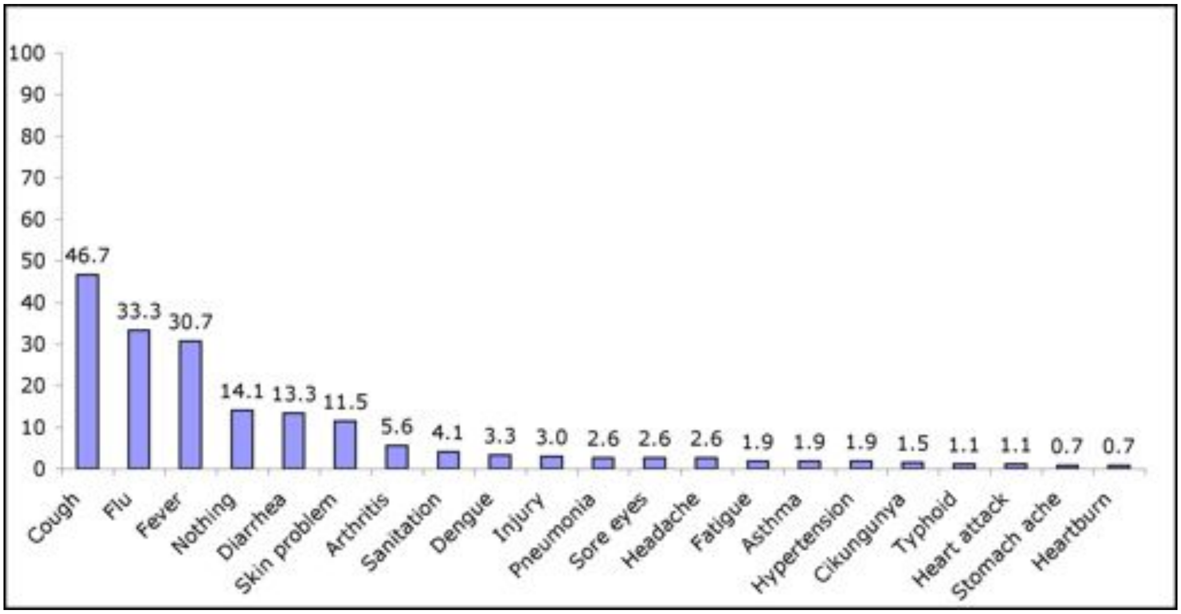


Figure 20: Percent of respondents listing health problems after the emergency (West Sumatra, Indonesia)

There was high knowledge of HWTS before the emergency occurred, particularly with boiling. Every survey respondent reporting knowing boiling, and 96.7% reporting boiling water every day. While 18.9% reported knowing a chlorination option, the majority (70.6%) reported they "never use" this option. Respondents reported similarly high rates of "never use" when they knew of water treatment with filters or alum.

Table 34: HWTS options known before emergency (West Sumatra, Indonesia)

		Report using				
	Know	Never Use	Rarely	Once/week	Daily	Don't know
Boiling (number (%))	270 (100)	2 (0.7)	4 (1.5)		261 (96.7)	3 (1.1)
Chlorine (number (%))	51 (18.9)	36 (70.6)	6 (11.8)	4 (7.8)	5 (9.8)	
Filter (number (%))	23 (8.5)	19 (82.6)	1 (4.3)		3 (13.0)	
Alum (number (%))	20 (7.4)	17 (85.0)	1 (5.0)	1 (5.0)	1 (5.0)	

8.5 Coverage

The estimated size of the affected population in the West Sumatra earthquakes was 181,665 households (745,000 individuals) in need of shelter. An estimated 600,000 people were reliant on tanker truck water. We investigated the three HWTS interventions that reached slightly over 2,500 families (1.4% of the affected population, or 13,694 people using the rate of 5.4 people per family) (Table 35). We only sampled families with access to Oxfam tankering and who had received a ShelterBox kit, so no statements can be made about the percent of population who received these options as our survey was recipient-based, not population-based. In each ShelterBox kit, 288 tablets (each treating 20 Liters of water) were provided, enough for 288 days of treated water per household (0.79 years). However, we conducted population-based random sampling in one targeted area of the CARE Air Rahmat distribution, where we surveyed 12.1% of targeted households, and found that 84.3% of households had received product. Each household was suppose to receive two bottles of Air Rahmat, enough to provide 66 days of treated drinking water to a family using 20 Liters of high quality water per day. The average household received 2.2 bottles of Air Rahmat, enough to provide 73 days of treated drinking water to a family using 20 Liters of high quality water per day (Table 36).

Overall, there was very high reported background coverage of boiling throughout these three populations targeted by other interventions, even though no NGO we knew of promoted boiling in this emergency. Self-reported boiling was higher in urban areas (such as on the road where the ShelterBox's were distributed than in rural areas (CARE areas).

Table 35: Coverage of HWTS (West Sumatra, Indonesia)

	CARE Air Rahmat	Oxfam Tankering	ShelterBox Tablets	Total	p-value
Total population targeted (households)	5000	958	624	2536	
Number (%) report using Oxfam water for drinking (n=79)	--	22 (27.8)	--	--	
Number (%) received ShelterBox tablets (n=76)	--	--	76 (100)	--	
Number (%) received Air Rahmat (n=115, n=76)	97 (84.3)	--	5 (6.6)	--	
Number (%) report boiling drinking water (n=270)	93 (80.9)	75 (94.9)	70 (92.1)	238 (88.1)	0.003

8.6 Correct use

Air Rahmat liquid chlorine solution and chlorine tablets were distributed in the response to the Indonesia earthquake. Knowledge and use statistics are presented in the following sections.

8.6.1 Air Rahmat

CARE provided Air Rahmat bottles, meant for treating 5, 10, or 20 Liters of water at a dosage of 1.875 mg/L. Users were instructed to add Air Rahmat to the correct line for the household storage container volume and wait 30 minutes before drinking at a group training during the family kit distribution.

The average household received 2.2 bottles of Air Rahmat, enough to provide 73 days of treated drinking water to a family using 20 Liters of high quality water per day (Table 36). The large majority of people received group trainings (95.9%) on how to use the Air Rahmat, with none reporting receiving household level training. Two respondents (2.1%) reported receiving no training, and one respondent each was trained by a neighbor and did not know (1.0%). Overall, 34 (35.4%) of respondents could describe the correct dosing of Air Rahmat for the volume they mentioned, 20 (20.8%) could not, and 42 (43.8%) answered they did not know. A total of 20 respondents (20.8%) knew to wait 30 minutes after treatment before drinking the water, with 16 respondents listing too few minutes (16.7%) and six respondents listing too many (6.3%). Over half of the respondents (56.3%) did not know the answer to this question. In total, 13.4% of respondents could describe the fully correct usage for Air Rahmat. This percentage increased to 15.5% if incorrect, but adequate water treatment was included.

Of the respondents, 19.8% reported ever using the Air Rahmat, 11.5% reporting still using the Air Rahmat currently, and 6.2% reported Air Rahmat treated water at the household at the time of the unannounced survey visit. Two of six households who reported Air Rahmat treated water had boiled water as well, and two of the six had been treated with Air Rahmat more than 15 days before the visit. Three of the six households had correct FCR levels. Of the three families with correct FCR levels, one had boiled water also, one reported treating water 30 days ago in the 20 Liter container provided and never used it, and one reported treating water 15 minutes before the survey. One family had finished both bottles and requested more from the enumerator. Over 80% of households reported boiled water at the household at the time of the unannounced survey visit.

The main reason for use of Air Rahmat was that it cleans water (41.2%) and that it was given to respondents (35.3%), and the main reasons for non-use were that water is clear (44.1%) and that boiling is easier (18.3%) (Table 37). Chlorine taste and smell concerns accounted for 8.5% of product non-use reasons.

Table 36: Air Rahmat product knowledge and use (West Sumatra, Indonesia)

	CARE Air Rahmat
Number (%) received HWTS option (n=115)	97 (84.3)
Number (min-max) bottles received (n=94)	2.2 (2-4)
Number (%) reporting group training received (n=97)	93 (95.9)
Number (%) reporting household training received (n=97)	0 (0)
Number (%) with correct knowledge of dosing (n=96)	34 (35.4)
Number (%) with correct knowledge of 30 minute wait (n=96)	20 (20.8)
Number (%) with fully correct use knowledge (n=97)	13 (13.4)
Number (%) include incorrect, but adequate treatment (n=97)	15 (15.5)
Number (%) report ever using (n=96)	19 (19.8)
Number (%) report current use (n=96)	11 (11.5)
Number (%) report Air Rahmat treated water today (n=97)	6 (6.2)
Number (%) AR respondents reporting boiling (n=97)	80 (82.5)
Number (%) with correct FCR in AR treated water (n=6)	3 (50.0)
Number (%) with FCR ≥0.2 mg/L in AR treated water (n=6)	3 (50.0)
Number (%) report Air Rahmat treated water today if product was not finished (n=92)	6 (6.5)

Table 37: Reasons for use and non-use of Air Rahmat (West Sumatra, Indonesia)

	Total		Total
Use because (n=17)		Do not use because (n=93)	
Cleans water (number (%))	7 (41.2)	Water is clear (number (%))	41 (44.1)
Prevents disease (number (%))	2 (11.8)	Boiling is easier (number (%))	17 (18.3)
Was given (number (%))	6 (35.3)	Bad taste or smell (number (%))	8 (8.6)
Easier than boiling (number (%))	2 (11.8)	No training / never used / afraid (number (%))	5 (5.4)
		Product finished (number (%))	5 (5.4)
		Hard to do (number (%))	4 (4.3)
		Emergency over (number (%))	4 (4.3)
		Don't like (number (%))	4 (4.3)
		River is safe (number (%))	2 (2.2)
		Accustomed to boiling (number (%))	2 (2.2)
		Family banned (number (%))	1 (1.1)

8.6.2 Oxfam Tankering

Due to user complaints, Oxfam had stopped adding the chlorine in the WTU treatment process, and no WTU water had detectible FCR at the five distribution tank locations and the WTU stand. Overall, 27.8% of the respondents reported using the Oxfam water for drinking (range 11-55% at the different tanks). A total of 21 of 22 (95.5%) people reporting use of Oxfam water on the day of the unannounced survey reported boiling that water. Upon arrival to one of the tanks, we observed a woman washing her clothes in the water.

8.6.3 ShelterBox Tablets

The ShelterBox tablets were packaged 48 to an unlabelled box with six boxes plastic wrapped together. Written directions in English were on a sticker affixed to the plastic wrap. No pictorial or local language directions were available. The directions instructed users to add one tab into 20 Liters and wait 10 minutes before drinking. The dosage of the tablet in this dosage regime was 12.0 mg/L, six times higher than that of the 2.0 mg/L dose Aquatab and 2.4 times the maximum allowable FCR level in drinking water of 5.0 mg/L according to the WHO.

We were unable to collect data in the same manner for the ShelterBox tablets as other HWTS interventions because of the extremely low knowledge. Of the 70 survey respondents who received the full ShelterBox tablet survey, 27 (38.6%) stated "water treatment" when asked "What are tablets in your ShelterBox for?". Another 35 (50%) responded "don't know" and another 10 (14.3%) did not recall receiving the tablet in their box. One respondent (1.4%) stated they were vitamins.

Six (8.6%) families had used tablets for water treatment, and one (1.4%) knew the correct dosage regime because the household had a child who could read English. That family was the only family (1.4%) reporting use today, but we could not test the water because it was with the men at the work site building new homes at the time. The remaining five families discontinued use.

We asked the families to list for us which items in their ShelterBox they "liked," "did not like," and "wished for more of." The most liked items were the kitchen supplies and blankets (Figure 21). The least liked items were the water tablets and mosquito bednets. One respondent asked us why he would have his child sleep under a net with chemicals in it because if the net killed the mosquitoes it would also kill his child, which provides one additional data point on the lack of willingness of the survey population to use chemical products.

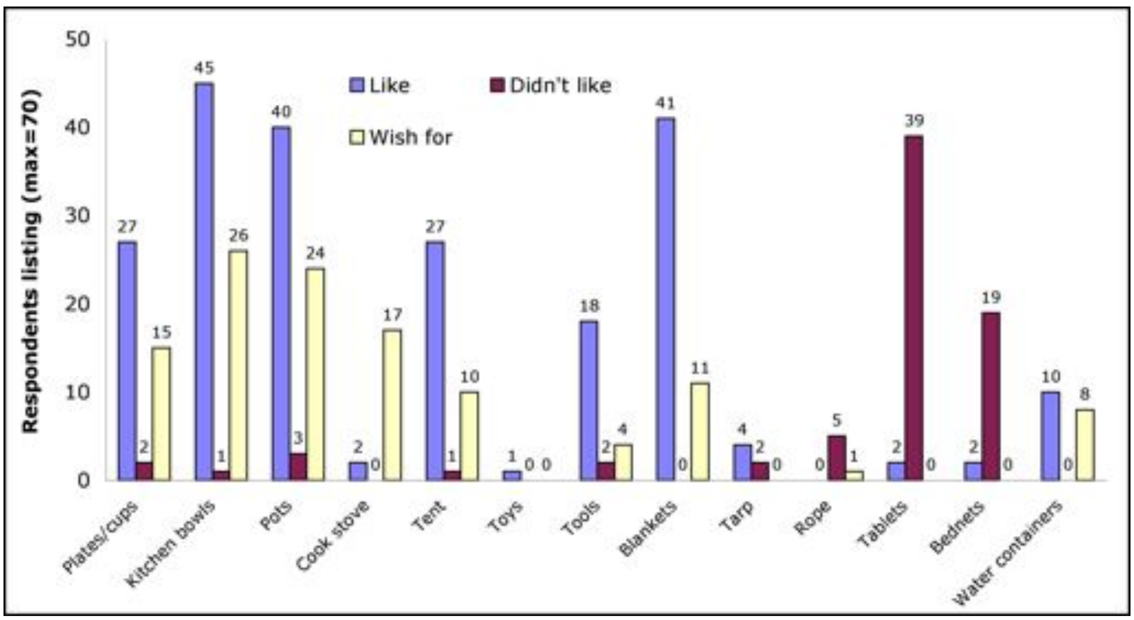


Figure 21: Recipient appreciation of ShelterBox items (West Sumatra, Indonesia)

8.6.4 Comparative analysis

Overall, it is clear that in this low diarrheal disease risk emergency, chlorine-based HWTS options were not widely distributed or used, and played no appreciable role in improving water quality due to lack of distribution by responders and lack of use by respondents if they received an option. In addition, WTU water tankered to five distribution sites was not widely used by the survey population. Overall, the striking result from this evaluation is that the survey population boiled water. A total of 88.1% of the survey population reported having boiled water at their household at the time of the unannounced survey visit. This cultural norm of boiling was attributed to a long-term government program to promote boiling to the entire population, the fact most households had gas burners that made boiling easy and not detrimental to the local environment, and the norm of having a 1-2 Liter cooler on the kitchen table in which to store boiled water (UNICEF, 2009a).

8.6.5 Univariate analysis

As in Nepal, we completed univariate analysis. In this case the outcome indicators are the dichotomous variables of reporting boiled water or using boiling correctly to reduce microbiological contamination by at least one log (90%) in stored household water (data presented in next section). The variables we postulated might impact the outcome variables in this circumstance include: whether or not the female HOH attended school or could read the newspaper, whether the house was damaged in the earthquake, whether the family lived in the same place as before the emergency, whether the household used a improved water source or not, whether the family received a kitchen kit, whether diarrhea was reported in the household or in children in the household, whether diarrhea was considered a health problem after the emergency, whether the household believes drinking water is safe, and the socio-economic status of the household.

Initial results from a univariate analysis show that female respondents who had attended school, households who had moved after the earthquake, and households using a improved source reported boiling at a higher rate (Table 38).

Socio-economic status quintiles were developed using principal component analysis based on household assets (including car, television, radio, gold or diamond jewelry, cow, buffalo, chicken, duck, refrigerator, motorcycle, and bicycle ownership and whether walls and floors of household were natural materials or not). The quintiles were not associated with the outcome variables of reported boiling or improved water from boiling.

We will continue to develop this model.

Table 38: Univariate analysis results (West Sumatra, Indonesia)

Postulated potential factors related to outcomes	Reported boiling	Microbiologically improved water from boiling
Female respondent attended school	**0.003** OR: 3.61 95% CI: 1.5-8.9	0.059
Female HOH can read newspaper	0.080	0.253
Home damaged in quake	0.710	0.332
Live in same place as quake	**0.004** OR: 0.34 95% CI: 0.2-0.7	0.963
Use improved source	**0.040** OR: 2.16 95% CI 1.0-4.6	0.082
Received kitchen kit	0.571	0.713
Diarrhea reported in household	0.524	0.142
Diarrhea reported in children in household	0.071	0.194
Diarrhea health problem after emergency	0.238	0.728
Believe drinking water is safe	0.130	0.324
Socio-economic status (5x2)	0.550	0.678

8.7 Microbiological improvement

As in Nepal, turbidity was low in all samples analyzed. Only two samples (0.8%) in the study were above 10 NTU (Table 39, Figure 22). There was no significant difference in turbidity between improved and unimproved sources (p=0.493).

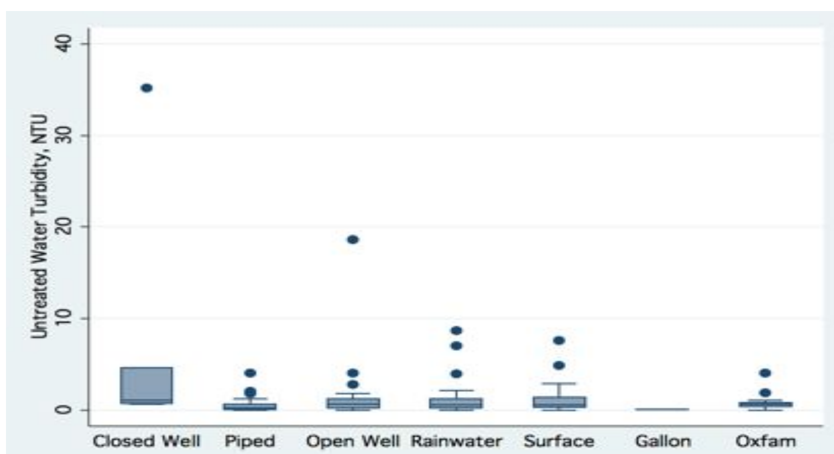


Figure 22: Turbidity by source (West Sumatra, Indonesia)

Table 39: Turbidity by source (West Sumatra, Indonesia)

	Average	Min	Max	<1 NTU	1-<10	10-100	>=100
Closed well (n=10)	4.39	0	35.2	7 (70.0)	2 (20.0)	1 (10.0)	0
Piped water (n=33)	0.57	0	2.2	26 (78.8)	7 (21.2)	0 (0)	0
Open well (n=32)	1.24	0	18.6	23 (71.9)	8 (25.0)	1 (3.1)	0
Rainwater (n=76)	0.90	0	8.65	55 (72.4)	21 (27.6)	0 (0)	0
Surface water (n=63)	0.73	0	7.59	49 (77.8)	14 (22.2)	0 (0)	0
Galon water (n=5)	0.18	0	0.69	5 (100)	0	0	0
Oxfam water (n=19)	0.78	0	4	16 (84.2)	3 (15.8)	0	0
Tanker water (n=3)	0.29	0.07	0.45	3 (100)	0	0	0
MSF/Helps water (n=1)	0.46	--	--	1 (100)	0	0	0
Improved (n=147)	*1.01*	*0*	*35.2*	*113 (76.9)*	*33 (22.4)*	*1 (0.7)*	*0*
Unimproved (n=95)	*0.91*	*0*	*18.6*	*72 (75.8)*	*22 (23.2)*	*1 (1.1)*	*0*
Total (n=242):	*0.97*	*0*	*35.2*	*185 (76.4)*	*55 (22.7)*	*2 (0.8)*	*0*

Fecal coliform concentrations (reported herein in colony forming units (CFU) of fecal (thermotolerant) coliform or *E coli* per 100 mL) of the different sources are presented in Table 40. Throughout this report we will report microbiological indicator on a log scale of risk – with <1 CFU/100 mL meeting the guideline values (WHO, 2004) as well as on a risk based log-scale, with between 1-<10 of low risk, 10-<100 of intermediate risk, 100-<1000 of high risk, and ≥1000 of very high risk ((WHO, 1997)). Improved sources were significantly less likely to be contaminated ($p<0.001$). Of particular interest is the contamination levels seen in the tanker water (Oxfam, Tanker, MSF).

Table 40: Fecal coliform contamination by source (West Sumatra, Indonesia)

CFU/100mL	<1	1-<10	10-<100	≥100
Closed well water (n=5)				5 (100)
Piped water (n=18)			4 (22.2)	14 (77.8)
Open well water (n=9)				9 (100)
Rainwater (n=66)	24 (36.4)	11 (16.7)	15 (22.7)	16 (24.2)
Surface water (n=25)			3 (12)	22 (88)
Galon water (n=2)	1 (50)		1 (50)	
Oxfam water (n=20)	12 (60)	1 (5)	6 (30)	1 (5)
Tanker water (n=2)				2 (100)
MSF/Helps water (n=1)				1 (100)
Improved (n=114)	*37 (32.5)*	*12 (10.5)*	*26 (22.8)*	*39 (34.2)*
Unimproved (n=34)			*3 (8.8)*	*31 (91.2)*
Total (n=148)	*37 (25.0)*	*12 (8.1)*	*29 (19.6)*	*70 (47.3)*

Oxfam WTU water (before boiling) was of higher microbiological quality than all other source waters combined (p=<0.001). However, 21/22 (95.5%) of Oxfam WTU reported water users boiled reported boiling their water before drinking it. Thus, the question is not whether the Oxfam water itself was safe to drink (as users refused to drink this water without boiling), but whether boiled Oxfam water was of better microbiological quality than boiled other source water. The answer is that after boiling, Oxfam WTU water was no longer of higher microbiological quality (p=0.641) than water boiled from an other source (Table 41). Thus, among this population of boilers, tankering water may have improved water quantity and access, but not quality.

Table 41: Microbiological contamination of boiled and unboiled Oxfam water (West Sumatra, Indonesia)

CFU/100mL	<1	1-<10	10-<100	>=100
Oxfam water (n=20)	12 (60.0)	1 (5.0)	6 (30.0)	1 (5.0)
Oxfam water (boiled) (n=17)	10 (58.8)	2 (11.8)	1 (5.9)	4 (23.5)
All other water (n=128)	25 (19.5)	11 (8.6)	23 (18.0)	69 (53.9)
All other water (boiled) (n=121)	57 (47.1)	20 (16.5)	19 (15.7)	25 (20.7)

The average fecal coliform contamination in pre- and post-boiled Oxfam WTU water and rainwater (the most used source in this survey population) are presented in Figure 23. As can be seen, while the Oxfam WTU water was slightly less contaminated than rainwater before boiling (blue bars), after boiling (red bars) there was no difference in the microbiological quality of the water – indicating that use of the Oxfam WTU water did not improve the microbiological quality of stored household water. Again, this seems to be because users did not trust the water, and boiled it.

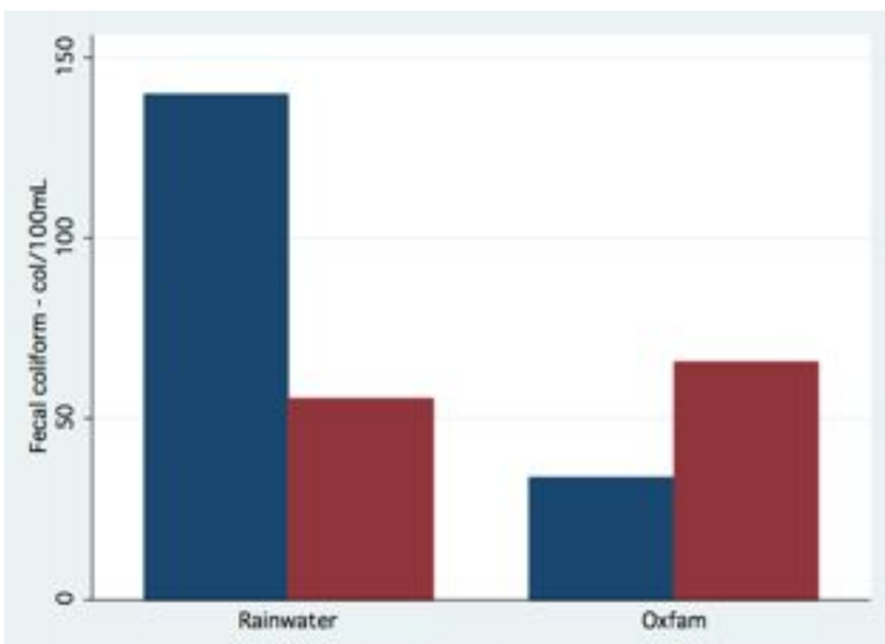


Figure 23: Average fecal coliform in pre- and post-boiled by water source (West Sumatra, Indonesia)

The question is whether boiling – as actually practiced by this emergency-impacted population – improved the microbiological quality of stored household water. Water that was reportedly boiled was significantly improved ($p<0.001$) when compared to stored household water from the same source. The mean fecal coliform concentration in boiled water was 105 CFU/100 mL (95% CI: 60.7-143) and unboiled household stored water was 641 CFU/100 mL (95% CI: 363-924).

Significantly, not all boiled water samples met WHO guideline values for having no fecal coliforms (0 CFU/100 mL) (Table 42, Figure 24). Moreover, 34 of 138 (24.6%) of stored household water samples from the same source did not need water treatment – as they started with no fecal coliforms. Overall, paired treated and untreated samples showed effective water treatment with boiling in 33 of 138 samples (23.9%) and improved (but not fully safe treatment in 28 of 138 samples (20.3%). The remaining samples were either: not contaminated to begin with (24.6%), or had contamination after boiling (51.4%).

Table 42: Fecal coliform contamination of boiled and unboiled water (West Sumatra, Indonesia)

CFU/100mL	<1	1-<10	10-<100	>=100
Boiled (n=138)	67 (48.6)	22 (15.9)	20 (14.5)	29 (21.0)
Unboiled (n=138)	34 (24.6)	12 (8.7)	27 (19.6)	65 (47.1)

If these number are reanalyzed looking at a breakpoint of 10 CFU/100 mL for drinking water safety instead of 0 (which is low risk for drinking water quality), the numbers become: 46 of 138 (33.3%) samples started with safe drinking water, boiling led to an additional 43 (31.2%) samples becoming safe, and 49 samples (35.5%) remained unsafe.

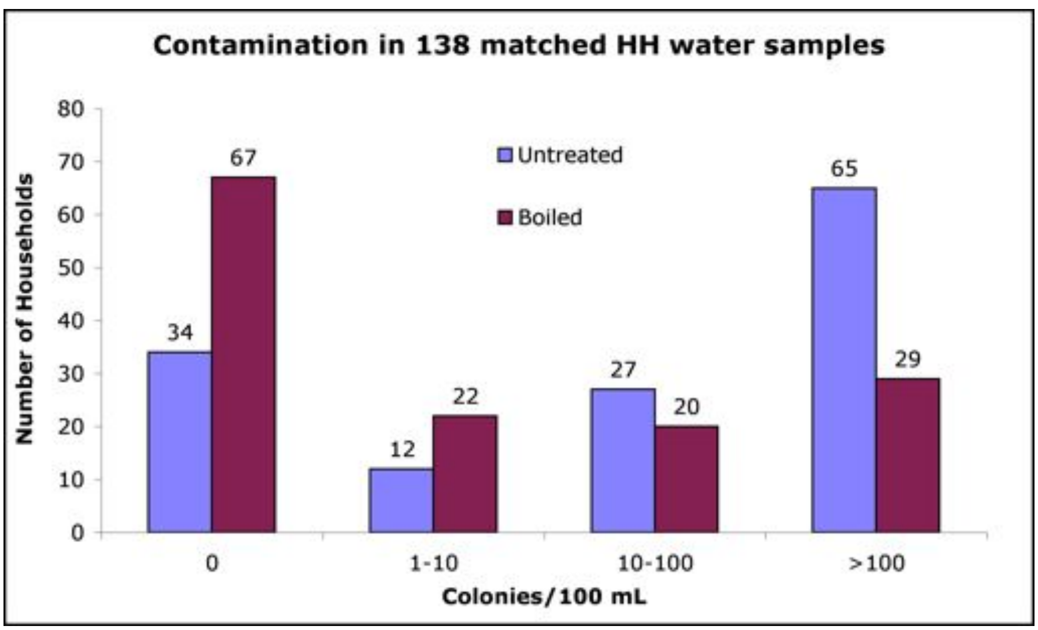


Figure 24: Fecal coliform contamination in boiled and unboiled samples (West Sumatra, Indonesia)

By multiplying the percent of the survey population reporting boiling (88.1%) by the percent of boilers with microbiologically improved water to <1 CFU/100 mL fecal coliform, a population based effectively treated to <1 CFU/100 mL proportion of 21.1% is calculated. Repeating this calculation using the breakpoint of 10 CFU/100 mL (31.2%% improved to this level) leads to a survey population-based effectively treated water to 10 CFU/100 mL of 27.5%.

8.8 Resistance to sub-optimal use

In Indonesia, there was simply not enough use of the distributed products to investigate sub-optimal use. We have discussed, in the previous section, some potential reasons for sub-optimal boiling.

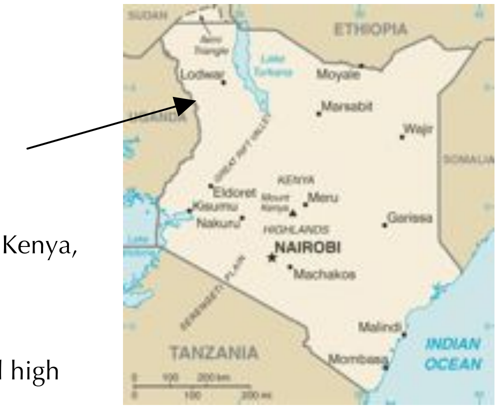
8.9 Cost analysis

The total budget for the three Oxfam/GB tankering projects in this emergency was 81,000£. As the project investigated herein was medium sized, it was estimated the cost was one-third of the total (27,000£), with the exchange rate at the time leading to a cost of 44,500 USD. There were a total of 958 families targeted with this response, for a cost per family of 46.5 USD. The amount tanked was 12,000 Liters/day, or 12.5 Liters/family/day, for a total volume treated and trucked in eight weeks of 701 Liters/family. Thus, the cost per liter treated and delivered was 6.6 US cents.

CARE included the Air Rahmat in the family kit, and as the Air Rahmat was a small portion of the volume within the large family kit, only the purchase and delivery costs of Air Rahmat from Jakarta to Pariaman were considered in the cost of this portion of the response. The cost of purchasing and transporting 10,000 Air Rahmat to Pariaman was 4,331 USD, or 43.31 US cents per bottle. As each bottle treats 800 Liters, the cost per liter treated of including the Air Rahmat in the family kit (without additional training) is 0.054 US cents. Trainings on Air Rahmat were supposed to have been conducted at the family kit distributions.

The cost of a ShelterBox is 490£ per box in the UK, and DHL ships the boxes to emergencies at no cost, and local Rotary Clubs in affected areas deliver the kits to recipients. We were not able to obtain information from ShelterBox on the cost of the tablets, but they represent an insignificant cost relative to the entire kit.

9 Turkana, Kenya Flooding and Cholera Outbreak



The normally arid Turkana region is located in the far northwest corner of Kenya, bordering Uganda to the west, Sudan and Ethiopia to the North, and Lake Turkana to the east (Figure 25). The region has been affected by drought, insecurity, poor or no harvests, high malnutrition rates, water scarcity, and high food prices and is the site of an ongoing WFP intervention.

Figure 25: Kenya map (from www.travelnotes.com)

9.1 Emergency description

Two days of heavy rains on January 2nd-3rd caused flash floods in Turkana East as the River Kerio overtopped her banks and flooded the valley for the first time since 1967 (Standard, 2010). A Kenya Red Cross Society (KRCS) assessment documented 4,294 displaced households (21,470 people) and five deaths in four highly affected sub-locations – Kangitit, Lokwii, Lotubae, and Elelea (KRCS, 2010a) (Figure 26). Five bridges, 20 pit latrines, the Morelum Irrigation Scheme, two schools, two health facilities, and 6,500 shelters were destroyed. In addition, 4,298 shoats (young sheep and goats), 184 cattle, 60 donkeys, and 193 camels washed away in the floods. The floods receded within 3 days. The storm also cut off the Kapenguria-Lodwar Road, which is a lifeline for Southern Sudan. Relief supplies destined for refugee camps in Kakuma, Kenya and Southern Sudan were delayed as transport was disrupted.

Figure 26: A flooded village in East Turkana (courtesy of KRCS)

In addition to the flooding, the larger northwestern region of Kenya has been the site of an ongoing cholera epidemic. Data obtained at the Lokori Health Center in the Turkana East Region documented a declining, but significant, number of cholera cases seen at the health center (Figure 27). Cholera case reporting was limited by the poor infrastructure in the region.

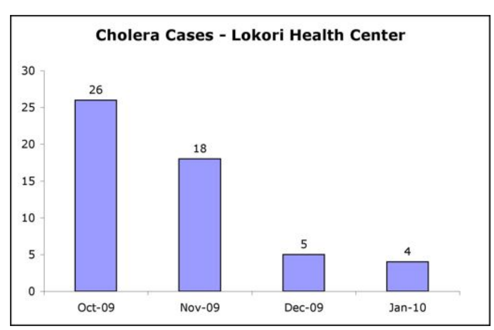


Figure 27: Cholera cases reported at the Lokori Health Center

9.2 Situational analysis and methods

KRCS is currently operating an ongoing nationwide flood response project (KRCS, 2010b). The goals of this project are to: 1) undertake search and rescue operations in flood-affected areas; 2) provide non-food items (NFIs) to affected populations; 3) contribute to a reduction in excess morbidity and mortality by providing health services; 4) provide sustained access to safe WASH promotion to affected populations; and, 5) provide logistical support in the field for transport and stocking of non-food relief.

As part of this larger flood response operation, the KRCS WASH team conducted two weeks of emergency response activities in Turkana East in January 2010. KRCS used staff and logistical resources from an existing sexual health project in the region to complete the response. HWTS options were included in the relief kits because while KRCS initially intended to disinfect all wells in the four highly affected sub-locations, they were unable to do so because of a lack of equipment and sufficient time. PuR and Aquatabs warehoused with KRCS in Kenya were distributed in an attempt to ensure safe water access for all families (whether or not they were using a disinfected well) in the NFI kit. The kit included two blankets, one tarp, one bednet, one kitchen set, two soaps, 2 20-L collapsible jerry cans, 100 Aquatabs (dosed for 20 Liters each) and 20 PuR sachets. All families in all four communities should have been reached with a kit (Figure 28). In total, KRCS reported that 66,700 PuR sachets and 225,800 Aquatabs were distributed in the four highly affected sub-locations (KRCS, 2010b). If the distribution numbers are accurate and if 20 PuR sachets and 100 Aquatabs were distributed per family, that would have provided 3,335 and 2,258 families with the products, or 77.7% and 52.6% of the affected population respectively.

Figure 28: A recipient with PuR and Aquatabs (Turkana, Kenya)

NFI kit distribution began January 8^{th}, was completed by January 17^{th}, and was accompanied by a 2-hour group training on hygiene, WASH practices, and water treatment. No materials to use PuR (10-Liter bucket, stirring rod, or cloth) were distributed. Half-day WASH training sessions with children in schools were also conducted. In addition, over 43 pit latrines were sited and excavated and 20 volunteers were trained in participatory hygiene and sanitation transformation in emergency response.

World Vision and Oxfam are coordinating the WASH response through the recovery phase, including the development and repair of water systems, and MSF is coordinating the ongoing health response. World Vision has been operating in the region for 15 years, working with the WFP on malnutrition and irrigation programs. World Vision in Turkana East had stocks of Aquatabs and PuR for distribution in community health clinics. The District Public Health Officer (DPHO) in Turkana East also received supplies from UNICEF, including 192,000 Aquatabs, 14

45 kg barrels of HTH, 484 jerrycans, 1,880 mosquito bednets, PuR sachets, hydrogen sulfide microbiological testing supplies, and DPD test kits. DPHO supplies had not yet been distributed at the time of the survey.

The major water source in Turkana East is the River Kerio, and water is obtained from the river directly and from boreholes, shallow wells, and community piping schemes that World Vision has installed and manages. Users pay a monthly fee to access these supplies.

9.2.1 Spatial analysis

Due to the remoteness of the region, maps of this area were extremely limited. Upon arrival, we met with the District Chief, who approved the study and arranged for us to meet with the sub-chiefs of the four highly affected sub-locations. Each sub-chief provided hand-sketched maps of the villages in their sub-location, along with the most recent unofficial census data collected last year of population per village. In addition, information about migration patterns of the population in the post-emergency situation was provided. With this information, we were able to develop a dual-stage PPS sampling methodology by sub-location and village. Within each village, we asked the enumerators to walk the length and breadth of the village and sample a random selection of houses for survey. A more rigorous method of household selection was not feasible within the context of the temporary and transitory housing type seen in this environment (Figure 29).

Figure 29: Representative households (Turkana, Kenya)

GPS points in each village of the four sub-locations were collected by the field researcher and the KRCS driver and mapped in Google Earth. As can be seen, the sub-locations of Kangitit, Lokwii, Lotubae, and Elelea are located along the road that begins in Lokori and follows the river to the north and the Sudan border (Figure 30).

A total of 39 villages in the four sub-locations were surveyed. As can be seen the sub-locations were near the river bed. The first sub-location (light blue) is Kangitit, the second (light green) is Lotubae, the third (pink) is Lokwii, and the fourth (blue) is Elelea. Kangitit is nearest the larger city of Lokori (to the south), Elelea the furthest away.

Figure 30: Map of communities surveyed (Turkana, Kenya)

9.2.2 Methods used in investigation

9.2.2.1 Household survey

A randomly selected sample (as described in Section 4.4.3) of 409 households targeted with HWTS distribution was surveyed using a questionnaire developed by the field researcher. The survey was translated by a native Turkana speaker and printed in the regional city of Eldoret, Kenya on January 22nd, 2010. Five enumerators were trained in Lokori, Turkana on January 24th and 25th, 2010. The enumerators back-translated the survey and hand-wrote edits onto the data sheets. The survey was administrated between January 25th and February 4th, 2010, a minimum of eight days and a maximum of 27 days after distribution.

The survey consisted of 34 questions on respondent and household characteristics, effect of the emergency, assets, diarrhea prevalence, and water knowledge and source before and after the emergency. This was followed by 13-15 questions on each HWTS option received and six product summary questions. The survey concluded with up to six questions about, water quality testing of, and collection of, current treated and untreated stored household drinking water. A maximum of 81 questions (all products received) and a minimum 35 questions (no products received) were asked, and the survey and associated water quality testing and sample collection took about 20-30 minutes per household.

9.2.2.2 Water quality testing

The enumerators tested FCR using Hach (Loveland, CO, USA) ColorWheel test kits during the survey at any household reporting household water treatment and collected samples of treated water (if available) and untreated water from each surveyed household in sterile WhirlPak™ bags. The bags were stored on cold packs collected each morning. The field researcher completed membrane filtration microbiological testing each afternoon/evening. The only deviations from Standard Methods included: 1) samples were incubated at ambient temperature as by keeping the doors and windows closed at all times the field researcher's room remained between 35-39°C (there was no electricity available); 2) due to the heat of the environment samples were cool, but not cold, when removed from the coolers for analysis; and, 3) on one sampling day the holding time of eight hours was exceeded (to 12 hours) because the field researcher had heat exhaustion in the afternoon after taking pictures at a funeral for a family. A dedicated turbidity tester was hired to test samples within 24 hours of collection the morning after they were collected.

9.3 Qualitative interview results

Formal qualitative interviews were not conducted in this setting, as KRCS staff who responded in East Turkana were responding to more recent emergencies and unavailable for formal recorded conversations during the time the field researcher was in Kenya. However, the field researcher was able to speak with national KRCS staff and they graciously provided information on the details and cost of the response, as well as assistance with coordinating study logistics.

9.4 Survey results

Survey results are presented in Table 43 for the entire survey population and stratified by sub-location, as during the survey significant differences in socio-economic status and impact of the emergency were noted in the four different sub-locations. Differences between sub-locations were quantified in dichotomous variables using the chi-squared test (p-values of <0.05 indicate a statistical significant difference between survey populations, but does not say which populations are different). As in the Nepal data, the denominator for total percentages is noted in the row variable description. Denominators for the sub-locations column percentages are not presented.

A total of 409 surveys were completed by five enumerators in 39 total communities within the four sub-locations. The majority of survey respondents were women, and the average respondent age was 38.1 with a range from 16-72 years. If the respondent was female, 5.5% had attended any school. The average school attendance was 6.1 years for those women who had attended, and 0.34 for the total female respondent population. In addition, 7.9% of female head of households could read the newspaper.

About a third of respondents (32.8%) reported paying for water before the emergency. This number slightly increased after the emergency to 37.2%. At an exchange rate of 80 KSH to 1 USD, the average monthly cost of water before the emergency was 1.53 USD, and after 1.65. The maximum paid was 7.5 USD per month. This increase in price after the emergency was not statistically significant (p=0.51). Respondents who did not pay for water before the emergency, but began paying for water after the emergency were more likely to have stored household water free of *E. coli* (57.9%) than other respondents (29.3%) (p=0.034), indicating their choice to pay for water improved their water supply.

Overall, only 18.2% of families had water available within 30 minutes of their home, indicating the majority of the surveyed population walked a great distance for their water. Additionally, 97.8% covered stored household water. Adult women were responsible for collecting water in 78.2% of households, followed by girls (29.9%), boys (2.0%), and adult men (0.7%). Jerrycans were ubiquitous in this environment, with 99.3% of families using them, and 75.8% using the collapsible jerrycan provided in the family kit.

There was a significant amount of damage to homes and displacement, as 98.5% of homes were reported damaged, and 35.0% of the surveyed population had moved and created a new home after the emergency. A total of 100 families reported 128 cases of cholera, for an attack rate of 3.9 cases per 1000 people.

The majority of the surveyed population received a family kit from KRCS (95.3%), and 82.4% reported receiving Aquatabs and 63.8% reported receiving PuR.

There were statistically significant differences seen between the sub-locations. Overall, Kangitit and Lokwii appeared to be slightly less affected by the emergency, as more respondents paid for water, there was slightly less damage from the flooding in Kangitit, people in Kangitit were less likely to use the family kit jerrycan (but no less likely to use jerrycans, indicating they had one already), and there was less HWTS option distribution in Kangitit and Lokwii. In addition there was higher rates of cholera reported in Lotubae. These differences are consistent with the increasing rural nature of Lotubae and Elelea as compared to Kangitit and Lokwii.

Table 43: Survey by sub-location (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	Total	p-value
Total population (people)	12,000	7,500	7,000	6,500	33,000	
KRCS considered affected population (people)	8,000	5,000	2,000	3,300	18,300	
Random survey by PPS to total population – goal	145	91	85	79	400	
Number of households surveyed – actual	151	92	87	79	409	
% of surveys conducted in each sub-location	36.9	22.5	21.3	19.3	100	
Villages surveyed	13	13	9	4	39	
Number (%) female respondents (n=407)	123 (82.0)	85 (92.4)	84 (96.6)	71 (91.0)	363 (89.2)	0.003
Average respondent age in years (min-max) (n=409)	39.4 (16-70)	37.0 (20-62)	39.0 (20-60)	35.8 (20-72)	38.1 (16-72)	
Number (%) female respondents attend school (n=362)	9 (7.4)	5 (5.9)	1 (1.2)	5 (7.0)	20 (5.5)	0.195
If FR school, average (min-max) years school (n=20)	6.8 (4-12)	4.2 (2-6)	2.0 (2-2)	7.5 (5-10)	6.1 (2-12)	
All FR average (min-max) years school (n=204)	0.50 (0-12)	0.25 (0-6)	0.24 (0-2)	0.54 (0-10)	0.34 (0-12)	
Number (%) female HOH can read newspaper (n=407)	18 (12.0)	7 (7.7)	2 (2.3)	5 (6.4)	32 (7.9)	0.196
Families reporting cholera (%) (n=409)	29 (19.2)	22 (23.9)	32 (36.8)	18 (22.8)	101 (24.7)	0.024
Number cases cholera reported	35	26	43	24	128	
Reported cholera attack rate (per 1000 people)	2.9	3.5	6.1	3.7	3.9	
Number (%) paid for water before emergency (n=409)	61 (40.4)	64 (69.6)	7 (8.0)	2 (2.5)	134 (32.8)	<0.001
Average monthly water cost (KSH, min-max)) (n=134)	186 (10-600)	64 (20-200)	77 (60-150)	165 (30-300)	122 (10-600)	
Number (%) paid for water after emergency (n=409)	67 (44.4)	70 (76.1)	13 (14.9)	2 (2.5)	152 (37.2)	<0.001
Monthly cost of water (KSH, min-max) (n=152)	201 (10-600)	67 (20-300)	122 (30-300)	165 (30-300)	132 (10-600)	
Hours spent daily collecting water (n=407)	2.8 (1-6)	2.8 (1-5)	2.6 (1-4)	2.6 (1-4)	2.7 (1-6)	
Number (%) with water in 30 minutes of house (n=408)	19 (12.6)	15 (16.3)	21 (24.1)	19 (24.1)	74 (18.2)	0.062
Number (%) homes damaged by flooding (n=409)	145 (96.0)	92 (100)	87 (100)	79 (100)	403 (98.5)	0.015
Number (%) moved after flooding (n=408)	44 (29.3)	38 (41.3)	31 (35.6)	30 (38.0)	143 (35.0)	0.257
Number (%) received "family kit" (n=408)	144 (95.4)	86 (93.5)	81 (94.2)	78 (98.7)	389 (95.3)	0.388
Number (%) with covered stored water (n=401)	146 (98.6)	91 (98.9)	80 (96.4)	75 (96.2)	392 (97.8)	0.437
Number (%) using jerry cans (n=401)	145 (99.3)	89 (97.8)	86 (100)	78 (100)	398 (99.3)	0.282
Number (%) using jerry cans from family kit (n=401)	98 (67.1)	71 (78.0)	71 (82.6)	64 (82.1)	304 (75.8)	0.032
Number (%) received Aquatabs (n=409)	118 (78.1)	70 (76.1)	75 (86.2)	74 (93.7)	337 (82.4)	0.007
Number (%) received PuR (n=409)	81 (53.6)	63 (68.5)	60 (69.0)	57 (72.2)	261 (63.8)	0.012
Number (%) received at least one product (n=409)	133 (88.1)	80 (87.0)	78 (89.7)	75 (94.9)	366 (89.5)	0.329

The 409 households surveyed included a total of 2,404 people (average 5.9 people per household, min=1, max=15), including 493 children under 5 (average 1.2 children per household, min=0, max=5) (Table 44). Diarrhea was self-reported for 9.7% of adults, and 17.4% of children under 5.

Table 44: Survey population and reported diarrhea in last 24 hours (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	Total
Total population (by household)	6.1 (1-15)	6.2 (2-10)	5.9 (2-9)	5.6 (3-9)	6.0 (1-15)
Under 5 population (by household)	1.0 (0-5)	1.4 (0-3)	1.2 (0-3)	1.3 (0.3)	1.2 (0-5)
% over 5 females with diarrhea	10.5	8.4	11.4	8.3	9.8
% over 5 males with diarrhea	12.4	8.4	6.8	8.5	9.6
% over 5 with diarrhea	*11.5*	*8.4*	*9.1*	*8.4*	*9.7*
% under 5 females with diarrhea	17.9	21.3	9.8	16.1	16.9
% under 5 males with diarrhea	18.3	23.2	13.7	16.3	18.1
% under 5 with diarrhea	*18.1*	*22.1*	*11.8*	*16.2*	*17.4*

Survey respondents were asked about their water source three times: 1) what source they used before the emergency; 2) if there was a change in source after the emergency, what source they used now; and, 3) in the last part of the survey, what source the actual current stored household water came from. In this emergency, there was a trend toward increased use of improved sources after the emergency (Table 45 and Figure 31). Before the emergency, there was a statistically significant difference (p=0.020) between the sub-locations on the percentage of the respondents who used improved sources, with Lotubae noticeably lower. After the emergency, this difference between the sub-locations was no longer significant (p=0.182) as Lotubae respondents used a higher percent of improved water. Overall, there was not a statistically significant increase in use of improved sources (p=0.093), as the rate increased from 67.4 to 72.8%. The sources for each sub-location are visually depicted before and after the emergency on the next page.

Table 45: Water sources before and after the emergency (Turkana, Kenya)

	Kangitit		Lokwii		Lotubae		Elelea		All	
	Before	After	Before	After	Before	After	Before	After	Before	After
Public Tap (%)	45.0	45.0	69.6	77.2	39.5	48.8	67.1	67.1	53.7	57.4
Borehole (%)	21.2	26.5	0	0	16.3	16.3	11.4	11.4	13.5	15.4
River (%)	33.1	28.5	30.4	22.8	44.2	34.9	21.5	21.5	32.6	27.2
Rainwater (%)	0.7	0	0	0	0	0	0	0	0.3	0
% Improved	*66.9*	*71.5*	*69.6*	*77.2*	*55.8*	*65.1*	*78.5*	*78.5*	*67.4*	*72.8*
% Unimproved	*33.1*	*28.5*	*30.4*	*22.8*	*44.2*	*34.9*	*21.5*	*21.5*	*32.6*	*27.2*

Figure 31: Before (top) and after (bottom) emergency reported water sources (Turkana, Kenya)

At the time of the unannounced survey visit, respondents reported having water from improved sources in 78.6% of households, continuing a slight upward trend of improved sources (Table 46). Again, differences between the sub-locations were seen, with Lokwii having a significantly higher percentage of improved sources than other sub-locations. This rate of improved water use is statistically significantly higher than both the before emergency ($p<0.001$) and after emergency ($p=0.040$) reported rates of improved source use.

Table 46: Actual water source reported at time of unannounced household survey (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	All	p-value
Number (%) Public Tap	79 (53.0)	87 (94.6)	46 (52.9)	51 (64.6)	263 (64.6)	
Number (%) Borehole	34 (22.8)	0 (0)	14 (16.1)	9 (11.4)	57 (14.0)	
Number (%) River	36 (24.2)	5 (5.4)	27 (31.0)	19 (24.1)	87 (21.3)	
Number (%) Rainwater	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Number (%) Improved	*113 (75.8)*	*87 (94.6)*	*60 (69.0)*	*60 (75.9)*	*320 (78.6)*	*<0.001*
Number (%) Unimproved	*36 (24.2)*	*5 (5.4)*	*27 (31.0)*	*19 (24.1)*	*87 (21.4)*	

Respondents were asked if they felt their water was safe to drink. The results varied by water source, with 96.5% of households reporting using 255 improved sources after the emergency considering their water safe versus 73.4% of households using 94 unimproved sources ($p<0.001$) (Table 47).

Table 47: Percent of respondents who perceive their water source as safe (Turkana, Kenya)

	Public Tap	Borehole	River	All
Perceived clean (number (%))	182 (77.8)	61 (96.9)	69 (62.2)	313 (76.5)
Perceived unclean (number (%))	10 (4.3)	2 (3.2)	25 (22.5)	37 (9.1)
Don't know (number (%))	42 (18.0)		17 (15.3)	59 (14.4)

The majority of respondents who perceived their water as clean did so because the "water was clear" or "from tap" (Table 48).

Table 48: Reasons respondents perceive water as clean (multiple answers possible) (Turkana, Kenya)

	Unimproved	Improved	All
Water clear (number (%))	66 (95.7)	195 (70.4)	261 (75.4)
From tap (number (%))	1 (1.4)	66 (23.8)	67 (19.4)
Free of bacteria (number (%))	2 (2.9)	14 (5.1)	16 (4.6)
Water warm (number (%))	0 (0)	1 (0.4)	1 (0.3)
Red Cross treated tank (number (%))	0 (0)	1 (0.4)	1 (0.3)
Totals (number)	*69 (100)*	*277 (100)*	*346 (100)*

Similarly, the majority of respondents who perceived their water as unclean did so because the "water was dirty" (Table 49).

Table 49: Reasons respondents perceive water as unclean (multiple answers possible) (Turkana, Kenya)

	Unimproved	Improved	All
Water dirty (number (%))	23 (92.0)	9 (81.8)	32 (88.9)
Has bacteria (number (%))	2 (8.0)	1 (9.1)	3 (8.3)
Is not treated (number (%))	0 (0)	1 (9.1)	1 (2.8)
Total (number (%))	*25 (100)*	*11 (100)*	*36 (100)*

The three largest health problems self-identified in an open-ended "what are the biggest health problems you face after the emergency" question to respondents were malaria (83.6%), fever (75.8%), and food shortage (43.8%) (Figure 32). Less than 10% of respondents self-reported either cholera/diarrhea (8.6%) or water (6.4%) as a problem after the emergency.

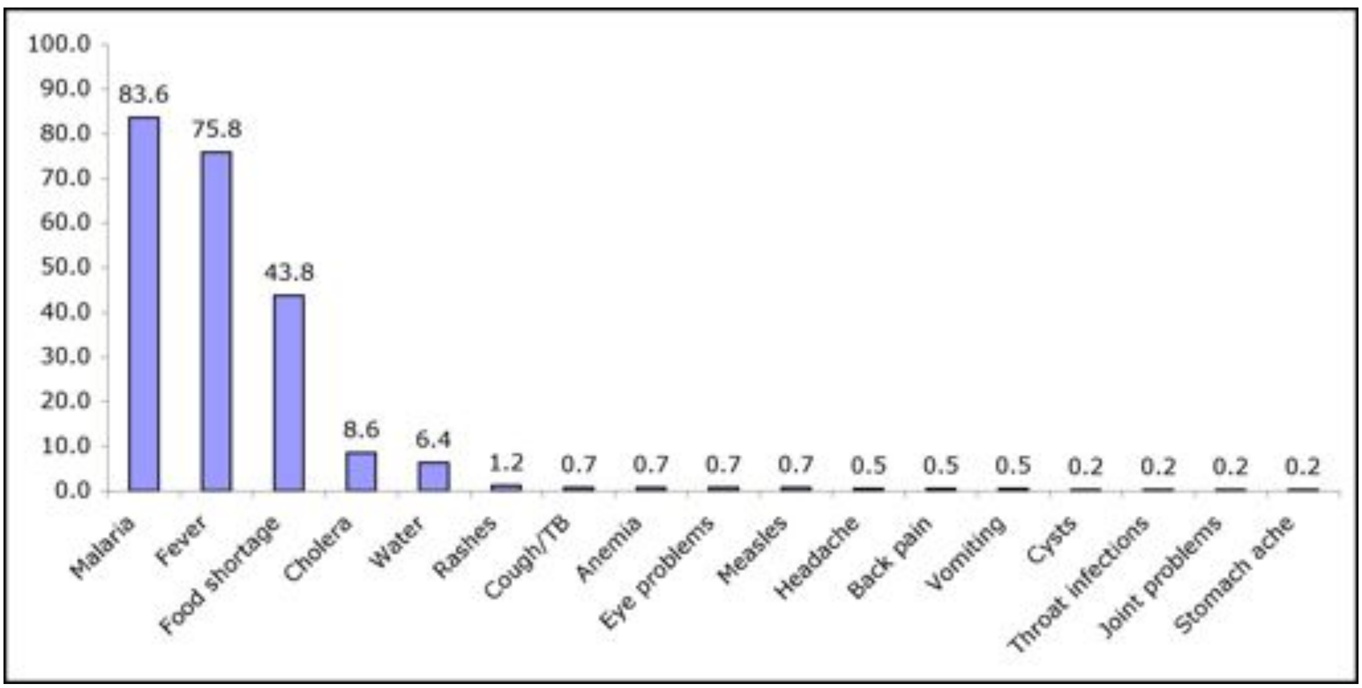


Figure 32: Percent of respondents listing health problems after the emergency (Turkana, Kenya)

There was high knowledge of boiling and the use of a local root (erut) for removing suspended solids from water before the emergency in this survey population (Table 50). To use erut, the root is dug up, pounded to release the liquid, and stirred in water for five minutes (Figure 33). The water is then let to settle. The majority of respondents who reported knowing an option reported using that option daily to treat their water before the emergency. A total of 404 (98.8%) of 409 respondents self-reported knowing at least one HWTS option before the emergency. There were differences by sub-location in knowledge of erut as a water treatment option (Table 51). Boiling and liquid chlorine did not vary between sub-location.

Table 50: HWTS options known before emergency (Turkana, Kenya)

		Report using			
	Know	Never Use	Rarely	Once per week	Daily
Boiling (number (%))	380 (92.9)	`	4 (1.1)	67 (17.6)	309 (81.3)
Erut (number (%))	157 (38.4)			48 (30.6)	109 (69.4)
Liquid chlorine (number (%))	41 (10.0)	1 (2.4)		3 (7.3)	37 (90.2)
PuR (number (%))	5 (1.2)			2 (40.0)	3 (60.0)
Tablet chlorine (number (%))	3 (0.8)		1 (33.3)		2 (66.7)
Kasekok seeds (number (%))	1 (0.2)			1 (100)	

Table 51: Prior knowledge of HWTS options, by sub-location (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	All	p-value
Know boiling (number (%))	135 (89.4)	87 (94.6)	82 (94.3)	76 (96.2)	380 (92.9)	0.192
Know liquid chlorine (number (%))	19 (12.6)	12 (13.0)	7 (8.0)	3 (3.8)	41 (9.8)	0.122
Know erut (number (%))	87 (57.6)	27 (29.3)	26 (29.9)	17 (21.5)	157 (38.4)	<0.001

Figure 33: Erut plant, erut root, and water treated with erut (Turkana, Kenya)

9.5 Coverage

The total affected population was estimated by KRCS to be 3,102 households (18,300 individuals) out of 5,592 households (33,000 individuals) in the four most affected communities. However, upon arrival to the emergency there was no indication of which households were considered affected and which were not. Overall, 89.5% of the total population (affected and not) received a HWTS option, with 337 (82.4%) receiving Aquatabs, 261 (63.8%) receiving PuR, and 232 (56.7%) receiving both (Table 52). There was no statistically significant difference between sub-locations that received at least one HWTS option (p=0.329). Moreover, univariate analysis showed no evidence of bias in distribution, which suggests that distribution was even and widespread. Each household was supposed to receive 100 Aquatabs (treating 20 Liters each) and 20 sachets of PuR (treating 10 Liters each), providing a total of 2,200 Liters of treated water, or enough treated water for a household for 110 days using 20 Liters of high-quality water per day. Each household was supposed to receive 100 Aquatabs (treating 20 Liters each) and 20 sachets of PuR (treating 10 Liters each), providing a total of 2,200 Liters of treated water, or enough treated water for a household for 110 days using 20 Liters of high-quality water per day. Respondents reported that their household received an average of 113 tablets (treating 2,260 Liters of water, or enough for one household for approximately 4 months), with a minimum of 10 and a maximum of 500 tablets received an average of 17.1 days before survey (Table 53). The reported Aquatab use rate, calculated by subtracting the remaining from the received and dividing by the days ago received, was on average 4.36 tabs/day (87.2 Liters/day). Respondents reported receiving an average of 14.9 sachets (sufficient to treat 149 Liters of water, or enough for one family for approximately 7.5 days), with a minimum of 1 and a maximum of 156 sachets received an average of 17.8 days before survey (Table 55). The PuR use rate, calculated by subtracting product remaining from product received and dividing by the number of days since received, was on average 0.55 sachets/day (min=0, max=1.7). This is equivalent to 5.5 Liters treated per day. Overall, the average number of days of water treatment received by the target population was 97.6 days, with a range from 0-578 days.

Table 52: Coverage of HWTS (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	Total
Total population (people)	12,000	7,500	7,000	6,500	33,000
Affected population (people)	8,000	5,000	2,000	3,300	18,300
Number (%) received Aquatabs (n=409)	118 (78.2)	70 (76.1)	75 (86.2)	74 (93.7)	337 (82.4)
Number (%) received PuR (n=409)	81 (53.6)	63 (68.5)	60 (69.0)	57 (72.2)	261 (63.8)
Number (%) received at least one product (n=409)	133 (88.1)	80 (87.0)	78 (89.7)	75 (94.9)	366 (89.5)

Although these were the most affected communities according to KRCS (and the only communities KRCS responded within), there was little way to tell the full impact of the flooding or the cholera outbreak to generate numbers for HWTS options to meet the demand of the full scope of the emergency.

9.6 Correct use

In Turkana, Aquatabs and PuR were distributed to the affected population.

9.6.1 Aquatabs

Two types of Aquatabs were distributed in the response: 1) 67-mg tablets meant for treating 20 Liters at a dosage of 2 mg/L chlorine; and, 2) 167-mg tablets, also meant for 20 Liters of water, but at a dosage of 5 mg/L chlorine. There was no deliberate strategy for distributing one tablet or another to a certain area.

Of the 292 (86.6%) of 337 recipients who could show the enumerators the tablets during the visit, 47.3% received the 67-mg tablet and 52.7% the 167-mg tablet (Table 53). There was a statistically significant difference between the sub-locations, with more people in Lokwii and Lotubae receiving the 167-mg tablet, and more people in Kangitit and Elelea receiving the 67-mg tablet.

Respondents reported that their household received an average of 113 tablets (treating 2,260 Liters of water, or enough for one household for approximately 4 months), with a minimum of 10 and a maximum of 500 tablets received an average of 17.1 days before survey. The reported Aquatab use rate, calculated by subtracting the remaining from the received and dividing by the days ago received, was on average 4.36 tabs/day (87.2 Liters/day). The large majority of respondents (96.1%) received group training on how to use Aquatabs, with more people in Lokwii and Elelea reporting group training. A total of six respondents reported receiving multiple group trainings. Overall, 3.3% of respondents received household level training on the option, mostly in Kangitit, where five or the ten (50%) respondents who received household trainings reported receiving multiple household trainings. Of the 337 Aquatabs respondents, 13 (3.9%) reported receiving no training.

The majority of respondents (89.9%) reported the fully correct way to use Aquatabs – adding 1 tablet to 20 Liters of water and waiting 30 minutes before drinking. There were no instructions given in the trainings to differentiate whether to use one tablet or the other in turbid water or not. Of the three respondents who did not say one tablet, two overdosed (adequate but incorrect treatment) stating 2 tabs for 20 Liters and 10 Liters, respectively, and one underdosed, stating 0.5 tablets for 20 Liters. Of the four respondents who did not report 20 Liter storage container volume, 3 overdosed (stating 10 Liters) and 1 underdosed (stating 30 Liters). The wait time was where the majority of the knowledge gap was, with 28 (8.3%) of respondents not stating 30 minutes. The minute wait range was from 0-720 minutes. If the percent of people reporting incorrect, but adequate, treatment is included, treatment knowledge rises to 92.0%.

Overall 98.5% of respondents reported ever using Aquatabs, and 86.7% reported they are still using the tablets. There was a different by sub-location in reported current use, with respondents in Elelea reporting lower use. However, only 15.4% reporting using the tablets today and having treated water available, while 5.2% of Aquatabs respondents reported having PuR treated water. If the respondents who reported running out of Aquatabs were subtracted from the denominator, the reported today use of Aquatabs rises to 17.6%. A correct FCR of between 0.2-2.0 mg/L was maintained in 52.1% of reported Aquatabs treated water, and a FCR of greater than or equal to 0.2 mg/L was maintained in 62.5% of reported Aquatabs treated water.

Of the 52 respondents reporting treatment with Aquatabs on the day of the unannounced survey visit, 49 (94.2%) were using 20 liter containers. The remaining three people used 10 Liter jerrycans. Thirty-seven of the 52 were using the 20 Liter jerrycans provided in the family kit (71.2%).

The main reason for use of the product is that it cleans the water (71.2% of respondents), and the main reason for disuse was due to running out of product (93.3%) (Table 54). A total of 4.4% stopped using the product due to objections to the chlorine taste and smell.

Table 53: Aquatabs knowledge and use (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	Total	p-value
Number (%) received Aquatabs (n=409)	118 (78.2)	70 (76.1)	75 (86.2)	74 (93.7)	337 (82.4)	
Number (%) received 67 mg tablet (n=292)	56 (54.4)	17 (25.0)	25 (37.3)	40 (74.1)	138 (47.3)	<0.001
Number (%) received 167 mg tablet (n=292)	47 (45.7)	51 (75.0)	42 (62.7)	14 (25.9)	154 (52.7)	
Number tablets (min-max) received (n=337)	107 (10-500)	129 (20-200)	115 (20-200)	102 (10-200)	113 (10-500)	
Number of days ago (min-max) received (n=337)	14.3 (5-20)	16.0 (10-20)	18.0 (13-30)	21.9 (14-30)	17.1 (5-30)	
Number (%) reporting group training (n=337)	108 (91.5)	67 (95.7)	75 (100)	74 (100)	324 (96.1)	0.004
Number (%) reporting household training (n=337)	10 (8.5)	1 (1.4)	0 (0)	0 (0)	11 (3.3)	0.067
Number (%) fully correct use knowledge (n=336)	105 (89.7)	61 (87.1)	65 (86.7)	71 (95.9)	302 (89.9)	0.219
Number (%) incorrect but adequate (n=336)	109 (93.2)	62 (88.6)	67 (89.3)	71 (95.9)	309 (92.0)	0.352
Report current use (n=337)	105 (89.0)	66 (94.3)	63 (84.0)	58 (78.4)	292 (86.7)	0.030
Report Aquatabs treated water today (n=337)	27 (22.9)	6 (8.6)	9 (12.0)	10 (13.5)	52 (15.4)	0.137
AT respondents reporting PuR treated water (n=337)	9 (7.6)	6 (8.6)	1 (1.3)	2 (2.7)	18 (5.3)	
Correct FCR in AT treated water (n=48)	13 (54.2)	1 (16.7)	6 (66.7)	5 (55.6)	25 (52.1)	0.071
FCR ≥0.2 mg/L in AT treated water (n=48)	14 (58.3)	2 (33.4)	6 (66.7)	8 (88.9)	30 (62.5)	0.165
Number (%) report Aquatabs treated water today if product was not finished (n=295)	27	6	9	10	52 (17.6)	

Table 54: Reasons for use and disuse of Aquatabs (Turkana, Kenya)

	Total
Use because (n=317 reasons, 292 respondents))	
Cleans water (number (%))	208 (71.2)
Prevents disease (number (%))	53 (18.2)
Instructed to do so or was given (number (%))	47 (16.1)
Water dirty after flooding (number (%))	9 (3.1)
Do not use because (n=45 reasons for 45 respondents)	
Product finished (number (%))	42 (93.3)
Do not like taste or smell (number (%))	2 (4.4)
No water (number (%))	1 (2.2)

9.6.2 PuR

The correct use of PuR is to add one sachet to 10 Liters of water, stir for 5 minutes, wait for the flocculant to settle, filter the water through a cloth into a second bucket, and wait 20 minutes before drinking.

Respondents reported receiving an average of 14.9 sachets (sufficient to treat 149 Liters of water, or enough for one family for approximately 7.5 days), with a minimum of 1 and a maximum of 156 sachets received an average of 17.8 days before survey (Table 55). The PuR use rate, calculated by subtracting product remaining from product received and dividing by the number of days since received, was on average 0.55 sachets/day (min=0, max=1.7). This is equivalent to 5.5 Liters treated per day. The large majority of respondents (96.9%) received group training on how to use PuR. Overall, 2.3% of respondents received household level training on the option, mostly in Kangitit, where six respondents who did not receive group training received household training. Of the 337 PuR respondents, 2 (0.7%) reported receiving no training.

To assess PuR knowledge we first asked respondents an open-ended "how do you use" PuR storytelling question, and recorded the steps respondents mentioned. In the responses 3 (1.2%) of respondents listed no steps, 4 (1.5%) listed one step, 20 (7.7%) listed two steps, 144 (55.2%) listed 3 steps, 70 (26.8%) listed four steps, and 20 (7.7%) listed all five steps (Figure 34). The most commonly missed step was filtering through a cloth.

We then followed up with specific questions about how many Liters do you add a sachet to (86.5% of respondents knew 10 Liters), how long do your stir (74.9% knew 5 minutes), how long do you wait before filtering (56.0% knew until settled or 5 minutes), and how many minutes do you wait before drinking after filtering (9.7% of respondents knew 20-30 minutes). Only 2.3% of people provided fully correct knowledge answers to all of these four questions.

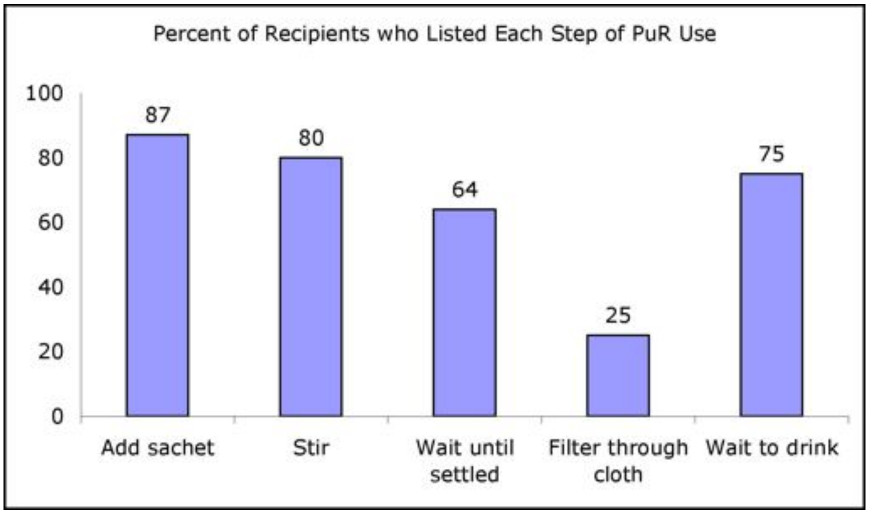


Figure 34: Percent of respondents who reported knowing each step of PuR use (Turkana, Kenya)

Overall 98.5% of respondents reported ever using PuR, and 85.0% reported they are still using the sachets. Households in Kangitit were more likely to report they were still using the PuR. However, only 9.2% reporting using PuR today and having treated water available, while 15.7% of PuR respondents reported having Aquatabs treated water. If the respondents who reported running out of PuR were subtracted from the denominator, the reported today use of PuR rises to 17.6%. A correct FCR of between 0.2-2.0 mg/L was maintained in 63.6% of reported PuR treated water, and a FCR of greater than or equal to 0.2 mg/L was maintained in the same amount of samples.

Of the 24 respondents reporting treatment with PuR on the day of the unannounced survey visit, all were using jerrycans, including 13 (54.2%) using the 20 Liter jerrycans from the family kit, 3 (12.5%) using 10 Liter jerry cans, and the remainder using 20 Liter jerrycans.

The main reason for use of the product is that it cleans the water (63.8% of respondents), and the main reason for disuse was due to running out of product (82.5%) (Table 56).

Table 55: PuR knowledge and use (Turkana, Kenya)

	Kangitit	Lokwii	Lotubae	Elelea	Total	p-value
Number (%) received PuR (n=409)	81 (53.6)	63 (68.5)	60 (69.0)	57 (72.2)	261 (63.8)	0.012
Number sachets (min-max) received (n=260)	15.7 (1-156)	14.9 (6-21)	13.5 (2-20)	15.1 (5-30)	14.9 (1-156)	
Number of days (min-max) ago received (n=258)	14.0 (5-20)	16.4 (10-20)	18.3 (13-25)	23.9 (18-30)	17.8 (5-30)	
Number (%) report group training (n=261)	74 (91.4)	63 (100)	59 (98.3)	57 (100)	253 (96.9)	--
Number (%) report household training (n=261)	6 (7.4)	0 (0)	0 (0)	0 (0)	6 (2.3)	--
Number (%) report 10 Liters for volume (n=260)	59 (72.8)	61 (96.8)	54 (91.5)	51 (89.5)	225 (86.5)	
Number (%) report stirring for 5 minutes (n=259)	63 (78.8)	51 (81.0)	47 (79.7)	33 (57.9)	194 (74.9)	
Number (%) report settling for 5 minutes (n=257)	51 (64.6)	33 (55.6)	33 (56.9)	25 (43.9)	144 (56.0)	
Number (%) report waiting 20-30 minutes (n=258)	8 (10.0)	4 (6.34)	5 (8.6)	8 (14.0)	25 (9.7)	
Number (%) report fully correct use (n=261)	1 (1.2)	2 (3.2)	2 (3.3)	1 (1.8)	6 (2.3)	0.805
Number (%) report ever using (n=260)	80 (98.8)	63 (100)	57 (96.6)	56 (98.2)	256 (98.5)	0.496
Number (%) report currently still using (n=260)	72 (88.9)	62 (98.4)	46 (78.0)	41 (71.9)	221 (85.0)	<0.001
Number (%) report PuR treated water today (n=261)	11 (13.6)	10 (15.9)	1 (1.7)	2 (3.5)	24 (9.2)	0.019
Number (%) PuR respondents reporting AT treatment (n=261)	19 (23.5)	5 (7.9)	8 (13.3)	9 (15.8)	41 (15.7)	
Correct FCR in PuR treated water (n=22)	7 (77.8)	5 (50.0)	1 (100)	1 (50)	14 (63.6)	0.510
FCR ≥0.2 mg/L in PuR treated water (n=22)	7 (77.8)	5 (50.0)	1 (100)	1 (50)	14 (63.6)	0.510
Number (%) report PuR treated water today if product was not finished (n=261)	11	10	1	2	24 (10.5)	

Table 56: Reasons for use and disuse of PuR (Turkana, Kenya)

	Total
Use because (n=241 reasons, 221 respondents))	
Cleans water (number (%))	141 (63.8)
Prevents disease (number (%))	51 (23.1)
Instructed to do so or was given (number (%))	30 (13.6)
Removes dirt (number (%))	19 (8.6)
Do not use because (n=40 reasons for 40 respondents)	
Product finished (number (%))	33 (82.5)
Too hard (number (%))	3 (7.5)
Water clear (number (%))	2 (5.0)
Aquatabs easier (number (%))	1 (2.5)
Don't know how to use (number (%))	1 (2.5)

9.6.3 Comparative analysis

Of the 227 who answered the question "which HWTS did you prefer" of the 232 people who received both Aquatabs and PuR, 123 (54.2%) preferred Aquatabs, 89 (39.2%) preferred PuR, and 15 (6.6%) had no preference/did not know. The largest reason for use was because the products make water clean but Aquatabs was noted as being easier to use (p=<.001) than PuR comparing easier to use to all other reasons (Table 57).

Table 57: Reasons for Aquatabs or PuR preference (Turkana, Kenya)

	Aquatabs	PuR
Tastes better (number)	2	2
Easier to use (number)	44	11
Have used before (number)	0	1
Makes water clean (number)	74	70
Smells better (number)	4	7

After completing the Nepal survey, it was determined that adding in Likert-scale perception questions to the survey might be of utility to understand comparisons between HWTS options. These questions were not analyzed in Indonesia or Haiti because households did not generally receive more than one HWTS option, but are presented for Kenya, where household received both PuR and Aquatabs.

Thus, in Kenya 11 Likert-scale questions were asked for each option the respondent received. Respondents were asked to strongly agree, agree, disagree, or strongly disagree with each statement, and the answer was coded as 3, 2, 1, and 0, respectively (Table 58). Statistically significant differences between the options were noted for: 1) "I like the smell" as people preferred the smell of PuR to Aquatabs (which makes sense as the chlorine dose is less and the smell and taste are reduced as the organic materials are removed before reacting with the chlorine); 2) respondents felt the trainings on the option were more useful for PuR than Aquatabs, which makes sense as PuR needs more intensive training; and, 3) respondents felt they had the materials to use PuR, which is counterintuitive, and may be a misunderstanding on the respondents part of the question. All of the Likert-scale question data in this context, however, is suspect, as respondents did not know how to use the PuR correctly and thus could not provide accurate comparisons between two water treatment methods that were effective.

Table 58: Likert-scale question results (Turkana, Kenya)

	Aquatabs Average (n) (95% CI)	PuR Average (n) (95% CI)	p-value (ttest)
I like the taste of treated water	2.23 (n=337) (2.17-2.28)	2.29 (n=256) (2.16-2.27)	0.782
I like the smell of treated water	1.89 (n=337) (1.82-1.96)	2.82 (n=256) (2.01-2.13)	<0.001
Treated water tastes better than untreated	2.24 (n=336) (2.19-2.29)	2.27 (n=222) (2.20-2.34)	0.455
Treated water is safer than untreated	2.24 (n=265) (2.18-2.30)	2.32 (n=225) (2.26-2.40)	0.056
Trainings on option were useful	2.07 (n=334) (2.01-2.14)	2.24 (n=257) (2.16-2.31)	0.002
Option takes too much time	1.62 (n=327) (1.50-1.73)	1.63 (n=248) (1.50-1.75)	0.534
Option is easy to do	2.00 (n-334) (1.91-2.09)	2.09 (n=252) (1.99-2.19)	0.203
I have right materials to use option	1.85 (n=330) (1.76-1.93)	2.08 (n=253) (1.98-2.17)	<0.001
Other options are easier than this one	1.34 (n=251) (1.24-1.44)	1.35 (n=196) (1.25-1.48)	0.898
This option is better water treatment than others	1.57 (n=327) (1.46-1.67)	1.57 (n=251) (1.45-1.67)	0.961

In summary, adequate knowledge of Aquatabs and PuR use was 92.0% and 2.3%, respectively, in this survey population. A total of 76 of 409 (18.6%) targeted households reported water treatment with a product distributed by KRCS (52 households (12.7% of 409) with Aquatabs, and 24 (5.9% of 409) with PuR). Of the households where treated water samples were tested for FCR, 44 of 70 (62.9%) had adequate FCR, with 30 of 48 (62.5%) Aquatabs users tested treated water having adequate FCR and 14 of 22 (63.6%) PuR users tested treated water having adequate FCR. By multiplying the total number with treated water (76) by the rate of correct treatment (0.629), a total number of users with correctly treated water of 47.8 is calculated. Thus, there was a final total of 11.7% (47.8/409) of the targeted population having adequate FCR in their drinking water due to this combined intervention at the time of the unannounced visit. The breakdown of this overall percent by HWTS option is: 32.5 of 409 (7.9%) for treated water with FCR in it from Aquatabs and 15.3 of 409 (3.7%) for treated water with FCR in it from PuR.

Overall, in a targeted population that had low knowledge of chlorine based options before the emergency (10.8% reported knowing any chlorine option), a high rate of distribution (89.5% of the target population received at least one product) and adequate knowledge of Aquatabs treatment (92.0%), and an 11.7% reported use of products is possible from a single distribution. However, these results clearly show that the distribution of PuR with only a single group training is insufficient in an emergency context when the target population is unfamiliar with the product, as only 2.3% of respondents knew the correct use. Aquatabs was found to be easier to use within a single group training context when there is no follow-up from the distributing NGO. There did not appear to be a high demand for the product from a disease reduction perspective, but there also did not seem to be low taste-resistance to the products. Lastly, one household reported water treatment with boiling, and one household reported water treatment with Erut. Both households could provide treated and untreated water samples, but due to small sample size, no statistical results could be presented.

9.6.4 Univariate analysis

The outcomes of interest in this emergency were the dichotomous variables of receiving Aquatabs, receiving PuR, reporting water treatment with any product, having FCR greater than or equal to 0.2 mg/L in drinking water, or having a minimum of a 1-log (90%) reduction in *E. coli* in untreated water) (results presented in subsequent section). The variables we postulated might impact the outcome variables in this circumstance include: whether or not the female head of household could read, whether the household was damaged in the flooding, if the family lived in the same place as before the flood, in the household used improved water sources, if the family is migratory, if the respondent knew boiling, chlorination, or erut before the emergency, diarrhea was reported in the household or in children in the household, whether cholera was reported in the household, whether cholera/diarrhea was considered a health problem after the emergency, whether the household believes drinking water is safe, whether the household covered their storage container, whether the household received group training or household training, and the socio-economic status of the household.

Initial results from a univariate analysis shows that no factors were statistically associated with whether the households received Aquatabs except a belief drinking water is safe, suggesting a non-biased distribution by KRCS (Table 59). A number of factors were significant for reporting receiving PuR, including prior knowledge of boiling and not having prior knowledge of erut, diarrhea in the house, and using a improved sources. All of these characteristics have to do with knowledge, and it may be that the causality of this link is not a bias in KRCS distribution, but instead the fact that respondents who knew more about HWTS were more likely to recognize and report they received PuR in the family kit. No significant factors were identified for the outcome variables of reporting treated water, FCR greater than or equal to 0.2 mg/L, or a one log (90% reduction) of *E. coli* (except socio-economic status discussed below).

Socio-economic status quintiles were developed using principal component analysis based on household assets (including mobile phone, radio, sheep, cattle, camel, donkey, and goat ownership and having part of your house (roof, walls, or floor) constructed out of non-natural materials). The quintiles were not associated with receiving Aquatabs or PuR, reported treated water, or maintaining adequate FCR. However, people of higher socio-economic status were more likely to reduce *E. coli* by at least one log (90%) than people of lower socio-economic status.

We did not consider whether or not the individual products ran out in this analysis. We did investigate whether the data was confounded by village i.e. whether or not the data was clustered by households in one village all having the same outcome variables due to social norms or social support reason) and 20% of the variance in the data set for FCR was confounded by village, which is not an insignificant amount. We will continue to work to develop this model further to predict behavior, however further development is outside the scope of this report.

Table 59: Univariate analysis results (Turkana, Kenya)

	Received AT	Received PuR	Reported treated	FCR (AT only)	E coli Improved
Female HOH able to read	0.745	0.799	0.945	0.879	1.0
Home damaged in flood	0.309	0.479	0.371	0.268	0.154
Live in the same place as before flood	0.949	0.593	0.219	0.626	0.797
Use improved source	0.253	**<0.001** OR: 2.29 95% CI: 1.4-3.7	0.307	0.146	0.522
Family is migratory	0.278	0.348	0.792	0.791	0.254
Knew boiling before emergency	0.338	**0.003** OR: 3.14 95% CI: 1.4-6.9	0.795	0.170	0.305
Knew chlorination before emergency	0.069	0.332	0.621	0.264	0.451
Knew erut before emergency	0.717	**<0.001** OR: 0.23 95% CI: 0.1-0.4	0.808	0.396	0.540
Diarrhea reported in household	0.120	**0.001** OR: 2.01 95% CI: 1.3.-3.1	0.181	0.265	0.798
Diarrhea reported in children in household	0.052	0.172	0.582	0.777	0.741
Cholera reported in household	0.082	0.072	0.830	0.737	0.264
Cholera health problem after emergency	0.054	0.087	0.552	0.264	0.132
Believe drinking water is safe	**0.004** OR: 3.06 95% CI: 1.4-6.8	0.124	0.758	0.632	0.578
Covered household drinking water	0.613	0.613	0.534	0.244	0.309
Received household training	--	--	0.234	0.607	0.557
Received group training	--	**--**	0.481	0.890	1.00
Socio-economic status quintiles (5x2)	0.140	0.161	0.645	0.595	**0.018** 5x2 (not presented)

9.7 Microbiological improvement

In Turkana, FCR, turbidity, and *E. coli* microbiological samples were collected and analyzed.

Water turbidity was higher in this emergency than in the others, as over 20% of samples were in the 10-100 NTU range (requiring a double dose of chlorine-based HWTS options) and 2.5% were above 100 NTU, which is unacceptable for chlorine-alone treatment (Table 60, Figure 35). When stratified by source the community tank systems had the lowest average turbidity, although all options had samples that were in the >100 NTU range.

Table 60: Turbidity by source (Turkana, Kenya)

	Average	Min	Max	<1 NTU	1-<10	10-100	>=100
Borehole (n=53)	28.4	0.5	228	1 (1.9)	25 (47.2)	24 (45.3)	3 (5.7)
Community tap (n=235)	7.5	0	250	126 (53.6)	81 (34.5)	25 (10.6)	3 (1.3)
River (n=69)	20.3	0.14	186	9 (13.0)	32 (46.4)	25 (36.2)	3 (4.3)
Total (n=357):	*13.0*	*0*	*250*	*136 (38.1)*	*138 (38.7)*	*74 (20.7)*	*9 (2.5)*

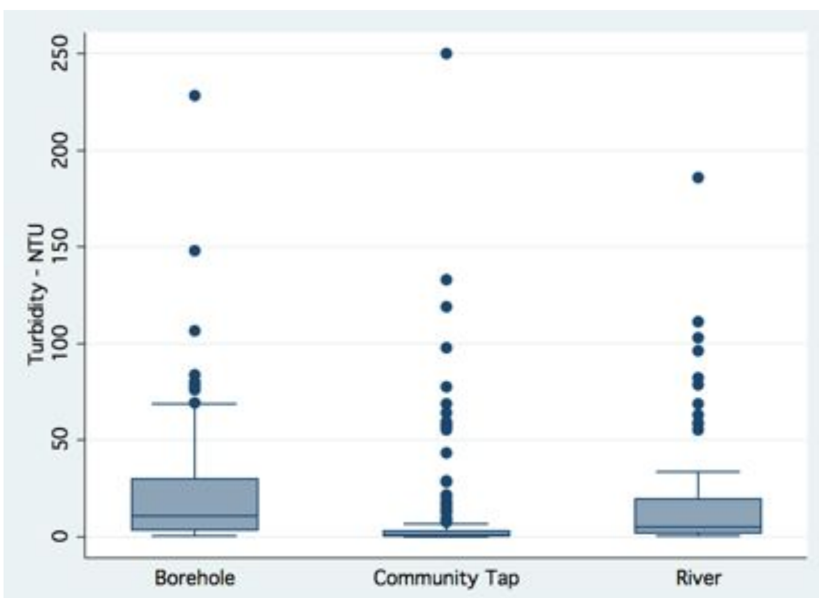


Figure 35: Turbidity by source (Turkana, Kenya)

FCR results were stratified by HWTS option received (Figure 36,

Table 61). The results are slightly unexpected, as the higher dose Aquatabs (5 mg/L 167-mg tablets as opposed to 2 mg/L 67-mg tablets) should yield a higher FCR in treated water which was not observed. In addition, PuR would be expected to provide a higher FCR than chlorination alone treatments because of the removal of organic materials that causes chlorine demand during the flocculation stage. However, this non-significant difference FCR (p=0.930) is consistent with the incorrect PuR use seen in this study, perhaps because the organic materials remain in the jerry can. Overall, 62.8% of reported treated water had adequate FCR. Further investigation into the reasons for this inconsistency is warranted.

Table 61: FCR by treatment option (Turkana, Kenya)

	Average (mg/L)	Min (mg/L)	Max (mg/L)	<0.2 mg/L	0.2-2.0 mg/L	>2.0 mg/L
Aquatabs (n=48)	0.77	0	3.5	18 (37.5)	25 (52.1)	5 (10.4)
PuR (n=22)	0.23	0	0.5	8 (36.4)	14 (63.6)	
Total (n=70)				*26 (37.1)*	*39 (55.7)*	*5 (7.1)*
Aquatabs – 67 mg (n=31)	*0.75*	*0*	*3*	*10 (32.3)*	*18 (58.1)*	*3 (9.7)*
Aquatabs – 167 mg (n=15)	*0.87*	*0*	*3.5*	*7 (46.7)*	*6 (40.0)*	*2 (13.3)*

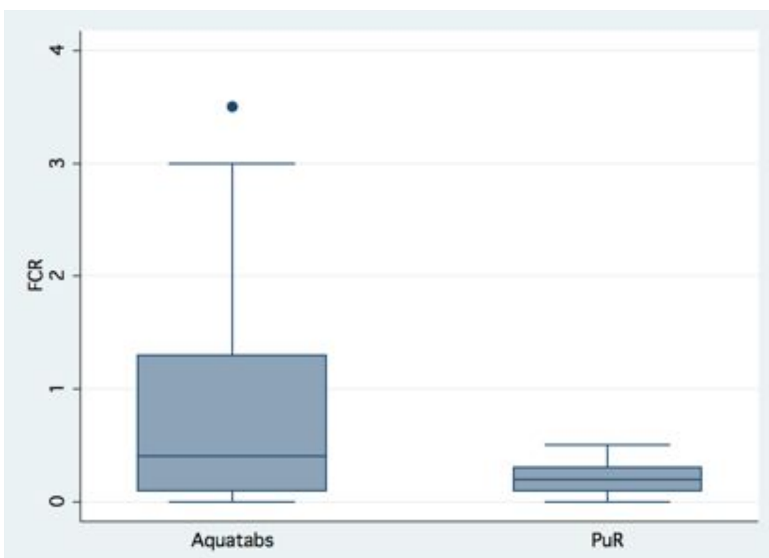


Figure 36: FCR by treatment option (Turkana, Kenya)

When turbidity was analyzed for all samples from households reporting water treatment, almost 20% of samples reported treated with PuR and Aquatabs were greater than 100 NTU and thus were not appropriate for chlorination only treatment. The average turbidity in reported PuR treated samples was higher than the average turbidity in Aquatabs treated samples. Additionally, however, the average turbidity in samples treated with 67-mg tablets was higher than 167-mg tablets, which could account for the discrepancy in the FCR results between the two options.

Table 62: Turbidity by HWTS option (Turkana, Kenya)

	Average	Min	Max	<1 NTU	1-<10	10-100	>100
Aquatabs (n=52)	14.4	0.19	111	10 (19.2)	22 (42.3)	9 (17.3)	11 (21.2)
PuR (n=24)	29.0	0.11	82.1	5 (20.8)	5 (20.8)	10 (41.7)	4 (16.7)
Total (n=76)				*15 (19.7)*	*27 (35.5)*	*19 (25.0)*	*15 (19.7)*
Aquatabs – 67 mg (n=27)	*20.3*	*0.46*	*111*	*3 (11.1)*	*15 (55.6)*	*8 (29.6)*	*1(3.7)*
Aquatabs – 167 mg (n=13)	*4.0*	*0.19*	*28.5*	*7 (53.8)*	*5 (38.5)*	*1 (7.7)*	*0 (0)*

E. coli in untreated household water samples was higher in unimproved as compared to improved sources, although this difference was not statistically significant (p=0.127). River water was the most contaminated source type.

Table 63: *E. coli* concentrations by source water (Turkana, Kenya)

CFU/100 mL	<1	1-<10	10-<100	100-<1000	≥1000
Borehole (number (%)) (n=38)	19 (50.0)	5 (13.2)	5 (13.2)	5 (13.2)	4 (10.5)
Community tap (number (%)) (n=10)	1 (10)	0 (0)	5 (50.0)	3 (30.0)	1 (10.0)
River (number (%)) (n=12)	3 (25.0)	1 (8.3)	1 (8.3)	2 (16.7)	5 (41.7)
Improved (number (%)) (n=48)	*20 (41.7)*	*5 (10.4)*	*10 (20.8)*	*8 (16.7)*	*5 (10.4)*
Unimproved (number (%)) (n=12)	*3 (25.0)*	*1 (8.3)*	*1 (8.3)*	*2 (16.7)*	*5 (41.7)*
Total (number (%)) (n=60)	*23 (38.3)*	*6 (10.0)*	*11 (18.3)*	*10 (16.7)*	*10 (16.7)*

A total of 61 treated/untreated water pairs were analyzed for *E. coli* contamination, 43 reported treated with Aquatabs and 18 reported treated with PuR. In reported treated Aquatabs water, 20 of 43 (46.5%) pair samples tested had <1 CFU/100 mL of *E. coli* before treatment, 18 of 43 (41.9%) reported samples were improved to <1 CFU/100 mL, and five of 43 (11.6%) remained contaminated. When the effective treatment percent (41.9%) is multiplied by the percent of the targeted population reporting treatment (12.7%), a population effective use percentage of Aquatabs to treat water to <1 CFU/100 mL of *E. coli* of 5.3% is calculated. When this effective use percentage is calculated considering 10 CFU/100 mL as the breakpoint, as the number of samples improved to less than 10 CFU/100 mL reduces to 15 of 43 (34.9%) in the Aquatabs reported treated samples, and the effective use percentage is thus 4.4%

In reported PuR treated samples, 4 of 18 (22.2%) pair samples tested already had <1 CFU/100 mL of *E. coli* before treatment, 7 of 18 (38.9%) were improved to <1 CFU/100 mL, and 7 of 18 (38.9%) remained contaminated. When the effective treatment percent (38.9%) is multiplied by the percent of the targeted population reporting treatment (5.9%), a targeted population effective use percentage of PuR to treat water to <1 CFU/100 mL of *E. coli* of 2.3% is calculated. There is no change in this effective use percent when considering 10 CFU/100 mL as the indicator, and the number of samples improved to less than 10 CFU/100 mL remains at 7 of 18 (38.9%), even though the already <10 CFU/100 mL increases to 7 of 18 (38.9%)

Overall, 6.7% of the target population had improved water quality to less than 10 CFU/100 mL of *E. coli* due to the KRCS HWTS distribution. Despite the improper use of PuR, PuR remained effective at reducing bacteria, and in fact accounted for a relatively higher percentage of reduction because the water treated with PuR was more contaminated before treatment. A high percentage of Aquatabs untreated water (53.5%) was uncontaminated before treatment.

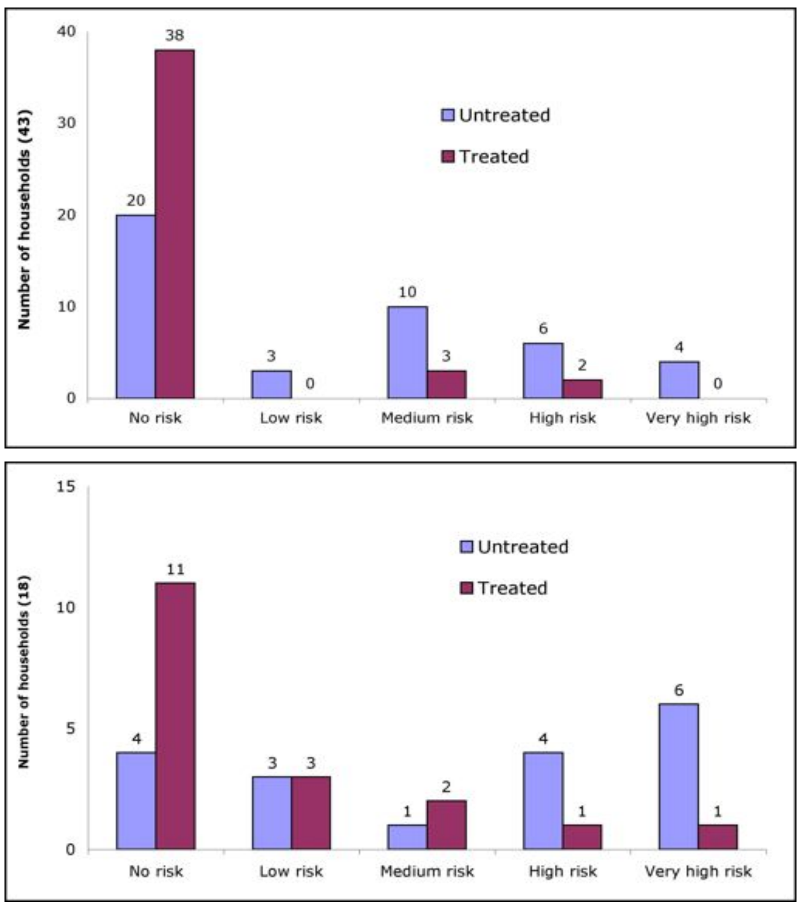


Figure 37: Treated / untreated water pairs for Aquatabs (top) and PuR (bottom) (Turkana, Kenya)

9.8 Resistance to sub-optimal use

A large problem with PuR was noted in this emergency. Without having the appropriate storage containers and supplies to use the PuR, or the training necessary to know how to use it correctly, the target population used PuR as they would Aquatabs – by adding it to water and waiting 30 minutes before drinking. This incorrect use led to discoloration of, and flocculant presence in, treated water. Of 24 samples reportedly treated with PuR collected from households, 19 (79.2%) were analyzed for presence of flocculant and 15 (78.9%) had noticeable flocculant in the sample. The use of PuR usually reduces turbidity significantly, however in this sample the average turbidity before PuR treatment was 29.0 NTU (min=0.11, max=82.1), and the average turbidity in treated water samples was 34.1 NTU (min=1.16, max=118). Although this increase in turbidity was not statistically significant by ttest (p=0.58), it is quite unusual that PuR did not reduce turbidity. Although Procter & Gamble states that no health effects would occur from ingestion of the flocculant in PuR (personal communication from Greg Allgood), the discoloration and flocculant presence could be a detriment to user adoption. Despite all this, the microbiological efficacy of PuR in this context was almost as good as that of Aquatabs (38.9% adequately treated as compared to 41.9% adequately treated with Aquatabs), indicating that even though the visual impact may be negative, the water treatment is still as effective as chlorination-alone options.

Figure 38: Incorrect use of PuR

9.9 Cost analysis

Program costs for this response were obtained from KRCS WASH staff in Nairobi. The total cost for the 2-week operation in the Turkana region, including consumables and transport and staff costs for the people normally working in the region on the existing sexual health project, was 37,750 USD. The consumable costs alone were: 400 KSH for 2 two jerry cans, 80 KSH for 2 soaps, 300 KSH for 100 Aquatabs, and 140 KSH for 20 PuR sachets. This totals 920 KSH, or 11.5 USD per household for the response at an exchange rate of 80 KSH to 1 USD. The initial assessment found that 18,300 people (or 3,050 families at 6.0 people/family) were affected by the floods. The cost to provide the WASH consumables detail above in the family kit for this amount of people would be 35,075 USD. Considering that staff costs are quite low in the region, this estimate is likely accurate.

For comparison, the costs of water supply improvements in the Turkana region were obtained from World Vision and local drillers. The cost of drilling a borehole is between 17,000 and 21,000 USD. A community tank system, such as World Vision supports, costs about 6,000 USD for construction costs and 320 USD/month for maintenance. The construction figures including a donation of pipes and water treatment materials from the Ministry of Water. The community supports tanks, cement, labor, and construction costs with the 6,000 USD outlay. This 320 USD/month maintenance fee is collected from each family, as seen in the data presented on the water costs per household in the survey responses.

Thus, the cost of the WASH emergency response distribution could have been utilized to provide two wells or about six community tank systems that could be maintained into the future.

10 Haiti Earthquake

Figure 39: Haiti map (http://en.wikipedia.org/wiki/Haiti)

Haiti occupies the Western third of the island of Hispaniola in the Caribbean (Figure 39), shared with the Dominican Republic. Haiti is the poorest country in the Americas, and suffers from political instability, environmental degradation including almost complete deforestation, food insecurity, and frequent natural disasters, including hurricanes, floods, and earthquakes.

10.1 Description of Emergency

On January 12, 2010, a 7.0 magnitude earthquake struck 17km southwest of Port-au-Prince, Haiti. Nearly one-third of Haiti's population, almost three million people, were affected by 'extreme', 'violent', or 'severe' shaking (USGS, 2010). An estimated 222,517 people died and 310,928 were injured (OCHA, 2010). This powerful quake in an area of poor quality construction materials caused extensive damage to shelters and an estimated 682,693 people were internally displaced into 433 spontaneous and transitional settlements in the Port-au-Prince and Jacmel area alone (Figure 40). Out-migration of an estimated 482,000 people from affected areas also strained resources in rural Haiti (CDEMA, 2010).

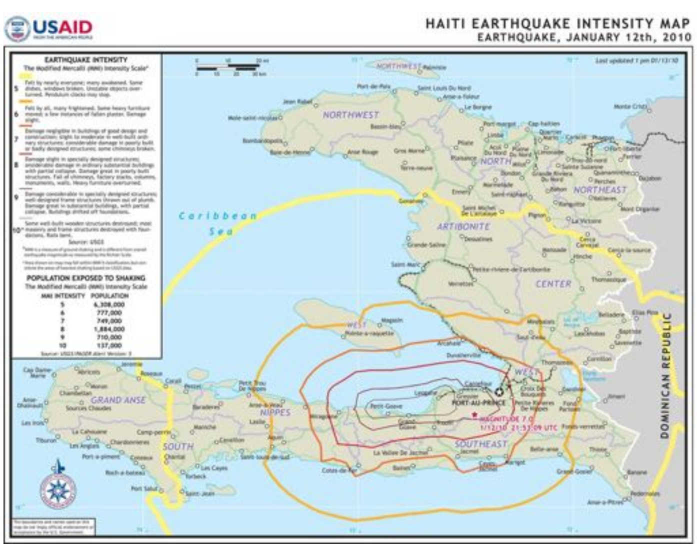


Figure 40: Earthquake intensity maps (USGS, 2010)

The immediate humanitarian response was complicated by the: 1) inability to import goods due to damage to the airport and port; 2) inability to transport goods due to rubble and temporary shelters blocking roadways; 3) loss of life and resources within humanitarian organizations; 4) communications difficulties; 5) lack of staff capacity to respond; and, 6) the overwhelming scale of the disaster. The Water, Sanitation, and Hygiene (WASH) cluster alone estimated 1.1 million people hosted in approximately 651 spontaneous settlements in Port-au-Prince, Jacmel, Gressier, Leogane, Grand Goave, and Petit Goave were in need of services (OCHA, 2010). Despite these obstacles, however, as of March 15th, within eight weeks of the disaster, 876,000 of the 900,000 people in need in the Port-au-Prince area (primarily in spontaneous settlements) had been reached with safe water supplies such as tanker trucked water, treated water, or safe water sources from government, NGO, and international agency sources.

10.2 Situational analysis and methods

Before the earthquake, numerous household water treatment and safe storage products (HWTS) were promoted in Haiti to improve microbiological quality of stored water and reduce diarrheal disease (Figure 41), including: 1) Aquatabs brand sodium dichloroisocyanurate tablets sold commercially; 2) Gadyen Dlo sodium hypochlorite solution sold in rural areas by the NGO Deep Springs International (DSI); 3) Dlo Lavi sodium hypochlorite solution socially marketed by Population Services International (PSI); 4) Klorfasil powdered sodium dichlororisocyanurate promoted in rural areas; 5) commercial bleaches or powdered HTH ('Klowoks') sold in markets; 6) Biosand filters produced locally by Clean Water for Haiti (CWH) and Pure Water for Haiti (PWH); and, 7) combined filtration/chlorination systems distributed in more than 30 rural communities by the currently inactive, but regrouping, Gift of Water (GOW). The Procter & Gamble PuR flocculant/disinfectant sachet had been socially marketed in Haiti, but was discontinued, as was a ceramic filter factory established with support from Potters for Peace. Boiling is not widely promoted in Haiti due to extensive deforestation. All of the above non-commercial projects were small, reaching a few thousand to a few tens of thousands of targeted families.

Figure 41: HWTS options available before the emergency (Haiti)

In a national survey, 45.6% of urban and 24.4% of rural populations in Haiti reported treating drinking water, the large majority (42.0% and 21.2% of respondents) by adding bleach or chlorine (MSPP, 2007), indicating widespread pre-earthquake knowledge and reported use of chlorine based HWTS options. Small percentages (0.1-3.4%) reported boiling, filtering, solar disinfection, settling & decanting, PuR, adding citrus, and other.

Following the earthquake, there was widespread interest from manufacturers and some implementers in responding with HWTS options. Upon arrival to Haiti on February 15, 2010, the field researcher identified six programs that had actually distributed HWTS in the acute emergency context, including (Figure 42):

- Before the earthquake, DSI distributed locally-manufactured safe storage containers and sodium hypochlorite via 35 community health workers (CHWs) to 1,500 families in 50 communities around Leogane. In response to the earthquake, DSI plans to distribute 15,000 systems in Leogane commune, covering 20% of urban and 80-90% of rural families. As of February 16, 2010, DSI had reached 2,880 families with safe storage containers and Aquatabs chlorine tablets through an expanded network of 165 CHW distributors.
- The Haiti Response Coalition (HRC) is a network of small-to-medium NGOs distributing donations, including an unknown number of Aquatabs, in 48 Port-au-Prince spontaneous settlements.
- FilterPure manufactures ceramic filters in the Dominican Republic and delivered 350 filters to the NGOs PWH, Guerrilla Aid, and Konpay.
- CWH is a Haitian based NGO that has distributed about 11,000 biosand filters (BSFs) over the last seven years. Within six weeks of the earthquake, CWH distributed 238 BSFs through a network of pastors-in-training to families (and some institutions) in Port-au-Prince.
- Four hundred Klorfasil bottles were flown into Haiti the week after the earthquake. Seventy were distributed in one spontaneous settlement chosen because the distributing NGO: 1) worked in that area before; 2) residents had access to water sources; and, 3) water supply aid had not yet reached the settlement.
- DSI provided Aquatabs and/or sodium hypochlorite to four former GOW communities still operating programs.

In addition, three million PuR sachets were available in Haiti. Confirmed PuR distribution occurred only by one NGO, which was unable to provide information for surveying. Over 30 million Aquatabs of various sizes were ordered specifically for the Haiti response from the manufacturer, plus many NGOs stock Aquatabs that may have been used as well. Via word-of-mouth we heard of additional Aquatabs distributions, but were unable to confirm where they occurred. Any omissions of distributed products are unintentional, and due to the difficulties in finding information in the acute emergency context. Commercial options (like Klowoks) were also available to the population after the emergency.

Figur
e 42: HWTS treatment options distributed (Haiti)

10.2.1 Spatial analysis

Coordinates from 430 (97.3%) of 442 surveyed households were collected by enumerators during the survey (Figure 43). Three coordinates (0.7%) were discarded due to improbable placement. The USGS image overlay depicts Modified Mercalli Intensity ground-shaking measurement, of 10 (highest intensity, thinnest line) to 7 moving from northwest to southeast. The legend for this figure is as follows: 1) medium blue markers indicate DSI program surveyed households that received Aquatabs and safe storage container in urban (see the red roads) and mountainous (no roads) areas; 2) spontaneous settlements that received Aquatabs distributions are the red/black bullets in Port-au-Prince; 3) surveyed families who received a ceramic filters from Konpay are in brown markers near Jacmel to the south; 4) the green markers are surveyed families that received BSF from CWH; 5) the spontaneous settlement that received Klorfasil is shown with an orange marker; and, 6) households surveyed in the rural community that was formally with GOW that received Aquatabs from DSI are shown in light blue markers. The epicenter is depicted by the red star. As can be seen, the HWTS distributions were over a large geographical area, with some options localized in one community (like the ceramic filters) and others spread over a large area (like the biosand filters).

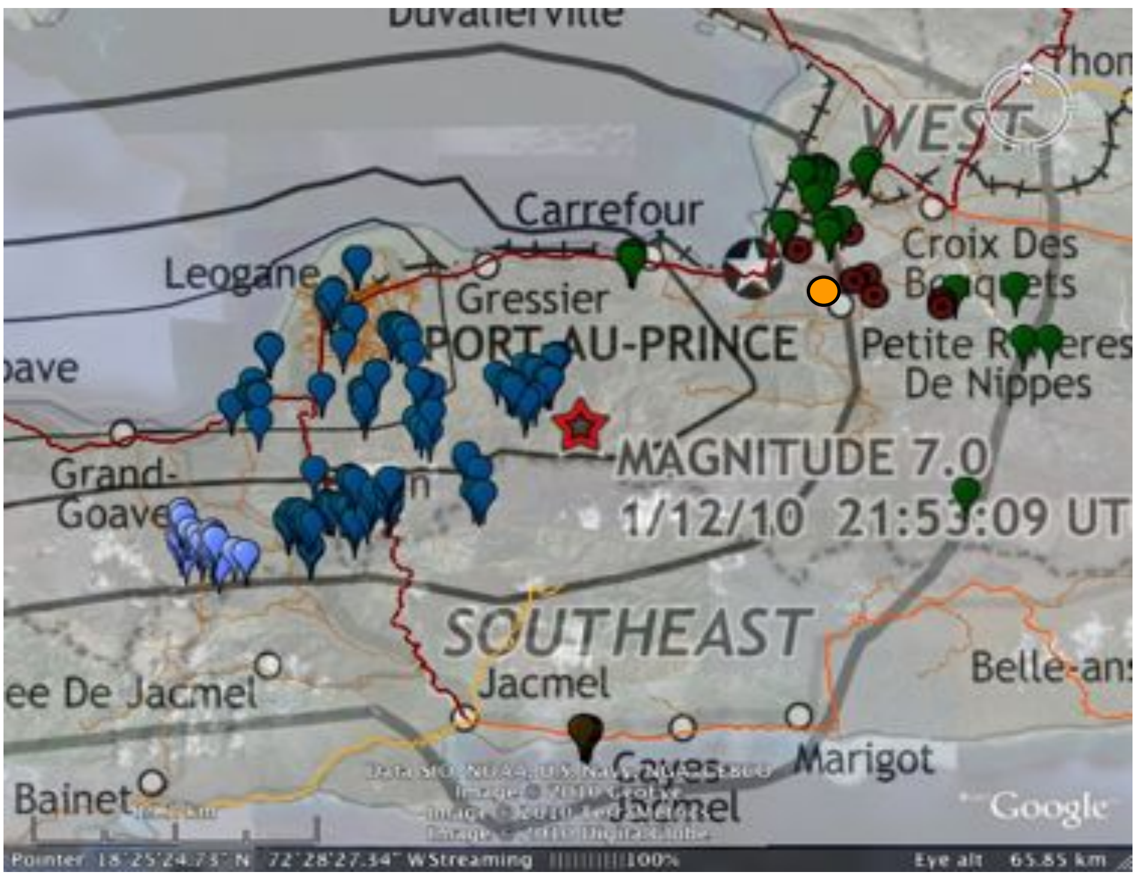


Figure 43: Map of households surveyed (Haiti)

10.2.2 Methods used in investigation

10.2.2.1 Household survey

A randomly selected sample of 442 households that had received HWTS options was conducted using a questionnaire developed by the field researcher. The survey tool was translated into Kreyol and printed before arrival in Haiti. Back-translation and pre-testing occurred during enumerator training on February 18-19, 2010, and survey changes hand-completed. The survey was administered from February 19^{th}-March 11th, 2010, and consisted of: 1) 30 questions on respondent and household characteristics, assets, diarrhea prevalence, and water knowledge and source before and after the earthquake; 2) 12-20 questions specific for each HWTS option received; and, 3) questions about, water quality testing of, and collection of, current treated and untreated stored household drinking water. The survey and water quality testing and sample collection took about 20-30 minutes per household.

We randomly selected recipients of HWTS options from each of the six programs that had distributed product during the acute emergency context for survey, including:

- **DSI Aquatabs/buckets.** Fifty of the 124 CHWs who had actually received systems for distribution were randomly selected. Enumerators contacted them, obtained a written list of recipient households, and randomly selected four households for survey. Because one CHW had not distributed, two had not received supplies, and one was not locatable, four surveys each with 44 CHWs and 3 surveys each with 2 CHWs were conducted (182 surveys).
- **HRC Aquatabs.** One to two settlements in each Port-au-Prince geographical area HRC distributed within (six settlements total) were randomly selected and convenience sampling of 10-18 families who received Aquatabs in each settlement was conducted (87 surveys total).
- **Ceramic Filters.** The NGO Konpay provided a partial list of 30 recipients, which was used by the enumerators to find and survey recipient households (43 surveys).
- **CWH BSF.** CWH provided all filter installation sheets. Every fourth filter installation data sheet (excluding institutions) was selected for survey (60 total). The enumerators surveyed 85.0% of selected households in two sampling days (51 surveys).
- **Klorfasil.** A convenience sample in the area of the spontaneous settlement present during distribution was conducted (50 surveys).
- **Former GOW Aquatabs.** Every fifth house from a list of 230 participant households obtained from the CHW in Baudin, the most earthquake affected community, was selected. Twenty-nine (72.5%) of 40 selected households were reached in one sampling day (29 surveys).

10.2.2.2 Water quality testing

The enumerators tested FCR using Hach ColorWheel test kits during the survey at any household reporting household water treatment or tanker truck water supplies and collected samples of treated water (if available) and untreated water from each surveyed household in sterile WhirlPak™ bags. The bags were stored on cold packs. The field researcher completed membrane filtration microbiological testing each afternoon/evening. The only deviations from Standard Methods included: 1) the holding time of eight hours was exceeded (to 12 hours) because of the time taken for transit each day from the survey location back to Leogane. A dedicated turbidity tester was hired to test samples within 24 hours of collection the morning after they were collected.

10.3 Qualitative interview results

Due to logistical and transportation constraints in this emergency, we were able to conduct a recorded qualitative interview with one responder, an email interview with another, and verbal informal conversations with an additional four responders.

One respondent expressed how critical it was to work with other organizations to both locate populations where HWTS was appropriate and complete a full WASH response, stating "One of the main reasons that we chose this [HWTS] as a response is because this is what we are good at, this is what we are doing prior to the emergency. And so we kind of knew we would be responding with this sort of intervention and the question was more where is that most appropriate and how do we do that" and "we have done some water distribution ... but that's not our specialty so we haven't done much" and "we are talking with other organizations that are also filling in different parts of the response", listing other groups focusing on "sanitation", "working on hand pump repair", and "doing hand pump assessments."

At the outset of the emergency "most of the progress was on tanker trucks and getting water to where it was needed and I felt that was a good, quick way to respond and I felt like that has worked so far. I think, here in Haiti, once you get outside of the city, there is not a whole lot that works other than water treatment so it's a real necessity to do that" as well. They noted that they are "specifically mostly concentrating on household water treatment and hygiene promotion," and the end, "we selected [our exact rural location], because we had stronger partners here and the networks were already in place." "I think it took some time for us to figure out where exactly we fit in, to get moving. I felt we had an advantage in that we were already on the ground and had some things in place but I wish we would have been able to get moving more quickly than we did. I think a lot of that had to do with never having been in an emergency before," but "because of the partnerships we have we are able to link into existing community networks with individuals who are already trained in a lot of different community health interventions" and that this was an advantage in responding.

The respondent stated "we selected [the HWTS option] because it's easy on transportation and has easy instructions so shortly after the earthquake we made a purchase," although also noted that the "hardest things would probably be logistics for getting things in country and getting things around where they need to go." When asked if they felt HWTS was appropriate in this emergency, they stated "I think it depends on the situations and the exact context that the people are living in. There's a lot of difference between urban and rural and camps and outside of the camp. But I do think it's appropriate because a lot of people in Haiti are used to treating the water and the point of use. And people are used to using chlorine and so this is something that fits into the local context."

This organization plans to continue to follow-up, train, monitor, and work with the rural households who received HWTS options in the emergency to see if there is "long term behavior change of families who have not been treating before, motivating them to treat now." Because they are not sure the emergency distribution is "sufficient to make this [HWTS treatment] work long term."

Numerous respondents noted that they distributed products in the first week after the earthquake, before establishment of tanker truck water distributions, and they felt these distributions were critical. Once tanker truck distribution was established they felt HWTS options were of less utility. In one situation, actually, the NGO is planning to collect distributed product and redistribute them to populations without tanker truck access). However, the respondents expect greater utility of HWTS in future once tanker truck water distribution is phased out as the emergency evolves.

One manufacturer a HWTS option expressed frustration that "the most difficult task has been to find organizations to distribute and manage programs," echoing the push that manufacturers exerted on the response in Indonesia. Another respondent expressed frustration that they would like to purchase filters that could be provided to families before the NGO left the country, but that they could not find a manufacturer anywhere who had enough filters in stock to meet their anticipated order of tens of thousands.

Lastly, one respondent stated providing Aquatabs to all people allows them control and to treat their own water, and that is a human rights issue to provide HWTS to all people in the emergency, whether or not they are receiving tanker truck water.

10.4 Survey results

Survey results are presented in Table 64 for the entire survey population and stratified by program. Differences in programs were quantified in dichotomous variables using the chi-squared test (p-values of <0.05 indicate a statistical significant difference between survey populations, but does not say which populations are different). As in other data, the denominator for total percentages is noted in the row variable description. Denominators for the program column percentages are not presented.

A total of 442 surveys were completed by five enumerators, with between 29-182 households per program. Slightly over 60% of the survey respondents were women, and the average respondent age was 38.2 with a range from 7-78 years. Respondent gender was inversely correlated with enumerator gender (p=<0.001) indicating the respondents preferentially interviewed someone of the opposite sex, rather than approach the female head of household, as requested. Respondents in spontaneous settlements were younger (34.7 years) on average than those not (39.7) (p<0.001). If the respondent was female, 77.4% had attended any school. The average school attendance was 9.2 years for those women who had attended, and 7.1 for the total female respondent population. In addition, 70.8% of female head of households could read the newspaper. There was a statistically significant higher rate of female HOH ability to read in urban Port-au-Prince areas compared to rural areas.

Over half of respondents (54.9%) reported paying for water before the emergency. This number decreased after the emergency to 39.0%. At an exchange rate of 40.25 Gourdes to 1 USD, the average monthly cost of water before the emergency was 0.62 USD, and after 0.65 USD. The maximum paid was 3.11 USD per month.

Overall, 93.7% of families had water available within 30 minutes of their home, and 98.7% covered stored household water. Adult women were responsible for collecting water in 47.7% of households, followed by girls (42.7%), boys (24.7%), and adult men (22.2%). Buckets were the preferred storage container in this environment, with 78.0% of the total survey population using them, and a higher percentage of the rural than urban population using them.

Respondents reported a significant amount of damage to homes and displacement, as 80.7% of homes were reported damaged, and 70.7% of the survey population had moved and created a new home after the emergency. People outside of Port-au-Prince and in rural areas were less likely to report damage to their home or moving after the earthquake.

While most respondents reported having received at least one HWTS option, survey eligibility was based on program participation.

Table 64: Survey results by program (Haiti)

	DSI AT/bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total	p-value
Number of households surveyed (n=442)	182 (41.2)	87 (19.7)	43 (9.7)	51 (11.5)	50 (11.3)	29 (6.6)	442 (100)	
Number (%) female respondents (n=440)	125 (68.7)	56 (64.4)	22 (52.4)	21 (41.2)	32 (64.0)	10 (35.7)	266 (60.5)	<0.001
Average respondent age in years (min-max) (n=441)	38.6 (15-75)	25.5 (7-70)	36.6 (17-69)	42.4 (19-78)	33.3 (15-56)	46.4 (17-76)	38.2 (7-78)	
Number (%) female respondents attend school (n=266)	95 (76.0)	46 (82.1)	16 (72.7)	20 (95.2)	24 (75.0)	5 (50.0)	206 (77.4)	0.095
If FR school, average (min-max) years school (n=203)	9.2 (1-19)	9.3 (2-18)	8.3 (1-15)	11.8 (4-20)	7.6 (1-17)	7.4 (3-12)	9.2 (1-20)	
All FR average (min-max) years school (n=263)	6.9 (0-19)	7.6 (0-18)	6.0 (0-15)	11.2 (0-20)	5.7 (0-17)	3.7 (0-12)	7.1 (0-20)	
Number (%) female HOH who can read newspaper (n=442)	129 (73.3)	68 (81.9)	26 (65.0)	41 (87.2)	34 (69.4)	15 (55.6)	313 (70.8)	0.015
Number (%) paid for water before emergency (n=426)	61 (34.7)	82 (95.3)	11 (27.5)	32 (65.3)	45 (91.8)	3 (11.5)	234 (54.9)	<0.001
Average water cost (Gourdes, min-max)) (n=231)	30.8 (2-75)	19.0 (1-50)	72.0 (30-125)	26.1 (1-50)	18.0 (4-70)	6.7 (5-10)	25.0 (1-125)	
Number (%) paid for water after emergency (n=428)	46 (25.8)	55 (64.7)	11 (27.5)	29 (59.2)	24 (49.0)	2 (7.4)	167 (39.0)	<0.001
Average water cost (Gourdes, min-max) (n=164)	34.1 (2-75)	16.9 (2-50)	70.5 (20-125)	25.0 (1-50)	15.8 (2-60)	5 (5-5)	26.0 (1-125)	
Hours spent daily collecting water (n=435)	1.7 (0.0-12)	0.9 (0.0-10)	0.40 (0.0-2.5)	0.5 (0.0-2.5)	2.4 (0.2-10)	1.9 (0.0-8.0)	1.4 (0.0-12)	
Number (%) with water in 30 minutes of house (n=442)	173 (95.1)	81 (93.1)	43 (100)	51 (100)	39 (78.0)	27 (93.1)	414 (93.7)	
Number (%) homes damaged by earthquake (n=441)	151 (83.0)	82 (94.3)	17 (40.5)	41 (80.4)	50 (100)	15 (51.7)	356 (80.7)	<0.001
Number (%) moved after earthquake (n=434)	115 (65.0)	84 (96.6)	7 (16.7)	38 (77.6)	50 (100)	13 (44.8)	307 (70.7)	<0.001
Number (%) with no household stored water (n=442)	1 (1.1)	29 (33.3)	5 (11.6)	10 (19.6)	3 (6.0)	10 (34.5)	59 (13.3)	
Number (%) with covered stored water (n=378)	179 (98.9)	57 (98.3)	36 (100)	40 (97.6)	46 (97.9)	15 (100)	373 (98.7)	0.919
Number (%) using buckets (n=378)	161 (91.0)	28 (48.3)	27 (71.1)	32 (78.1)	29 (64.4)	18 (94.7)	295 (78.0)	<0.001
Number (%) received HWTS option (n=442)	176 (96.7)	83 (95.4)	43 (100)	51 (100)	45 (90.0)	27 (93.1)	425 (96.2)	

The 442 households surveyed included a total of 2,528 people (average 5.8 people per household, min=1, max=24), including 287 children under 5 (average 0.6 children per household, min=0, max=5) (Table 65). Diarrhea was self-reported for 14.7% of adults, and 44.3% of children under 5. Overall, there was a small number of children per household in this emergency compared to the others.

Table 65: Survey population and reported diarrhea in last 24 hours (Haiti)

	DSI AT/ bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total
Total population (by household)	6.1 (1-24)	5.6 (1-18)	5.1 (1-10)	5.7 (1-13)	5.2 (1-11)	6.3 (2-18)	5.8 (1-24)
Under 5 population (by household)	0.9 (0-4)	0.6 (0-5)	0.2 (0-1)	0.4 (0-3)	0.7 (0-3)	0.6 (0-3)	0.6 (0-5)
% over 5 females with diarrhea	12.4	24.4	15.4	21.3	23.5	7.7	16.9
% over 5 males with diarrhea	9.7	15.8	4.8	21.8	17.3	5.6	12.1
% over 5 with diarrhea	*11.1*	*20.7*	*10.0*	*21.5*	*20.5*	*6.5*	*14.7*
% under 5 females with diarrhea	30 (41.1)	10 (43.5)	2 (40.0)	5 (50.0)	9 (50.0)	3 (42.9)	59 (44.4)
% under 5 males with diarrhea	37 (43.0)	10 (40.0)	2 (50.0)	7 (58.3)	8 (44.4)	4 (44.4)	68 (44.2)
% under 5 with diarrhea	*67 (42.1)*	*20 (41.7)*	*4 (44.4)*	*12 (54.5)*	*17 (41.5)*	*7 (43.8)*	*127 (44.3)*

Survey respondents were asked about their water source three times: 1) what source they used before the emergency; 2) if there was a change in source after the emergency, what source they used now; and, 3) in the last part of the survey, what source the actual current stored household water came from. In this emergency, as can be seen in Table 66, there was almost no difference in the use of improved sources before and after the emergency. Respondents in urban areas in Port-au-Prince and Jacmel were more likely to use improved sources than those in rural areas of Leogane.

Table 66: Improved water sources reported before, reported after, and actual in the emergency (Haiti)

	DSI AT/ bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total	p-value
Before emergency improved sources (n=432)	89 (49.4)	83 (96.5)	37 (88.1)	47 (94.0)	34 (72.3)	15 (55.6)	305 (70.6)	<0.001
After emergency improved sources (n=436)	92 (50.6)	83 (96.5)	35 (83.3)	45 (90.0)	36 (73.5)	15 (55.6)	306 (70.2)	<0.001
Actual use of improved sources (n=383)	96 (53.3)	57 (98.3)	34 (89.5)	35 (85.4)	40 (85.1)	13 (68.4)	275 (71.8)	<0.001

As can be seen from the tables below, the reason the percentage using improved sources stayed the same is that households replaced using bottled or community source improved sources (that they paid for) with provided tanker truck supplies. Thus the tanker truck distribution did not improve improved source access, it kept that percentage at the same level and decreased the financial burden on the household. The actual sources used in household stored water at the time of the unannounced survey visit are described in the water quality section later in this report.

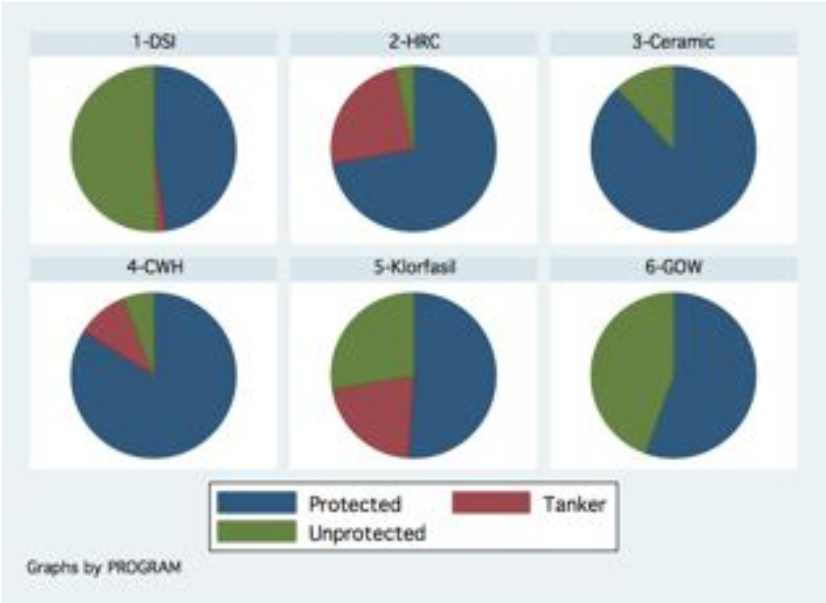
Table 67: Reported water sources before the emergency (Haiti)

	DSI AT/bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total
Community source (number (%))	71 (39.4)	42 (48.8)	18 (42.9)	32 (64.0)	11 (23.4)	12 (44.4)	186 (43.1)
Well (number (%))	1 (0.6)	3 (3.5)	2 (4.8)	4 (8.0)	2 (4.3)	0 (0)	12 (2.8)
Open well (number (%))	7 (3.9)	0 (0)	0 (0)	1 (2.0)	2 (4.3)	0 (0)	10 (2.3)
River (number (%))	4 (2.2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	4 (0.9)
Bottled water (number (%))	8 (4.4)	13 (15.1)	1 (2.4)	3 (6.0)	6 (12.8)	1 (3.7)	32 (7.4)
Unimproved spring (number (%))	80 (44.4)	3 (3.5)	5 (11.9)	2 (4.0)	11 (23.4)	12 (44.4)	113 (26.2)
Trucked water (number (%))	3 (1.7)	21 (24.4)	0 (0)	5 (10.0)	10 (21.3)	0 (0)	39 (9.0)
Improved spring (number (%))	6 (3.3)	4 (4.7)	16 (38.1)	2 (4.0)	4 (8.5)	2 (7.4)	34 (7.9)
Rainwater (number (%))	0 (0)	0 (0)	0 (0)	1 (2.0)	1 (2.1)	0 (0)	2 (0.5)
Total (n=432) (number (%))	180 (100)	86 (100)	42 (100)	50 (100)	47 (100)	27 (100)	432 (100)

Table 68: Reported water sources after the emergency (Haiti)

	DSI AT/bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total
Community source (number (%))	70 (38.5)	33 (38.4)	17 (40.5)	26 (52.0)	7 (14.3)	12 (44.4)	165 (37.8)
Well (number (%))	2 (1.1)	3 (3.5)	2 (4.8)	4 (8.0)	4 (8.2)	0 (0)	15 (3.4)
Open well (number (%))	7 (3.8)	0 (0)	0 (0)	3 (6.0)	2 (4.1)	0 (0)	12 (2.8)
River (number (%))	5 (2.7)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	5 (1.1)
Bottled water (number (%))	7 (3.8)	8 (9.3)	0 (0)	4 (8.0)	4 (8.2)	1 (3.7)	24 (5.5)
Unimproved spring (number (%))	78 (42.9)	3 (3.5)	7 (16.7)	2 (4.0)	11 (22.4)	12 (44.4)	113 (25.9)
Trucked water (number (%))	4 (2.2)	35 (40.7)	0 (0)	8 (16.0)	19 (38.8)	0 (0.0)	66 (15.1)
Improved spring (number (%))	9 (4.9)	4 (4.7)	16 (38.1)	2 (4.0)	2 (4.1)	2 (7.4)	35 (8.0)
Rainwater (number (%))	0 (0)	0 (0)	0 (0)	1 (2.0)	0 (0)	0 (0)	1 (0.2)
Total (n=432) (number (%))	*182 (100)*	*86 (100)*	*42 (100)*	*50 (100)*	*49 (100)*	*27 (100)*	*436 (100)*

As can be seen below, the rural programs with DSI and GOW targeted populations with a higher percentage of unimproved sources.



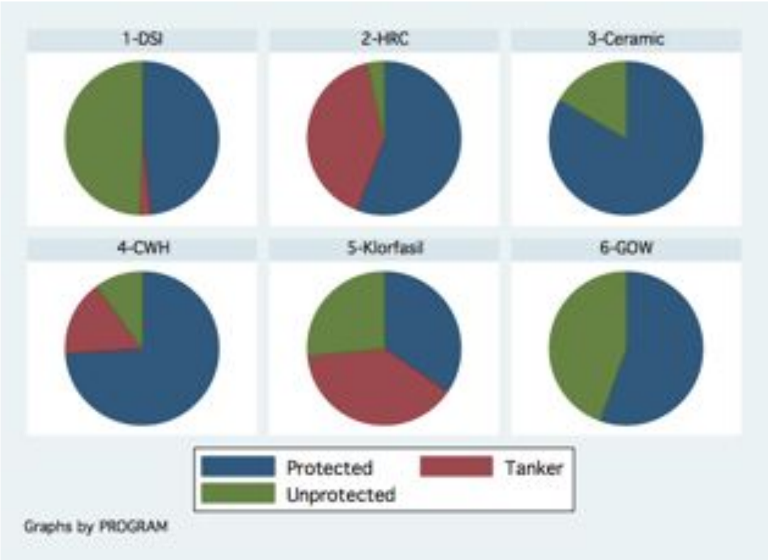


Figure 44: Before (left) and after (right) emergency reported water sources (Haiti)

Respondents were asked if they felt their water was safe to drink. The results were not significant by improved or unimproved source (p=0.151), but were significant by program (<0.001 comparing safe to unsafe) (Table 69).

Table 69: Percent of respondents who perceive their water source as safe (Haiti)

	DSI AT/ bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total
Perceived safe (number (%))	139 (76.4)	40 (46.5)	34 (79.1)	30 (58.8)	25 (50.0)	21 (72.4)	289 (65.5)
Perceived unsafe (number (%))	22 (12.1)	25 (29.1)	3 (7.0)	5 (9.8)	14 (28.0)	2 (6.9)	71 (16.1)
Don't know (number (%))	21 (11.5)	21 (24.4)	6 (14.0)	16 (31.4)	11 (22.0)	6 (20.7)	81 (18.4)

The majority of respondents who perceived their water as safe did so because the water was treated (Table 70). Respondents were more likely to answer with this response if they had been part of or exposed to the DSI or GOW program before the earthquake (p=0.029).

Table 70: Reasons respondents perceive water as safe (multiple answers possible) (Haiti)

	All		All
Water treated (number (%))	153 (53.3)	People tell me to use (number (%))	3 (1.0)
Free of microbes (number (%))	102 (35.5)	I buy it (number (%))	3 (1.0)
Water clear (number (%))	10 (3.5)	From tap (number (%))	2 (0.7)
Have always used it / familiar / everyone uses (number (%))	7 (2.4)	Good taste / not salty (number (%))	2 (0.7)
		No other water (number (%))	1 (0.3)
Doesn't make sick (number (%))	3 (1.0)	It comes from ground (%))	1 (0.3)
Totals (number)	*287*		

The majority of respondents who perceived their water as unclean did so because the "water was dirty" or it "had bacteria" (Table 71).

Table 71: Reasons respondents perceive water as unsafe (multiple answers possible) (Haiti)

	All		All
Water dirty (number (%))	20 (22.5)	Tastes bad (number (%))	4 (4.5)
Has bacteria (number (%))	20 (22.5)	Don't trust (number (%))	4 (4.5)
Is not treated (number (%))	14 (15.7)	Water truck, radio show, "clear is not clean", people died in water, salty, makes itch (number (%))	1 each (1.1% each)
Source is bad (number (%))	11 (12.4)		
Makes belly hurt / makes sick / gives diarrhea (number (%))	10 (11.2)		
Total:	*89*		

The three largest health problems self-identified in an open-ended question to respondents were food shortage (47%), diarrhea (44%), and stress (27%) (Figure 45). In addition, three respondents (0.7% each) reported blood pressure, typhoid, eye problems, and sadness; two respondents (0.5% each) reported vaginal problems, tonsils, asthma, fear, vomiting, and hygiene problems; and one respondent (0.2% each) reported microbes, traumatized, allergies, hard life, expensive life, unease, bad breath, bloody urine, hemorrhage, swelling, and social problem. Water problems were the fourth largest problem noted, at 19% of the respondents.

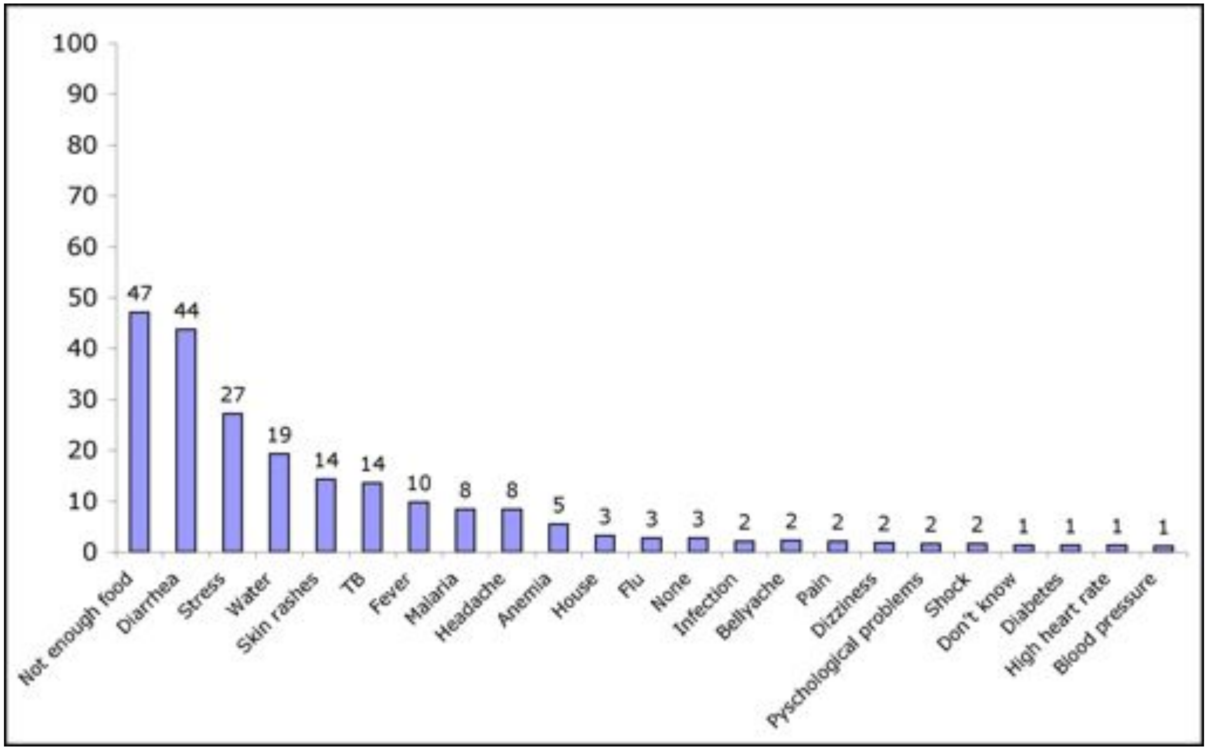


Figure 45: Percent of respondents listing health problems after the emergency (Haiti)

There was high knowledge of HWTS in this context before the emergency, with the average family reporting knowing 1.9 options, including 1.2 chlorine-based options. However, less than half of the respondents who knew the options reported using them every day. Jik and Klowoks are liquid bleach solutions and/or calcium hypochlorite sold in the market used to treat household water. Racket is a cactus sliced open and stirred in the water that is a natural flocculant. A total of 392 (88.7%) of 442 respondents self-reported knowing at least one HWTS option before the emergency.

Table 72: HWTS options known before emergency (Haiti)

	Know (n=442)	Report using (n=know)			
		Never Use	Rarely	Once per week	Daily
Aquatabs (number (%))	322 (72.9)	84 (26.3)	105 (32.9)	12 (3.8)	118 (37.0)
Boiling (number (%))	218 (49.3)	64 (29.4)	110 (50.5)	9 (4.1)	35 (16.1)
Jik / Klowoks (number (%))	148 (33.5)	19 (13.1)	73 (50.3)	9 (6.2)	44 (30.3)
Add citrus (number (%))	61 (13.8)	12 (19.7)	35 (57.4)	3 (4.9)	11 (18.0)
Gadyen Dlo (number (%))	49 (11.1)	9 (18.4)	15 (30.6)	5 (10.2)	20 (40.8)
Add racket (number (%))	24 (5.4)	10 (41.7)	13 (54.2)	1 (4.2)	0 (0)
Dlo Lavi (number (%))	17 (3.8)	10 (58.8)	3 (17.6)	2 (11.8)	2 (11.8)
PuR (number (%))	12 (2.7)	8 (66.7)	2 (16.7)	0 (0)	2 (16.7)
Filter (number (%))	9 (2.0)	3 (33.3)	3 (33.3)	0 (0)	3 (33.3)

Table 73: Average number of HWTS options known before emergency (Haiti)

	DSI AT/ bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)	Total
Average total options known (min-max)	2.1 (0-7)	1.7 (0-4)	2.0 (0-9)	2.1 (0-6)	1.5 (0-4)	2.0 (0-4)	1.9 (0-9)
Average chlorine options known (min-max)	1.3 (0-4)	1.1 (0-3)	1.2 (0-5)	1.3 (0-3)	1.1 (0-3)	1.4 (0-2)	1.2 (0-5)

10.5 Coverage

The size of the affected population in the Haiti earthquakes was estimated at three million people (517,241 households). Despite the high interest from organizations and manufacturers in HWTS use in the emergency, and large stocks of certain products available, distribution of HWTS options in the acute emergency was quite low, as only 4,618 families were confirmed by the field researcher to be reached with HWTS (Table 74). This includes 2,880 DSI systems, 350 ceramic filters, 238 biosand filters, 350 Klorfasil families, and 800 (assuming 200 families in each of the 4 GOW communities) reached with Gadyen Dlo. This is 0.77% of the 3,000,000 affected population, assuming a family size of 5. It must be noted this number is conservative, as there were Aquatabs and PuR distributions by HRC and other organizations that were unable to be quantified, as well as programs we might not have identified. However, it is clear that HWTS was not a significant response for providing safe drinking water to the affected population in the Haiti earthquake. In fact, tankering water was the primary, priority response, especially for spontaneous settlements in the Port-au-Prince area, reaching an estimated 876,000 of 900,000 people in need during the acute situation. HWTS did play a role in reaching some rural populations outside the tanker truck distribution networks drinking unimproved water sources during the acute emergency context. Also, as of this writing, the DSI program has reportedly distributed over 10,000 systems, reaching 80-90% coverage in the Leogane rural communes, and ceramic and biosand filters distributions are continuing. This suggests that modest gains in the acute emergency can lead to longer-term gains as the emergency progresses.

Table 74: Coverage of HWTS (Haiti)

	Households reached
DSI Aquatabs/bucket systems (Leogane urban and rural households)	2,880
HRC Aquatabs distribution (Port-au-Prince spontaneous settlements)	Unknown
Ceramic filters (Jacmel households)	350
Biosand filters (Port-au-Prince households)	238
Klorfasil distribution (Port-au-Prince spontaneous settlements)	350
Gadyen Dlo liquid solution to former GOW communities (rural)	800
Total:	4,618 (0.77%)

Overall, 425 (96.2%) of the 442 respondents received at least one HWTS option. There were only five families (in the Klorfasil camp) who received two options – in each case they received Aquatabs and Klorfasil). The amount of water treatment varied by program, with the DSI Aquatabs and GOW Aquatabs and Gadyen Dlo provided on a rolling basis, varying amounts targeted for the HRC Aquatabs distribution, one filter provided in the ceramic and biosand filter distributions, and one bottle of Klorfasil provided for five families in the Klorfasil distribution. One bottle of Klorfasil treats 20,206 Liters of water, or enough water for a family using 20 Liters of water per day for 510 days (1.4 years). Sharing a bottle between five families leads to each family having access to treated water for 102 days.

Table 75: Percent of respondents who received each HWTS option (Haiti)

	DSI AT/ bucket (Leogane)	HRC Aquatabs (PaP camps)	Ceramic filters (Jacmel)	CWH BSF filters (PaP)	Klorfasil camp (PaP)	GOW program (rural)
Number (%) received Aquatabs	169 (92.9)	83 (95.4)			24 (48.0)	1 (3.5)
Number (%) received Gadyen Dlo	7 (3.9)					25 (86.2)
Number (%) received Klorfasil					26 (52.0)	
Number (%) received ceramic filters			43 (100)			
Number (%) received biosand filters				51 (100)		
Number (%) received at least one product	*176 (96.7)*	*83 (95.4)*	*43 (100)*	*51 (100)*	*45 (90)*	*26 (89.7)*

10.6 Correct use

To describe knowledge and use of the HWTS options described in Haiti we will present the results by option: Aquatabs, other chlorine options, and filters.

10.6.1 Aquatabs

The majority of respondents (249 of 259 (96.1%)) received 67-mg tablets meant for treating 20 Liters at a dosage of 2 mg/L chlorine (Table 76). A few 8.5-mg tablets (4 of 259 (1.5%)) and 33-mg tablets (6 of 259 (2.3%)) meant for treating 1 Liter and 10 Liters, respectively, at a dosage of 5 mg/L chlorine were also reported by respondents. DSI and HRC only distributed the 67-mg tablets, but respondents obtained the other tablets through alternate distributions or by purchasing the Aquatabs.

Respondents reported receiving an average of 29.3 tablets (treating 586 Liters of water, or enough for one family for approximately 1 month), with a minimum of 2 and a maximum of 400 tablets received an average of 15.2 days before survey. The Aquatab use rate, calculated by subtracting the remaining from the received and dividing by the days ago received, was on average 1.72 tabs/day. Slightly over half (55.2) of respondents received group training on how to use Aquatabs, while slightly over one quarter (26.4%) received household level training. Another 15.2% reported other training (such as radio spots), and 17 respondents (6.1%) reported receiving no training.

The majority of respondents (68.4%) reported the fully correct way to use Aquatabs – adding 1 tablet to 20 Liters of water and waiting 30 minutes before drinking. If the percent of people reporting incorrect, but adequate, treatment is included, treatment knowledge rises to 83.4%. There was a higher rate of correct knowledge in the DSI rural and GOW rural programs than the urban programs ($p<0.001$).

Overall 80.4% reported they are still using the tablets, and 66.1% reported Aquatabs treated water on the day of the unannounced survey visit. There was variation (7-50%) in Aquatab use in the six HRC spontaneous settlements. If the respondents who reported running out of Aquatabs were subtracted from the denominator, the reported today use of Aquatabs rises to 90.2%. A correct FCR of between 0.2-2.0 mg/L was maintained in 76.5% of reported Aquatabs treated water, and a FCR of greater than or equal to 0.2 mg/L was maintained in 84.3% of reported Aquatabs treated water. Again, higher rates of correct and adequate treatment were seen in the DSI rural programs.

The main reason for use of the product is that it cleans the water (89.0% of respondents), and the main reason for disuse was due to running out of product (71.7%) (Table 77). No respondent reported objections to the chlorine taste and smell. Six respondents did not report receiving the Aquatabs, but indicated they had treated water with Aquatabs, indicating that they had purchased them, and this explains the disparity between the denominator of 183 respondents reporting treated and 185 respondents having FCR tested (as six who reported purchase had FCR tested and four recipients were not tested for FCR).

Table 76: Aquatabs knowledge and use (Haiti)

	DSI AT/bucket rural	DSI AT/bucket urban	HRC Aquatabs camps	Klorfasil camp	GOW rural	Total
Number (%) received Aquatabs (n=442)	104 (93.7)	65 (91.6)	83 (95.4)	24 (48.0)	1 (3.5)	277 (62.7)
Number tablets (min-max) received (n=271)	17.6 (10-70)	31.7 (10-400)	42.9 (2-360)	29.1 (10-60)	50	29.3 (2-400)
Number of days ago (min-max) received (n=239)	10.6 (1-30)	10.8 (0-36)	24.2 (1-60)	22.9 (2-50)	--	15.2 (0-60)
Number (%) reporting group training (n=277)	71 (68.3)	31 (47.7)	40 (48.2)	10 (41.7)	1 (100)	153 (55.2)
Number (%) reporting household training (n=277)	29 (27.9)	15 (23.1)	24 (28.9)	5 (20.8)	0 (0)	73 (26.4)
Number (%) reporting other training (n=277)	4 (3.8)	21 (32.3)	12 (14.5)	5 (20.8)	0 (0)	42 (15.2)
Number (%) reporting no training (n=277)	0 (0)	5 (7.7)	7 (8.4)	5 (20.8)	0 (0)	17 (6.1)
Number (%) fully correct use knowledge (n=275)	85 (81.7)	41 (63.1)	43 (53.1)	19 (79.2)	0 (0)	188 (68.4)
Number (%) incorrect but adequate (n=275)	87 (83.7)	50 (76.9)	64 (79.0)	20 (83.3)	0 (0)	221 (83.4)
Report current use (n=275)	100 (96.2)	59 (92.2)	45 (54.9)	16 (66.7)	1 (100)	221 (80.4)
Report Aquatabs treated water today (n=277)	97 (93.3)	51 (78.5)	18 (21.7)	16 (66.7)	1 (100)	183 (66.1)
AT respondents reporting other treated water (n=277)	0 (0)	0 (0)	2 (2.4)	1 (4.2)	0 (0)	3 (1.1)
Correct FCR in AT treated water (n=185)	85 (86.7)	33 (61.1)	13 (76.5)	10 (62.5)	--	141 (76.2)
FCR ≥0.2 mg/L in AT treated water (n=185)	94 (95.9)	37 (68.5)	13 (76.5)	12 (75.0)	--	156 (84.3)
Number (%) report Aquatabs treated water today if product was not finished (n=245)	100 (97.1)	59 (90.8)	45 (78.9)	16 (84.2)	1 (100)	221 (90.2)

Table 77: Reasons for use and disuse of Aquatabs (Haiti)

	Total
Use because (n=357 reasons, 218 respondents)	
Cleans water (number (%))	194 (89.0)
Prevents disease (number (%))	117 (53.7)
Instructed to do so or was given (number (%))	23 (10.6)
Water dirty after flooding (number (%))	5 (2.3)
Combats microbes (number (%))	15 (6.9)
Protects health (number (%))	3 (1.4)
Do not use because (n=46 reasons for 46 respondents)	
Product finished (number (%))	33 (71.7)
Received too recently (number (%))	7 (15.2)
Haven't bought (number (%))	2 (4.3)
Didn't do, no information, not ready, not necessary (number (%))	1 each (2.2)

10.6.2 Other chlorine options

Two other chlorine options were distributed in this emergency: 1) Gadyen Dlo, a bottle of liquid sodium hypochlorite solution where users add one cap to a 20-Liter bucket and wait 30 minutes before drinking distributed to families who were familiar with the product before the emergency; and, 2) Klorfasil powdered sodium dichloroisocyanurate in a bottle with a dispensing cap that is manipulated to obtain the correct number of grains for the 20-Liter bucket distributed in one spontaneous settlement in Port-au-Prince by the promoter of Klorfasil who flew to Haiti with bottles.

For the Gadyen Dlo, all respondents reported receiving some training, and all had adequate knowledge of how to use the product (Table 78). The majority reported current use (69.2-85.7%), and using the product today (69.2-71.4%), and all reported users had adequate FCR. Please note that FCR for users of Gadyen Dlo in the GOW community is not reported because the users filter the water after chlorination, which removes the FCR. Also, it must be stated that the sample size here becomes quite small, and not representative.

For the Klorfasil respondents, 11.5% received no training, and while 91.7% reported current use, only 50% reported using the product to have stored treated household water today. Five (19.2%) of respondents were using Aquatabs for treating water instead. Eight (66.7%) of 12 reported users had correct FCR in their drinking water. Again, the sample size here is quite small.

The majority of respondents for both Gadyen Dlo (84.2%) and Klorfasil (95.5%) use the products because they treat the water, and the non-users reported the product was finished (Table 79).

Table 78: Gadyen Dlo and Klorfasil knowledge and use (Haiti)

	Gadyen Dlo		Klorfasil
	DSI AT/bucket	GOW Rural	Klorfasil camp
Number (%) received option (n=HH surveyed)	7 (3.9)	25 (86.2)	26 (52.0)
Number of days ago (min-max) received (n=recipients)	29.9 (15-60)	24.1 (12-60)	--
Number (%) reporting group training (n=recipients)	4/7 (57.1)	8/13 (61.5)	8/26 (30.8)
Number (%) reporting household training (n=recipients)	3/7 (42.9)	5/13 (38.5)	9/26 (34.6)
Number (%) reporting other training (n=recipients)	0/7 (0)	0/13 (0)	6/26 (23.1)
Number (%) reporting no training (n=recipients)	0/7 (0)	0/13 (0)	3/26 (11.5)
Number (%) fully correct use knowledge (n=recipients)	7/7 (100)	10/13 (76.9)	--
Number (%) incorrect but adequate (n=recipients)	7/7 (100)	13/13 (100)	--
Report current use (n=recipients)	6/7 (85.7)	9/13 (69.2)	22/24 (91.7)
Report option treated water today (n=recipients)	5/7 (71.4)	9/13 (69.2)	13/26 (50.0)
Recipients reporting other treated water (n=recipients)	0 (0)	0 (0)	5/26 (19.2)
Correct FCR in treated water (n=treated)	4/5 (80)	--	8/12 (66.7)
FCR ≥0.2 mg/L in AT treated water (n=treated)	5/5 (100)	--	8/12 (66.7)
Number (%) report treated water today if product was not finished (n=recipients)	5/7 (71.4)	9/11 (81.8)	13/26 (50.0)

Table 79: Reasons for use and disuse of Gadyen Dlo and Klorfasil (Haiti)

Gadyen Dlo		Klorfasil	
Use because (n=30 reasons, 19 respondents)		*Use because (n=32 reasons, 22 respondents)*	
Cleans water (number (%))	16 (84.2)	Cleans water (number (%))	21 (95.5)
Prevents disease (number (%))	9 (47.4)	Prevents disease (number (%))	9 (40.9)
Instructed to do so or was given (number (%))	4 (21.1)	Instructed to do so or was given (number (%))	1 (4.5)
Water dirty after flooding (number (%))	1 (5.3)	Combats microbes (number (%))	2 (9.1)
Do not use because (n=2 reasons for 2 respondents)		*Do not use because (n=1 reason for 1 respondent)*	
Product finished (number (%))	2 (100)	Product finished (number (%))	1 (100)

10.6.3 Filtration options

Haiti was the only emergency where we documented filtration options being distributed, and although the relative numbers were small, we were pleased to include these options in the study. All recipients of both the ceramic and biosand filters received some type of training, and 95.2% and 90.2%, respectively, reported they were still using the filters. However, 72.1% and 52.9%, respectively, were using the filters on the day of the unannounced survey visits. No recipient of a filter was using another option to treat their water. The main reason for use was cleans water (94.9% and 73.0%) and the disuse was due one of the ceramic filters breaking and the biosand filter families not having water. In addition, during the household visits some families who received the biosand filter complained of sand running through into the water, which will be discussed in the next section.

Table 80: Filter knowledge and use (Haiti)

	Ceramic filters	Biosand filters
Number (%) received filter (n=program)	43 (100)	51 (100)
Number of days (min-max) ago received	No data	No data
Number (%) report group training (n=recipients)	36 (83.7)	28 (54.9)
Number (%) report household training (n=recipients)	7 (16.3)	18 (35.3)
Number (%) report other training (n=recipients)	0 (0)	5 (9.8)
Number (%) report no training (n=recipients)	0 (0)	0 (0)
Number (%) report currently still using (n=recipients)	40/42 (95.2)	46/51 (90.2)
Number (%) report filter treated water today (n=recipients)	31/43 (72.1)	27/51 (52.9)
Number (%) filters recipients reporting other treatment (n=recipients)	0 (0)	0 (0)

Table 81: Reasons for filter use and disuse (Haiti)

Ceramic Filters		Biosand Filters	
Use because (n=51 reasons, 39 respondents))		*Use because (n= 63 reasons, 46 respondents)*	
Cleans water (number (%))	37 (94.9)	Cleans water (number (%))	46 (100)
Prevents disease (number (%))	8 (20.5)	Prevents disease (number (%))	11 (23.9)
Instructed to do so or was given (number (%))	1 (2.6)	Instructed to do so or was given (number (%))	2 (4.3)
Combats microbes (number (%))	4 (10.3)	Combats microbes (number (%))	2 (4.3)
Protects health (number (%))	1 (2.6)	Water dirty after flooding (number (%))	2 (4.3)
Do not use because (n=1 reasons for 1 respondent)		*Do not use because (n=3 reasons for 3 respondents)*	
Product broke (number (%))	1 (100)	Don't have water (number (%))	3 (100)

10.6.4 Comparative analysis

Overall, respondents self-reported current use of HWTS options in: 92% of rural section DSI households (88% with Aquatabs, 4% with Gadyen Dlo), and 75% in urban section households (Aquatabs); 24% of HRC households (22% Aquatabs, 2% marketed chlorine products); 53% of CWH households; 72% of FilterPure households; 66% of Klorfasil spontaneous settlement households (26% Klorfasil, 34% Aquatabs, 6% marketed chlorine options), and 52% of GOW households (3% Aquatabs, 38% Gadyen Dlo, and 7% marketed chlorine options). In total, 11/442 (2.5%) households treated water with a HWTS they had not received as part of emergency response distribution, including five families who used Aquatabs, one family using Jik liquid chlorine, one family using Klowoks chlorine powder, and two families using an alternate tablet called PYAM.

As only five surveyed families in the Haiti emergency received more than one HWTS option, comparative analysis cannot be completed in this context. In addition, because each of the populations that were targeted by the programs were so different, and so geographically dispersed, it is not possible, as it was in Nepal and Turkana, to calculate a total number of the affected population that had treated water because of this intervention. We therefore use the number of targeted respondents in each of the programs who have treated water at the time of the unannounced visit, but adjust to account for what percentage of the respondents are adequately treating their water by multiplying the percent of people who report treatment by the percent of those who report treatment who have adequate residual (Table 82). That provides a number showing the percent of the recipient population with adequate residual.

Table 82: Adequate FCR in respondents by program (Haiti)

	% of recipients reporting use	% of those reporting use with adequate FCR	% of recipients with adequate FCR
Aquatabs (DSI-rural)	93.3	95.9	89.5
Aquatabs (DSI-urban)	78.5	68.5	53.8
Aquatabs (HRC camps)	21.7	76.5	16.6
Aquatabs (Klorfasil camp)	66.7	75.0	50.0
Gadyen Dlo (DSI)	85.7	100	85.7
Klorfasil (Klorfasil camp)	50.0	66.7	33.5

10.6.5 Univariate analysis

In Haiti, the outcome variables of interest include the dichotomous variables of reporting water treatment, having FCR greater than or equal to 0.2 mg/L in drinking water, or having a minimum of a 1-log (90%) reduction in *E. coli* in untreated water. Because of sample size considerations we could only complete this analysis on the DSI sampled households that received Aquatabs. The variables we postulated might impact the outcome variables in this circumstance include: whether or not the female respondent had gone to school or the female head of household could read, whether the household was damaged in the earthquake, if the family lived in the same place as before the earthquake, in the household used improved water sources, if the respondent knew a chlorine option before the emergency, if diarrhea was reported in the household or in children in the household, whether diarrhea was considered a health problem after the emergency, whether the household believes drinking water is safe, whether the household covered their storage container, whether the household received group training or household training, and the socio-economic status of the household.

Results from a univariate analysis shows that respondents in the whole dataset were more likely to report treated water if: 1) they had moved after the earthquake; 2) they used an unimproved source; and, 3) they felt their water was safe (the causality on this is likely the other way – they felt their water was safe because it was treated).

The only data set we had sample size on was the DSI distributions to calculate relationships between the outcomes of FCR, microbiological effectiveness, and inputs. Being in lower SES quintiles and using unimproved sources was associated with having FCR in drinking water, indicating correct targeting to at-risk populations in the DSI program. Households with at least a 90% (1-log) reduction of *E. coli* from untreated to treated drinking water reported less diarrhea in the household as well (although the confidence interval of this result crossed over 1).

Socio-economic status quintiles were developed using principal component analysis based on household assets (including beds, bicycles, motorcycles, car/trucks, radios, televisions, mobile phones, refrigerators, generators, poultry, donkey, cow, and sheep/goat ownership and having part of your house (roof, walls, or floor) constructed out of non-natural non-temporary materials in the DSI sub-population only. We will continue to work to develop this model further to predict behavior, however further development is outside the scope of this report.

Table 83: Univariate analysis results (Haiti)

	Reported treated (whole dataset)	FCR (DSI only)	*E. coli* improved (DSI only)
Female respondent attend school	0.807	0.913	0.859
Female HOH able to read	0.857	0.721	0.359
Home damaged in earthquake	0.411	0.430	0.210
Live in the same place as before earthquake	**0.001** OR: 2.16 95% CI: 1.3-3.5	0.502	0.777
Use improved source	**<0.001** OR: 0.16 95% CI: 0.1-0.4	**0.003** OR: 0.20 95% CI: 0.1-0.7	0.111
Knew chlorination before emergency	0.642	0.969	0.142
Diarrhea reported in household	0.754	0.194	**0.045** OR: 0.53 95% CI: 0.2-1.4
Diarrhea reported in children in household	0.148	0.831	0.347
Believe drinking water is safe	**<0.001** OR: 2.88 95% CI: 1.6-5.0	0.156	0.738
Covered household drinking water	0.499	0.693	0.453
Received household training	0.437	0.467	0.953
Socio-economic status quintiles (5x2)	--	**0.003** 5x2 – not shown	0.212

10.7 Microbiological improvement

In Haiti, FCR, turbidity, and *E. coli* microbiological samples were collected and analyzed.

Water turbidity was low across all sources used for drinking water in this emergency (Table 84, Figure 46). Untreated water samples were obtained from 316 of 442 (71.5%) of surveyed households. Of the 128 households surveyed without an untreated water sample collected, 35 (27.3%) were because there was only treated water in the household, 59 (46.1%) were because there was no water at all in the households, and 34 (26.6%) were because the enumerator did not collect the untreated sample if there was not a matched treated sample and/or the household did not provide an untreated sample. It is possible that in these 34 households there was no water in the house at the time of the visit, but that should have been marked differently on the survey form.

Turbidity was sampled in 299 of the 316 collected untreated samples (67.6% of total households surveyed). Only 10 samples were above 10 NTU (3.3%), indicating the need for either a double chlorine dosage or filtration prior to disinfection. These ten higher turbidity levels were from tanker trucks (3), improved spring (1), unimproved springs (1), and community sources (4). Treated-untreated sample pairs were available for 29/31 (93.5%) and 23/27 (85.2%)

households reporting ceramic and biosand filter use, respectively. No significant turbidity reduction was noted after ceramic filtration, with untreated and treated water samples of average 2.0 and 3.4 NTU, respectively (p=0.316). A significant increase in turbidity was noted in BSF treated water (p=0.015) with untreated and treated water samples of average 1.4 and 2.9 NTU, respectively, attributed to the sand flowing into the water from the filter. These levels of turbidity are all below the <5 NTU WHO guideline value for drinking water, and thus an impact of the filters on turbidity is not meaningful here.

Table 84: Turbidity by source (Haiti)

	Average	Min	Max	<1 NTU	1-<10	10-100	>=100
Unimproved (n=92)	1.3	0	11.0	54 (58.7)	37 (40.2)	1 (1.1)	0 (0)
Improved (n=161)	1.6	0	20.5	95 (59.0)	60 (37.3)	6 (3.7)	0 (0)
Tanker trucks/bottled (n=46)	2.8	0	33.0	21 (45.7)	22 (47.8)	3 (6.5)	0 (0)
Total (n=299):	*1.7*	*0*	*33*	*170 (56.9)*	*119 (39.8)*	*10 (3.3)*	0 (0)

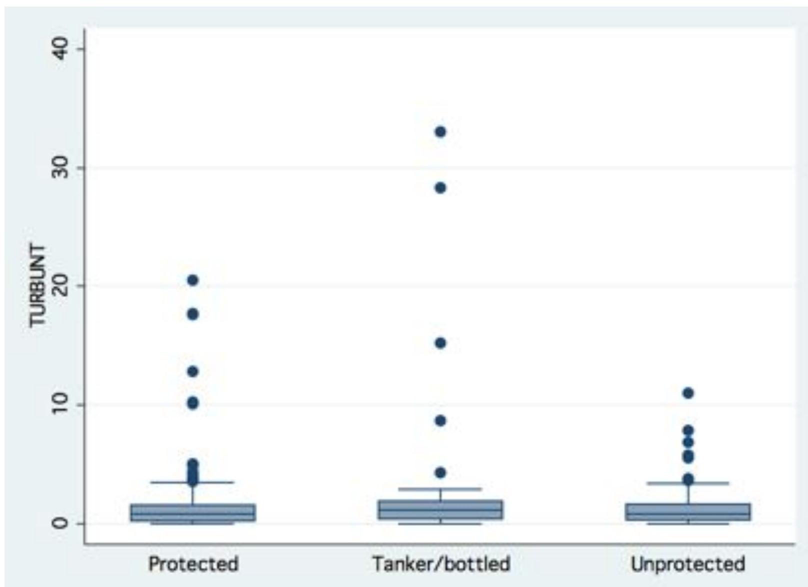


Figure 46: Turbidity by source (Haiti)

FCR results were stratified by HWTS option received. As can be seen below (Table 85, Figure 47), both Aquatabs and Gadyen Dlo samples tested generally fell within the recommended range of 0.2-2.0 mg/L FCR. Water treated with Jif / Klowoks / PYAM had a wide range of FCR, likely because there is no consistent dosage for these products, and Klorfasil tended to a slight underdose, likely due to users not using the product correctly (the actual dose should be 3.75 mg/L). Please note that chlorine-treated water samples from the GOW program households surveyed (which employs filtration after chlorination) were not included in this analysis because the filtration reduces chlorine residual in the treated water. Overall, 83.1% of reported treated water had adequate FCR.

Table 85: FCR by treatment option (Haiti)

	Average (mg/L)	Min (mg/L)	Max (mg/L)	<0.2 mg/L	0.2-2.0 mg/L	>2.0 mg/L
Aquatabs (n=185)	1.0	0.0	3.5	29 (15.7)	141 (76.2)	15 (8.1)
Gadyen Dlo (n=5)	1.2	0.5	2.5	0 (0)	4 (80.0)	1 (20.0)
Klorfasil (n=12)	0.5	0	1.5	4 (33.3)	8 (66.7)	0 (0)
Jif / Klowoks / PYAM (n=5)	1.5	0	3.5	2 (40.0)	1 (20.0)	2 (40.0)
Total (n=207)	*1.0*	*0*	*3.5*	*35 (16.9)*	*154 (74.4)*	*18 (8.7)*

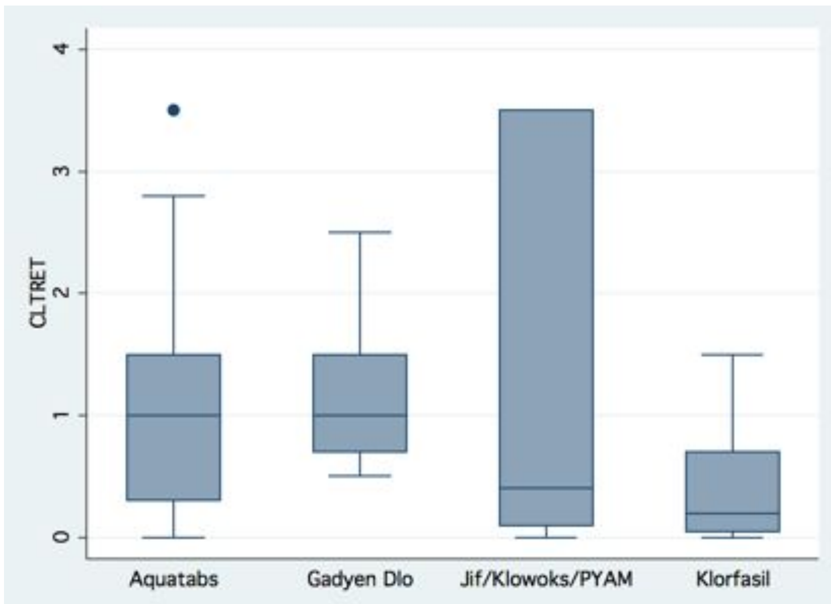


Figure 47: FCR by treatment option (Haiti)

E. coli contamination in improved sources (average 88 CFU/100 mL, min=0, max=1000, stdev=187) was significantly lower (p<0.001) than unimproved sources (323 CFU/100 mL; min=0, max=1800, stdev=503) (Table 86, Figure 48). The 14 of 25 tanker truck samples with *E. coli* contamination ranged from 14-1000 CFU/100 mL. FCR was 0 mg/L in 17 of 22 (77.3%) untreated tanker truck water samples. Overall, 27.5% of samples had no *E. coli* contamination.

Table 86: *E. coli* concentrations by source water (Haiti)

CFU/100 mL	<1	1-<10	10-<100	100-<1000	>=1000
Community source (number (%)) (n=80)	22 (27.5)	17 (21.2)	21 (26.3)	16 (20.0)	4 (5.0)
Well (number (%)) (n=5)	1 (20.0)	0 (0)	2 (40.0)	2 (40.0)	0 (0)
Open well (number (%)) (n=3)	1 (33.3)	0 (0)	1 (33.3)	0 (0)	1 (33.3)
River (number (%)) (n=1)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)
Unimproved spring(number (%)) (n=33)	6 (18.2)	5 (15.2)	10 (30.3)	5 (15.2)	7 (21.2)
Trucked water (number (%)) (n=17)	6 (35.3)	1 (5.9)	5 (29.4)	3 (17.7)	2 (11.8)
Improved spring (number (%)) (n=13)	6 (46.2)	4 (30.8)	2 (15.4)	1 (7.7)	0 (0)
Rainwater (number (%)) (n=1)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)
Improved (number (%))(n=116)	*35 (30.2)*	*22 (19.0)*	*31 (26.7)*	*22 (19.0)*	*6 (5.2)*
Unimproved (number (%)) (n=37)	*7 (18.9)*	*5 (13.5)*	*12 (32.4)*	*5 (13.5)*	*8 (21.6)*
Total (number (%)) (n=153)	*42 (27.5)*	*27 (27.7)*	*43 (28.1)*	*27 (17.7)*	*14 (9.2)*

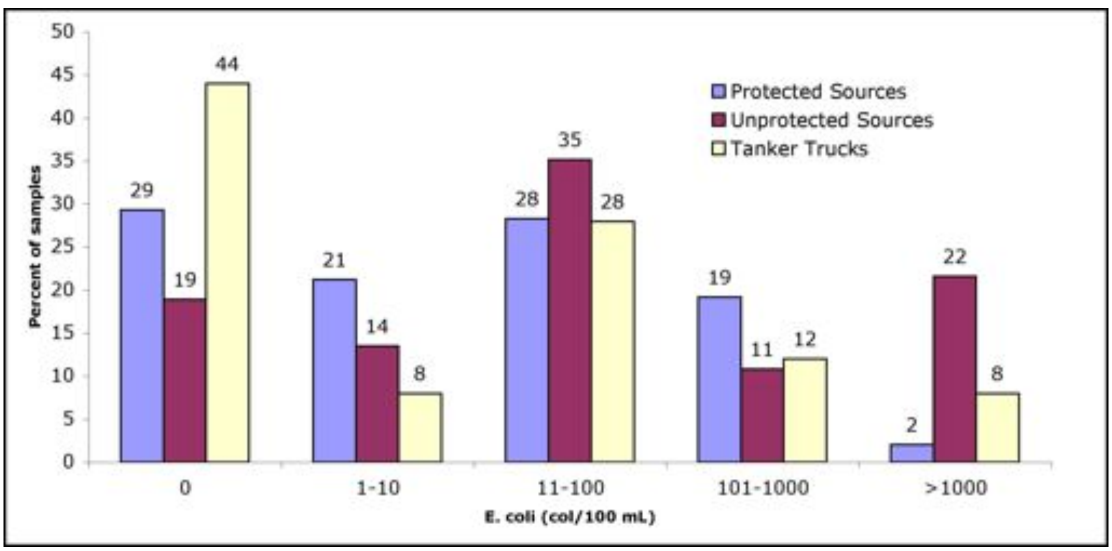


Figure 48: *E. coli* contamination in source waters (Haiti)

A total of 143 treated/untreated water pairs were analyzed for *E. coli* contamination. Five samples were completed in Jik or PYAM or unknown water treatment, which leaves 138 samples remaining. First, the percent of samples treated with HWTS options that were uncontaminated before treated, as well as the percent of samples that became <1 CFU/100 mL after treatment, and that moved from above 10 CFU/100 mL before treatment to below 10 CFU/100 mL after treatment, is presented. As can be seen, over 85% of samples were contaminated in the DSI and HRC Aquatabs programs, allowing the Aquatabs to reduce the microbiological contamination significantly. There was very little contamination in the ceramic filter households before treatment, lowering their efficacy significantly.

Table 87: Microbiological effectiveness of treatment (Haiti)

	% samples uncontaminated at <1 CFU/100 mL	% reducing contamination to <1 CFU/100 mL	% samples uncontaminated at <10 CFU/100 mL	% reducing contamination from ≥10 to <10 CFU/100mL
Aquatabs - DSI (n=58)	8/58 (13.8)	42/58 (72.4)	21/58 (36.2)	33 (56.9)
Aquatabs – HRC (n=13)	1/13 (7.7)	8/13 (61.5)	5/13 (38.5)	6/13 (46.2)
Aquatabs – GOW/Klorfasil (n=4)	4/4 (100)	0/4 (0)	4/4 (100)	0/4 (0)
Gadyen Dlo (n=10)	4/10 (40)	3/10 (30)	6/10 (60)	1/10 (10)
Klorfasil (n=5)	2/5 (40)	2/5 (40)	2/5 (40)	2/5 (40)
Ceramic Filters (n=29)	16/29 (55.2)	8/29 (27.6)	22/29 (75.9)	6/29 (20.7)
Biosand Filters (n=19)	3/19 (15.8)	3/19 (15.8)	4/19 (21.1)	7/19 (36.8)

By multiplying the percent of respondents who reported using the product, by the percent of effective use as shown above, we can calculate the percent of recipients who adequately treated their water to reduce microbiological contamination with each option (Table 88, Figure 49). As can be seen in the table below, the most effective use was seen in the DSI program, which combined high product use with high microbiological contamination in untreated waters. Note there are slight differences in the effective treatment percentages depending on which metric is used, either reduced contaminated water to <1 CFU/100 mL or reduced contaminated water over 10 CFU/100 mL to below 10 CFU/100 mL. Gadyen Dlo percentages are not presented due to small sample size.

Table 88: Effective use of HWTS options (Haiti)

	% recipient households reporting use	% reducing contamination to <1 CFU/100 mL	% effective use to <1 CFU/100 mL	% reducing from >10 to <10 CFU/100mL	% effective use to <10 CFU/100 mL
Aquatabs - DSI (urban, rural) (n=58)	78.5-93.3	72.4	**56.8-67.5**	56.9	**44.7-53.1%**
Aquatabs – HRC (n=13)	21.7	61.5	**13.0%**	46.2	**10.0%**
Aquatabs – GOW/Klorfasil (n=4)	--	0	**--**	0	**--**
Gadyen Dlo (n=10)	--	30	**--**	10	**--**
Klorfasil (n=5)	50.0	40	**10.0%**	40	**10.0%**
Ceramic Filters (n=29)	72.1	27.6	**19.8%**	20.7	**10.8%**
Biosand Filters (n=19)	52.9	15.8	**8.4%**	36.8	**19.5%**

Overall, when calculated by program looking at all the different options recipients used in each of the programs 59% of DSI-rural, 50% of DSI-urban, 15% of HRC, 8% of CWH, 20% of FilterPure, 10% of Klorfasil, and 13% of GOW surveyed households were using the HWTS option they received to reduce *E. coli* to international standards in their drinking water at the time of the unannounced survey.

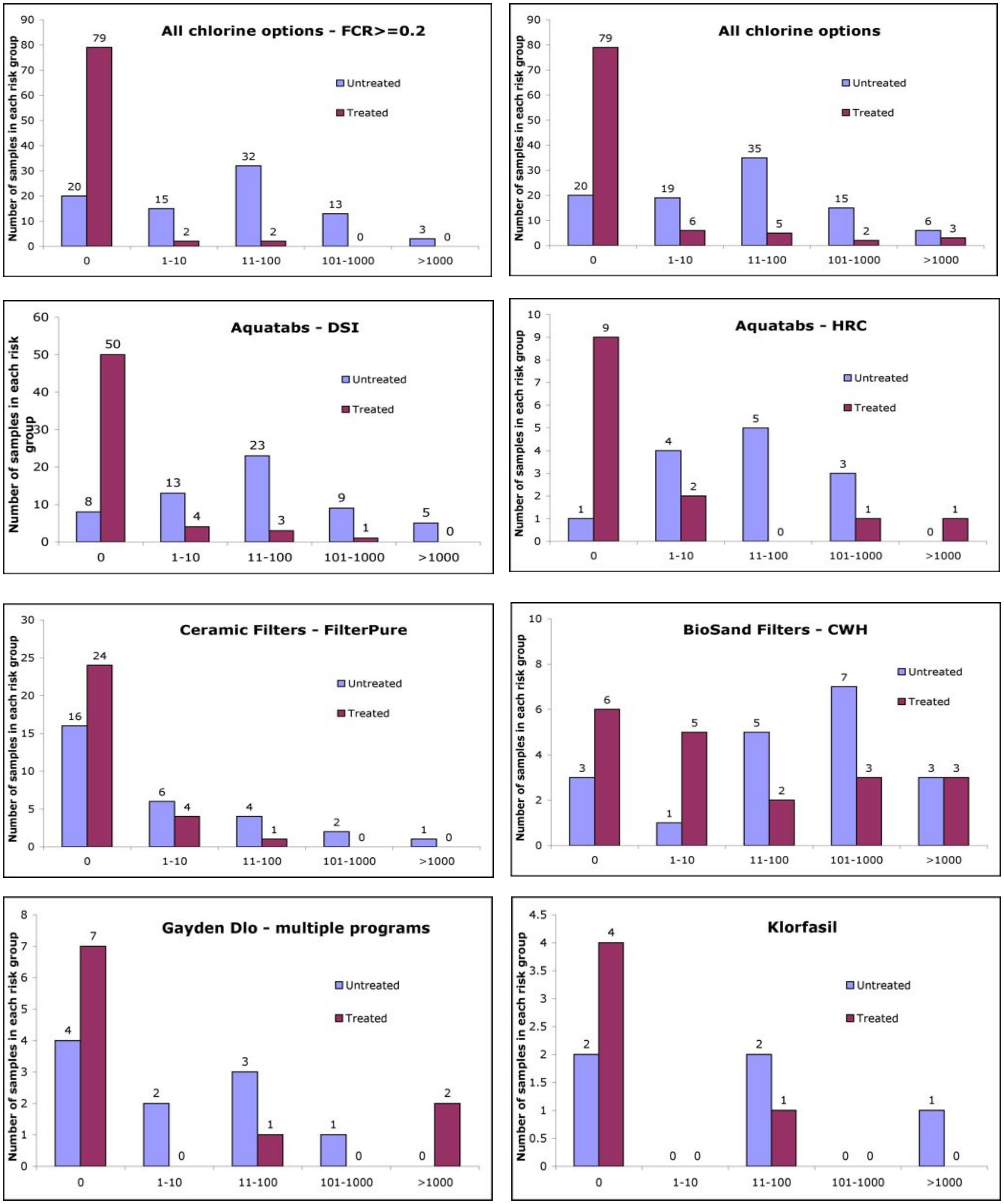


Figure 49: Treated / untreated water pairs for HWTS options (Haiti)

10.8 Resistance to sub-optimal use

The only sub-optimal use issue seen in the Haiti earthquake response was the respondents who mentioned they had stopped using their biosand filter due to sand flowing out of the filter. Upon investigation, we found that the filters were installed incorrectly, with no standing water level to allow the development of a schmutzdecke for increased microbiological performance compared to normal sand filters. This would explain the lack of microbiological reduction seen. In addition, the user complaints about sand flowing out of the tap is probably due to incorrect installation of the screen or gravel layer. This is not the users using the product sub-optimally, but the installers failing to assembly the product properly. Because the recipients were over such a large geographical area and the product requires some technical precision in assembly, it was not possible to for them to fix the product on their own or obtain technical support.

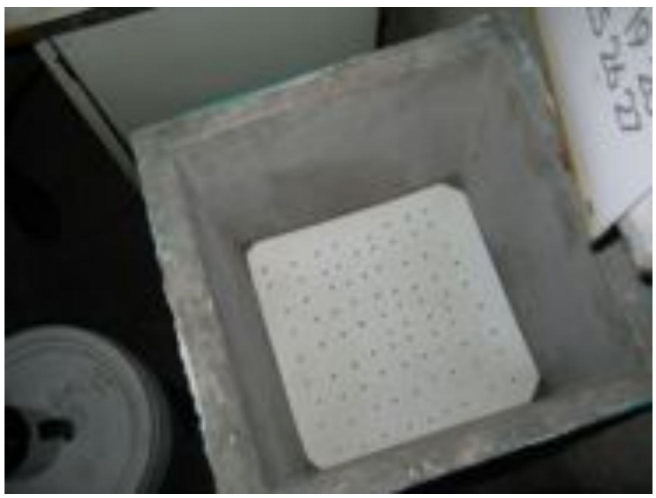


Figure 50: Improperly installed biosand filter (Haiti)

10.9 Cost analysis

Cost data was generally unavailable within the context of the Haiti earthquake response. Equipment and supplies for all of the HWTS projects – the Aquatabs order from Ireland that DSI purchased and provided to HRC, the ceramic filters from the DR, the Klorfasil, the additional generators to make Gadyen Dlo – were all flown into the emergency via volunteer small planes landing on makeshift airstrips throughout the country. Transportation and logistics costs were high, but not especially able to be accounted. DSI estimates installation of one system is 15 USD and the cost of one filter from FilterPure is about 25 USD. An NGO reported tanker truck water cost of 29 USD/1000 Liters of delivered water. Assuming that a HWTS option can produce 20 Liters of water per day, it becomes more cost-efficient to use HWTS after 25.9 days in the case of a DSI system (excluding consumable costs of 10 US cents per month after the initial three month supply including in the 15 USD installation cost) or 43.1 days for the ceramic filter. However, this does not account for the benefits of centrally treated water, rather than depending on each individual family to treat their own water.

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