Point of Use Water Treatment in Emergency Response

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Disclosure of Interest. Daniele Lantagne completed this work as an employee of the London School of Hygiene & Tropical Medicine (LSHTM), and Thomas Clasen is also an employee of LSHTM. LSHTM has been engaged by manufacturers and distributors of Point of use water treatment (PoUWT) 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): Bulk sodium hypochlorite solution being prepared for distribution in Myanmar cyclone (PSI/Myanmar), safe storage of boiled water in Burmese Refugee Camp (Lantagne/CDC), rural woman in western Kenya using PuR (Allgood/P&G), and variety of PoUWT products distributed by all actors in Pakistan earthquake (MSF/Belgium). Used with permission.

POINT OF USE WATER TREATMENT IN EMERGENCY RESPONSE

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EXECUTIVE SUMMARY

An estimated 4 billion cases of diarrhea each year, causing 1.8 million deaths mainly among children under five years of age, are caused by unsafe drinking water, poor sanitation, and poor hygiene. In the development context, five point-of-use water treatment (PoUWT) options - chlorination, flocculant/disinfectant powder, solar disinfection, ceramic filtration, and biosand filtration – have been shown to improve household water microbiological quality and reduce diarrheal disease in users, and another, boiling, is widely promoted. Based on this evidence, the World Health Organization (WHO) promotes PoUWT to provide safe drinking water for the 884 million people without access to improved water supplies and the millions more drinking microbiologically unsafe water.

Safe drinking water is also an immediate priority in most emergencies. When normal water supplies are interrupted or compromised due to natural disasters, complex emergencies, or outbreaks, responders often encourage affected populations to boil or disinfect their drinking water to ensure its microbiological integrity. Recently, PoUWT options verified in the development context have been recommended for use in emergencies.

As an intervention that reduces diarrheal disease burden, PoUWT could potentially be an effective emergency response intervention: 1) after flooding events or natural disasters that lead to displacement; 2) in some complex emergency settings when relief cannot progress to development; and, 3) in response to outbreaks caused by untreated drinking water. PoUWT may be especially effective during the initial phase of an emergency when responders cannot yet reach the affected population with longer-term solutions. However, differences between the emergency and development contexts may affect PoUWT effectiveness, and raise questions about generalizability of PoUWT results from development into emergency contexts.

The objectives of writing this report are to: 1) document the recent experience in PoUWT use in emergency response; and, 2) identify the lessons learned from that experience and develop a set of recommendations to guide operational research on PoUWT in emergencies and identify the most effective deployment. To complete these objectives, we completed a literature review and implementer survey on PoUWT in emergencies. We then summarized the results into lessons learned and research indicated.

Literature review

A total of 28 journal articles, project evaluations, and manuals were identified describing PoUWT interventions in emergencies. By PoUWT method, this included 9 (33.3%) 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%) on the 2004 Asian Tsunami, 1 (3.6%) on solar disinfection (SODIS), and 1 (3.6%) on a commercial filter. As can be seen, research on one commercial product, PuR, provides the majority of the research identified, and although chlorine tablet distribution is common in emergencies, and solar disinfection and biosand filtration are common development interventions, no evaluations were identified using these options. However, two PuR studies also investigated chlorine tablet distribution.

This literature provides some evidence PoUWT is effective in non-acute emergency settings. PuR use has been shown to reduce diarrheal disease in one long-term refugee camp, and PuR and Aquatabs were shown to improve microbiological quality of household water in cyclones. Sodium hypochlorite use improved microbiological quality of water after the tsunami and during a complex emergency. Ceramic filters have been shown to improve microbiological quality of water during and after flooding. In addition, survey respondents consider the majority of PoUWT options they have used to be successful, suggesting high acceptability of PoUWT among those promoting and distributing them. However, almost all evidence showing PoUWT effectiveness was collected in stable emergency situations in many ways similar to development circumstances, where organizations had the capacity to conduct trainings and follow-up. We do not know if PoUWT can be implemented rapidly and effectively in an acute emergency situation, or in situations where training and follow-up is infeasible.

Health impact and microbiological reduction are gold standards for measuring PoUWT impact, however, these metrics can be difficult to assess 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 method to reduce diarrhea, were less valuable. Appropriate metrics to assess PoUWT impact, considering what is realistic to collect and analyze in emergencies rather than the perceived need to obtain health outcomes, should be utilized in future evaluations.

Training is key for PoUWT uptake in, and continued use after, emergencies. High usage of PuR in emergencies was associated with a training session and additional follow-up education. Sodium hypochlorite use in emergencies was seen in 3-20% of household waters, although higher long-term uptake levels (76.7% in Haiti) were documented when families had yearly follow-up education. A correct usage of 26.3% in ceramic filter users was documented 16 months after initial training. Lack of microbiological improvement in boiled water in Indonesia indicates not all users are boiling correctly, and additional training is needed. Direct comparison of these percentages should be avoided, however, as some studies sampled the entire community population and others only households receiving the intervention. No study identified in the literature review documented greater than 20% uptake of PoUWT in the acute emergency situation.

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, ceramic filter replacement parts) were less than product cost except for sodium hypochlorite bottles. Although cost may not factor significantly in emergency response programs, cost-recovery is critical if continued access to PoUWT in the post-emergency stage is desired.

Each PoUWT option has benefits and drawbacks, and thus, situations where they are most appropriately implemented. In emergencies, ceramic filters appear 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 the SWS 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 PoUWT method, especially those that do not provide for

residual protection against re-contamination. Using new products in an emergency is not recommended unless user product efficacy and acceptability has previously been assessed in field trials.

Lastly, 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. In addition, another recommended dosage, 0.5 mg/L 30 minutes after treatment, will likely not maintain sufficient residual during household storage of water. A dosage of 2 mg/L for clear water (and double that for turbid) is recommended if this does not exceed the local taste threshold.

Survey results

Data was collected from implementers of PoUWT projects in emergencies using a Word Form survey distributed via email. The 40 respondents described 75 projects representing a diverse geographic coverage across Africa, Asia, and the Americas. Sixty-four (85.3%) projects were implemented in emergencies identified as having high diarrheal disease risk from the literature review (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, communities, and the internally displaced. Overall, the projects targeted areas with unimproved water supplies (56.7% of supplies), and the specific PoUWT option used in single-option projects was mostly appropriate for the local water sources. However, PuR was targeted 31.8% of the time to protected sources, which is unnecessary. In addition, chlorine tablets were targeted 72.2% of the time to protected sources, providing another indication the higher dose tablet of 5 mg/L is unnecessary.

Technical assistance on PoUWT implementation in emergency response was primarily found locally or from within the respondents' organizations. This result highlights that technical assistance should be available locally and specifically targeted for each implementing organization. Although 89.3% of respondents noted that they had assessed their project in some manner, few of these assessments were independent or made available for our 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 PoUWT projects in emergencies are growing at an exponential rate, but this may be the result of systematic or reporting bias. Implementers found it difficult to respond to many logistical questions, and thus an amount of water treated in respondents' projects could not be calculated.

Product reasons (such as availability and knowledge) dominate the PoUWT option selection process as opposed to user reasons, and product factors were considered the easiest factors in implementing PoUWT. 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 varied between PoUWT options, indicating implementation strategies should be specialized for each PoUWT option.

Lessons learned and research indicated

In development settings, PoUWT options have been shown to improve the microbiological quality of household water and reduce diarrheal disease in users. There is comparatively little rigorous evidence of PoUWT in emergency settings. However, from the evidence and user surveys, it is known that: 1) PoUWT can be an effective water intervention in non-acute (more developmentalist) emergencies; 2) current PoUWT projects correctly target emergencies with high diarrheal disease risk; 3) considering user preference in PoUWT option selection facilitates implementation; 4) training is crucial to uptake of PoUWT 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 PoUWT options; and, 8) chlorine dosage should be considered in light of user acceptability.

In addition, it is known that: 1) there is less documented success of PoUWT in acute emergencies; 2) introducing an untested PoUWT product in an emergency may not be effective; 3) some PoUWT options may be more appropriate in particular emergencies that others; 4) PoUWT should always be one strategy among many to ensure safe water access in emergencies; and, 5) the relevance of sustainable long-term access to the products should be considered in project planning.

A main result from the investigations documented in this report is that additional research on PoUWT in emergencies is needed. PoUWT use appears to be increasing in emergency response, despite the fact that most documented feasible PoUWT in emergency projects have been implemented at relatively small-scale with significant follow-up, rather like developmentalist PoUWT projects. There is little documented feasibility of PoUWT in larger-scale, more acute emergency situations. Of particular concern is the low uptake rate in acute, unexpected emergencies of all PoUWT options – with no study conducted in the acute emergency documenting greater than 20% uptake, and one study documenting higher uptake the longer the time after the emergency a filter was received.

Based on the information documented in this report, further research on PoUWT in emergencies should focus on: 1) conducting PoUWT project evaluations in large-scale immediate-onset acute emergency situations, using appropriate metrics for program efficacy; 2) evaluating all PoUWT options, including standard interventions not supported by a commercial enterprise, and understand the benefits, drawbacks, and appropriateness for each PoUWT option within specific types and stages of emergencies; 3) evaluating all PoUWT 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 PoUWT in emergencies, such as potential pre-exposure to the PoUWT products, and developing training materials and strategies specifically targeted at these determinants; 5) comparing PoUWT options to other options to reduce diarrheal disease in emergencies, and understanding the potential role for PoUWT as part of a larger water and sanitation strategy in emergencies at various emergency stages; 6) documenting how organizations select PoUWT products –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 PoUWT stimulates long-term uptake of available, affordable PoUWT products in the post-emergency situation.

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CONTENTS

1 INTRODUCTION 14

2 EMERGENCIES, HEALTH, AND WATSAN 15

2.1 Emergencies 15

2.2 Population migration and health needs in emergencies 18

2.3 Trends in funding 19

2.4 Theoretical model for role of interventions to reduce waterborne disease in emergencies 21

2.5 Existing water supply strategy in emergencies 22

3 PoUWT OPTIONS 24

3.1 Diarrheal disease and PoUWT in the development context 24

3.2 Applicability of PoUWT development experience to emergencies 31

4 LITERATURE REVIEW ON PoUWT IN EMERGENCIES 33

4.1 Flocculation/Disinfection 34

4.2 Chlorine tablets 45

4.3 Sodium hypochlorite 46

4.4 Chlorine dosage and other chlorine donors 49

4.5 Ceramic filters 50

4.6 Boiling and safe storage 53

4.7 Emerging PoUWT technologies 55

4.8 Specific emergency: The 2004 tsunami 56

4.9 Summary 58

5 SURVEY OF PoUWT PROJECTS IN EMERGENCIES 59

5.1 Methods 59

5.2 Results 60

5.3 Discussion 70

6 LESSONS LEARNED AND RESEARCH INDICATED 73

6.1 Lessons learned 73

6.2 Further research 77

6.3 Thematic questions 80

6.4 Recommendations for implementing PoUWT in emergencies 82

6.5 Summary of research needed 83

REFERENCES 84

List of Figures

Figure 1: Complex emergencies (2008) 16
Figure 2: Time trend of natural disasters (UNISDR, 2006) 18
Figure 3: Emergencies where interventions to prevent diarrhea are indicated 21
Figure 4: A woman in Delhi using the SWS (WHO/Pierre Virot) 25
Figure 5: A PuR sachet (P&G) 26
Figure 6: A SODIS user (SANDEC/EAWAG) 26
Figure 7: A ceramic filter (PFP) 27
Figure 8: A concrete BSF (Pure Water for the World) 27
Figure 9: Storing boiled water (Lantagne) 28
Figure 10: Number and percent of families collecting PuR weekly in refugee camp (data adapted from (SP, 2006)) 36
Figure 11: PoUWT options used and considered successful in emergency responses 61
Figure 12: Project location and setting in emergency projects 62
Figure 13: Year of project initiation 63
Figure 14: Project assessments completed 63
Figure 15: Water sources used in 75 emergency projects 64
Figure 16: Percent protected sources for one-option projects 65
Figure 17: Reasons for selection of PoUWT option in 75 projects 66
Figure 18: Reasons for selection of PoUWT option in 54 one-option projects 67
Figure 19: Easiest and most difficult factors in implementation in 75 projects 68
Figure 20: Easiest and most difficult factors in implementation in 54 one-option projects 69

List of Tables

Table 1: Funding for humanitarian assistance, 2005 (adapted from (DI, 2006)) 20
Table 2: Sphere water supply standards and key indicators 22
Table 3: Benefits, drawbacks, and appropriateness of PoUWT options 29
Table 4: Product cost of PoUWT options(including only product cost) (adapted from (Lantagne, 2006b) and (Clasen, 2007a)) 31
Table 5: Humanitarian and developmentalist principles (adapted from (Maxwell, 1999) 32
Table 6: Reports identified describing PoUWT interventions in emergencies 33
Table 7: Journal articles, program evaluations, and manuals identified describing PoUWT interventions in emergencies 34
Table 8: Respondents and response rate 60
Table 9: Projects by emergency type and continent 62
Table 10: Concerns and positives about PoUWT product expressed by users 70

ACRONYMS

BSF	BioSand Filtration
CDC	US Centers for Disease Control and Prevention
CMR	Crude Mortality Rate
EPA	US Environmental Protection Agency
IDP	Internally Displaced Person
IMC	International Medical Corps
LSHTM	London School of Hygiene and Tropical Medicine
OECD	Organisation for Economic Co-operation and Development
OR	Odds Ratio
P&G	Procter & Gamble Company
PFP	Potters for Peace
PoUWT	Point-of-Use (or POU) Water Treatment
PSI	Population Services International
RtD	Relief to Development Continuum
SODIS	Solar Disinfection
SP	Samaritan's Purse
SWS	CDC Safe Water System
USAID	United States Agency for International Development
UNICEF	United Nations Children's Fund
WATSAN	Water and sanitation
WHO	World Health Organization

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1 INTRODUCTION

An estimated 4 billion cases of diarrhea each year, causing 1.8 million deaths mainly among children under 5 years of age, are caused by unsafe drinking water, poor sanitation, and poor hygiene (Boschi-Pinto, 2008). A growing body of evidence from the development context has shown treating water at the household level improves the microbial quality of stored household water and reduces the burden of diarrheal disease in users (Clasen, 2007c). Based on this evidence, the World Health Organization (WHO) promotes Point-of-Use Water Treatment (PoUWT) 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 whose drinking water is microbiologically unsafe (UNICEF/WHO, 2008; WHO, 2005b).

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 disinfect their drinking water to ensure its microbiological integrity. More recently, PoUWT options that have been verified in the development context – such as chlorination, flocculant/disinfectant powders, solar disinfection, ceramic filtration, and sand filtration – have been recommended for use in emergencies. However, it is unknown at this time whether these interventions will be more, less, or as effective in the emergency context as in the development context.

The objectives in writing this report are to: 1) document the recent experience in PoUWT use in response to emergencies; and, 2) identify the lessons learned from that experience, develop a set of recommendations to guide operational research on PoUWT in emergencies, and identify where deployment can be most effective. To complete these objectives, we: 1) completed a literature review on emergencies, health, and water and sanitation (watsan) interventions and present a framework describing the potential role for water interventions, including PoUWT, in emergencies (Section 2); 2) describe the PoUWT options commonly used in development and emergency situations (Section 3); 3) summarize the available literature on PoUWT in emergencies (Section 4); 4) present results from a survey of implementers who have completed PoUWT projects in emergencies (Section 5); and, 5) summarize the lessons learned and future research indicated based on the investigations documented in this report (Section 6).

2 EMERGENCIES, HEALTH, AND WATSAN

In this section, we investigate the appropriateness of PoUWT in emergency response by: 1) reviewing the current knowledge on health consequences and trends of different emergency types; 2) reviewing the health effects of emergencies on affected populations; 3) presenting information on trends in emergency-response funding; 4) developing a theoretical framework for the appropriateness of water interventions, including PoUWT, in emergencies; and, 5) discussing the current standard practices for water and sanitation interventions in emergencies.

2.1 Emergencies

For the purpose of this report, emergencies will be categorized as: '*natural disasters*', '*complex emergencies*', and '*outbreaks*'.

2.1.1 Natural disasters

Natural disasters are "catastrophic events with atmospheric, geologic, and hydrologic origins" that include "earthquakes, volcanic eruptions, landslides, tsunamis, floods, and drought" (Watson, 2007). Although many myths surround the increased risk of outbreaks in post-natural disaster situations (de Ville de Goyet, 2000; Watson, 2007), the reality is 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. 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).

In the post-flooding event period, morbidity and mortality increase due to injuries, fecal-oral diseases, vector-borne diseases, and rodent-borne diseases (Ahern, 2005; Shultz, 2005). Ahern *et al.* collated information from 36 studies published between 1991-2004 investigating the health effects of floods. Fifteen of these studies documented increased diarrheal disease incidence or high diarrheal disease rates in the post-flooding period. In one study conducted after the 1988 Bangladesh floods, diarrhea was identified as the most common illness (34.7%) and watery diarrhea was the most common cause of death for those younger than 46 years of age (Siddique, 1991). In addition, large diarrheal disease outbreaks have been attributed to preceding floods, including a cholera epidemic with over 16,000 cases in West Bengal in 1998 (Sur, 2000) and an outbreak of *Vibrio cholerae* and enterotoxigenic *E. coli* involving over 17,000 cases in Bangladesh in 2004 (Qadri, 2005). Flooding has also been identified as a significant risk factor for paratyphoid fever (odds ratio 4.52) (Vollaard, 2004) and *Cryptosporidium parvum* (no Odds Ration (OR) available) (Katsumata, 1998). Lastly, outbreaks of Hepatitis A, Hepatitis E, and Leptospirosis after flooding events have been documented (Watson, 2007).

When population displacement occurs after a natural disaster, the outbreaks are generally concurrent with local causes of morbidity and mortality, including diarrhea, cholera, and Hepatitis A and E following flood events that lead to displacement (Watson, 2007). Measles and acute respiratory infections are also common due to the crowded

conditions common after displacement. Vector-borne diseases, such as malaria and dengue, are also a concern over time as habitat increases. These health effects are similar to what is seen in refugee situations (described in Section 2.2.1).

The measures recommended to reduce the risk of outbreaks after natural disasters are, in order of priority: 1) safe water, sanitation and site planning to prevent diarrhea; 2) primary health services for prevention, diagnosis, and treatment of common diseases; 3) surveillance for common endemic and epidemic-prone diseases; 4) immunization against measles and vitamin A supplementation; and 5) prevention of malaria and dengue by decreasing vectors (Watson, 2007).

2.1.2 Complex emergencies

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). These emergencies are generally characterized by "extensive violence and loss of life; massive displacements of people; widespread damage to societies and economies, the need for large-scale, multi-faceted humanitarian assistance, and the hindrance or prevention of humanitarian assistance by political and military constraints".

To understand the health consequences of complex emergencies, the current UN complex emergency list was mapped (Figure 1). As can be seen, the states considered complex emergencies are highly variable. As each state will have different health needs, no overarching inference can be made on the water and sanitation needs of complex emergencies, and the utility of the definition for health purposes is questionable.

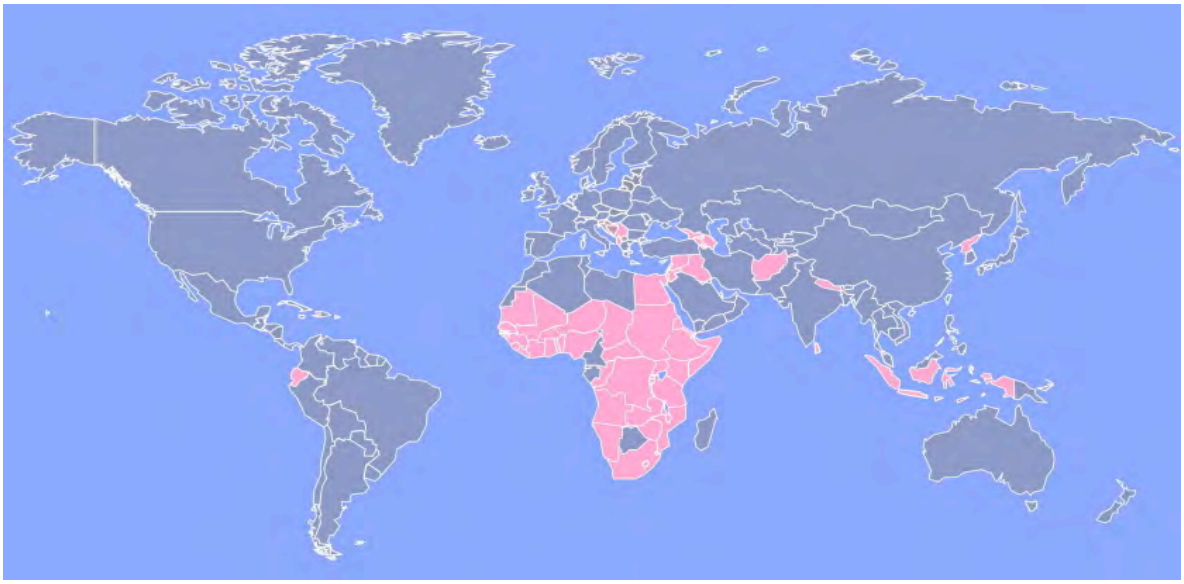


Figure 1: Complex emergencies (2008)

2.1.3 Disease outbreaks

"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, 2008a). Common waterborne disease outbreaks include cholera, typhoid fever, shigellosis, dysentery, and hepatitis A and E. Cholera is a serious epidemic disease requiring notification to the WHO under the International Health Regulations (WHO, 2008b), and recent data shows that cases of cholera are increasing, particularly in Africa. In 2007, a total of 177,963 cholera cases, including 4,031 deaths (case fatality rate of 2.3%) from 53 countries were reported to the WHO (WHO, 2008b). This represented a 46% increase in the mean number of cases reported in 2002-2005. Cases in Africa accounted for 93.6% of the global total. In addition, countries in Asia reported cases for the first time since 2000, accounting for 6.4% of global cases. Despite the increases seen over time, these figures likely represent only a small fraction of the cholera disease burden, as WHO estimates that only 5-10% of cholera cases worldwide are reported, due to inadequate surveillance systems and under-reporting motivated by fear of trade sanctions and lost tourism. Particularly concerning is the fact the incidence rate (166 cases/1,000,000 population) and case fatality rate (1.8%) in Africa is much greater than in Asia (1.74 cases/1,000,000; 0.6%) or Latin America (0.01/1,000,000; no deaths) (Gaffga, 2007).

2.1.4 Scope of emergencies

Between 1995 and 2004, 3,197 recorded natural disasters, 363 complex emergencies, and 1,374 epidemics were recorded in the literature (Spiegel, 2007). Geographical differences were found in the distribution of disasters. The majority of the largest natural disasters occurred in Asia (67%), followed by Latin America and the Caribbean (13%), with a range in mortality from 1,500-2,500,000 deaths. The largest complex emergencies occurred in Africa (53%), followed by Asia (33%), with a mortality range of 1,000-3,000,000. The largest outbreaks occurred in Africa (83%) followed by Asia (17%), with a mortality range of 550-4,500. A significant overlap between complex emergencies and natural disasters was found (87%), although no overlap between natural disasters and epidemics was noted.

Natural disasters alone affected 2.5 billion people, caused 890,000 deaths, and cost 570 billion USD in economic consequences between 1995 and 2004 (UNISDR, 2008). Of particular concern is that natural disasters and their impacts have been increasing in recent decades (Figure 2), due to increases in populations living in hazard-prone locations, unplanned settlements and environmental degradation, and climate change causing more intense hurricanes, higher rainfall intensities, and heat-waves (UNISDR, 2006). In addition, the World Meteorological Report for 2007 noted an increase in climate-related disease in Asia, and predicted with high confidence increases in endemic morbidity and mortality due to diarrheal disease primarily associated with: 1) climate change in South and South-East Asia; and, 2) increases in the abundance and/or toxicity of cholera in south Asia due to increases in coastal water temperature (Cruz, 2007). It was also predicted, with medium confidence, that natural habitats of waterborne diseases in north Asia are likely to expand in the future. Cholera is already currently increasing worldwide and in Africa (Gaffga, 2007; WHO, 2007).

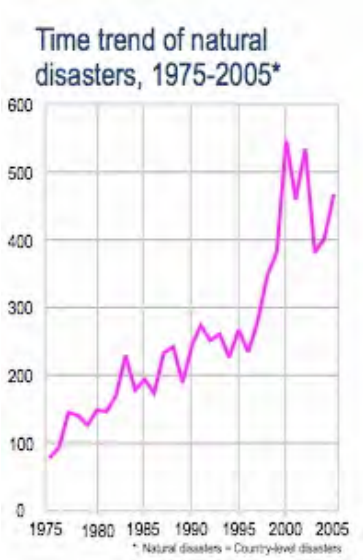


Figure 2: Time trend of natural disasters (UNISDR, 2006)

2.2 Population migration and health needs in emergencies

As can be inferred from the previous subsection, the category of emergency does not fully describe the health effects on the affected population. A more complete understanding of the health effects of emergencies is obtained when also considering population migration. When an emergency occurs, affected populations either: 1) leave, cross an international border, and become a '*refugee*'; 2) flee, remain within their own country, and become considered an '*internally displaced person'* (IDP); or, 3) stay within their community and potentially become '*entrapped*'. The health needs of each of these populations will be discussed in the following sections.

2.2.1 Health needs in refugee camps (and post-natural disaster situations)

In the early to mid-1990's the use of crude mortality rates (CMR) and excess mortality became widespread as indicators of health in refugee camps and following natural disasters (Toole, 1990). Responders developed nomenclature to help characterize the prevailing circumstances and health conditions based on the fact a CMR of 1/10,000/day was, at the time, double the background level in sub-Saharan Africa. The '*emergency phase'* was thus defined as when CMR exceeded 1/10,000 people/day, and the '*post-emergency phase'* was when mortality rates returned to background rates. Measles, diarrheal diseases, and acute respiratory tract infections were identified as the major causes of death in the emergency phase, accounting for 50-95% of deaths. In established refugee camps, the major causes of death were identified as diarrheal diseases and acute respiratory infections. According to Toole and Waldman (1990), "most excess mortality in refugee populations has been caused by measles, diarrheal diseases, undernutrition, acute lower respiratory tract infections, and malaria, the same diseases that affect nonrefugee [sic] populations" and "thus it is not the *type* of illness but rather the *incidence* and *high mortality rates* that make these populations remarkable". Toole and Waldman (1990) recommend providing: food, clean water, interventions to prevent communicable diseases, curative programs, and health information systems as soon as possible to reduce the disease burden.

The progression of disasters as described by Toole and Waldman has been adapted and is known as the relief-to-development (RtD) continuum (Burkholder, 1995). Burkholder *et al.* describe three stages of an emergency. The *'acute emergency phase'* is "chaotic as thousands of persons seek refuge after physical or emotional trauma"; the response is "complicated by security concerns, logistic and resource constraints, and lack of coordination". The *'late emergency phase'* focuses on "public health programs rather than acute needs". The *'post-emergency phase'* is when "the health profile of the refugee camps begins to mirror that of a typical village". At this point "the emphasis of humanitarian assistance shifts from relief to development". These early 1990's papers remain the basis of refugee health literature and intervention strategy.

2.2.2 Health needs of IDPs

The different impact of emergencies on refugees and IDPs were noted as early as 1990, when Toole and Waldman found that CMRs among IDPs were significantly higher (at 2.7-30/10,000/day) than in refugees in camps (0.33-10.6/10,000/day) and local host populations (0.47-0.66/10,000/day). This disparity was attributed to the fact IDPs do not have the same international protection as refugees, and less humanitarian aid is available to this population.

In 2007, more than 26 million people were considered internally displaced (IDMC, 2008). This represents a six percent increase from 2006. Almost half (12.7 million) of IDPs are in Africa, and 11.3 million IDPs in 13 countries are estimated to receive no significant humanitarian assistance from their governments. The disease burden in IDP situations varies significantly depending on the situation, for some IDPs receive humanitarian assistance and are in established camp settings while others are interspersed with host populations and may receive no assistance. In DRC, a high national CMR of 0.7 deaths/10,000/day was documented in IDPs, with most deaths, as in refugee camps situations, "from easily preventable and treatable illnesses rather than violence" (Coghlan, 2006). The highest CMR rates were found in the most insecure provinces. In Ethiopia and Sudan diseases that are comparatively rare in refugee situations, such as measles and pellagra, have been reported in IDPs (Salama, 2001).

2.2.3 Health needs of entrapped populations

In areas affected by armed conflict, people are often unable or unwilling to leave their homes for extended periods of time. Water supplies for such populations are frequently interrupted or suspended altogether, forcing affected populations to rely on lower quality supplies and reducing access and quantity (Bastable, 2008). Although little research has been conducted about the health needs of populations that are entrapped within their own communities, it is postulated they have significant health needs (Checchi, 2007).

2.3 Trends in funding

In addition to an increase in the number of emergencies (Section 2.1.4), there has also been a large increase in funding for emergency response. Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee members alone have increased funding from 436 million donated in 1970, to 5.1 billion in 1990, to 8.4 billion in 2004 (DI, 2006). This increased level of funding is attributed to increased diversity of funding sources, engagement of new donors, and strong public concern. In 2005 alone, an estimated 18 billion USD

was donated for humanitarian aid (Table 1). Despite this increase in funding, a large disparity was seen on a per-emergency basis – with only one-third of the need met in the five least-funded emergencies, compared with over 75% of the needs met in the best-funded emergencies. The economic recovery, health protection, and water and sanitation sectors are among the most underfunded sectors in humanitarian aid, with a total of 269 million USD donated from 2000-2005, meeting only 35% of the estimated needs.

Table 1: Funding for humanitarian assistance, 2005 (adapted from (DI, 2006))

Donor	**Funding (billion USD)**
Humanitarian assistance from OECD DAC members (bilateral, multilateral)	8.3
Humanitarian assistance from OECD DAC members (post-conflict, peace-building)	3
Humanitarian assistance from non-DAC countries	0.5-0.9
Public contributions to NGOs	4.0
Public contributions to ICRC	1.8
Public contributions to UN agencies	0.5
Total (estimated)	**18**

2.4 Theoretical model for role of interventions to reduce waterborne disease in emergencies

The health consequences of emergencies and population displacement, together with the projected increase in scope of emergencies and funding for emergency response, shows there is a strong need to understand the existing and potential role for water and sanitation interventions (including PoUWT) in emergencies. A working model of the potential role for interventions to decrease diarrheal disease in emergencies, developed by summarizing the information in this section, was developed (Figure 3). As can be seen, PoUWT could be a potentially effective intervention: 1) after flooding events or natural disasters that lead to displacement; 2) in some complex emergency settings; and, 3) in response to outbreaks caused by untreated drinking water.

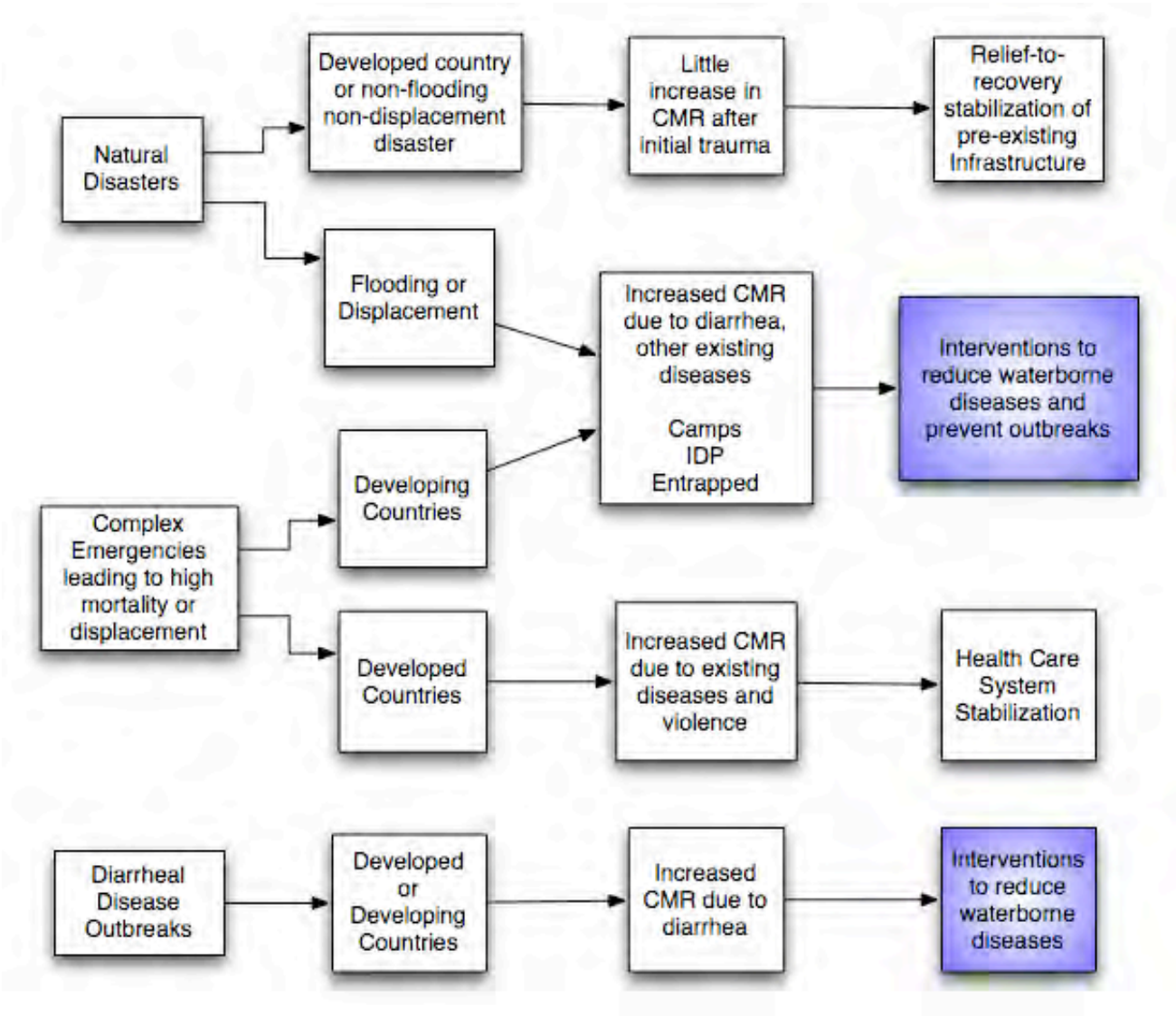


Figure 3: Emergencies where interventions to prevent diarrhea are indicated

2.5 Existing water supply strategy in emergencies

Before discussing the potential and existing role for PoUWT options, it is necessary to understand the existing water supply and treatment strategy of responders in emergencies.

In response to critiques of NGO response during the Goma refugee crisis (Griekspoor, 2001; GROUP, 1995), a group of emergency NGOs and the Red Cross and Red Crescent societies gathered to form the "Sphere Project" and develop minimum standards for NGOs in disaster response (SPHERE, 2004). The "Humanitarian Charter and Minimum Standards in Disaster Response" (Sphere) handbook was drafted in 1998, published in 2000, and revised in 2004. Over 400 organizations in 80 countries have contributed to its development. The Sphere Handbook provides a humanitarian charter, standards, key indicators, and guidance notes in five key sectors (water and sanitation, nutrition and food security, shelter, settlement and non-food, and health services) and addresses seven cross-cutting issues (children, older people, disabled people, gender, protection, HIV/AIDS, and the environment) in all sectors. In the water supply and sanitation sector the standards are: 1) access and water quantity; 2) water quality; and, 3) water use facilities and goods (Table 2).

Table 2: Sphere water supply standards and key indicators

Water Supply Standard	Key Indicators
1: access and water quantity	- a minimum of 15 liters of water per person per day; - a maximum of 3 minutes to fill a 20-liter container; - a maximum queuing time for water of 15 minutes; - a maximum distance to water point of 500 meters; and, - consistently available water.
2: water quality	- no fecal coliforms per 100 mL at the point of delivery; - low sanitary survey risk; - residual chlorine levels of 0.5 mg/L and turbidity below 5 NTU for piped water supplies or populations at risk of a diarrhea epidemic; - people drink water preferentially from protected sources and steps are taken to minimize post-delivery contamination; and, - no negative health effect from short term use or planned time of use of the water supply.
3: water use facilities and goods	- each household has two water collective vessels of 10-20 liters, plus storage vessels of 20 liters, all with narrow necks and/or covers; - 250g of soap per person per month; - appropriate communal bathing facilities; and, - appropriate communal laundry facilities.

Despite the successes of Sphere, there has been criticism of the Handbook, including that: 1) the indicators are not evidence-based; 2) the Handbook has not been fully accepted by the UN, is informal, and provides only recommended guidance; and, 3) the indicators apply more easily to ideal conditions in refugee camps, and not to complex situations, which could foster unrealistic expectations in more complex emergencies (Griekspoor, 2001;

ODI, 2005). For example, UNHCR recommends a minimum of 20 liters of water per person per day in emergency situations, compared to the Sphere recommendation of 15 liters of water per person per day (UNHCR, 2009).

The key Sphere water indicators were developed based on perceived wisdom of acknowledged experts and working group members, as opposed to more formal research. Investigation of this unvalidated perceived wisdom was identified as a key research need during the recent WASH Evidence Base / Knowledge Base in Emergencies workshop (Lantagne, 2009). Although the Sphere Standards and Indicators represent the most accurate summary of knowledge to date, seeking only to meet the standards without understanding the specific circumstances of each emergency is not recommended.

To understand the specific circumstances on the ground, emergency organizations generally conduct an initial rapid assessment upon arrival to determine how to meet the basic needs of the population as quickly as possible (Lantagne, 2009). The perceived wisdom at this point in time is that water quantity is more important than water quality, as "the priority should be to provide equitable access to an adequate quantity of water of intermediate quality, rather than to provide an inadequate quantity of water which meets the minimum standard for quality" (SPHERE, 2004). Immediate actions for water supply provisions include: protection and monitoring of existing sources, provision of household water containers, chlorination, providing water in temporary tapstands or tanks, organizing a tankering water system, development of alternative sources, and/or moving people to areas with better water (Davis, 1995). Concurrent to this provision of water quantity, hygiene promotion and latrine building activities are ongoing. Water supply interventions are not occurring in isolation, and the water, sanitation, and hygiene staff and cluster working groups will be addressing all avenues to reduce the risk of diarrheal disease (SPHERE, 2004).

Theoretically, as the emergency progresses and begins to stabilize, the goal shifts to more comprehensive assessments, longer-term planning, and fully meeting the Sphere Indicators with higher-quality services (Lantagne, 2009). Ideally, as the emergency moves from the relief to the development stage, the population would have long-term access to a supply of protected water. However, not all emergencies progress along this relief-to-development continuum, so this cannot be assumed for all situations.

Thus, the potential role for PoUWT depends on specific circumstances within the emergency. Clearly, in all cases, PoUWT will be one potential intervention, operating in conjunction with water supply, sanitation, and hygiene interventions, to reduce disease. PoUWT may have a different role (or lack of role) in the acute emergency stage prior to rehabilitation of water supplies, in a stable refugee camp with centralized water supply, or in a refugee camp cited in a location with no protected water supply. The relative appropriateness of PoUWT may vary in these different contexts, and this theme is discussed extensively throughout this report.

3 PoUWT OPTIONS

PoUWT has been shown to improve the microbiological quality of water and reduce the burden of diarrheal disease in developing countries. In this section we review the existing literature on PoUWT and discuss its potential applicability to the emergency context.

3.1 Diarrheal disease and PoUWT in the development context

The WHO estimates that improving water, sanitation and hygiene could prevent at least 9.1% of the global burden of disease and 6.3% of all deaths (Pruss-Ustun, 2008). The largest single portion of this burden is represented by diarrheal disease, accounting for an estimated 39% of all disability-adjusted life years (DALYs). This reflects an estimated 4 billion cases of diarrhea and almost 2 million deaths each year, mostly among young children in developing countries (Boschi-Pinto, 2008; UNICEF, 2007c). Diarrheal diseases lead to decreased food intake and nutrient absorption, malnutrition, reduced resistance to infection, and impaired physical growth and cognitive development (Baqui, 1993; Guerrant, 1999).

Environmental health interventions to reduce diarrheal disease in the development context fall into four general categories: improved water supply, household water treatment, handwashing promotion, and sanitation provision. Each of these interventions has been shown to reduce diarrheal disease in developing countries (Esrey, 1985; Esrey, 1991; Fewtrell, 2005). Five PoUWT 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 (Clasen, 2007c; Stauber, 2009). In the following subsections these five options, and boiling, are discussed. The text of the next six subsections has been adapted from Centers for Disease Control and Prevention (CDC)/United States Agency for International Development (USAID) fact sheets that were written by the primary author (CDC/USAID, 2008). The benefits, drawbacks, and appropriateness of each option are summarized in Table 3.

3.1.1 Household chlorination

Chlorination was first used to disinfect public water supplies in the early 1900s, and helped drastically reduce waterborne disease in cities in Europe and the United States (Cutler, 2005). Although there had been small trials of point-of-use chlorination prior (Mintz, 1995), larger trials began in the 1990s as part of the Pan American Health Organization (PAHO) and the CDC response to epidemic cholera in Latin America (Tauxe, 1995). Although many chlorine donors are used and available, the majority of household chlorination research has been conducted using liquid sodium hypochlorite for the chlorine supply and the Safe Water System (SWS) implementation strategy. The SWS has three elements: 1) point-of-use water treatment by consumers with a locally manufactured dilute sodium hypochlorite (chlorine bleach) solution; 2) safe storage of treated water; and, 3) behavior change communications to improve water and food handling, sanitation, and hygiene practices in the home and in the community. To use the SWS, families add one full bottle cap of the solution to clear water (or 2 caps to turbid water) in a standard sized

container, agitate, and wait 30 minutes before drinking. At concentrations that are used in PoUWT projects, the hypochlorite solution is effective at inactivating most bacteria and viruses that cause diarrheal disease (CDC, 2008a). However, it is not effective at inactivating some protozoan oocysts, such as *Cryptosporidium*. Numerous studies have shown complete removal of bacterial pathogens in SWS treated water in developing countries (Crump, 2004b; Crump, 2005; Quick, 2002; Quick, 1996; Quick, 1999). In seven randomized, controlled trials, the SWS has resulted in diarrheal disease reductions in users ranging from 22-84% (Crump, 2005; Luby, 2004; Lule, 2005; Quick, 2002; Quick, 1996; Reller, 2003; Semenza, 1998). These studies have been conducted in rural and urban areas, and include adults and children that are poor, living with HIV, and/or using highly turbid water.

Figure 4: A woman in Delhi using the SWS (WHO/Pierre Virot)

As detailed above, liquid sodium hypochlorite for household water treatment in the development context has been extensively researched. However, other chlorine donors are commonly used for water treatment in emergencies, including: sodium dichloroisocyanurate (NaDCC) tablets; a wide variety of other chlorine tablets including calcium hypochlorite tablets; distribution of 1% liquid hypochlorite '*mother solution*' made on site; local generation of sodium hypochlorite using an electrolytic generator; or, promotion of household bleach for water treatment. Each of these options has benefits and drawbacks as compared to other chlorine donors. Tablets tend to be higher priced and centrally produced, yet have a longer shelf-life of 3-5 years. Mother solution and local chlorine generation are both inexpensive to produce on-site, but need quality control to ensure they are correctly made, and have a shelf-life of only 1-18 months. Commercial bleach is widely available, but variations in concentration make determining an appropriate chlorine dose difficult (Lantagne, In press). These other chlorine donors have not yet been widely researched, although studies have begun on NaDCC tablets, which were recently approved by the USEPA and recommended by the JECFA for approval by the WHO for long-term use as a water treatment product and are increasingly available and used in the development context (Clasen, 2007b). A study on Aquatabs NaDCC tablets in Bangladesh documented intervention households had significantly lower thermotolerant coliforms than control households (geometric mean, 2.8 [95% CI: 2.2, 3.6] versus 604.1 [95% CI: 463.2, 787.9]; $P < 0.0001$), and 61.7% (116/188) of intervention household samples met WHO guidelines for 0 thermotolerant coliforms in drinking water. However, 11.7% of samples exceeded the WHO guideline value for free chlorine of 5.0 mg/L, indicating the need to ensure that tablet dose and vessel size are compatible (Clasen, 2007b). These reductions in microbiological indicators were confirmed in another study in Ghana (Quick, 2009). A full discussion of these options will be presented in the literature review (Section 4.4). In some emergencies, iodine tablets are also distributed, although iodine is not recommended for long-term water treatment (WHO, 2004).

3.1.2 Flocculant/disinfectant powders

Although numerous flocculant/disinfectant powders, such as WaterMaker (made in South Africa), Bishan Gari (Ethiopia) and Thanh Mai (Vietnam) are sold, the Procter & Gamble Company (P&G) PuR Purifier of Water™ product (Pakistan) is the only rigorously evaluated powder. The PuR product is a small sachet containing powdered ferric sulfate (a flocculant) and calcium hypochlorite (a disinfectant). PuR was designed to replicate the processes used in a water treatment plant, incorporating the multiple barrier processes of removal of particles followed by disinfection. To treat water with PuR, users open the sachet, add the contents to an open bucket containing 10 liters of water, stir for 5 minutes, let the solids settle to the bottom of the bucket, strain the water through a cotton cloth into a second container, and wait 20 minutes for the hypochlorite to inactivate the microorganisms. PuR has been documented to remove the vast majority of bacteria, viruses, and protozoa, even in highly turbid waters (Crump, 2004a; Souter, 2003). PuR has also been documented to reduce diarrheal disease from 16% to greater than 90% in five randomized, controlled health intervention studies (Agboatwalla, 2004; Chiller, 2006; Crump, 2005; Doocy, 2006; Reller, 2003). In addition, PuR reduces levels of heavy metals, such as arsenic, and chemical contaminants, such as some pesticides, from water (Souter, 2003).

Figure 5: A PuR sachet (P&G)

3.1.3 Solar Disinfection

Solar disinfection was developed in the 1980's to inexpensively disinfect water used for oral rehydration solutions used to treat diarrhea. In 1991, the Swiss Federal Institute for Environmental Science and Technology (SANDEC, EAWAG) began to investigate and implement the specific method SOlar DISinfection (SODIS) as a PoUWT option to prevent diarrhea in developing countries, and the majority of research on solar disinfection has been completed on the SODIS method. Users of SODIS fill 0.3-2.0 liter plastic soda bottles with low-turbidity water, shake them to oxygenate the water, and place the bottles on a roof or rack for 6 hours (if sunny) or 2 days (if cloudy). The combined effects of UV-induced DNA alteration, thermal inactivation, and photo-oxidative destruction inactivate disease-causing organisms. In the laboratory, SODIS has been documented to inactivate the viruses, bacteria, and protozoa that cause diarrheal diseases (Berney, 2006; Mendez-Hermida, 2007). In four randomized, controlled trials, SODIS reduced diarrheal disease from 9-86% (Conroy, 1996; Conroy, 1999; 2001; Hobbins, 2003). One of these studies documented a reduction in the risk of cholera transmission in children under six in households using SODIS (OR 0.12, p=0.014) (Conroy, 2001).

Figure 6: A SODIS user (SANDEC/EAWAG)

3.1.4 Ceramic Filtration

Gravity-fed ceramic filters, using either pot- or candle-shaped filter elements, have been used traditionally in many countries to treat drinking water at the household level (Sobsey, 2002). Numerous locally manufactured and commercial ceramic filters are currently available in developing and developed countries. One locally manufactured design is the Potters for Peace filter, which is flowerpot-shaped, holds 8-10 liters of water, and sits inside a plastic or ceramic receptacle. The filters are produced locally, where they are formed, fired, and impregnated with colloidal silver. The impregnated filters remove most bacteria and protozoa from source water. The colloidal silver also prevents growth of bacteria within the filter itself. Many commercial filters are candle-style filters. Most ceramic filter systems are based on a filter/receptacle model. Families fill the top receptacle or the ceramic filter itself with water, which flows through the ceramic filter or filters into a storage receptacle. The treated water is then accessed via a spigot. The effectiveness of ceramic filters at removing microbial pathogens depends on the production quality of the ceramic filter. Higher quality ceramic filters are effective at removing most protozoa and bacteria, but not viruses (Lantagne, 2001a). Field studies have reported 60-70% reductions in diarrheal disease associated with use of commercial filters (Clasen, 2006a; Clasen, 2004) and 46-49% reductions associated with locally made filters (Brown, 2007; Brown, 2008). Studies have also shown significant bacterial contamination when poor-quality locally produced filters are used, or the receptacle is contaminated at the household level (Lantagne, 2001b). Because of the lack of residual protection, it is important that users be trained to properly care for and maintain the ceramic filter and receptacle.

Figure 7: A ceramic filter (PFP)

3.1.5 BioSand Filtration

The Biosand Filter (BSF) is a slow sand filter adapted for use in the home. The version of the BSF most widely implemented consists of layers of sand and gravel in a concrete or plastic container approximately 0.9 meters tall, and 0.3 meters square. The water level is maintained to 5-6 cm above the sand layer by setting the height of the outlet pipe. This shallow water layer allows a bioactive layer ('*schmutzdecke*') to grow on top of the sand. Diarrheal disease causing organisms are removed through mechanical trapping, adsorption, and predation by schmutzdecke organisms. A diffuser plate with holes in it is placed on the top of the sand layer to prevent disruption of the biolayer when water is added to the system. To use the BSF, users simply pour water into the BSF, and collect finished water out of the outlet pipe into a bucket. In laboratory and field testing, the BSF consistently reduces bacteria by 81%->99% and protozoa by >99% (Kaiser, 2002). Initial research has shown that the BSF removes less than 90% of indicator viruses (Sobsey, 2005), and the first health impact study on BSF documented a 47% reduction in diarrheal disease in users (Stauber, 2009).

Figure 8: A concrete BSF (Pure Water for the World)

3.1.6 Boiling

Boiling is arguably the oldest and most commonly practiced household water treatment method, and it has been widely promoted for decades (Sobsey, 2002). Although boiling time recommendations vary significantly, from 0-20 minutes, waterborne microbes that are pathogenic to humans are killed or inactivated even before the water reaches 100°C. The World Health Organization (WHO) thus recommends that water be heated until it reaches the boiling point (WHO, 2005a). Some organizations, such as the CDC and Unites States Environmental Protection Agency, recommend a rolling boil of one minute, in order to ensure that users do not stop heating the water before the true boiling point is reached (USEPA, 2008). Water should be stored in the same container in which it was boiled, handled carefully, and consumed within 24 hours to minimize recontamination. Boiling is effective at inactivating all waterborne bacteria, viruses, and protozoa that cause diarrheal disease (Clasen, 2008c). However, studies of the effectiveness of boiling in actual practice in developing countries have shown mixed results. In Vietnam and India, boiling reduced the level of thermotolerant coliforms by 99% and 97%, respectively, as compared to source water samples among householders reporting always or almost always boiling their water (Clasen, 2008b; Clasen, 2008c). In three tsunami-affected areas of Indonesia, reported boiling, adequate boiling, and adequate boiling with safe storage were all not associated with a decreased risk of stored water contamination (Gupta, 2007). This disparity may be due to inconsistent boiling, recontamination of boiled water in storage, differences in practices within the study populations, and the impact of the emergency. To date, there have been no studies assessing the health impact associated with boiling water. However, one study reported a 45% reduction in diarrheal disease due to solar pasteurization in Kenya (Iijima, 2001), and some case-control studies in cholera outbreaks have noted boiling as being protective against cholera (Weber, 1994). While boiling is widely practiced, especially in Asia, it may be difficult to achieve adoption in other cultures outside of the emergency response (Wellin, 1955).

Figure 9: Storing boiled water (Lantagne)

Table 3: Benefits, drawbacks, and appropriateness of PoUWT options

	Benefits	Drawbacks	Appropriateness
Household chlorination	- documented reduction of most bacteria and viruses in water; - residual protection against contamination; - acceptability to some users because of ease-of-use; - documented health impact; - scalability; and, - low cost	- relatively low protection against parasitic cysts; - lower disinfection effectiveness in turbid waters contaminated with organic and some inorganic compounds; - potential user taste and odor objections; - necessity of ensuring quality control of solution; and, - misunderstanding about the effects of chlorination by-products	Most appropriate in areas with a consistent supply chain, with relatively lower turbidity water, and situations where educational messages can reach target population to encourage correct and consistent use.
Flocculant / disinfectant powders	- documented reduction of bacteria, viruses, and protozoa in water; - reduction of some heavy metals and pesticides; - residual protection against contamination; - documented health impact; - acceptability to users because of visual improvement in the water; and, - sachets are easily transported due to their small size, long shelf life, and classification as non-hazardous material for air shipment.	- the need for multiple steps to use the product, which requires a demonstration to teach new users; - the need for users to have, employ, and maintain two buckets, a cloth, and a stirring device; and, - the higher relative cost per liter of water treated compared to other household water treatment options.	Most appropriate in areas with a consistent supply chain, and in situations where product an actually be demonstrated and educational messages can reach target population to encourage correct and consistent use.
Solar disinfection	- documented reduction of viruses, bacteria, and protozoa in water; - documented reduction of diarrheal disease in users; - acceptability to some users because of the simplicity of use; - no cost to the user after obtaining the plastic bottles; - minimal change in taste of the water; and, - minimal likelihood of recontamination due to safe storage.	- the need for pretreatment (filtration or flocculation) of waters of higher turbidity; - user acceptability concerns because of the limited volume of water that can be treated at once; - the lack of visual improvement in water aesthetics to reinforce benefits of treatment; - the length of time required to treat water; and, - the large supply of intact, clean, suitable plastic bottles required.	Most appropriate in areas where there is availability of bottles and repeated community motivation and training for users on how to correctly and consistently use SODIS for treating household drinking water.

	Benefits	Drawbacks	Appropriateness
Ceramic filtration	- documented reduction of bacteria and protozoa in water; - acceptability to users because of the simplicity of use and the aesthetic improvement in treated water; - documented reduction of diarrheal disease among users; - potentially long life if the filter remains unbroken; and, - one-time cost.	- low effectiveness against viruses; - lack of residual protection can lead to recontamination if treated water is stored unsafely; - variability in quality control of locally produced filters; - filter breakage and need for spare parts; - filters and receptacles that need to be regularly cleaned, especially when using turbid source waters; and, - a low flow rate of 1-3 liters per hour (slower in turbid waters).	Most appropriate in areas where there is capacity for quality ceramics filter production, a distribution network for replacement of broken parts, and user training on how to correctly maintain and use the filter.
BioSand Filtration	- documented removal of protozoa and bacteria; - acceptability to users because of high flow rate (~20 liters/hour), ease-of-use, and visual improvement in the water; - production from locally available materials; - one-time installation with low maintenance requirements; and, - long life.	- comparatively low inactivation of viruses; - absence of post-filtration residual protection so that if water is filtered into an open or unclean bucket there is potential for contamination; and, - the difficulty in producing and transporting a 100-350 pound filter housing and the high initial cost that make scalability more challenging.	Most appropriate in areas where there is external funding to subsidize the initial cost of the filter, education for users, locally available sand, and a transportation network capable of moving the buckets and sand.
Boiling	- existing presence in many households of materials needed to boil; - documented inactivation of bacteria, viruses and protozoa, even in turbid or contaminated water; and, - socio-cultural acceptance of boiling for water treatment in some cultures.	- lack of residual protection against contamination; - lack of epidemiologically confirmed health impact; - potential for burn injuries and increased risk of respiratory infections from indoor stoves or fires; - potentially high cost of carbon-based fuel source (with concurrent deforestation risk) and the opportunity cost of collecting fuel; - potential user taste objections; and, - potential for incomplete water treatment if users do not bring water to full boiling temperature.	Most appropriate in areas with an affordable and accessible supply of cooking fuel, a cultural tradition of boiling, and where water is stored safely after boiling.

3.1.7 A note on cost

The cost of PoUWT options varies considerably, depending on the metric (up-front cost, recurring cost, per liter treated, per month at household, etc.) used. One important variable in PoUWT cost is that some options, such as flocculant/disinfectant sachets or chlorine, are consumables (with mainly variable costs) while other options, such as filters, are durables (with mainly fixed costs). The per liter treated cost of a durable product will vary based on the assumed lifespan of the filter/durable. An important lesson from the development context, however, is that the product cost is a small portion of the total cost (distribution, education, programming) of implementation of a PoUWT project (Banerjee, 2007). In addition, cost may be deemed less of a barrier in the emergency context than in the development context, and thus cost becomes a more significant issue only in programs that are seeking to ensure sustainable long-term access to PoUWT consumables or replacement parts.

Despite these limitations, there is value in presenting the raw product costs for each of the PoUWT options (Table 4) to provide a sense of product costs on a per liter treated and per month household level.

Table 4: Product cost of PoUWT options(including only product cost) (adapted from (Lantagne, 2006b) and (Clasen, 2007a))

	Product Cost	**Per Liter Treated**	**Per month at household level**
Sodium hypochlorite	0.33 (average PSI sales cost)	0.0003	0.20
NaDCC	0.01 USD (ex-factory in Ireland)	0.0005	0.30
PuR	0.035 USD (ex-factory in Pakistan)	0.0035	2.10
SODIS	0.45 USD/year	0.0006	0.04
Ceramic filtration	~7.50-30 USD	0.001-0.004 (10 L/day, 24 month life)	0.31-1.25
Biosand filtration	12-100 USD	0.0008-0.007 (20 L/day, 24 month life)	0.50-4.16
Boiling	Variable	Variable	0.272-1.68 (Vietnam, (Clasen, 2008c))

3.2 Applicability of PoUWT development experience to emergencies

As seen in the information presented in this section, the majority of research on PoUWT has 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). Some of the potential differences between emergency and development principles are presented in Table 5.

Table 5: Humanitarian and developmentalist principles (adapted from (Maxwell, 1999)

Humanitarian Principles	Developmentalist principles
Humanity	Empowerment
Impartiality	Participation
Neutrality	Sustainability
Independence	Self-reliance
	Equity (gender, regional)
	Partnership
	Capacity building / strengthening
	Transparency and accountability

The differences in implementing organization principles can have significant impact on PoUWT projects. An organization whose goal is to provide safe water for the duration of the emergency only might select a different PoUWT 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 tend to have a higher crude mortality rate (Toole, 1990), a higher likelihood of outbreaks due to population migration (Watson, 2007), a higher level of funding which affects the decision tree for what water and sanitation option to select (de Ville de Goyet, 2000), and competing priorities for staff responding to the emergency (CARE, Undated),

All of these factors raise questions about the generalizability of PoUWT results from development settings into emergency settings. Some factors, such as a higher disease burden, would potentially increase the effectiveness of PoUWT in the emergency as compared to the development setting. Other factors, such as less staff time to train users on the PoUWT option due to competing priorities, would potentially decrease the effectiveness of PoUWT options in the emergency context. The applicability of successful development-based interventions like PoUWT to the emergency context is discussed as a theme throughout this document.

As seen in Section 2.4, there is need in certain types of emergencies for interventions to reduce the risk of waterborne disease. PoUWT, which has been widely investigated in the development context, may be an appropriate tool to implement in some of these emergencies. The purpose of our work in this report is to summarize the current knowledge of PoUWT in emergencies via a literature review (Section 4), collate information on PoUWT projects and implementer perceptions based on data collected from an email survey of implementers (Section 5), and summarize lessons learned and recommend further research to address gaps in knowledge on PoUWT in emergency response (Section 6).

4 LITERATURE REVIEW ON PoUWT IN EMERGENCIES

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

In total, 40 journal articles, project evaluations, and manuals were identified (Table 6). As can be seen, the majority of the research was conducted on one PoUWT product, the Procter & Gamble PuR flocculant/disinfectant sachet. Procter & Gamble has a corporate commitment to providing PuR in emergencies, and requesting organizations distributing PuR to write an evaluation. These evaluations were provided to the authors, and provide solid information, but the reader should note the preponderance of data presented in this report that has been supported by one company.

Table 6: Reports identified describing PoUWT interventions in emergencies

	Journal articles	Project Evaluations	Manuals
Flocculant/disinfectant powder (PuR)	2	17	1
Chlorine tablets (Aquatabs)	0	0	0
Liquid sodium hypochlorite (SWS)	4	2	1
Ceramic filtration	1	3	0
Boiling and Safe Storage	3	1	0
Tsunami	1	1	1
Other	0	1	0
SODIS, Biosand filtration	1	0	0
TOTAL	**12**	**25**	**3**

Although 40 reports were provided on PoUWT in emergencies, only 28 provided information on emergencies (natural disasters, complex emergencies, and outbreaks) as defined for this report (Table 7). In the following sections, we summarize this research. First, the lessons learned from emergency projects using chlorine-based consumable PoUWT options, including flocculation/disinfection, chlorine tablets, and liquid hypochlorite solution, are discussed, followed by discussions on chlorine dosage, use of mother solution, and chlorine generators in emergency response projects. Second, we summarize lessons learned from filtration projects in the emergency context. Lastly, we describe lessons learned from other interventions, boiling, and safe storage projects, and from the specific emergency of the December 2004 Indian Ocean tsunami.

Table 7: Journal articles, program evaluations, and manuals identified describing PoUWT interventions in emergencies

PoUWT Option	Emergency type	Country	Methods	Outcomes	Source
PuR	Refugee camp	Liberia	RCT, WQ testing	Diarrhea, FRC	(Doocy, 2006)
PuR	Refugee camp	Uganda	Project evaluation	Families collecting PuR	(SP, 2006)
PuR	Flooding	Haiti	Survey	Knowledge, FRC	(CARE, Undated; Colindres, 2007)
PuR	Feeding program	Ethiopia	Survey, WQ testing	FRC	(CARE, Undated)
PuR	Complex	DRC	Survey	Knowledge	(IMC, 2008)
PuR/chlorine tablets	Flooding	Bangladesh	Survey, WQ testing	FRC, uptake, diarrhea	(Hoque, Undated)
PuR/chlorine tablets	Flooding	Bangladesh	Survey, WQ testing	FRC, uptake, diarrhea	(Johnston, 2008)
PuR	Seasonal flooding	Vietnam	Survey, WQ testing	FRC, uptake	(Handzel, 2006; UNICEF, 2007a)
PuR	--	--	Manual	--	(Aquaya, 2005)
Sodium hypochlorite	Flooding/cholera	Madagascar	Survey, WQ testing	FRC, uptake	(Dunston, 2001a)
Sodium hypochlorite	Cholera	Madagascar	Case-control	Cholera risk	(Reller, 2001)
Sodium hypochlorite	Flooding	Madagascar	Survey, WQ testing	FRC, uptake	(Mong, 2001)
Sodium hypochlorite/boiling	Tsunami	Indonesia	Survey, WQ testing	FRC, *E. coli,* uptake	(Gupta, 2007)
Sodium hypochlorite	Complex	Haiti	Survey, WQ testing	Diarrhea, FRC	(Brin, 2003)
Sodium hypochlorite	Complex	Haiti	Survey, WQ testing	FRC, uptake	(Ritter, 2007)
Sodium hypochlorite	--	--	Manual	--	(CDC, 2008b)
Ceramic filtration	Tsunami	Sri Lanka	Survey	Uptake, use	(Palmer, 2005)
Ceramic filtration	Flooding	Dominican Rep.	RCT survey, WQ testing	Fecal coliform, uptake, use	(Clasen, 2006a)
Ceramic filtration	Flooding	Haiti	Survey	Uptake, WTP	(Caens, 2005)
Ceramic filtration	--	Multiple	Filter factory evaluation	Best practices	(Lantagne, 2006a)
Safe storage	Refugee camp	Sudan	Clinic record review	Diarrhea	(Walden, 2005)
Safe storage/mother solution	Refugee camp	Malawi	RCT, WQ testing	Diarrhea, fecal coliform	(Roberts, 2001)
Boiling	Flooding	USA	Survey	Knowledge	(Ram, 2007)
Tsunami	Tsunami	India, Sri Lanka, Indonesia	Interviews, site visit	Evaluation	(Clasen, 2005)
Tsunami	Tsunami	Indonesia	WQ testing	WQ testing	(Gupta, 2006)
Tsunami	--	--	Manual	--	(WHO, 2005a)
Nerox filter	IDP camp	Pakistan	Survey	Uptake	(Zehri, 2008)
SODIS	Cholera outbreak	Kenya	RCT	Diarrhea	(Conroy, 2001)

Abbreviations: FRC (Free residual chlorine), WQ (water quality), RCT (randomized, controlled trial), WTP (willingness to pay)

4.1 Flocculation/Disinfection

All of the research identified on flocculant/disinfection powders in emergencies has been conducted using the P&G product PuR. It is estimated that 70 million (63.6%) of the 110 million total sachets provided since 2003 have been for emergencies (Allgood, 2008). Some of the larger emergency response projects with PuR have included: the 2004 Tsunami in Asia (16 million sachets); the ongoing acute watery diarrhea outbreak in Ethiopia (15 million sachets); the 2005 Pakistan earthquake (10 million sachets); flooding in Bangladesh (3-4 million sachets); and, the 2008 Cyclone Nargis Myanmar flooding (2.5 million sachets). These larger responses have not yet been comprehensively researched or evaluated. However, evaluations of smaller-scale PuR emergency response projects supported by P&G funds have been completed. PuR is the most documented PoUWT option in emergencies. This body of work is summarized in the following sub-sections.

4.1.1 PuR – diarrheal disease reduction

PuR is the only PoUWT option that has been shown to be effective at reducing diarheal disease in an emergency situation in a published randomized, controlled intervention trial. In this trial, conducted during the rainy season, 400 households in two Liberian refugee camps were provided with a bucket, mixing spoon, decanting cloth, funnel, safe storage container, and 21 sachets of PuR per week (Doocy, 2006). Materials that were stolen during the course of the intervention were promptly replaced. The primary caretaker received an initial training, which included a demonstration of the correct use of PuR, distribution of pictoral instruction materials, and a requirement to demonstrate they could correctly use PuR. Weekly active diarrheal disease surveillance and water quality testing occurred in intervention and matched control households (provided with a safe storage container only) for 12 weeks following training. Households using PuR reported 91% less diarrheal incidence than control households, and diarrhea prevalence was reduced by 83% compared with baseline data. A compliance rate, verified by weekly chlorine residual testing, of 95.4%, was measured. The mean free chlorine residual level was 1.6 mg/L. Respondents reported appreciating the visual improvement and taste of the treated water, and the observed diarrheal disease reduction.

The conditions in the Doocy study represent a best-case PoUWT emergency intervention – in a controlled environment, with free distribution of product, replacement of all materials necessary, and initial training and weekly follow-up with families in an epidemic diarrhea situation. However, the Doocy paper was identified as a probable outlier in a review of the health impact of PoUWT interventions, as "it seems possible that the population and conditions presented in the camp may not be strictly comparable with those of the other studies comprising this review" (Clasen, 2006b). Other PuR intervention trials have documented more modest, but still significant, diarrheal disease reductions of 19-64% (Agboatwalla, 2004; Chiller, 2006; Crump, 2005; Reller, 2003). Reporting and courtesy bias, epidemic diarrhea, and high compliance were identified as potential explanations for the high impact seen in the Liberia study (Doocy, 2006).

4.1.2 PuR – emergency response project evaluations

Evaluations have been conducted on four targeted emergency response projects using PuR – distribution in a refugee camp in Northern Uganda, after flooding in Haiti, in a feeding project in Ethiopia, and in conflict-affected health zones in eastern DRC.

The collaborative Samaritan's Purse (SP), P&G, and Population Services International (PSI) project provided PuR to war-affected, displaced persons in Northern Uganda in 2005 (SP, 2006). The project location, Aler Camp, was a stable long-term refugee camp chosen because it was situated on a site where hard rock prevented borehole construction and data indicated residents relied on surface sources for the majority of their water needs. Prior to project initiation, SP completed focus groups and obtained community support for a water project, and arranged for block leaders and block helpers to coordinate the initial household trainings. The trainings were conducted first by experienced PSI staff, and then by PSI-trained SP staff. Each household was then provided with a starter kit of a jerry can, 2 buckets, a stirring stick, 4 filtering cloths, 1 scissor/razor blade, 1 funnel, seven sachets of PuR, and soap. Households were then asked to collect seven additional sachets each week from a central location in the camp.

Data on the number of families collecting their weekly sachets of PuR shows a steady increase in collection throughout the length of the project (Figure 10). SP associated this increase with an "increased perceived value of PuR as well as pointing to a behavior change in the community". Although a survey of 100 randomly selected recipients was conducted each week, no water quality, chlorine residual, or rigorous diarrheal disease data were collected. Users expressed high satisfaction with PuR, stating "One day my husband asked me what medication I was using that has made our children to last for so long without diarrhea. My answer was PuR and he could not believe", "I have come to believe that prevention is better than cure since PuR has prevented going to the hospital", and "The children are going to school everyday because they are now healthy".

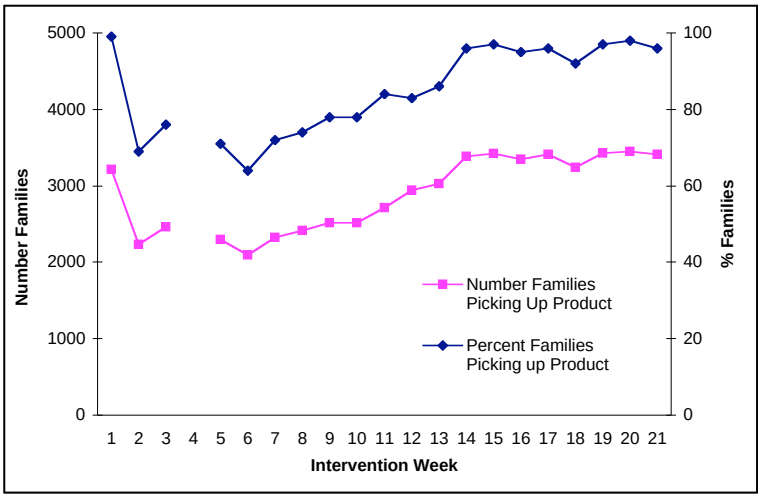


Figure 10: Number and percent of families collecting PuR weekly in refugee camp (data adapted from (SP, 2006))

In total, 388,193 sachets of PuR were distributed during the 21-week intervention, with one week of distribution (week 4) combined with the previous week due to insecurity. SP attributed the feasibility of the project in

meeting its goals – education, introduction of PuR, and reduction of waterborne disease – in part to the PSI training curriculum and trainings, which were "highly recommended" to other agencies. In fact, many of the same factors for project feasibility as in the Doocy Liberia trial – appropriate selection of intervention site, free distribution of all materials needed to treat water, and adequate training and follow-up – were also present in this intervention. The project ended when the camps dispersed after peace was attained, although the population might have access to the PSI socially marketed PuR available in Uganda, at a cost of 0.114 USD per sachet (Allgood, 2008).

In contrast to the feasible projects in the refugee camp situations as detailed above, two separate evaluations of one of the first emergency response projects using PuR identified significantly more challenges in an acute emergency situation. In response to Tropical Storm Jeanne in 2004, 410,000 PuR sachets were donated to relief efforts in Gonaives, Haiti (Colindres, 2007). NGOs that had competing demands and different water supply strategies, as well as no training in the use of PuR, chose not to distribute the PuR, and sachets were warehoused until the non-emergency response NGO PSI worked with local community leaders to conduct community demonstrations of PuR three to six weeks after the emergency. One hundred households that had received PuR in these community demonstrations were interviewed two weeks after the distribution. Although 92% of households reported using PuR sometime during the previous week, and 78% correctly answered all five knowledge questions about how to use PuR, only 22% households reported using PuR at the time of the unannounced visit, and only 10% of households had correct chlorine residual levels in their stored drinking water. In addition, only 25% of those surveyed indicated they would be willing to pay the social marketing price (~0.10 USD per sachet) for PuR in Haiti.

A separate report on the Gonaives response detailed "a variety of reasons that limited the usefulness of PuR in the specific circumstances during the emergency response to hurricane Jeanne" including: the lack of knowledge of NGOs and governmental agencies about PuR prior to the emergency, including how to use it and answers to technical questions about product safety; the fact the sachets were labeled in a language the population could not read, and were about to expire; the fact many households had lost all their possessions and did not have the materials to use PuR; the degrading security situation; and, the fact many NGOs distributed bottled water and bladdered water to the population as the first-line water supply intervention (CARE, Undated). The following logistical concerns were also raised in the report: "Given that the relief organizations and government agencies were unfamiliar with PuR, as were the affected population, mass awareness raising and training was going to be an enormous problem" and "The reality for many relief organizations in Gonaives was that their staff were already fully committed to various relief operation activities and unavailable for running training sessions on how to use PuR". Lastly, the report concludes "It should not be assumed that PuR is appropriate to all emergencies where safe drinking-water is required".

In contrast to the experience in Gonaives, an emergency response project with PuR in Ethiopia was reported to be feasible (CARE, Undated). In 2004, funding limitations in a community-based therapeutic care (CTC) project necessitated the use of BP100 biscuits, which need to be mixed or taken with water, as opposed to Plumpy'nut, which does not, but is more expensive. Concerns were raised about the potential for the BP100 to put malnourished kids at "greater risk of diarrheal disease than if they were treated only with Plumpy'nut", and a project to distribute PuR with the BP100 biscuits was planned. The appropriate hardware to use PuR, including jerry cans, buckets, and filter cloths, were purchased, and a monitoring and evaluation project planned. Training demonstrations were given to beneficiary families at the clinics, and seven PuR sachets were distributed to the family each week when the child came in for their CTC visit. A one-liter bottle to store water specifically for the malnourished child was also provided.

During focus-group discussion follow-ups, women commented on the chlorine taste but stated although it "was noticeable at first but they were now accustomed to it". Adequate residual chlorine was found in 16 (94.1%) of 17 source waters tested and adequate turbidity removal occurred in 15 (88.2%) of 17 source waters tested. The sources not meeting adequate water quality criteria were pond water sources with initial turbidity over 500 NTU. No controlled diarrheal disease or health impact data was obtained, although self-reported diarrhea decreased during the BP100/PuR combined intervention period. The main concern expressed by project staff was the fact that families did not have access to PuR after the five to six week malnutrition intervention period.

The CARE report concludes by comparing PuR interventions in Haiti and Ethiopia based on acceptance, emergency context, follow-up, and priority. In Haiti PuR was not accepted by relief agencies because it was unknown and "in the acute phase, impractical"; in the complex emergency context with concurrent security concerns and a rapid-onset acute emergency bulk water sources were determined to be a more appropriate intervention; training and follow-up was not possible in the circumstances; and, food, shelter, and potential violence were more pressing issues than water supply at the time of the intervention. In Ethiopia, PuR was accepted by the families as part of the malnourishment treatment regime; the emergency was stable and slow-onset; the weekly established clinics provided an ideal training site; and, the immediate priority for the family was the treatment of the malnourished child.

The goal of the last project evaluation that has been conducted on PuR use in emergencies, with International Medical Corps (IMC) in three conflict-affected health zones in eastern DRC, was to "decrease incidence of water-borne diseases in households in eastern DRC" (IMC, 2008). IMC trained locally community health workers to sensitize project participants on: the benefits of clean water, the impact of waterborne illnesses, safe water storage, handwashing, and methods to sanitize water. Over 6,300 participants from 750 households in the three zones were trained during 21 sensitization sessions. In addition, special education sessions for teachers, local health leaders, and community health workers were conducted. Additional behavior change communication measures included training manuals, leaflets, t-shirts, radio spots, football matches, quiz show competitions, and billboards. PuR, soap, jerry cans, and buckets were distributed to each household. Results from a household survey documented at project end 95% of households knew about sanitizing water, 85% could name two ways to prevent diarrhea, and self-reported diarrheal disease incidence fell from 56-78% at baseline in the three communities to 13-16%. There was no water quality testing to confirm PuR usage or controlled diarrheal disease data collected.

4.1.3 P&G / UNICEF collaboration

In 2006, P&G and UNICEF entered into a Memorandum of Understanding to complete a seven-country demonstration project using PuR within UNICEF projects responding to natural disasters and outbreaks. Work commenced in Bangladesh, Ethiopia, Kenya, Mozambique, Pakistan, Uganda, and Vietnam. Each country received 48,332 USD and an initial stock of 100,000-250,000 sachets of PuR. Two of the project countries, Bangladesh and Vietnam, conducted extensive evaluations. One clear result emerging from the reports is that many of the projects in the collaboration were not actually conducted in emergencies. The projects in Ethiopia, Kenya, and Pakistan targeted areas with poor water quality comprising situations similar to an IDP camp, schools using surface water, and an area with arsenic and bacteriologically contaminated wells, respectively. In Mozambique, the area was affected by cholera during the study, but no quantitative or qualitative evaluations were reported. In Uganda, Bangladesh, and Vietnam, the interventions targeted families depending on surface water normally, although in Vietnam it was during

seasonal annual flooding (which could be considered an emergency). The distribution of sachets in the response to Cyclone Sidr in Bangladesh is the only intervention in the P&G/UNICEF collaboration that unequivocally can be considered an emergency response project. The results from the Bangladesh and Vietnam projects are discussed below. Both studies also provide the only insights into comparing the use of different PoUWT options in emergencies, as in Bangladesh data was collected on both PuR and Aquatabs use and in Vietnam PuR was compared to use of alum and boiling.

4.1.3.1 P&G / UNICEF – Bangladesh

The Bangladesh collaboration completed the most extensive evaluations of any of the P&G/UNICEF projects, comparing PuR and Aquatabs acceptance and use in flood-affected areas in Bangladesh and during the natural disaster emergency of Cyclone Sidr.

In 67 flood-affected villages in Bangladesh from September 2006-February 2007, both PuR and Aquatabs were included in the relief packages for 4,800 families (Hoque, Undated). Relief kits included 20 sachets of PuR (sufficient to produce 200L of treated water), 20 Aquatabs (sufficient to produce 400L of treated water), food, two 20-liter buckets, one plastic water container, and other non-water related items. Trainings for the recipients were conducted in two locations. First, a 1-hour demonstration of PuR and Aquatabs was conducted during the distribution. Second, project motivators conducted 2-3 hour community level trainings in a subset of the 67 villages and addressed concerns raised by users, such as one woman who was told by her neighbors that the new "water medicine" (PuR) was "brought for the first time from a foreign country and we should not use it right away".

To assess the project, follow-up surveys and water quality testing were conducted with 200 families in 17 villages. Fourteen of these randomly selected 17 villages had received the community training from the project motivators. The initial 200 families were randomly selected, although if a family did not have treated water at the time of the unannounced visit, a replacement was obtained. A total of 239 families were visited to obtain 200 families that were using either product on the day of the unannounced visit. Of the 200 families surveyed, 200 had received PuR and 176 had received Aquatabs, and 150 were using PuR that day, with 50 using Aquatabs. The water quality results indicated that no treated water samples had detectible thermotolerant coliform, and all samples had free chlorine residual. The mean chlorine residual in Aquatabs households (1.45 mg/L) was significantly higher than in PuR households (0.28 mg/L). The free chlorine residual is important because a maximum of 0.3 mg/L has been identified as the level at which users in Bangladesh object to the chlorine taste. The importance of the motivator led community trainings, particularly for PuR usage, is highlighted by the fact that "the rates of use of PuR and Aquatabs in the 14 motivation follow-up villages were 89% and 30% respectively and in the three not follow-up villages were 54% and 26% respectively".

Respondents generally preferred PuR over Aquatabs: 98.5% were '*satisfied*' with PuR, compared to 84.5% with Aquatabs ($p<0.001$); 47% of PuR users were '*OK*' with the smell, compared to 30% of Aquatabs users ($p<0.005$); and 84% considered PuR a '*preferred*' method, compared to 41% for Aquatabs ($p<0.001$). A similar percentage of respondents, 63% of PuR users and 60% of Aquatabs users, had problems with the long time involved to treat water. Only 44.5% of those surveyed indicated they would buy PuR at Tk0.3 (0.004 USD); 30.5% would buy Aquatabs at the same price. The production cost of PuR is approximately 10 times this price (for treating 10L) and the production

cost of Aquatabs is about double this price (for treating 20L), indicating that both products would need to be subsidized (and in the case of PuR, heavily subsidized) in the Bangladeshi market. However, 99.5 and 94% of people indicated they would use PuR and Aquatabs, respectively, if the products were distributed for free.

A second, similar study was conducted comparing Aquatabs and PuR use and acceptance after both products were distributed in response to Cyclone Sidr in Bangladesh in 2007 (Johnston, 2008). At least five million Aquatabs were widely distributed by various stakeholders throughout the emergency without specific trainings for recipients. UNICEF also distributed 120,000 PuR sachets with trainings for recipients in two specific locations. Within 1-2 weeks of PuR distribution, an evaluation was conducted that included water quality testing and a questionnaire. The results of this second study were similar to the Hoque study in the flood-affected households. No thermotolerant coliforms were detected in water treated with Aquatabs or PuR, and a greater number of households were using and preferred PuR over Aquatabs. 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. One difference seen in the second study as compared to the first is that the chlorine residual levels were not significantly different between PuR and Aquatabs users, as Aquatabs users stored the water longer in order to allow the chlorine residual to dissipate before drinking. Self-reported diarrheal disease reduction data was collected, with the control group reporting 12.8% of under-5 year old children with diarrhea in the last 24 hours, as compared to 5.7% for the Aquatabs group, and 2.9% for PuR. This health data should be interpreted with caution, as the methods and statistical analysis of the data were not presented in the report.

In the Johnston study, no training was provided to the Aquatabs users, while training was provided to the PuR users. It is difficult to determine whether the users preferred PuR over Aquatabs because they received better training and were thus using the product correctly, or whether they preferred water treatment with PuR over water treatment with Aquatabs. The report concluded with the statement that PuR was more effective because of less chlorine smell and turbidity removal, but it was noted that PuR "requires more effort in distribution" for users to use correctly, and that for maximum efficacy, it is best if the product is pre-positioned.

These differences in reported preference and willingness to pay may be important in assessing the longer-term adoption and use of these products. However, they should not obscure the critical finding in both settings, which is that both interventions succeeded in making the water microbiologically safe at the household level.

4.1.3.2 P&G / UNICEF – Vietnam

In the Vietnam project, PuR was first tested for efficacy and effectiveness in the laboratory, and the Institute of Hygiene and Public Health was selected by the Ministry of Health to complete the testing (UNICEF, 2007b). After the verification testing, 2,353 households in an area affected by annual flooding who use water directly from surface sources for drinking were provided with an instructional leaflet and 90 sachets of PuR, intended for 90 days of water treatment. Quantitative data on usage and diarrheal disease incidence was collected by 93 PuR motivators who filled in information in a book while performing weekly visits to all the households. In addition, a follow-up qualitative survey and water testing were conducted with 10.3% (243) of the households.

The majority of families used surface water for drinking, with 223 (92%) of families reporting using alum to treat water for drinking prior to receiving PuR, and 219 of those 223 (98%) reporting they followed up alum treatment with boiling. The Vietnamese government recommends treating surface water with alum followed by boiling prior to drinking. Since the PuR was distributed, 231 (95%) of households reported using PuR everyday, 12 (5%) reported using on some days, and 3 households reported they never used due to the chlorine smell (2) and not wanting to use the PuR without supervision (1). Quantitative data from the commune motivators' booklets shows increased use of PuR over the three months, moving from 78% of families reporting using in September to 85% reported using in November. According to the report, this data suggests "that the longer people used PuR sachets, the more they understood its value and used the treated water for the right purpose of drinking" (UNICEF, 2007b).

Although 230 of the households (95%) had chlorine residual in their stored drinking water at the time of unannounced survey visit, the average was 0.5 mg/L – lower than one would expect from PuR treated water. This could be due to the fact that 90% of households reported they recognized a "strong taste" in PuR treated water, and 21.5-40.9% of families boiled the water after treating with PuR due to the strong smell of chlorine. In addition, "all interviewees thought that using more than 10 liters of river water with one PuR sachet could reduce the smell of chlorine". It is possible that the reason some higher than expected turbidities were seen (10.3% of samples were >2 NTU), was not the recontamination in storage as postulated in the report, but because users were treating a larger amount of water with one sachet of PuR in order to reduce the chlorine taste and smell.

Interestingly, 207 (85%) of interviewees responded they needed PuR more during the dry season than the rainy season due to the higher turbidity of the less diluted surface water available during the dry season. However, only 80% reported they would buy the sachets if they were sold at a reasonable price (0.013-0.032 USD), which is below the PuR production cost of 0.035 USD. It was noted in the report that, "Unfortunately we already face the issue of product unavailability shortly after PuR was introduced in the demonstration project".

An external field visit to the Vietnam project conducted by CDC noted that "the high use of alum in these communities obviously facilitated the introduction of PuR as the concept of clarifying water by stirring and settling is the same for both products", and all interviewees preferred PuR because it was "easier to use, [and] clarified water more quickly than alum" (Handzel, 2006). It was also noted that "ten liters per day [of treated water] was seen as adequate for most, but not all families", and "it is useful to know that family members can be taught to prioritize small amounts of treated water for drinking which will maximize health impact of the intervention" as "most families ration the treated water and use it for drinking and possibly cooking and use other water for cleaning and washing". The Handzel report attributed the boiling after PuR to the "habit of boiling alum treated water and lack of familiarity with PuR" as opposed to a deliberate attempt to reduce taste as the UNICEF report suggested. CDC also worked with UNICEF to determine the best way to analyze the diarrheal disease reduction data collected in the community volunteers' notebooks, and a decision was made to discard that data (see box). Lastly, the

> UNICEF Vietnam was too ambitious to include data on diarrhea for collection and later for analysis of the PuR Demonstration project impact. The data is too difficult to collect accurately by the IEC motivators at the commune level. Through reviewing the record books, almost all the data collected on diarrhea are not reliable. Together with CDC consultants, UNICEF decided not to use the data in the survey report.
>
> (UNICEF, 2007a)

Handzel report stated "The results of this intervention cannot be extended to an emergency response" for families in the project depend on river water normally, and were trained twice and visited weekly. "This will probably not be possible during an emergency when sachets would likely be distributed quickly and with minimal follow-up". These conclusions highlight the difference between PuR responses in acute emergencies and planned responses in ongoing emergency situations.

4.1.4 PuR – standard operation procedure

In cooperation with the Aquaya Institute, P&G developed a Standard Operating Procedure (SOP) for the deployment of PuR in emergency settings in 2005 (Aquaya, 2005). In addition to discussing how to use PuR, and tips for implementation, the SOP discusses overcoming potential obstacles for distribution, which include: lack of familiarity with the product and its usage, chlorine odor and taste, color change during the treatment process, lack of available buckets and cloth, and acceptance of the product by government and community leaders. To overcome these potential obstacles, it was recommended "PuR should be distributed to communities with an accompanying demonstration of its usage. Teams of emergency responders should train hygiene educators to perform initial demonstrations as well as provide an opportunity for follow-up questions by community members. A demonstration in which the presenter prepares PuR-treated water using a local source of water is the best way to educate people on proper use. It is important that the presenter drink the water at the end of the presentation to show confidence in the product". In addition, the SOP states to advise that chlorine taste and odors are "indicators of water safety", that color change during the treatment process is an indicator of correct treatment, that in some cases containers and cloths will need to be provided with PuR, and to coordinate emergency response with the local authorities.

4.1.5 Lessons learned from PuR emergency response projects

A significant amount of research has been conducted on the use of PuR in emergencies, and clear lessons learned emerge from an examination of the data, including:

PuR can be an effective intervention in some emergencies to improve water quality and health. The efficacy of PuR in improving water quality and reducing diarrheal disease has been well established in the literature and the development context. The diarrheal disease reduction documented in the Liberian refugee camp as well as the microbiological improvement of water documented in the Bangladesh cyclone response confirms these improvements can also be seen in emergencies.

There is a need for improved metrics to assess project impact in emergencies. Despite the fact that health impact and microbiological improvement are considered gold standards in measuring the impact of PoUWT, these metrics are difficult to accurately collect and analyze by local staff in an emergency situation. In addition to the Liberia refugee camp, five studies that were reviewed collected diarrheal disease data. Only one of these five studies collected controlled diarrheal disease data, and none reported statistical significance. The self-reported data in the Uganda refugee camp, the feeding project in Ethiopia, the project in Eastern DRC, and the flood-affected area in Vietnam all were discarded for the purposes of this report, either by the organization itself or because the data was not seen as accurate enough for inclusion by the authors. The data from the Bangladesh cyclone Sidr response should be used with caution, as no statistical analysis of the data was reported. In contrast, however, many projects were

able to gather valuable information to assess project impact, such as chlorine residual at the household level, turbidity reduction at the household level, number of families who collected their sachets each week, and quantitative information on use and acceptance. It is recommended that future projects focus on determining the most appropriate metrics to measure project feasibility, based on capacity to collect and value of the data for analysis, rather than a perceived need to obtain health outcomes.

Choosing the correct emergency situation to respond to with PuR is critical to project feasibility. The feasible PuR emergency response projects reviewed in this document shared certain characteristics, including being conducted in a stable emergency, in locations where the water source was appropriate to treat with PuR (turbid or surface sources), free distribution of product, and with organizational capacity to conduct trainings and follow-up. Even the refugee camp situations (such as Uganda and Liberia) were stable long-term situations, not acute emergencies. No project documented feasibility in an acute emergency, and it is not clear feasibility can be replicated in an acute emergency or unstable situations (such as the Haiti flooding response) where there is not organizational capacity to conduct extensive training and follow-up.

Local product registration is necessary and takes time. Local product registration and validation procedures should be understood and accounted for in pre-emergency planning. Lack of local validation was a hindrance in the Haiti flooding response, and local validation of the product was necessary prior to initiating projects in Mozambique, Pakistan, and Vietnam.

The appropriate number of sachets to distribute is usually 1 sachet per day per family. The Uganda refugee camp situation, Ethiopia feeding project, and Vietnam flood-affected areas project all distributed 1 sachet per day per family. As documented in Vietnam, that number of sachets was found to be appropriate for most families' drinking water needs, and chlorine residual was maintained in stored household water at this distribution amount at high levels in the Ethiopia feeding project and in Vietnam (95%). Although some projects distributed more sachets (3 sachets per family per day in the Liberia refugee camp diarrheal disease impact study), and some projects do a one-time distribution of sachets, it appears from the data that one sachet per family per day is enough, provided there is education to the families to prioritize PuR treated water for drinking.

Recipients need to have the materials necessary to prepare water with PuR. PuR as a water quality intervention requires, at minimum, two buckets, a stirring rod, and a cloth. In an emergency situation these materials can be difficult to locate. In the Liberia refugee camp, Uganda refugee camp, Ethiopia feeding project, and Bangladesh flooding and cyclone response projects at minimum buckets were distributed, and all the projects mentioned except Bangladesh also distributed cloth and stirring rods. In the Vietnam flood-affected area response, households were accustomed to using alum for flocculation, and thus had the treatment materials already.

Training + follow-up can lead to high uptake of PuR. High usage of PuR as measured by chlorine residual in household drinking water was associated with an initial training session and then additional household or community follow-up education. Group demonstrations followed by weekly follow-up in the Liberia refugee camp led to 95.4% of people with chlorine residual in stored drinking water and group demonstrations followed by weekly clinic visits in the Ethiopia feeding project led to all but one sample having chlorine residual at the household level. In the Bangladesh flood-affected area response, uptake of PuR was higher in households that received centralized training

and community follow-up (89%) than in communities receiving only centralized training (54%). In the Vietnam flood-affected area response, 95% of people had chlorine residual in their stored drinking water after centralized training and weekly follow-up. In contrast, in Haiti, where only community trainings were conducted, only 10% of recipients had chlorine residual in their drinking water. In the Uganda refugee camp, individual trainings were conducted, without weekly follow-up, and an increased rate of pick-up of product was noted, however no household follow-up was conducted to measure chlorine residual. While group demonstrations generally only take 45 minutes to conduct and have the visual flocculation cues that encourage user adoption, follow-up training was identified as key in these studies to answer user questions and encourage longer-term uptake. The practicality of this type of training in acute emergency situations is unknown.

Taste and smell are barriers in some areas, but not others. Taste and smell of chlorine residual can be a significant barrier in uptake and use of chlorine-based PoUWT products. In the studies summarized, there were a variety of responses to the chlorine taste. In the Liberian refugee camp, respondents reported appreciating the taste, in the Haiti flooding 97% of people reported PuR treated water tasted better than non-treated water, and in the Ethiopian feeding project taste was not found to be a barrier. Turbid water treated with PuR will generally have less taste than water treated with chlorine donors alone, because PuR removes the organic materials in turbid water that react with the chlorine and create additional offensive-tasting compounds. In contrast, taste was identified as a significant barrier in the Bangladesh flood-affected area and cyclone responses, and in the Vietnam flood-affected area project it was postulated that people disliked the taste so much they boiled water after PuR treatment to remove the taste. This data is consistent with other data showing that chlorine taste acceptability is site-specific, and, in general, there is greater acceptance of chlorine taste in African regions than Asian regions (Lantagne, 2008).

Access to PuR post-emergency should be considered in project planning. The importance of access to PuR for recipients in the post-emergency situation will depend on the project goals of the organization and the type of emergency. In some circumstances, the project goal will be to provide immediate relief only and in others to provide relief that translates into long-term usage of household water treatment. Numerous projects reviewed questioned the sustainability and long-term access to PuR for recipient populations, or the utility of providing PuR for only a short time. If PuR becomes available in more countries through social marketing and marketing projects, it may become more possible for users to transition from emergency to long-term use of PuR.

Recipients are not willing to pay the full cost of PuR. The cost of PuR ex-factory in Pakistan is 0.035 USD per sachet. Importation and distribution costs increase the price of PuR sachets in-country. For example, the average cost per sachet in the PSI PuR social marketing projects is 0.115 USD. The willingness to pay expressed by users surveyed in these studies ranged from only 25% of respondents willing to pay the social marketing price for PuR in Haiti, with the median reporting a willingness to pay of only 0.027 USD; to only 44.5% of respondents being willing to pay for PuR at 1/10th of the production cost of 0.004 USD; to 80% of respondents in Vietnam expressing a willingness to pay 0.013-0.032 USD. Research into whether behavior change communication or subsidies could encourage continued use of PuR in the post-emergency situation is indicated.

4.2 Chlorine tablets

Despite the fact that distribution of chlorine tablets is a common intervention in emergency response (WHO, 2005a), and that 14 (35%) of the 40 survey respondents indicating that they had used tablets (Section 5.2.1), not a single paper or project report on tablet usage in emergencies was identified in the literature search, or was sent in with a survey response. Although some references were identified that detailed the number of tablets distributed or where to purchase the tablets in an equipment catalogue of an NGO, there were no specific reports evaluating a chlorine tablet project in an emergency identified except for the data presented above from Bangladesh in the flocculant/disinfectant section (Edmondson, 2008).

As was discussed in Section 4.1.3.1, Aquatabs were distributed with less programmatic support, but were being used in homes and were effectively treating water as measured by presence of free chlorine residual and absence of thermotolerant coliform in both the flood-affected areas and the Cyclone response (Hoque, Undated; Johnston, 2008). Although respondents were significantly more satisfied with PuR as compared to Aquatabs, 94% of people indicated they would use Aquatabs if they were distributed for free. Although it is unknown from the data what percent of people would be using Aquatabs in the absence of the PuR intervention, what is clear is that 65% of households in the PuR targeted communities had received Aquatabs through mass distribution projects, and 10% had water treated with Aquatabs at the time of the unannounced visit. This data indicates that there is usage of Aquatabs in emergency response, even when people are receiving a preferable product and little training.

However, it was noted that there were extensive problems with the bulk distribution of Aquatabs in response to Cyclone Sidr, including that no training was provided, people did not like the smell and taste of the treated water, and there were problems with dosage because different size tablets were distributed (Johnston, 2008).

The taste issues seen with Aquatabs could be because the majority of responding organizations, including UNICEF in Bangladesh, use tablets with a chlorine dosage of 5 mg/L of chlorine residual (Edmondson, 2008). This is an extremely high dose, meant for worst-case scenarios. This issue is discussed in further depth in Section 4.4.

Based on the foregoing, the following conclusions can be drawn with respect to chlorine tablets in emergency response:

Chlorine tablets are not all equivalent, and emergency responders should be aware of potentially important differences. The chlorine donor, the intended chorine dosage, and the volume of water to be treated vary by chlorine tablets. These differences significantly influence efficacy and user acceptability, and responders should be aware of how product composition will affect performance in their emergency situation. Overdosage, as seen in the study in Bangladesh, can lead to user acceptability problems.

Chlorine tablets are widely used, but little researched, in emergencies. The disparity between the number of survey respondents who have used and consider chlorine tablets a successful PoUWT option and the lack of evaluation of chlorine tablet projects is striking. It is recommended that chlorine tablet projects be evaluated in the future.

Though potentially less acceptable than flocculant-disinfectants, chlorine tablets may offer equivalent protection at the household level at a significantly lower cost. Under emergency circumstances, chlorine tablets may offer a cost-effective alternative to flocculant-disinfectants and certain other options, particularly where high levels of turbidity are not anticipated.

Ensuring correct dosage is a barrier to chlorine tablet use in emergencies. The high dosage of 5 mg/L of chlorine residual used by some responding organizations is a barrier to use due to taste unacceptability.

4.3 Sodium hypochlorite

All of the research identified on the use of liquid sodium hypochlorite in emergencies was conducted using the CDC SWS. The principal focus of the CDC SWS project has been the establishment of products and projects in developing country settings that are intended to provide users with sustainable means of treating drinking water until they can be reached by piped, treated water. Over the last ten years, local production and distribution of sodium hypochlorite solution has been established in collaboration with PSI in 19 countries and with other NGO partners in six additional countries. Because the products are available locally and in some cases known to the population, the SWS products have also been used extensively in emergency response to cholera outbreaks, natural disasters, and complex emergencies.

4.3.1 SWS response to cholera

The SWS was initially developed in response to research linking the spread of cholera in South America in the early 1990's to unsafe storage of water at household level (Swerdlow, 1992), and SWS projects have been used for cholera response ever since the first national scale projects were established with PSI in the late 1990's. PSI Zambia and PSI Madagascar each launched SWS projects immediately before or during large cholera outbreaks, and initial social marketing product sales were spurred by demand created from these epidemics (POUZN, 2007). A project evaluation in 2000 in Madagascar found that product demand created by the cholera epidemic, and then three subsequent cyclones, stimulated both the rapid growth of a national scale project and confirmed use of the SWS as measured by chlorine residual in stored household drinking water in 11.2% of households in one target community, and 19.7% in households in neighborhoods in the last stages of community mobilization (Dunston, 2001b). The cost of the SWS bottle to users was 0.30 USD to treat 2,000 liters, and product cost recovery was 46%. In a case-control study in the 2001 cholera outbreak in Fort Dauphin, Madagascar, use of the SWS (Odds Ratio=0.1, 95% CI=0.0-1.2) and boiling (Odds Ratio=0.4, CI=0.1-1.1) were associated with statistically insignificant reductions in the risk of illness (Reller, 2001).

No additional studies on the use of the SWS and cholera have been conducted since the initial projects in Madagascar, although the SWS is still used extensively for cholera response. In 2007, PSI worked with local and international emergency relief organizations in 12 countries to distribute over 2.3 million bottles of sodium hypochlorite solution for cholera response (Wilson, 2008). In Kenya, a project coordinated by CDC responds to cholera epidemics with technical assistance from trained staff, pre-prepared local language educational materials, and

the locally available PSI WaterGuard product. It is unknown, however, how effective these projects are, as follow-up with recipients has not yet been conducted.

4.3.2 SWS response in natural disasters

Existing local SWS products have been used to respond to natural disasters in a number of circumstances, including cyclone response in Madagascar, the 2004 tsunami in Indonesia, and the recent cyclone in Myanmar. In the spring of 2000, Cyclone Hudah struck the north coast of Madagascar, and CARE, CDC, and PSI responded by providing 11,700 relief kits consisting of bottles of sodium hypochlorite solution and foldable jerry cans. An evaluation conducted five months after the emergency confirmed, through the presence of chlorine residual in household drinking water at the time of an unannounced visit, that 25% of recipients were still using sodium hypochlorite solution to treat their water (Mong, 2001). Recipients were willing to pay a median price of 0.38 USD for additional bottles of hypochlorite in the post-emergency phase, which was more than the social marketing product cost to users of 0.30 USD.

CARE Indonesia distributed the SWS solution to affected populations in communities after the December 2004 tsunami. A follow-up evaluation found that 3 to 14% of populations in three intervention locations were using the product, as measured by chlorine residual in stored household drinking water at the time of an unannounced visit, four months after the emergency (Gupta, 2007). Chlorination of drinking water was found to be protective against contamination by *E. coli,* while reported boiling, the traditional treatment method, was not.

PSI/Myanmar's WaterGuard project was launched in 2004, and because the project was operational and produces the sodium hypochlorite solution locally, PSI was immediately able to increase production after the cyclone. As of July 2008, PSI had distributed 2,700 20-liter bulk jerry cans and 80,715 250-mL bottles of sodium hypochlorite solution to organizations responding to the emergency (Wilson, 2008). Although that volume of solution is theoretically enough solution to treat 190 million liters of water, it is unknown how effectively the solution was distributed or how widely it was used at the household level because no follow-up evaluations have yet been conducted.

4.3.3 SWS projects in complex emergencies

The political, social, and economic environment in Haiti has led to a designation of the entire country as in a state of "complex emergency" (UN, 2008). Despite this designation, there are feasible and growing PoUWT projects in Haiti. One example is the Jolivert Safe Water for Families (JSWF) Project in rural, northern Haiti, which began in September 2002. Sodium hypochlorite is produced locally at the Jolivert Clinic using a hypochlorite generator. Families purchase this disinfectant in refillable 250 ml bottles either at the clinic (0.16 USD per bottle) or from 25 designated resellers throughout the surrounding towns and communities (0.20 USD per bottle, with the margin going to the reseller). Three Haitian technicians produce the hypochlorite solution, offer trainings to bring new families into the project, conduct household visits to provide ongoing training and chlorine residual testing, sell the hypochlorite solution, and maintain records. All project staff are fully paid from project income. After a pilot project evaluation documented significant reductions in microbiological contamination in stored water of SWS users – from an average 3,000 cfu/100 mL of total coliform in non-users water to 35 cfu/100 mL in users water, and an average 160 cfu/100

mL of *E. coli* in non-users water to <1 cfu/100 mL in users water (Brin, 2003), the project began expanding from the initial 200 families, and now has over 4,000 families enrolled.

The Jolivert project has been able to operate continuously and expand in a complex emergency environment, and respond to numerous emergencies – including floods, hurricanes, political upheaval, and riots – because of the local production and management of the project, focus on training and one-to-one community-based follow-up with the users, and a steady, sustainable growth plan. The project distributed free bottles of solution for six weeks in response to the 2004 flooding event, by working with the local community, churches, and resellers to distribute tickets for free solution to affected families (Gallo, 2008). A recent analysis of project documentation found that the average household purchases 6.24 bottles of sodium hypochlorite per year, that 76.7% of random household visits conducted by technicians between October 2002 and April 2007 had a positive chlorine residual in stored drinking water, and that cost of the sodium hypochlorite solution was not a barrier to joining the project or regular purchase of the sodium hypochlorite solution (Ritter, 2007). A manual has been developed to assist organizations in developing projects in complex emergencies, and recommends following a step-by-step plan to start a project starting with a feasibility analysis and continuing with organizing the project staff, selecting the project products, developing a behavior change strategy, establishing and evaluation a pilot project, and developing a plan for moving forward (CDC, 2008b).

A significant amount of research has been conducted on the use of SWS in different emergencies, and clear lessons learned emerge from an examination of the data, including:

The SWS product can be an effective intervention in some emergencies to improve water quality and health. The efficacy of the SWS in improving water quality and reducing diarrheal disease has been well established in the development context. The documented microbiological improvement of water in the Indonesian Tsunami response and the Haiti complex emergency response confirms these improvements can also be seen in emergencies. However, many projects, such as the Myanmar cyclone response and cholera responses, have not been evaluated, and further research is indicated.

There is uptake of the SWS in emergencies, in the post-emergency phase, and over time. Projects have documented the presence of chlorine residual in stored household drinking water after SWS product introduction in emergencies of 11.2-19.7% after cholera outbreaks and social mobilization in Madagascar, 25% five months after distribution of relief kits during cyclones in Madagascar, 3-14% four months after distribution of relief kits in Indonesia, and 76.7% over 4.5 years of an ongoing complex emergency project in Haiti. As can be seen, there is a large variation in the levels of uptake. As with PuR, it appears there are higher levels of uptake (as in the Haiti project) when there is ongoing follow-up with families using the product.

Taste and smell are barriers in some areas, but not others. Although chlorine taste and smell was not mentioned in these studies as a barrier, the chlorine dose used in the SWS is the same as used in PuR and chlorine tablets, and thus the taste and small concerns will be similar.

Access to SWS products during and after the emergency. The SWS can only be used for emergency response if there is an existing SWS project in country or near the emergency situation. This limits the use of the SWS

in emergencies, but also ensures there is continued access to SWS products to recipients after the emergency is over. Locally-made or locally-available products, such as the SWS, may be more appropriate for a relief-to-development model if the organization wishes to continue the project after the emergency response has finished.

Recipients may be willing to pay the full cost of the SWS post-emergency. The current average product cost of PSI socially marketed SWS products is 0.33 USD to treat 1,000 liters of water. PSI SWS costs have been reduced since the introduction of the Madagascar project through product optimization (Lantagne, 2005). The current cost of the SWS product was not identified as a barrier in the Haiti complex emergency project, and the 2001 willingness to pay seen in the Madagascar cyclone and cholera response projects now exceeds the current cost of the SWS product in Madagascar.

4.4 Chlorine dosage and other chlorine donors

The commercially available chlorine-based PoUWT options – PuR, Aquatabs, and the SWS product – are all based on a fixed chlorine dosage to ensure adequate water treatment for a range of water sources. The chlorine dosage of P&G 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, 2004a). The dosage of chlorine tablets 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 (Lantagne, 2008; WHO, 2004). The standardized dosage for SWS 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 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, 2008). 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 at the household level (Bartram, 2005).

In contrast to the commercially available chlorine-based options, 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 to leave a free residual chlorine concentration of 0.4 to 0.5 mg/l after 30 minutes, which 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 mother solution is then distributed to users. It is unknown if the solutions are pH stabilized to prevent degradation, or if a dosing device (such as a cap or spoon) are distributed along with the solution.

Although distribution of mother solution for water treatment is a standard emergency response PoUWT intervention, like chlorine tablets, no references describing the practice were identified in the literature search. However, in one journal article on safe storage and chlorination in a Malawi refugee camp situation, mother solution distributed by a health committee member was found to be only 27% and 8% of the required concentration when tested (Roberts, 2001). Given the difficulties discussed throughout these chlorine-based product sections on balancing quality, dosage, and taste acceptability further research is needed investigating the concentration and dosages of mother solution as distributed in emergency response projects.

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). The development organizations are wary of the mother solution model because accurately making quality-controlled, known concentration mother solution in the field is difficult as powder and particularly bleaches (Lantagne, In press) 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 most likely not adequate for storing water in the home. The emergency organizations are 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 a 5 mg/L tablet is often used in emergencies. Further discussion is needed to align the chlorine dosages used in development and emergency contexts, although the authors of this report recommend that in areas where there is no taste objection to chlorine, a dosage of 2 mg/L should be used for clear water and double that (4 mg/L) for turbid water. In areas where there is taste objection, a lower dose can be considered after water quality testing. A dosage of 5 mg/L is unlikely to be necessary in any water that can be adequately treated with chlorine.

Lastly, mother solution can also be generated using commercial hypochlorite generators that consist of a probe and an electrolytic cell. When the cell is submerged in salt and water, the chemical reaction between the salt, water, and electricity creates low concentration (0.8%) sodium hypochlorite. Generators are often purchased during an emergency by a donor agency and widely distributed. For example, one survey response from a manufacturer of electrolytic cells detailed over 1,100 generators that have been distributed in emergencies throughout Central and South America. Each generator is capable of providing enough sodium hypochlorite solution for approximately 24,000 families. However, establishing local quality manufacturing of hypochlorite using a generator, including pH stabilization of the solution to prevent degradation, and then managing distribution of the solution into containers that correctly dose and treat the water used by families is not trivial, even in the development context (CDC, 2008b; POUZN, 2007). No known follow-up, aside from the Jolivert Safe Water for Families project in Haiti, described previously in Section 4.3.3, has been completed with any of the projects that have delivered hypochlorite generators for emergency response. Further research is needed investigating the fate of the hypochlorite generators distributed in emergency response projects.

4.5 Ceramic filters

Like the chlorine-based PoUWT options, ceramic filters have been shown to be effective in the development context. However, ceramic filters have not been as widely evaluated in emergencies. Three evaluations of Oxfam

projects were identified in the literature review, including a report from a Sri Lanka project after the tsunami, a journal articled from a Dominican Republic project after flooding, and a report from a Haiti project after flooding. In addition, lessons learned from the establishment of local filter manufacturing factories will be discussed.

In response to the December 2004 tsunami, both Oxfam and the American Red Cross (ARC) distributed ceramic filters in Sri Lanka (Palmer, 2005). Oxfam distributed candle filters three months after the tsunami in Galle to people moving out of emergency camps, and in Trincomalee six months after the tsunami to people moving into transitional shelters. ARC distributed locally manufactured pot filters six months after the tsunami to people in Weligama moving back into their homes. Families in Galle received one cursory training, as the focus was to quickly provide a water treatment option as people were leaving the camps. Families in Trincomalee and Weligama received more substantial training. In Trincomalee, emergency staff had the time to train people since the acute emergency phase had passed, and people were moving into semi-permanent shelters. In Weligama the project was considered a pilot project, and thus more resources were allocated for training. An evaluation to assess acceptability was conducted six months after the tsunami – three months after distribution of the filters in Galle, and 1-2 weeks after distribution in Trincomalee and Weligama.

The evaluation found only 23% of people in Galle had sufficient filtered water to fill a cup at the time of the household visit, in contrast to 79% in Trincomalee and 96% in Weligama. Factors associated with higher levels of use included: having used wells as opposed to piped water as a source of drinking water before the tsunami, future planned well use, practicing any type of water treatment, a greater length of time between the tsunami and distribution of the filter, higher quality of shelter, higher intensity of programmatic support, and the distribution of pot as opposed to candle filters. Barriers to use were insufficient filter training and lack of living space. Families preferred the pot filter style over the candle filter style, and reported some technical problems in learning how to use and maintain the candle style filters. Factors associated with having filter problems included: being in an emergency shelter type, receiving the filter earlier in the emergency, having less programmatic support, and having a candle style filter. The evaluation concluded "filters were well received among recipients living in transitional and permanent shelters who received adequate programmatic support. However, filters should not be given out in the acute stages of an emergency response when internally displaced persons are living in emergency shelters and distributing organizations have too few resources to spend on ensuring high levels of use and correct use". Students from the Asian Institute of Technology have conducted a follow-up to this study, and their report is currently in draft.

A study of an Oxfam flooding response in the Dominican Republic in 2003, where ceramic candle filters were distributed in seven affected communities, focused on understanding long-term usage of the filters after distribution (Clasen, 2006a). After water quality testing found contamination in source waters that victims returned to after leaving temporary shelters, Oxfam initiated a pilot project to provide 431 families with a 15 USD candle-style ceramic filer distributed free of charge. Recipients were told the candles were effective for six months, and local businesses sold replacement filters for about 4.50 USD. Community mobilizers identified and trained recipient families, and then delivered the filters to the communities. In a randomized, controlled trial among 80 households in one of the seven communities for the entire six-month design life of the candle filter, thermotolerant coliform was found to be consistently lower among intervention households than control households (2.9 CFU/100 mL verses 32.9/100 mL, $p<0.0001$). Overall, 70.6% of samples from the intervention households met WHO guidelines for zero TTC/100 ml compared to 31.8% for control households ($p<0.001$).

A cross-sectional study of 115 households 16 months following filter distribution found that 102 (88.7%) of the recipient households still had their filters, with the remaining 13 having given the filters to family members or sold them. Of the 102 that still had the filters, 68 (66.7%) were still using them, with the remaining 34 having broken (22), clogged (6), or began leaking granulated activated carbon into the finished water (4). The problem with the remaining two filters was not identified. Of the 68 filters in use, 56 were considered to be operating properly (48.7% of total 115 households visited). Of these 56 households, 22 had replaced the candles within six months of distribution, 11 between six months and one year, 20 were using the same filter elements after 16 months, and 2 were unknown. Water quality testing in this follow-up found that while source waters remained highly contaminated, and 30 (54%) samples from the 56 working filters were free of thermotolerant coliforms. Thus, after 16 months, there was adequately treated water in 30 (26.1%) of 115 households that had received a filter. These results suggest that ceramic water filters can be an effective intervention for providing populations affected by disasters with safe drinking water during resettlement. They may also be a potentially sustainable long-term solution, provided householders have access to affordable replacement candle filters. It was stated in the paper that although training on the use and maintenance of the filters is "vital", "the evidence from the Dominican Republic is that it does not have to be extensive" to lead to long-term usage of the filter.

Establishing a consistent supply chain for affordable replacement candle filters can be difficult. In Haiti, an Oxfam project distributed about 1,118 double bucket filter systems free of charge to the poorest families and schools in areas around Cap-Haitien after flooding in 2003 (Caens, 2005). An additional 250 filters were sold at low price (subsidized by 90%) to stores three months after distribution to stimulate a replacement filter supply chain. Although users self-reported liking the filter and health benefits, willingness to pay for the filter was less than the replacement cost, and stores in the area were not willing to take the risk to import the filters with no market established. Users are now not able to obtain replacement parts. Comments such as: "I thought Oxfam would continue to distribute the filter" and "I want to buy a filter because it is cheaper compare to Culligan water gallons" were noted. The thesis concluded: "It is important to ensure a planned transition from the emergency response phase to a more conventional development program".

The NGO Potters for Peace is one organization that works to establish local pot-style filter factories in the development context. A document summarizing the lessons learned from the establishment of the 17 filter facilities worldwide (Lantagne, 2006a) identified four key elements for filter factory success (as measured by continuing production) including:

- Partner NGOs experience with marketing and health to support the filter production with filter distribution and demand creation;
- The availability of technical support and multiple visits by Potters for Peace;
- Understanding of local situations that impact the filter facility, including that all three of the filter factories in conflict areas (Sudan, Haiti and Iraq) stopped production; and,
- That having a sustainable marketing plan is more critical than starting with a large amount of initial funding.

Only eight of the 17 (47%) filter factories that were established have continued to produce filters. Those filter factories that have continued production (Nicaragua, El Salvador, Guatemala, Ghana, Cambodia, Honduras, Myanmar, Mexico), can provide ceramic filters in an emergency situation. Those filter factories that ceased production (Cuba, Bali, Sri Lanka, Ecuador, Thailand, Iraq, Haiti, Sudan, Bangladesh) many of which are in areas that

are prone to emergencies, cannot supply in emergencies because an ongoing development strategy was not feasible at the time.

Some key lessons learned from the research that has been conducted on ceramic filtration in emergency response include:

Ceramic filtration can be an effective intervention in some emergencies to improve water quality. The efficacy of ceramic filtration in improving water quality and reducing diarrheal disease has been well established in the development context. The microbiological improvement of water documented in the Dominican Republic response suggests that these improvements can also be seen in emergency and post-emergency contexts.

Choosing the correct emergency situation to respond to with ceramic filters is critical to project feasibility. Ceramic filters appear to be a more appropriate intervention after the acute emergency has passed, when recipients are moving from transitional into more permanent living structures and there is time for user training on the care and maintenance of the filter. In the Sri Lanka tsunami response project, lack of living space was identified as a barrier to use and being in an emergency shelter type was associated with having a greater number of problems with the filter.

Trainings are needed to teach users how to correctly use the filter. User training was identified as a factor contributing to higher usage of ceramic filtration in both the Sri Lanka tsunami response and the Dominican Republic flooding response. Although trainings were not extensive, and follow-up visits were not needed to ensure continued usage, some training at the outset on care and maintenance of the filter was identified as "vital".

There can be uptake of ceramic filtration in emergencies, in the post-emergency phase, and over time. In one Sri Lanka tsunami response community, 23% of people were using the ceramic filter three months after distribution. In the Dominican Republic, 48.7% of households had correctly operating filters 16 months after distribution with 54% of water samples from operating filters (26.1% of total) free of thermotolerant coliform. In Haiti, users expressed a desire to continue using the filter. All of these studies highlight the fact that a one-time distribution of ceramic filters with training can lead to some long-term usage of household water treatment.

The establishment of a replacement part supply chain should be considered. The importance of access to replacement ceramic filter parts for the recipients in the post-emergency situation will depend on the project goals of the organization and the type of emergency, and may be considered unimportant or vital. In some circumstances, the project goal will be to provide immediate relief only and in others to provide relief that translates into long-term usage of household water treatment. It is clear from the research to date that provision of ceramic filters in emergencies can lead to uptake post-emergency, although the establishment of a replacement part supply chain is hampered by obtaining the replacement parts at a cost that users are willing to pay.

4.6 Boiling and safe storage

Boiling and safe storage promotions are considered standard emergency response PoUWT interventions, similar to chlorine tablets and mother solution. However, little research has been completed on boiling or safe

storage. No project reports on boiling promotion or safe storage in emergencies were available, despite four (10%) of the 40 survey respondents having promoted boiling in an emergency situation.

4.6.1 Boiling

The WHO, CDC, and USEPA all recommend boiling water in the home in the event of an emergency. Although boiling has been shown in the development context to improve microbiological quality of water (Clasen, 2008c), no intervention study to date has documented diarrheal disease reduction associated with boiling, although experts agree correct boiling is likely effective at reducing disease and research is ongoing. Use of a narrow-mouthed water storage container, reported boiling, adequate boiling, and adequate boiling with water storage were not associated with decreased risk of *E. coli* in stored water in a study five months after the tsunami in Indonesia (Gupta, 2007).

4.6.2 Safe storage

Two journal articles documenting the effectiveness of safe storage interventions were identified in the literature review. The first was in June 2004, during an outbreak of shigellosis in Abou Shouk camp in the Northern Darfur, Sudan (Walden, 2005). Because water testing at the 25 boreholes in the camp showed only one source with slight contamination and cases were from all areas of the camp, it was assumed that post-collection contamination of water stored in containers in the households was occurring. In order to break the contamination cycle and control the outbreak, a mass water container disinfection project was launched. Over a period of five days, 13,224 storage containers were cleaned using 100–150 milliliters of 5% chlorine solution and small stones. Each container took 15-20 minutes to clean. The campaign involved: house-to-house visits to clean containers, information distribution, and targeted cleaning of containers missed in the house-to-house cleaning at water points. Although gathering statistically rigorous data in the outbreak situation was not possible, clinic health records showed a reduction of watery and bloody diarrhea in the weeks following the cleaning project.

The second study was a randomized, controlled trial conducted in a Malawian refugee camp to determine the effectiveness of improved storage alone on water quality and diarrheal disease. Intervention households were provided with 1-3 improved 20-liter buckets with a lid and a spout in exchange for their normal household containers (Roberts, 2001). Mean fecal coliform counts were found to be 53.3% lower in improved buckets as compared to the normal buckets, and children in households with improved buckets had a 31.1% reduction of diarrheal disease incidence as compared to controls, although the p-value was only 0.06, on the edge of significance.

4.6.3 Public health messaging about standard practices

A sobering example of the lack of effectiveness of boiling and chlorination messages comes from the United States in a survey of in eight mobile home communities affected by boil water orders after Hurricane Rita in 2005 (Ram, 2007). Only 77 (39%) of the 196 people interviewed from the eight communities were aware their community had been under a boil water order in the aftermath of the hurricane. Fifty-nine of the 77 (77%) were at home, and not evacuated, during the time of the boil water order. Of those 59, only 27 reported boiling their water, with 23 people reporting not boiling, and 9 reporting being unable to boil due to lack of electricity or fuel. In total, of the 97 respondents were in their home during the time of the boil water order, only 30 (31%) knew about the boil water

order, and only 10 (10%) reported boiling. In addition, only 7% of the people who boiled correctly specified the recommended duration to boil water (1 minute).

Respondents were also asked about other water disinfection methods. Overall, 163 (83%) of the 196 respondents identified at least one method of water treatment, with 44 (27%) identifying chlorination with household bleach. However, only 1 (2%) of the 44 respondents knew the recommended chlorine dosage. Thus, despite 92% of respondents having household bleach in their home prior to the hurricane, and 87% having bleach in their home after the hurricane, respondents were unaware how to use it to treat their water.

Some key lessons learned from the small amount of research that has been conducted on boiling and safe storage promotion in emergency response projects to date include:

Boiling is a standard emergency response and has been widely recommended for decades. Boiling is an effective PoUWT method that has been recommended for decades and, if household items have not been destroyed by the emergency, boiling may not require additional hardware to implement immediately. Boiling may be particularly appropriate among entrapped populations, or those who otherwise choose not to leave their homes, when they have the materials (cooking fuel and a pot) to practice the method.

Better communication strategies are needed to ensure boiling is completed correctly. The disparity in the data on efficacy of boiling in improving microbiological quality of water indicates that not all users are boiling correctly, and that better communication strategies, as seen in Hurricane Rita, are needed to train users to boil correctly.

Safe storage should be encouraged under all circumstances. Safe storage alone can minimize the risk of disease by preventing fecal contamination of drinking water at the household level. It is an important complement to any PoUWT method, especially those that do not provide for residual protection against re-contamination. Safe water handling, like handwashing with soap, will yield continuing benefits to populations well after the emergency subsides, and should be an essential component of communications programs in emergency response.

4.7 Emerging PoUWT technologies

There are numerous emerging technologies for PoUWT. Some of these technologies are implemented in the emergency context prior to completion of efficacy research in the development context. This situation occurred in a study on the Nerox filter, a gravity filter system with a microfilter membrane to mechanically remove organisms and turbidity. Although the filter has been independently tested for microbiological efficacy, it has undergone little field testing and has not yet been shown to improve water quality in the field or reduce disease in users (Zehri, 2008). The Nerox filter was piloted with Oxfam in Pakistani IDP settlements in 2006. Nine months after 210 households received a filter, only 21 (10%) of householders reported they used the filter ever day, and on visual inspection, only 12 (5.7%) of the filters were in full working condition, with the bag, filter, and tubes still intact. Users also reported significant disadvantages to the filter, including that it takes too long to filter water (78%), is difficult to clean (23%), needs to be cleaned too often (24%), and that water becomes too hot (82%). This assessment highlights the fact emergencies are not the appropriate circumstance to field test a new, untested product. One new product is the Life-

Straw pipe-style filter, manufactured by Vestergaard-Frandsen, SA, which has been cited in commercial and trade publications as a potentially useful PoUWT device for those who are away from their homes. Unlike other options, the device is deployed on a personal-level, rather than household level. An assessment of the device has recently been completed a non-emergency context in Ethiopia, but the results have not yet been published. No assessments have been completed in the emergency context. Prior to implementing in emergencies, product acceptability and product design studies should be implemented with users who can provide iterative feedback on the intervention design to increase acceptability and efficacy in the field.

4.8 Specific emergency: The 2004 tsunami

The most thorough evaluation of PoUWT in a single emergency situation was conducted by Thomas Clasen and Lucy Smith and summarized the lessons learned from interviews and field visits that commenced eight weeks after the 2004 Asian tsunami in India, Sri Lanka, and Indonesia (Clasen, 2005).

The report detailed the different types of water supply and sources throughout the phases of the emergency, starting with the immediate emergency phase, in which survivors relied on serviceable groundwater sources at refuge locations; followed by the use of packaged water and tanker truck water, with some minimal use of mobile water treatment plants and household water treatment in the stabilization phase; and finally the use of tanker truck water and storage tanks in the recovery phase until the government was able to re-establish water supply.

Despite the wide availability of household water treatment product following the Tsunami, PoUWT "did not play a significant role in the initial phases of the tsunami response with the possible exception of boiling". Boiling was the most widely promoted intervention because it was "observed that because boiling was well-known and widely accepted, it did not require programmatic support for its promotion, thus allowing them [NGOs] to focus on providing basic water and sanitation needs". Although 140,000 bottles of sodium hypochlorite were delivered to Aceh from an existing project in Jakarta, it was found that without training sessions and sensitization, there was little uptake. A new distribution strategy that incorporated trainings was found to be more effective. In addition, millions of chlorine tablets were reported sent to tsunami-affected countries, but only limited household use could be confirmed, and even though over 15 million flocculant/disinfectant sachets were sent in response, much of the product was not distributed in the initial phases because of lack of capacity to train users. Small numbers of ceramic filters were distributed in the emergency, although there was only sporadic distribution and use in the early stages. Implementers of SODIS and biosand interventions decided to wait until after the recovery phase to develop projects.

In summary, PoUWT, other than boiling, was not suitable in the immediate aftermath of the tsunami for five key reasons:

- It was more important to emphasize water quantity over water quality in the tsunami emergency;
- PoUWT was unnecessary given the fact that water was supplied in bulk from tanker trucks because saline intrusion prevented the use of local sources;
- Due to the scale of the emergency human and other resources for PoUWT programmatic support was not available;

- There were concerns that sending mixed messages about water treatment practices would dilute the effectiveness of the standard boiling messages; and,
- Concerns were raised about the sustainability of PoUWT methods in the post-emergency situation.

Despite the fact that tanker truck water was, by default, the recommended strategy for safe water provision in Aceh post the Tsunami, no surveillance system to monitor tanker truck quality was established. A rapid assessment conducted from June 3-5, 2005 found that only 42 (56%) of 75 truck water samples in trucks waiting in line at the water treatment plant to refill their truck had greater than 0.1 mg/L of free chlorine residual, and 9 (17%) of 54 truck water samples tested for *E. coli* were positive (Gupta, 2006). Three factors were identified that contributed to these water quality results, including: 1) wait times at the filling station of 5-97 minutes led drivers to fill their trucks from untreated sources; 2) water at the filling station was underchlorinated according to WHO guidelines; and, 3) sediment in tanker trucks accumulated from transporting untreated sources exerted chlorine demand when filled with chlorinated water.

The conclusions from the Clasen report and the Gupta paper highlight the need for appropriate assessment prior to initiation of PoUWT projects, as discussed in Section 3.1.7. PoUWT options will not be appropriate in all stages of all emergencies, and understanding their appropriate role is key to feasible implementations. It was recommended that a further evaluation of PoUWT later on in the recovery phase be conducted, and to "clarify the conditions under which proven approaches to household water treatment may be useful in emergencies and assess their role in the medium- and long-term response," as compared to the immediate response.

Although the recommended follow-up study was not completed, five months after the tsunami, an evaluation in three Indonesian sub-districts in households who received free distribution of liquid sodium hypochlorite solution was conducted (Gupta, 2007). Two sub-districts (Nias and Simeulue) were rural, island communities, and the third (Aceh Besar) comprised of temporary living camps and tent camps. The survey found reported use of sodium hypochlorite to be 28%, 21%, and 12% in Aceh Besar, Nias, and Simeulue, respectively. Confirmed use of sodium hypochlorite, as measured by presence of chlorine residual, was found to be 14%, 14.7%, and 2.64%, respectively. Factors found to be associated with decreased risk of *E. coli* contaminationin stored water (including adjusted odds ratios and 95% confidence intervals) included: 1) reported use of sodium hypochlorite (Acheh Besar (aOR 0.52, 0.27-0.98), Simeulue (aOR 0.46, 0.36-0.60)); 2) presence of free chlorine residual (Aceh Besar (aOR 0.42, 0.23-0.77), Nias (aOR 0.28, 0.16-0.51), Simeulue (aOR 0.38, 0.15-0.98)); 3) observed use of washing soap with hands (Simeulue (aOR 0.62, 0.44-0.86)); and, 4) use of a latrine (Simeulue (aOR 0.40, 0.28-0.55)).

Interestingly, use of a narrow-mouthed water storage container, reported boiling, adequate boiling, and adequate boiling with water storage were not associated with decreased risk of *E. coli* in stored water (Gupta, 2007). The health consequences of inadequate boiling and/or recontamination after boiling are unknown. This evaluation highlighted the fact that not all interventions promoted (such as boiling) were effective at maintaining stored water quality, and, although there was low use of sodium hypochlorite, it was the only intervention effective in all sub-districts. It also highlights the fact that after reestablishment of pre-existing water sources, there was little use of PoUWT after the Tsunami.

In response to the large interest in household water treatment following the Tsunami, the World Health Organizations International Network to Promote Household Water Treatment and Safe Storage issued a FAQ sheet entitled "Household Water Treatment and Safe Storage Following Emergencies and Disasters: South Asia Earthquake and Tsunami". This FAQ provided an overview of the options for water treatment, and some information on how to use the products (WHO, 2005a).

4.9 Summary

The summary of lessons learned, research indicated, and themes identified from this literature review will be presented in conjunction with the summary of the survey results in Section 6.

5 SURVEY OF PoUWT PROJECTS IN EMERGENCIES

Following the literature review, we conducted a survey to: 1) solicit information on the scope of PoUWT interventions in emergencies; and, 2) obtain information from implementers about their perceptions of the nature and results of PoUWT interventions. Implementers, as the people working on the ground within the emergency response, have a valuable perspective on the utility of PoUWT that differs from manufacturers, donors, or researchers, who might only see the PoUWT products in ideal conditions. However, implementer perceptions can be biased for various reasons: 1) project success could be overstated due to donor concerns or considerations; 2) implementers could only see their project, and not understand how their individual project fits into the larger picture; or, 3) implementers might not use rigorous analysis to inform their responses. The results presented should be interpreted in view of these potential limitations.

5.1 Methods

5.1.1 Survey design

Data was collected from implementers with experience using PoUWT 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 PoUWT in emergencies, and their experience with PoUWT in emergencies. We endeavored to use language that was simple, concise, non-leading, and unbiased. The survey began with a set of open-ended questions about PoUWT in emergencies, and continued with one page of specific, forced-choice questions about individual projects, using one or more PoUWT 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 in this section: 1) by respondent, with answers to general open-ended questions; 2) by project, with project specific information; and, 3) by projects where only one PoUWT option was implemented. Because many of the forced-choice questions were based on project, which could have had one or more PoUWT option promoted, valuable information to allow for comparison between the PoUWT options was gained from the project responses that included only one PoUWT option. Respondents were requested to complete the survey on their personal computer, and email back the response. The survey was authorized by the LSHTM Ethics Committee.

5.1.2 Survey distribution

An initial email requesting survey responses and including the survey and information and consent forms was distributed to 340 recipients from the authors' mailing list on May 29, 2008. Recipients were encouraged to pass on the survey to any organization or individual working on PoUWT in emergencies. In addition, the author sent targeted emails to three individuals from the International Meeting of the Household Water Treatment and Safe Storage Network in Ghana in June 2008. The survey was closed on September 30, 2008. Given the nature of the survey, it is not possible to calculate an exact response rate, although information about respondents based on the email chains was collated and is presented in Table 8.

Table 8: Respondents and response rate

	Individuals Emailed	Respondents	Response Rate
Initial email	307	13 (24.1%)	4.2%
Traceable forwards	324	6 (11.1%)	1.9%
Targeted email	3	3 (5.6%)	100%
Not traceable	Unknown	32 (59.3%)	Unknown
TOTAL	Minimum of 634	54	Unknown

5.2 Results

5.2.1 Summary results by respondent

Fourteen (26%) of the 54 survey responses were excluded from the analysis. One survey each was excluded because: 1) the response described a PoUWT project in a development context only; 2) the survey form was completed in an unenterable manner; 3) the respondent had not used PoUWT in an emergency, although provided perspective that PoUWT is not appropriate in all emergencies; and, 4) the response did not discuss on-the-ground projects. Lastly, almost identical survey responses were received from 12 resellers of one particular PoUWT device, and only one response was included in the analysis.

Fifteen (37.5%) of the remaining 40 respondents were from international development NGOs, including PSI (7), and one respondent each from Rotary International, BushProof, ThirstAid, Pure Home Water, Peace Corps, Society of Women and AIDS, Cantaro Azul, and PATH. Seventeen (42.5%) of the 49 respondents were from international emergency NGOs, including IFRC (4), Oxfam (4), UNICEF (2), and one respondent each from AmeriCares, Action Contre la Faim, Norwegian Church Aid, CARE, RedR/India, World Vision, and CHF International. Five (12.8%) researchers (from ICDDR,B, CDC, Aquaya Institute, Johns Hopkins University, and Cascade Designs), two (5.1%) manufacturers (of SteriPure and PuR), and one (2.6%) individual round out the 40 respondents.

The 40 included respondents described projects using 82 PoUWT interventions (Figure 11). The average number of PoUWT options used in all projects described by each respondent was 2.05 (range 1-8). The respondents listed 74 PoUWT interventions as "most successful", using their own definition of success (Figure 11). The average number of most successful options per respondent was 1.90 (range 1-7). Note that some options had more respondents consider them successful that reported using them. This is because some respondents did not fill out project information on every PoUWT option they have implemented.

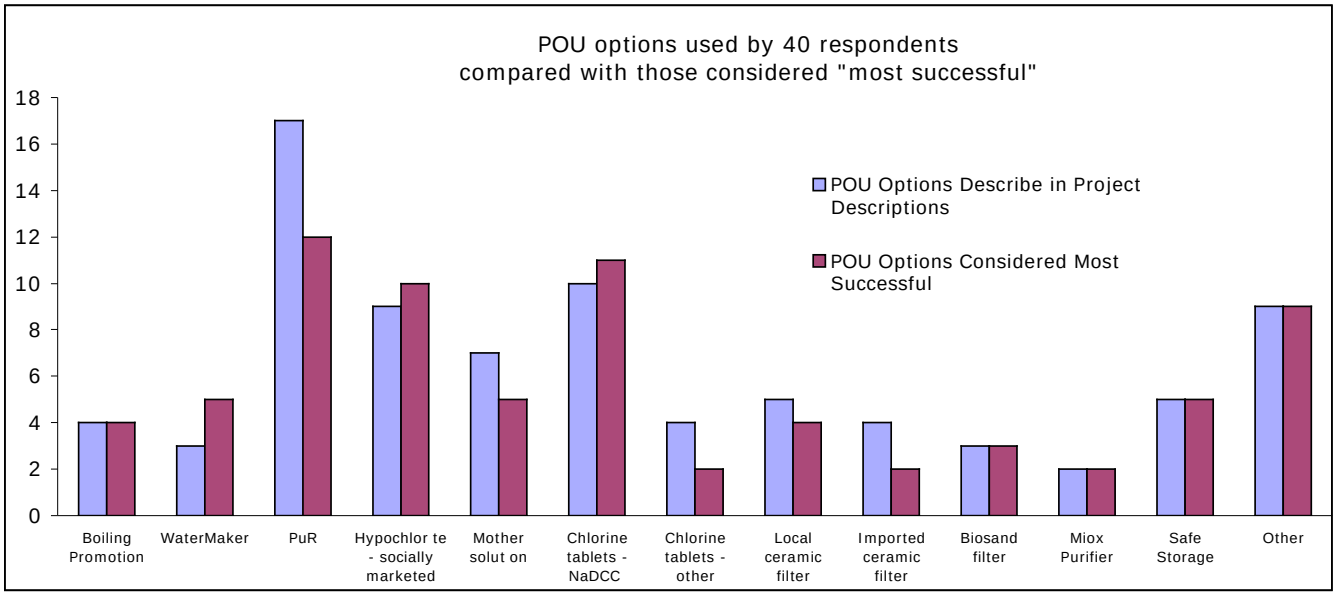


Figure 11: PoUWT options used and considered successful in emergency responses

Thirty-six (90%) of the 40 respondents replied "yes" when asked "is there a useful role for PoUWT options in emergencies", with the remaining 4 (10%) answering "depends". Thirty-four (85%) respondents replied "yes" when asked "would you use the PoUWT option(s) you used in an emergency setting again", with the remaining 6 answering "depends". Two respondents (5%) answered "depends" to both questions.

5.2.2 Results by project

The 40 respondents described 77 projects using one or more PoUWT options in emergencies (average 1.93 per respondent, range 1-8). Two were identical projects described by different responders, and in these cases the survey response from the person closest to the field was included in the analysis and the duplicate response dropped.

5.2.2.1 General project characteristics

The 75 included projects occurred in 25 countries (Table 9). Thirty-one (41.3%) projects took place in 13 countries in Africa, including Angola (2), Chad (1), DRC (4), Ethiopia (2), Ghana (1), Guinea (1), Kenya (5), Madagascar (2), Mozambique (3), South Africa/Namibia (1), Sudan (2), Uganda (5), and Zambia (2). Ten of the projects (13.3%) took place in five countries in the Americas, including Columbia (1), the Dominican Republic (3), Mexico (1), Peru (2), and the USA (3). The remaining 34 projects (45.3%) took place in seven countries in Asia, including Bangladesh (9), India (6), Indonesia (9), Myanmar (4), Philippines (1), Sri Lanka (4), and Thailand (1).

Forty-eight projects were implemented in response to a flooding event (cyclone/waterloggging, flood, or tsunami), 14 responding to outbreaks, and 2 responding to mixed flooding and cholera events (Table 9). The remaining 11 projects (14.7%) were implemented in complex emergencies and in response to earthquakes.

Table 9: Projects by emergency type and continent

	Africa	Americas	Asia	*Total*
Natural disaster: cyclone/waterlogging	1	1	10	*12 (16%)*
Natural disaster: flood	10	6	11	*27 (36%)*
Natural disaster: tsunami			9	*9 (12%)*
Natural disaster: earthquake		3	4	*7 (9.3%)*
Natural disaster: flood and Outbreak: cholera	2			*2 (2.7%)*
Outbreak: cholera	11			*11 (14.7%)*
Outbreak: Ebola, Hepatitis E, typhoid	3			*3 (4%)*
Complex emergency	4			*4 (5.3%)*
Total:	*31 (41.3%)*	*10 (13.3%)*	*34 (45.3%)*	*75*

The majority (68%) of PoUWT projects were implemented in rural areas. The remaining were in urban areas (21.3%), or mixed urban/rural (10.7%) locations. Recipients lived primarily in communities (58.7%), followed by IDP (28.0%), refugee (6.7%), and mixed (6.7%) settings (Figure 12).

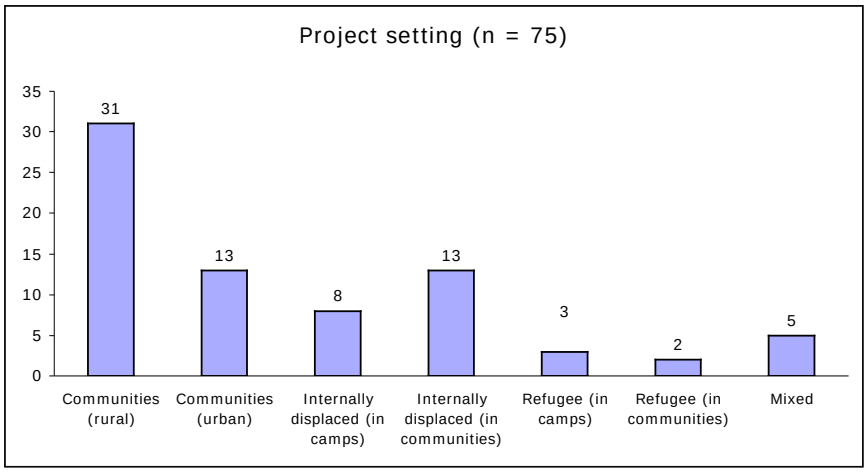


Figure 12: Project location and setting in emergency projects

Fifty-one (68%) projects began in the acute emergency stage, with 6 (8%) beginning in the late emergency stage and 5 (6.7%) in the post-emergency stage. Twelve projects (12%) were defined as being part of an ongoing complex emergency. The eight projects that did not identify the emergency type as complex emergency, but did detail their projects began in complex emergencies were five outbreaks (four cholera, 1 hepatitis E) and three responses to cyclones and floods. One respondent did not respond to this question.

The projects began between 1999 and 2008. Eight projects started in 2008 and one respondent declined to answer this question. The 66 projects started between 1999-2007 show an exponential growth rate (R^2=0.92) in PoUWT project implementation in emergency response (Figure 13). However, this data should be interpreted with caution, as it is possible there is bias in survey responses to projects that have been recently completed. The average

number of weeks to respond to the emergency with PoUWT implementation was 3.7 weeks (range 0-36), which varied by emergency stage, with 2.1 weeks to respond (average) in the acute emergency, 5.1 weeks (average) to respond in late emergency, and 20.8 weeks to respond (average) in the post-emergency situation.

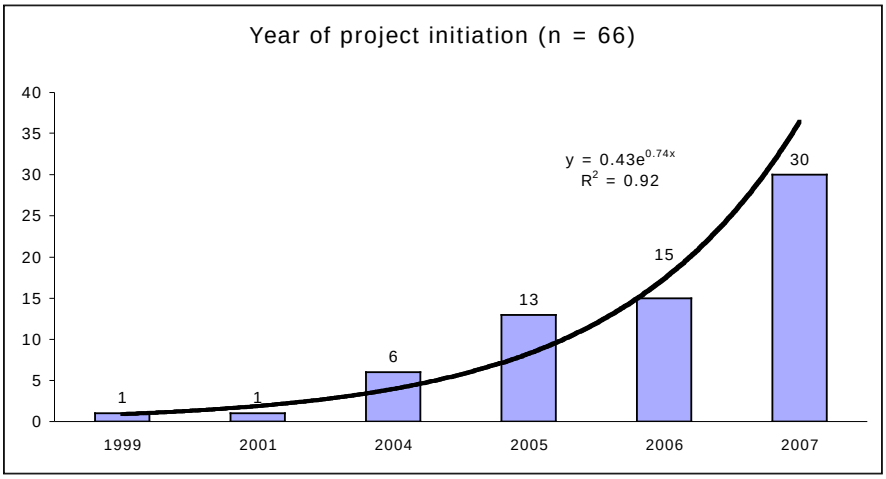


Figure 13: Year of project initiation

Technical assistance was obtained locally from within the respondents' organizations in 39 (50.6%) projects, and obtained locally from outside the respondents' organization in 22 (28.6%) projects. Technical assistance was also obtained from within the respondents' organizations internationally in 23 (29.9%) projects, and outside their organizations internationally in 4 (5.2%) projects. The only project where it was indicated that technical assistance was needed but not available was a project implementing a mother solution in a cholera outbreak.

Respondents reported that project assessments were completed for 68 (90.7%) total projects. An average of 1.2 assessments per project (range 0-3) were reported (Figure 14).

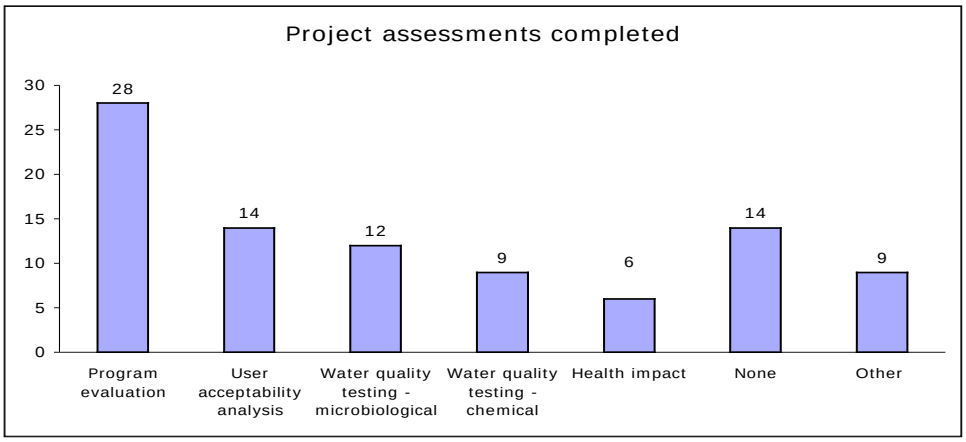


Figure 14: Project assessments completed

5.2.2.2 Water sources in projects and by PoUWT intervention

Survey respondents reported an average of 2.16 sources (range 1-3) were used in the projects (Figure 15). Seventy (43.3%) of the 162 total sources listed were 'improved' (WHO/UNICEF, 2000). Water from improved sources is not necessarily safe to drink, as the source water could be contaminated or recontaminated during transport and storage, but it is an indicator the water is likely safer than unimproved sources (Clasen, 2003). Five of the improved sources were "treated infrastructure" water, and likely safe to drink. The remaining 92 sources (56.7%) were unimproved (such as surface water, open well, unprotected spring, and other), with concurrent higher risk of contamination.

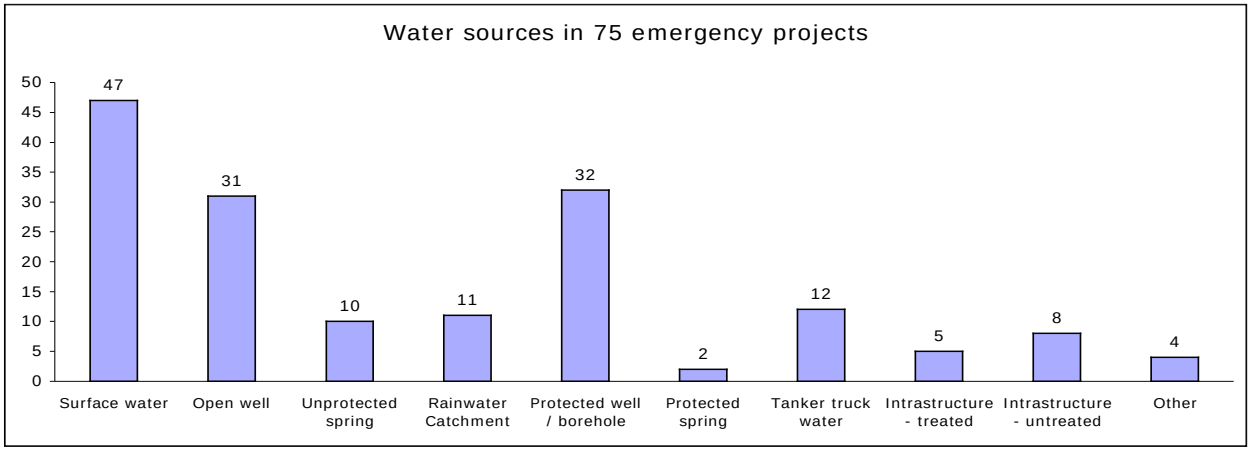


Figure 15: Water sources used in 75 emergency projects

Source water data from the 56 projects that reported using only one PoUWT option was analyzed. Fifty-four of the 56 projects were sub-categorized into four PoUWT option categories by the authors – including filters, flocculant / disinfectant, sodium hypochlorite, and chlorine tablets. The remaining two options were one alum and one boiling project, and were not categorized for the purpose of this analysis. Flocculant / disinfectants – which remove turbidity as well as disinfect the water - were targeted more often to unprotected water sources which are likely more contaminated, and chlorine tablets were targeted more often (72.2%) to areas with protected water sources (Figure 16). Filters and sodium hypochlorite were targeted approximately equally to areas with protected and unprotected sources.

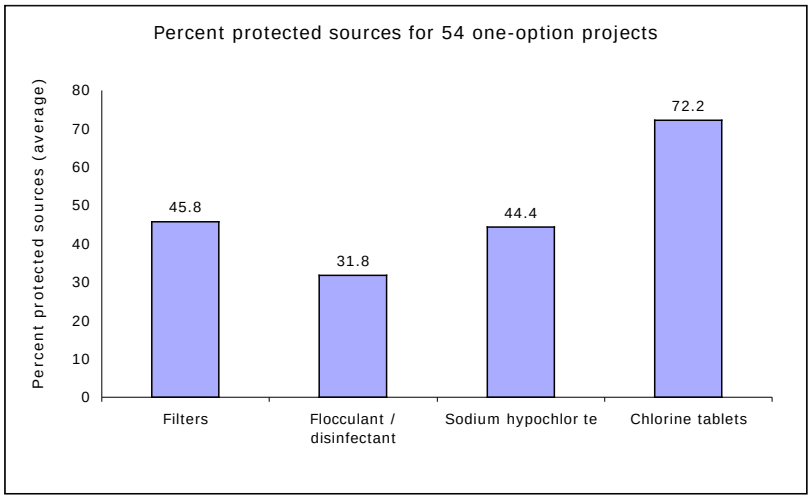


Figure 16: Percent protected sources for one-option projects

5.2.2.3 Results from data that was difficult for responders to provide

Data was collected on the units of PoUWT product distributed, the cost of the product to the responding organization, the time to receive the products, and whether the products were available locally or imported. This data was particularly difficult for many of the respondents to reply to, as many did not know the cost of product, or total number distributed. Respondents provided sufficient information to calculate the potential number of liters treated of water for 58 (77.3%) projects, although the data was considered too unreliable to present in this report.

The data obtained from the "target population size" question was dropped from the analysis because respondents did not answer this question for 31 (41.3%) projects. In addition, the data obtained from respondents for the remaining 44 projects was not comparable – as some respondents listed the number of confirmed cases of cholera, some listed the entire population affected by the emergency, and some listed the number of people who received products.

5.2.3 Implementer perceptions on projects

The PoUWT options implemented in the 75 projects were presented in Figure 11 on page 61. A total of 184 reasons for selecting the particular PoUWT option(s) used were detailed (Figure 17). An average of 2.45 reasons were detailed per project (range 0-5). The main reasons for using the option(s) fell into four general categories (collated by the authors): availability, knowledge, sustainability, and appropriateness for water quality. The fact the product was available was the single largest reason for use, with respondents listing this reason in 64% of projects, accounting for 26.0% of the total 184 reasons for option selection. The responses related to knowledge (54 total responses), including prior experience with option and prior knowledge of product, accounted for the largest percentage (29.3%) of the 184 reasons by category. The responses related to sustainability – including cost-effectiveness, availability to

population post-emergency, and product sustainability – accounted for 25.0% of the 184 reasons. The 12 responses for "appropriate for water quality" accounted for another 6.5% of the reasons. The 10 "other" reasons for option selection detailed by the respondents were the option was recommended by a donor (2), the local government (2), or headquarters (2), that it was convenient, easy, or safe to use (3), and that technical support was available (1). Few responses have to do with any local conditions, such as local water quality (10 responses only) or user acceptability.

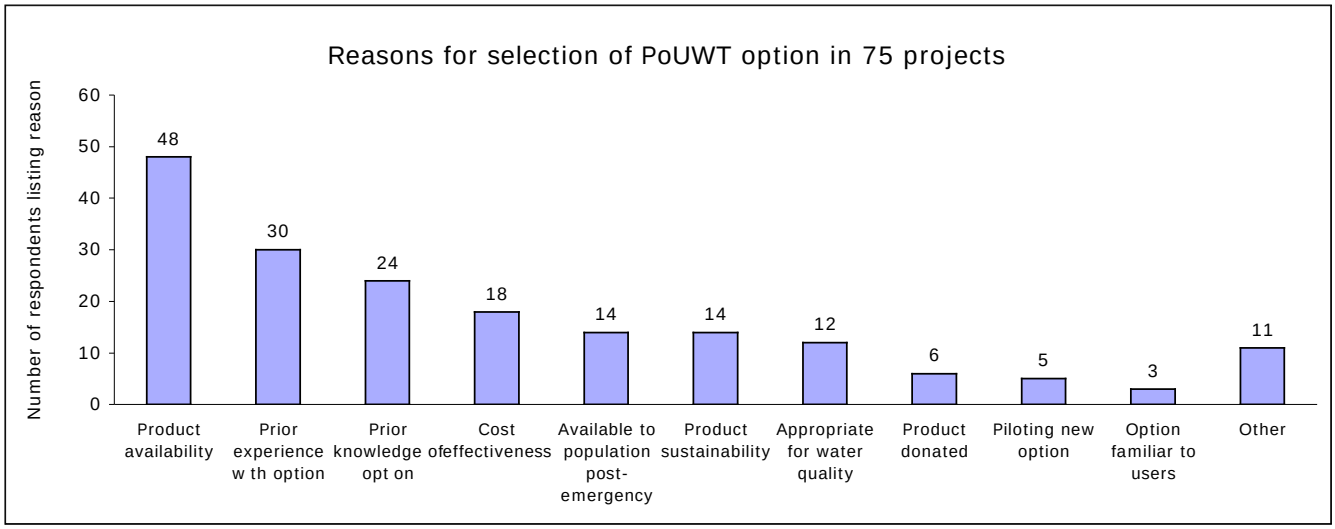


Figure 17: Reasons for selection of PoUWT option in 75 projects

The reasons for selection in the projects using only one PoUWT option was also analyzed using the same sub-categories created before. As can be seen from Figure 18, there is variation in why certain options were selected. Flocculant / disinfectants were selected more often because of product availability and appropriateness for water quality, and were the only option where it was mentioned that the product was selected because it was donated. Product sustainability was only mentioned as a reason for selection for locally manufactured or longer-lasting products, such as sodium hypochlorite and filters. Chlorine tablets were the only option where it was mentioned that one reason for selection was it was familiar to users.

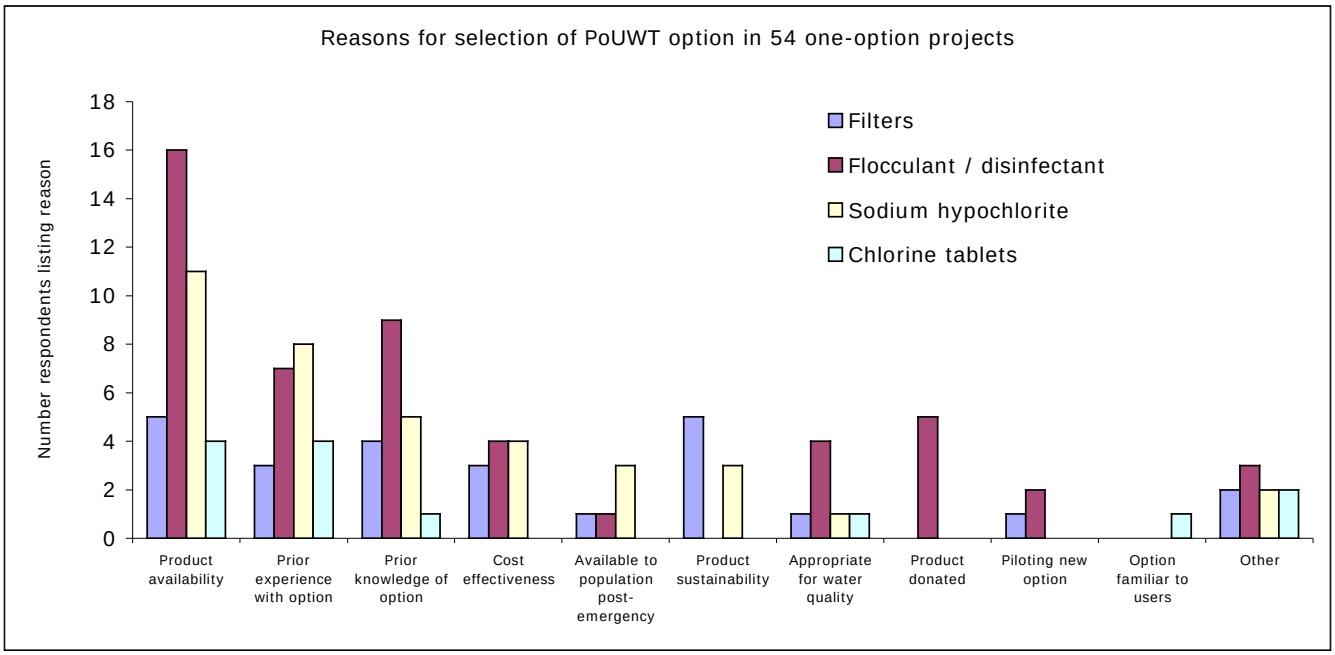


Figure 18: Reasons for selection of PoUWT option in 54 one-option projects

The "easiest" and "most difficult" factors in implementation reported by respondents are presented in Figure 19. As can be seen, the "product" responses, including product selection, product acquisition, and product distribution, were considered the easiest factors in implementation, while the "user" responses, including user acceptability and user training, and product distribution were considered the most difficult factors in implementation. The "other" factors identified as difficult in implementation included: none (2), lack of awareness of product (2), procuring necessary equipment (1), expense (1), warehousing (1), maintenance (1), evaluation (1), importation (1), and partnership with other NGOs (1).

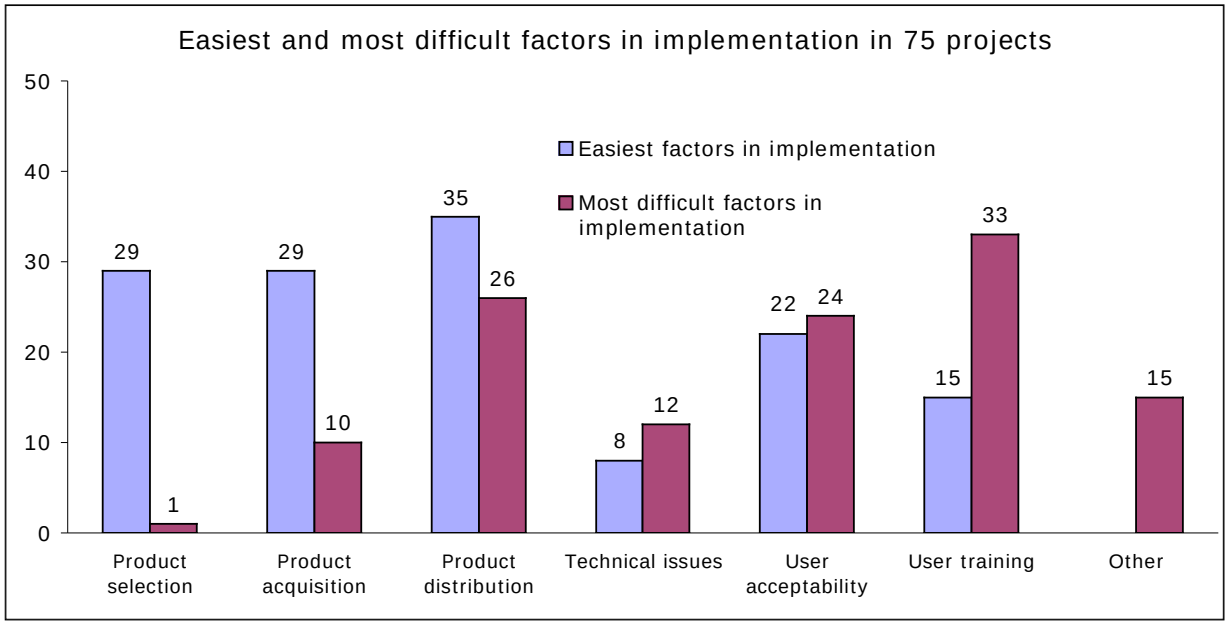
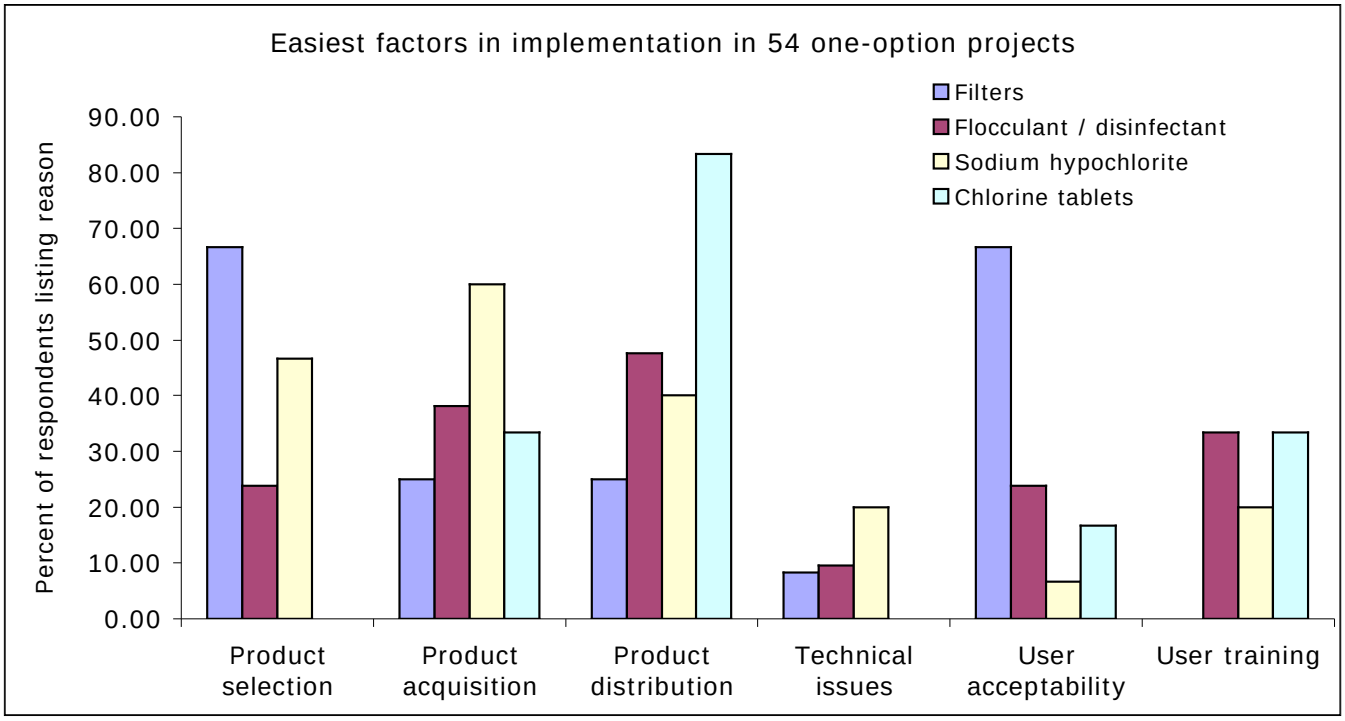


Figure 19: Easiest and most difficult factors in implementation in 75 projects

User training was identified as the most difficult factor in implementation. Users were trained using group demonstrations in 62 (80.5%) projects, written materials in 28 (36.4%), and one-on-one trainings in 20 (26.0%). Focus group demonstrations were completed in nine (11.7%) projects, and no trainings were conducted in six (7.8%) of the projects. Training of multipliers and media were identified as training strategies in one project each.

The easiest and most difficult factors in implementation in the projects using only one PoUWT option were also analyzed using the same sub-categories as in Figure 16. As can be seen from Figure 20, there is variation between the four option categories. User acceptability was noted as an easy factor in implementation in filter projects more so than the other options. Chorine tablets were noted as easiest to distribute. Difficulties with user acceptability were noted the most for chlorine tablets. Product distribution and user training was noted as a difficult issue for filter projects.



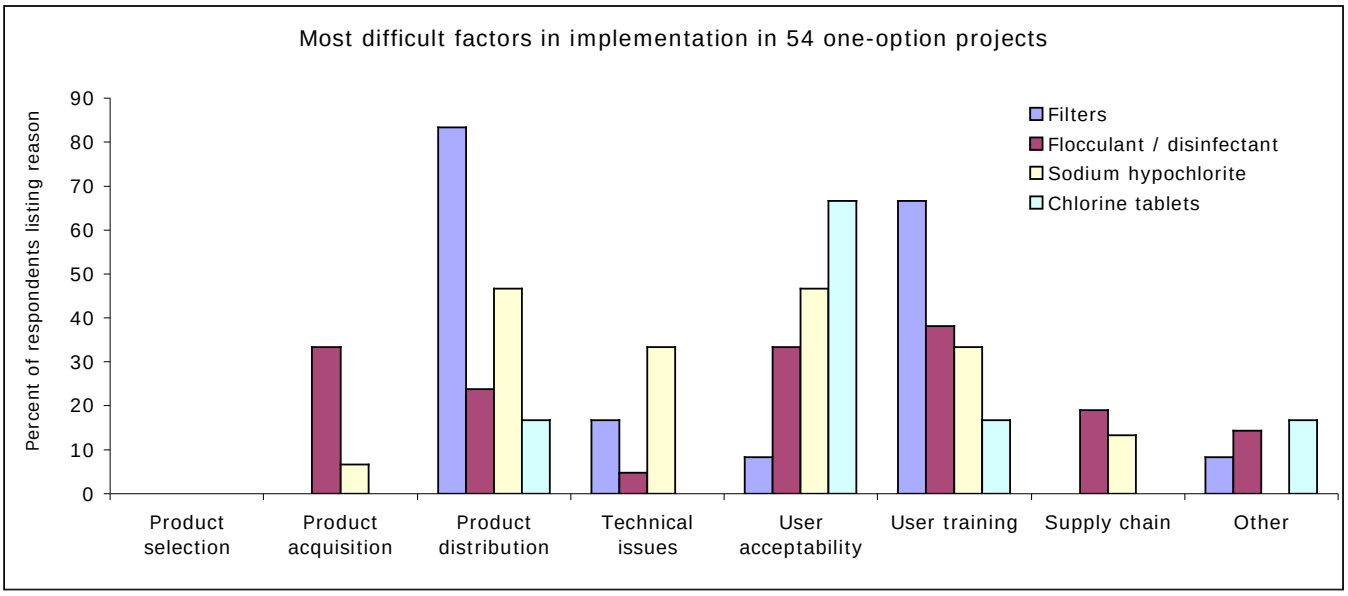


Figure 20: Easiest and most difficult factors in implementation in 54 one-option projects

Respondents were asked what 'concerns' and 'positives' users reported about the specific PoUWT products (Table 10). The main concerns expressed related to aesthetics, preference for piped water, and managing the use of the product (time to use, difficult of use, cleaning/maintaining the product). The other concerns expressed by users as reported by the respondents included (each mentioned once): lower efficacy in this product than another they had used, never seen product before, boiling familiar and practical, not enough volume of water was treated, price too

high to purchase post-emergency, not enough water was available, the product did not have a faucet, the product might be harmful, the product was not sufficiently available, and there was a religious objection to the product.

The majority of the positive responses expressed about the PoUWT product expressed by users and reported by respondents were health-related (providing safe water, health benefit).

Table 10: Concerns and positives about PoUWT product expressed by users

Concerns about product expressed by users (reported by respondent)		Positives about product expressed by users (reported by respondent)	
Concern	Number and % of 75 projects	Positive	Number and % of 75 projects
Aesthetics (taste, colour, odour)	34 (44.2%)	Providing safe water	42 (54.5%)
Preference for piped water	9 (11.7%)	Health benefit	38 (49.4%)
Takes too much time to use	8 (10.4%)	Ease of use	29 (37.7%)
Cleaning/maintaining product	7 (9.1%)	Aesthetic benefit	10 (13.0%)
Difficult of use	4 (5.2%)	Cost	1 (1.3%)
None	5 (6.5%)		
Other	11 (14.3%)		

5.3 Discussion

The survey was distributed widely to a diverse group of individuals involved in PoUWT in both the development and emergency contexts, including manufacturers, implementers, and water, sanitation, and health specialists. Although large-scale broadcast emails were not effective at generating responses, they were effective at making individuals aware of the survey who then forwarded it to members of their organizations who had completed PoUWT projects in emergencies and were appropriate respondents.

With internet surveys it is not possible to differentiate between the ineligible, unreachable, and non-respondent groups. Quality of an internet survey can be assured by sending the survey to the correct email list, providing confidentiality, ensuring the questionnaire is easy to answer on all computer platforms, ensuring the questionnaire is easy to fill in, and providing appropriate directions for the respondent. Although the survey was well-distributed, results could be subject to sampling bias and reporting bias, as individuals with negative or positive or null experiences could have chosen not to respond. It is not possible to determine the direction of the biases, except to acknowledge they could be there, and that the relatively low response rate exacerbates any biases.

The survey responses represented a diverse array of implementers in the emergency, development, research, and manufacturing fields, using a large variety of PoUWT options. It should be noted that boiling, arguably the PoUWT option with the most history, represented only 4 (4.8%) of the 82 PoUWT options responders reported using. Implementers consider the majority of the options they have used in emergencies to be "most successful" according

to their own personal definition of success, with the large majority considering PoUWT options useful in emergencies and stating they would use the options again. Respondents who answered depends to whether they found the PoUWT options useful or would use them again highlighted the perceptions that the use of PoUWT options in emergency depends on: 1) the local context, the customs, and the emergency situation itself; and, 2) the appropriateness of the specific PoUWT option.

The 75 projects described by the 40 respondents represented a diverse geographic coverage across Africa, Asia, and the Americas. Sixty-four (85.3%) projects were implemented in emergencies identified as having high diarrheal disease risk from the literature review (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 who have less access to improved water supplies, such as those living in rural areas, communities, and the internally displaced. Thus, the projects were generally targeted in contexts most at-risk of waterborne disease and thus in which they would have the most impact, based on emergency type and stage, project location, and situation.

Overall, the projects targeted areas with unimproved water supplies (56.7% of supplies), and the specific PoUWT option used in one-option projects was generally appropriate for the local water sources. However, 31.8% of PuR projects were targeted in areas with protected water sources, which is probably unneeded; and, 72.2% of Aquatabs projects were targeted to protected sources, indicating that the high dose tablets (5 mg/L) are, in most cases, unneeded. Thus, despite the water source being generally correct for the PoUWT option, there is a noticeable percentage of non-appropriate sources used with the options.

Geographical differences were noted in the PoUWT project, as all 20 projects describing an outbreak response were implemented in Africa, while all of the projects implemented in Asia (34) were in response to natural disasters. This is consistent with recent research showing a resurgence of cholera in Africa (Gaffga, 2007), although sampling bias may also play a part.

Technical assistance on PoUWT implementation in emergency response is primarily found locally or from within the respondents' organizations. This result highlights the fact that information for PoUWT in emergencies should be available locally and specifically targeted and written for each implementing organization. Although 89.3% of respondents noted that they had assessed their project in some manner, few of these assessments were independent or made available for our review. This could be due to the fact respondents did not have access to the reports, the reports were not finalized, or that the organization decided not to send in the reports. This loss of information to be incorporated into the literature review is unfortunate, as 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 PoUWT projects in emergencies are growing at an exponential rate, but this may be the result of systematic or reporting bias.

Implementers found it difficult to respond to questions about the number of units distributed, the cost of the product, the time to receive the product, whether the products were locally available or imported, and the target

population size. The relatively small amount of data obtained from these questions was dropped from the analysis due to unreliability. The highlights that implementers are often unaware of the logistics of using PoUWT. The scope of PoUWT product distribution in emergencies is not small, however, as organizations reported distributing enough hypochlorite solution, tablets, and PuR sachets to treat 3.3 billion, 1.65 billion, and 171 million liters of water, respectively, in response to emergencies in 2007 alone (Clasen, 2008a).

Product reasons (such as availability and knowledge) dominate the PoUWT option selection process as opposed to user reasons, and product factors were considered the easiest factors in implementing PoUWT. Concurrently, user acceptance and user training were identified as the most difficult factors in implementation. The easiest and most difficult factors in implementation varied between PoUWT options, indicating that implementation strategies should be specific for each of the individual PoUWT options. The lack of response stating that "product selection" was a difficult factor in implementation is unexpected, as this seems in direct contrast to the desire for information on how to select the most appropriate option, or which option is "best", that is often expressed by emergency implementers when conducting presentations or sessions on PoUWT. Despite the fact that the implementers express lack of clarity about which option to choose, or which option is best, they do not report having a problem selecting the option in the field.

Given that interventions in developing countries are often promoted for health reasons, but users change behavior due to other motivations, the utility of the respondents' reporting health reasons as the main user positive for PoUWT is unclear in this context.

The main limitations of the survey include: 1) the potential biases from non-response and voluntary response that could have led to implementers with non-feasible PoUWT projects to not return the survey; and, 2) the conclusions drawn by implementers are largely subjective, and are, in most cases, not supported by a rigorous and independent assessment.

6 LESSONS LEARNED AND RESEARCH INDICATED

In this section, we summarize the information gained from the literature reviews and survey into: 1) lessons learned; 2) further research indicated; and, 3) thematic questions. We end with recommendations to guide future deployment of PoUWT in emergency response and a summary of research needed.

6.1 Lessons learned

The literature review and survey results suggest nine key lessons learned, discusses in some detail below:

- There is comparatively little rigorous evidence of PoUWT in emergency settings;
- PouWT can be an effective water intervention in some non-acute emergencies;
- Current PoUWT projects correctly target emergencies with high diarrheal disease risk;
- Considering user preference in PoUWT option selection facilitates implementation;
- Training is crucial to uptake of PoUWT in emergencies;
- Adequate product stocks are necessary for emergency response;
- Difficulties in obtaining local registration hinder projects;
- Users should have all the materials necessary to use the PoUWT option; and,
- Chlorine dosage needs to be considered in light of user acceptability concerns.

6.1.1 There is comparatively little rigorous evidence on PoUWT in emergency settings

In development settings, five PoUWT options – sodium hypochlorite, flocculant/disinfectant powder, SODIS, ceramic filtration, and biosand filtration – have been shown to improve the microbiological quality of stored water and reduce diarrheal disease in users. In emergency settings, there is comparatively little evidence of the effectiveness of the intervention. In addition, while 89.3% of survey respondents noted that they had assessed their project in some manner, few of these assessments were independent or available. This lack of evidence has two main consequences: 1) the implementers 'perception' of success (as seen in the box) cannot be matched with quantitative data showing project feasibility; and, 2) lessons learned can not be collated and shared in the form of guidance.

> There is no doubt that WaterGuard and other water purification interventions saved lives.
>
> Mya Than Tun, PSI/Myanmar

6.1.2 PoUWT can be an effective water intervention in non-acute emergencies

There is some evidence of PoUWT intervention effectiveness in non-acute emergency settings. The use of PuR has been shown to reduce diarrheal disease in a long-tem Liberia refugee camp, and PuR and Aquatabs use improved the quality of stored water in a Bangladesh cyclone. Sodium hypochlorite was shown to be probably protective against cholera in Madagascar, and improved water quality in the Indonesian tsunami and in Haiti during a complex emergency. Ceramic filters have been shown to improve the microbiological quality of water during and

after the flooding emergency in the Dominican Republic. SODIS, an intervention rarely used in emergencies, was shown to reduce cholera risk in users in Kenya. In addition, implementers who responded to the survey consider the majority of the PoUWT options they have used in emergencies to be "most successful" according to their own personal definition of success. This suggests high acceptability of PoUWT products among the people responsible for promoting and distributing them, and is concurrent with evidence that use of PoUWT in emergencies is increasing. However, almost all evidence showing PoUWT effectiveness was collected in stable emergency situations that in many ways are similar to development circumstances, where organizations had the capacity to conduct trainings and follow-up. We do not know if PoUWT can be implemented rapidly and effectively in an acute emergency situation, or in situations where training and follow-up is infeasible.

6.1.3 Current PoUWT projects correctly target emergencies with high risk of diarrheal disease

The projects described in the survey were generally targeted to contexts most at-risk of waterborne disease, based on emergency type and stage, project location, and situation. In addition, in general, the correct PoUWT option was targeted for the water sources used, although not exclusively. These results highlight that the decision-making processes organizations are using to select PoUWT products, while they may not be transparent or formally recorded, lead to PoUWT being implemented with the most impact. This result should be considered, however, as there could be bias in survey reporting of only reporting appropriate projects.

> PoUWT is a "quick means to stop the spread of cholera".
>
> Henock Gezahegn, PSI/Ethiopia

6.1.4 Considering user preference in PoUWT option selection facilitates implementation

The reasons a specific PoUWT product were selected by implementers were reported to be predominantly product reasons (such as availability and knowledge) as opposed to user reasons (such as user familiarity or acceptance). Consistent with that, user acceptance and user training were identified as the most difficult factors in implementation. Analysis of the reasons for selection in projects using only one PoUWT option showed that flocculant/disinfectants were selected more often because of product availability and appropriateness for water quality, and were the only option where it was mentioned the product was selected because it was donated. Product sustainability was only mentioned as a reason for selection for locally manufactured or longer-lasting products, such as sodium hypochlorite and filters. In one project using chlorine tablets, it was mentioned that one reason for selection was it was familiar to users. In Vietnam, higher PuR acceptance and use was attributed to appreciation of the time savings of PuR compared to the previously recommended intervention, the use of alum and boiling. It is anticipated that if user preference were considered in the option selection decision that user acceptability of the promoted product(s) would increase.

> We started with chlorine tablets, basically because it was very easy to procure locally and deliver to quake affected [sic] families.
>
> Lucy Harman, CARE/Peru

6.1.5 Training is crucial to uptake of PoUWT in emergencies

In the development context, higher levels of user adoption have been documented when PoUWT options are promoted in schools or clinics, and when motivational interviewing and social marketing are employed as behavior

change communications strategies. A theme throughout the literature review and the survey results was the importance, and difficulty, of conducting user training on PoUWT options during emergencies, and all results indicate the importance of incorporating strong training into the PoUWT emergency strategy.

In addition, the training required may depend on the PoUWT option being promoted. High usage of PuR as measured by chlorine residual in household drinking water was associated with first a training session and then additional household or community follow-up education. With the SWS, the presence of chlorine residual in stored household drinking water after product introduction in emergencies has been seen at a low level of about 3-20% of households, although higher levels of uptake of 76.7% in Haiti have been documented when there is ongoing yearly follow-up with families using the product. For the durable PoUWT option of ceramic filtration a 26.1% correct usage was documented without follow-up training in the Dominican Republic 16 months after distribution, indicating less follow-up training may be needed for the durable options. Direct comparison of these percentages should be avoided, however, as some studies sampled the entire community population and others only households receiving the intervention. No study identified in the literature review documented greater than 20% uptake of PoUWT in the acute emergency situation – as PuR in Haiti had 10% uptake, SWS in Madagascar and 11.1-19.7% uptake, there was little uptake after the Tsunami in Indonesia, and longer time after the emergency before filter distribution was associated with higher uptake in Sri Lanka.

User training was identified as one of the most difficult factors in implementation in 33 out of 75 PoUWT projects, more than any other individual factor. In the development context, feasible PoUWT projects select a high-quality, culturally appropriate option, distribute the products reliably, and work with trusted local community educators to encourage healthy water practices. Based on the research conducted to date in the emergency context, it appears these factors of success translate to the emergency context, and it is recommended that materials be developed specifically for the emergency context to assist organizations in conducting the trainings necessary to ensure PoUWT project success.

> Household monitoring revealed that less than 30% of the beneficiaries could correctly use the products. This later improved to above 50%, but after extra efforts on one to one house to house visit.
>
> Overtoun Mgemezulu, Project Manager (HSP)

6.1.6 Adequate product stocks are necessary for emergency response

The ability to obtain and distribute PoUWT products is critical to project success in emergencies. Supply chain issues were identified as one of the most difficult issues in implementation in 6 (8%) projects, despite '*supply chain problems'* not being one of the forced-choice answers on the survey form. These problems were particularly noted for flocculant/disinfectants and sodium hypochlorite. A benefit of products that are locally-available prior to the emergency is that, if adequate stocks are maintained, the products can be deployed quickly and in multiple emergencies, as seen in the boxed quotes. A benefit of imported products with a long shelf-life is that they can be pre-positioned in case of an emergency. In areas prone to emergencies, an adequate stock of appropriate PoUWT products should be pre-positioned for response.

> A key factor to the success of this project was keeping an adequate inventory of the product available for disaster relief.
>
> Curt Bradner, Thirst Aid/Myanmar

6.1.7 Difficulties in obtaining local registration hinder projects

Even though PuR is robust and has been shown to be effective at treating a wide range of waters, lack of local product validation was a hindrance in the Haiti flooding response, and local validation of the product was necessary prior to initiating projects in Mozambique, Pakistan, and Vietnam. In addition, sodium hypochlorite and chlorine tablets have encountered difficulties and delays in local product registration (POUZN, 2007). To alleviate these delays, it is recommended that an international organizational, such as WHO or UNICEF, facilitate registration of effective PoUWT products for emergency use by developing a list of approved PoUWT products for emergency use.

6.1.8 Users should have all the materials necessary to use the PoUWT option

Although this lesson appears trivial, it is of note that no project documented significant success without either: 1) distribution of all the materials necessary to use the PoUWT option; or, 2) ensuring that the families already had the materials in their homes to use the option. Although many projects distributed PoUWT options without materials, none of these projects conducted evaluations or documented success. This lesson was documented most extensively for PuR, which requires more materials to complete water treatment, although is true for all of the PoUWT options. Organizations should ensure that users have all the materials necessary to treat their water with the PoUWT option provided. For PuR, this requires two buckets, a stirring rod, and a cloth. For chlorination products it requires a bucket or container of the correct size for the chlorine dose. For filtration options it requires the filter and any materials necessary to maintain or clean the filter. For boiling, families should have a reliable fuel source and container in which to boil the water.

6.1.9 Chlorine dosage needs to be considered in light of user acceptability concerns

The chlorine dosage used in PoUWT affects chlorination projects in emergencies, for if the taste is unacceptable, householders will not use the product. The differences in the dosages recommended by commercially available PoUWT projects and emergency organizations were discussed extensively in this report. Specific technical guidance for chlorine dosage needs to be developed at a central level to address these differences, and then agreed to by implementing organizations. Because acceptability of chlorine taste varies, it is recommended that in areas where there is no taste objection to chlorine, a dosage of 2 mg/L (for clear waters, and double that for turbid waters) should be used. A dosage of 5 mg/L is unlikely to be necessary in any water that can be adequately treated with chlorine.

6.2 Further research

There is a surprising lack of evaluations on PoUWT in emergencies. One commercial company, Procter & Gamble supported most of the evaluations identified in our literature review. While this does not render this work invalid, it does highlight the lack of evidence on PoUWT in emergencies, and the need for independent research on PoUWT sponsored by disinterested parties. Based on the information presented throughout this report and the lessons learned summarized above, we believe there is a need for additional evidence in seven key areas which are further discussed below and summarized at the end of this section:

- Project monitoring and evaluation using appropriate metrics;
- Efficacy of the *'standard interventions';*
- Lessons learned from projects with multiple PoUWT interventions;
- PoUWT effectiveness in acute emergencies;
- Behavioral differences between the emergency and development contexts;
- Relative appropriateness of different PoUWT options in emergencies; and,
- PoUWT effectiveness compared to other water & sanitation interventions.

6.2.1 Project monitoring and evaluation using appropriate metrics

There is a need for additional project evaluations of PoUWT projects in emergencies, particularly in the acute emergency setting and large emergencies with significant distribution of PoUWT products that are unevaluated, such as the Myanmar cyclone response with sodium hypochlorite and ceramic filters, or the Ethiopian acute water diarrhea response with sodium hypochlorite and PuR. These evaluations should use appropriate metrics of program effectiveness. Although health impact and microbiological improvement are considered gold standards in measuring the impact of PoUWT, these metrics are difficult to accurately collect and analyze by local staff in an emergency situation. For example, the majority of diarrheal disease reduction data collected in project evaluations presented in this report was discarded, either by the organization itself or because the data was not seen as accurate enough for inclusion by the authors. By contrast, however, many projects were able to gather valuable information to assess project impact, such as chlorine residual at the household level, turbidity reduction at the household level, number of families who collected their sachets each week, and quantitative information on use and acceptance. It is recommended that guidelines be developed for evaluating PoUWT projects in emergencies, and utilized universally. Uniform assessments would facilitate comparisons across a range of projects. For example, evaluations of PoUWT projects in emergencies include water quality testing in user households will provide valuable information on microbiological performance and correct/consistent use. These can be as simple as a presence/absence chlorine residual test for chlorine-based PoUWT options, or a presence/absence bacteriological indicator test for non chlorine-based PoUWT options. Because of the complexity in collecting reliable epidemiological data, assessments should not normally include health impact data, but may potentially take advantage of any baseline, surveillance, or clinical data that may be generated for other purposes.

> The most important part that was missing was close monitoring at household level to ensure correct utilization of products.
>
> Overtoun Mgemezulu, Project Manager (HSP)

6.2.2 Efficacy of the *'standard interventions'*

The standard PoUWT emergency interventions – chlorine tablets, mother solution, boiling promotion, and safe storage – are severely under-researched. Few studies were identified that investigated the efficacy of these interventions, despite the fact they are standard interventions in emergency response. It is recommended that evaluations of these types of projects be conducted. In addition, the lack of evidence for these interventions inhibits the development of technical guidance, and additional basic research is needed to assist in the development of technical guidance for these options.

6.2.3 Lessons learned from projects with multiple interventions

Nineteen (25.3%) projects described in the survey responses distributed more than one PoUWT options in one emergency situation. However, only four studies identified in the literature review investigated the distribution of more than one PoUWT option in a single emergency. Because multiple PoUWT options are promoted in so many emergency responses, further research on the efficacy of distribution of multiple PoUWT products in one emergency is indicated. Research in development settings has suggested that there may be higher levels of uptake overall if more product choices are offered. It would be useful to explore whether the clear logistical and user training disadvantages of deploying multiple interventions in an emergency setting are partially offset by achieving greater adoption.

6.2.4 PoUWT effectiveness in acute emergencies

Although 51 (68%) projects described in the survey were reported to have started during the acute emergency stage, few successes in implementing PoUWT were documented in the literature review. During the PuR distribution following the Haiti flooding, significant distribution problems were noted; and although user uptake of PuR was documented in the Vietnam and Bangladesh flooding events, it is an open question whether ongoing flooding is an acute emergency. Although the SWS was distributed successfully in Myanmar after the typhoon, no follow-up on use and acceptance was conducted. Lastly, although some sustained post-emergency use of ceramic filters was noted in Sri Lanka and the Dominican Republic, being in an emergency shelter was identified as a barrier to use of ceramic filters in Sri Lanka. Given the lack of success documented in implementing PoUWT in the acute emergency stage, and the large number of projects reported to occur in this stage, it is recommended that additional PoUWT interventions occurring in the acute emergency stage be evaluated. Of particular concern is the low uptake rate in acute, unexpected emergencies of all PoUWT options – with no study conducted in the acute emergency documenting greater than 20% uptake, and one study documenting higher uptake the longer the time after the emergency a filter was received. Further research on uptake in the acute emergency setting is recommended.

6.2.5 Behavioral differences between the development and emergency contexts

Currently, there is active and ongoing research and debate in the development context as to how to change behavior and encourage long-term adoption of PoUWT options. However, no research has investigated behavior change strategies for PoUWT in emergencies. It is unknown at this time whether users might be more willing to adopt PoUWT options post-emergency (perhaps due to perceived increased risk) or less willing (due to effects of trauma). Research to determine behavior change strategies for PoUWT in emergencies, compared to strategies used in the development context, is indicated.

6.2.6 Relative appropriateness of different PoUWT options in emergencies

> For the chlorine-based products, there are severe challenges to deploying in communities that have little prior familiarity with the chlorine odor and taste. I would be cautious about deploying chlorine-based products outside of areas where they are already well-known.
>
> Jeff Albert, Aquaya Institute

As discussed in Section 3, each of the PoUWT options has benefits and drawbacks and situations where they are more appropriately implemented than others. However, these benefits and drawbacks have not been investigated within the emergency context. In the comment sections of the survey, numerous survey respondents addressed the question of whether some PoUWT options were more appropriate is certain emergencies than others, and provided input on which PoUWT options might be more appropriate in which contexts. It is of note that: 1) some of the PoUWT options seen extensively in the development context – such as SODIS – had no respondents in the survey saying they used it within the emergency context; and, 2) implementation strategies for each of the PoUWT options vary within the development context, and will likely vary within the emergency context as well. Research is indicated to determine the benefits, drawbacks, and appropriateness for each PoUWT option within specific types and stages of emergencies.

6.2.7 PoUWT effectiveness compared to other interventions

This report has focused almost exclusively on the use of PoUWT in emergencies, and the concurrent potential for water quality improvements and diarrheal disease reduction. However, as discussed in Section 2.5, the provision of water and sanitation interventions in emergencies is not only based on one strategy, or for only one reason. The Sphere Standards for water are based on the importance of: 1) access and water quantity; 2) water quality; and, 3) water use facilities and goods, and incorporate the cross-cutting themes of children, older people, disabled people, gender, protection, HIV/AIDS, and the environment. Thus, rather than focus exclusively on only PoUWT, further research is indicated to develop guidelines on how to include PoUWT as part of the overall strategy in emergency response and, concurrently, to decide whether or not to use PoUWT at a particular time within a particular emergency at all. Interestingly, there was no research identified for this report that discussed the relative merits of PoUWT as compared to water supply, hygiene promotion, or sanitation within different types of emergencies, or at different stages of the same emergency. Two survey respondents did note a potential synergy between PoUWT and water supply within the same emergency over time in their survey comments, stating: "Using POU technologies provides safe water immediately in emergencies. They are usually faster to get up and running than small water treatment pumps"; and, "POU buys you time to do the rehabilitation or construction of a water sources correctly instead of quickly". Research on this topic, aimed at the development of guidance for implementing organizations, is indicated.

6.3 Thematic questions

6.3.1 Should new or untested PoUWT products be introduced in an emergency?

There are two components to this question: 1) Should new and untested PoUWT products be introduced in an emergency situation?; and 2) Should established, known effective PoUWT products that are unfamiliar to the users be introduced in an emergency?.

First, there are numerous private and public organizations working to develop new water treatment options for the emergency market. However, despite the enthusiasm of these organizations, the Nerox filter experience in Pakistani IDP settlements highlights that it is difficult to field-test a new product in an emergency situation. It is recommended that product acceptability studies be conducted with users who can provide iterative feedback on the intervention to increase acceptability and efficacy in the field, before using the intervention in emergency situations. However, sometimes organizations are faced with having an untested PoUWT option or none at all in a particular emergency, and then the organization will have to decide whether to distribute the untested product or not.

Second, although no research was identified that particularly addressed this issue, two survey respondents highlighted the belief that implementing PoUWT projects in emergencies is easier if the population is aware of the product prior to the emergency, stating: "There was "no particular difficulty [in implementing Aquatabs] as people were already extensively sensitized"; and, "In Indonesia the boiling practice is extremely well-socialized; thus, IDPs were well-equipped to continue the behavior". In addition, the difficulty of introducing a new PoUWT option that requires end-user cooperation was noted by survey respondents (see box).

It is recommended that further research be conducted on whether or not pre-emergency knowledge of a PoUWT option (either via a long-term development project such as social marketing or repeated exposure to the product during emergencies over time) increases user acceptability and adoption, and decreases the training requirement.

> Introducing a new product or behavior in the middle of a disaster is extraordinarily difficult, especially when it requires end-user operation.
>
> Jeff Albert, Aquaya Institute

6.3.2 Are developmentalist perspectives of sustainability, empowerment, and post-emergency access to product relevant?

Numerous evaluations of PoUWT projects in emergencies reviewed in the literature review discussed or evaluated metrics more commonly associated with development projects than emergency projects, such as: willingness to pay, access to the PoUWT product or replacement parts over time, and long-term uptake of the PoUWT option. In addition, survey respondents utilized language in their comments more indicative of developmentalist principles than emergency principles regarding empowerment and sustainability.

> POU offers emergency victims a means to exercise control over their situation.
>
> David Kaisel, Consultant

The answer to the question of whether developmentalist perspectives are relevant to emergency PoUWT projects will need to come from the implementing organization itself. The importance of access to PoUWT products for recipients in the post-emergency situation will depend on the project goals of the organization and the type of emergency, and may be considered unimportant or vital. In some circumstances, the project goal will be to provide immediate relief only, and in others the goal will be to provide relief that translates into long-term usage of household water treatment. However, the implementing organization should keep in mind that different PoUWT options have different potential for long-term use and uptake, and availability to the local population on a sustainable basis. Thus, it should be established at the project outset whether long-term usage is desired, and if so, an appropriate option selected.

> The … motivation was to do something for the tsunami victims. We knew that our products could only provide immediate, short-term relief and did not expect them to be used long-term.
>
> Paul Svrcek, Cascade Designs

> POU with non-consumables is "easy to use, rapid to distribute, and provides safe water long after [the] emergency"
>
> Adriaan Mol, BushProof

In addition, although no research was identified that investigated this, the potential for PoUWT use in emergencies to encourage long-term water treatment at the household was discussed in comments by survey respondents. Further research investigating the whether emergency use of PoUWT stimulates long-term uptake of available PoUWT products in the post-emergency situation is indicated.

6.3.3 How do we provide technical assistance and decision trees for implementers?

The survey respondents noted that technical assistance on PoUWT implementation in emergencies is primarily found locally or from within the respondents' own organization. This result highlights the fact that information for PoUWT in emergencies should be available locally and specifically targeted and written for each implementing organization. The question then becomes how the information on PoUWT in emergencies should be made available locally for field staff? To date, several respondents took the emailed survey form as an opportunity to ask technical questions about PoUWT in emergencies, and the authors have extensively been approached for technical assistance on PoUWT. In addition, the authors provided technical assistance to Oxfam and ICRC to develop manuals on PoUWT implementation in emergencies for field staff.

However, there is clearly a need for additional information at the global level that can be distilled into information at the implementation and field level. There are two factors that inhibit the development of global manuals for implementation and decision trees for when to use PoUWT in emergencies and which option to use: 1) The lack of evidence base specifically investigating PoUWT in emergencies that precludes evidence-based recommendations at this time; and, 2) The organization's own priorities on how they respond to an emergency will inform their decision-making on whether to use PoUWT and which option to select.

6.4 Recommendations for implementing PoUWT in emergencies

Although further research into PoUWT in emergencies is ongoing and the evidence-base will develop over time, the current high interest in use of PoUWT in emergencies necessitates the development of recommendations for best practices in implementing PoUWT in emergencies at this time. Thus, based on the literature review and the survey results, the following recommendations are made to organizations wishing to implement PoUWT in emergencies:

- Know that PouWT can be an effective water & sanitation intervention in some non-acute emergencies;
- As PoUWT is primarily a disease reduction intervention, correctly target emergencies that have high diarrheal disease risk for PoUWT intervention;
- Consider user preference in PoUWT option selection;
- Conduct trainings appropriate to the PoUWT option selected;
- Maintain adequate product stocks either by pre-positioning imported products or having access to locally-available products;
- Ensure the products are locally registered;
- Ensure users have all the materials necessary to treat water with the PoUWT option; and,
- Carefully consider the chlorine dosage used in chlorine-based products in light of user acceptability.

In addition it is recommended that implementing organizations keep in mind:

- There is less documented success of PoUWT in acute emergencies;
- Introducing an untested PoUWT product in an emergency adds complications to the project that may reduce effectiveness;
- Some PoUWT options may be more appropriate in particular emergencies that others, and in all cases PoUWT should be one strategy of many to ensure safe water access at different stages of the emergency; and,
- The relevance of developmentalist goals such as sustainability, empowerment, and long-term access to the products should be considered in project planning.

6.5 Summary of research needed

Clearly, a main result from the investigations documented in this report is that additional research on PoUWT in emergencies is needed. Currently, PoUWT use appears to be increasing in emergency response, despite the fact that most documented feasible PoUWT in emergencies projects have been implemented at relatively small-scale with significant follow-up, rather like developmentalist PoUWT projects. There is little documented feasibility of PoUWT (aside from in Bangladesh flooding events) in larger-scale, more acute emergency situations. In addition, while monitoring and evaluations of PoUWT interventions may have been completed, appropriate metrics for program effectiveness may not have been used and the results of monitoring and evaluation have not been widely disseminated, which prevents knowledge gained from these evaluations being collated and shared as lessons learned.

Based on the information documented in this report, further research on PoUWT in emergencies should focus on:

- Conducting PoUWT project evaluations in large-scale immediate-onset acute emergencies situations, using appropriate metrics for program efficacy;
- Evaluating all PoUWT options, including standard interventions not supported by a commercial enterprise, and understand the benefits, drawbacks, and appropriateness for each PoUWT option within specific types and stages of emergencies;
- Evaluating all PoUWT 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;
- Understanding the behavioral determinants of adoption for PoUWT in emergencies, such as potential pre-exposure to the PoUWT products, as compared to development determinants, and developing training materials and strategies specifically targeted at these determinants;
- Comparing PoUWT options to other options to reduce diarrheal disease in emergencies, and understanding the potential role for PoUWT as part of a larger water and sanitation strategy in emergencies at various emergency stages;
- Documenting how organizations select PoUWT products – whether because they are simply available, or because of an option selection framework, and developing appropriate option selection frameworks; and,
- Understanding whether emergency use of PoUWT stimulates long-term uptake of available, affordable PoUWT products in the post-emergency situation.

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