After the flood: an evaluation of in-home drinking water treatment with combined flocculent-disinfectant following Tropical Storm Jeanne — Gonaives, Haiti, 2004

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ABSTRACT

Tropical Storm Jeanne struck Haiti in September 2004, causing widespread flooding which contaminated water sources, displaced thousands of families and killed approximately 2,800 people. Local leaders distributed PūR®, a flocculent-disinfectant product for household water treatment, to affected populations. We evaluated knowledge, attitudes, practices, and drinking water quality among a sample of PūR® recipients.

We interviewed representatives of 100 households in three rural communities who received PūR® and PūR®-related education. Water sources were tested for fecal contamination and turbidity; stored household water was tested for residual chlorine.

All households relied on untreated water sources (springs [66%], wells [15%], community taps [13%], and rivers [6%]). After distribution, PūR® was the most common in-home treatment method (58%) followed by chlorination (30%), plant-based flocculation (6%), boiling (5%), and filtration (1%). Seventy-eight percent of respondents correctly answered five questions about how to use PūR®; 81% reported PūR® easy to use; and 97% reported that PūR®-treated water appears, tastes, and smells better than untreated water. Although water sources tested appeared clear, fecal coliform bacteria were detected in all sources (range 1 – >200 cfu/100 ml). Chlorine was present in 10 (45%) of 22 stored drinking water samples in households using PūR®.

PūR® was well-accepted and properly used in remote communities where local leaders helped with distribution and education. This highly effective water purification method can help protect disaster-affected communities from waterborne disease.

Key words | disaster epidemiology, drinking water disinfection, point-of-use water treatment, PūR®

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INTRODUCTION

Diarrheal disease causes an estimated 1.7 million deaths per year; 90% of these occur in children, the vast majority in developing countries where many people lack access to safe drinking water (World Health Organization 2004). Natural disasters can greatly magnify the burden of illness associated with inadequate water resources. Flooding is the second most common type of natural disaster after windstorms, but affects a larger geographic area and population than any other catastrophe (Hueb & Loretti 2004). During floods, water sources, especially unprotected wells and surface water sources, may become contaminated with industrial, human and animal wastes.

In general, epidemic disease is not a frequent occurrence after natural disasters. However, in the developing

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world, high rates of morbidity and mortality can result from common illnesses under these crisis conditions. Following severe floods in Bangladesh, diarrhea was determined to be the most common cause of illness and death among all age groups (Siddique *et al.* 1991). In 2004, the city of Dhaka suffered large outbreaks of entertoxigenic *Escherichia coli* and *Vibrio cholerae O1* after heavy flooding (Qadri *et al.* 2005).

Haiti, the poorest nation in the Western Hemisphere, has the region's highest infant and child mortality rates. One out of 13 Haitian children dies before his or her first birthday. Diarrhea is the leading cause of death in infants and the second leading cause of death (after malnutrition) in children under five (Cayemittes *et al.* 2000). The high incidence of childhood diarrheal disease is largely attributed to consumption of contaminated water. Only 10.7% of Haitians have access to piped water in the home, while 42.5% use a public tap, and >30% use shallow wells or unprotected surface water sources (MSPP/PAHO 1999).

Tropical Storm Jeanne hit Haiti on September 18, 2004, primarily affecting the northern coastal city of Gonaives and surrounding areas. Flash floods led to the deaths or disappearance of approximately 2,800 persons, and 80% of the city was damaged or destroyed. The previously limited municipal water supply was further compromised and other drinking water sources were contaminated with cadavers, excrement, and debris. In the weeks immediately following the floods, most Gonaives residents relied on 800 semi-functional wells, local rivers, and on purified water provided by non-governmental organizations (NGOs) to meet their drinking water needs. Unfortunately, NGOs were unable to provide purified water to some affected populations outside the city center. For those communities not reached by NGO purified water efforts, other options were needed.

The Proctor & Gamble Company, Populations Services International (PSI), and the Centers for Disease Control and Prevention (CDC) have collaborated for several years on the development, implementation, and evaluation of PūR®, a combined flocculent-disinfectant product for in-home water treatment. PūR® contains powdered ferric sulfate and calcium hypochlorite, the same ingredients used in many municipal water treatment systems, packaged into single-use sachets. One sachet is added to 2·5 gallons of water (1 US gallon is roughly 4 liters) and stirred for 5 minutes. Next, the water is decanted through a cloth into a second bucket, leaving the floc particles behind. The decanted water is left to stand for 20 minutes, allowing full chlorination before consumption.

Studies have shown that PūR® is effective in removing bacteria, viruses, and heavy metals, and greatly improves water clarity. (Rangel *et al.* 2003; Souter *et al.* 2003) Intervention trials in rural Guatemala, Kenya, and Pakistan showed a significant reduction in diarrheal illness among PūR® users (Reller *et al.* 2003; Crump *et al.* 2004, 2005; Chiller *et al.* 2006). When used in turbid waters, PūR® offers advantages over chlorination alone by removing organic matter. This reduces chlorine demand, the formation of chlorine by-products, and improves the appearance and taste of treated water.

In response to the crisis, 410,000 sachets of PūR® were donated to relief efforts in Gonaives. First attempts at emergency distribution of PūR® were through NGOs, such as CARE. These efforts proved to be very difficult because NGOs had competing demands, were unfamiliar with the new water treatment product, and may not have had sufficient training to effectively promote and distribute PūR®. As a result, thousands of PūR® sachets did not leave the warehouse for several weeks following the flooding.

PSI Haiti, which had planned a national campaign to socially market PūR®, filled the role of primary emergency distributor for PūR® in mid-October. They selected several communities that were not reached by other emergency water providers, established a strong network of community leaders, or *casecs*, who served as promoters, educators, and distributors of PūR®. The *casecs* and PSI introduced PūR® via community demonstrations approximately 3 to 6 weeks after the floods. During the subsequent two weeks PūR® was distributed by *casecs* to community households at no cost.

Little is known about point-of-use water treatment following natural disasters or in emergency settings (Dunston *et al.* 2001). Some studies, albeit few, have demonstrated the health benefits of point-of-use water treatment following disasters. A series of cyclones and a cholera epidemic in Madagascar prompted the introduction of a sodium hypochlorite solution for drinking water treatment which showed a tendency to be protective against cholera (Reller *et al.* 2001). Chlorination treatment of household drinking water containers in a Darfur, Sudan refugee camp appeared to correlate with a decrease in bloody and watery diarrhea (Walden *et al.* 2005).

There are no previously published evaluations of PūR® use in an emergency response situation to natural disasters. We evaluated the knowledge, attitudes, and practices related to water handling and health among members of three communities to better understand the effectiveness of the model for emergency distribution, the impact of educational messages about PūR® use, and the cultural acceptability of PūR® among Haitians.

METHODS

The study was conducted in the rural communities of Mapou Rollin, Sterling, and Lacoupe, approximately 15 kilometers north of central Gonaives, encompassing a population of approximately 9,000. Each community comprised many *lacours*, or clusters of three to five houses owned by an extended family.

We enrolled 100 households that had received PūR® in the three study communities by systematically sampling every second *lacour* and randomly selecting one home from each *lacour* to be included in the evaluation. If members of the selected household chose not to participate, were ineligible (<18 years of age), or did not receive PūR®, a second household from the same *lacour* was randomly selected. We interviewed the "water preparer" in each participating household.

Questionnaires were verbally administered in Creole by Haitian colleagues. Topics included demographics, health beliefs and practices, water collection, treatment, and storage practices, and PūR® specific knowledge and attitudes. Data was entered by a single investigator into an Access database and descriptive analysis was performed.

A CDC staff member tested residual free chlorine levels of stored drinking water in the home using a battery-operated digital chlorimeter (LaMotte Co., Maryland). Turbidity levels were determined for ten community drinking water sources using a digital turbidimeter (LaMotte Co., Maryland). Fecal coliform bacteria were quantified in samples from ten drinking water sources using membrane filtration and EC medium (*Standard Methods for the Examination of Water and Wastewater* 1998).

RESULTS

KAP survey

The 100 study households had a median of seven family members (range 2–13). Most houses were made of mud or adobe material with thatched roofs, 78% percent of houses had one or two rooms; the floor was dirt in 64%, and none of the houses had electricity (Table 1). Twenty-four percent of respondents reported having spent nights away from their homes as a result of the flooding.

All survey participants reported that diarrhea in children was a big problem for their communities. Seventy-two percent reported that the drinking water they collected was clean; however, 42% reported that the water

Table 1 | Household characteristics, Gonaives, Haiti, 2004

Variable	Value
Number of households included in study	100
Household structure	
Median number of family members	7 (range 2–13)
Median number of children <5 years of age	1 (range 0–4)
Education level of water preparer	
No formal schooling	20%
Primary school only	37%
Secondary school	41%
Housing construction	
< 3 rooms	78%
Dirt flooring	64%
No electricity	100%

sometimes makes their family sick. Thirty-two percent of respondents reported a child <5 in the household with diarrhea and 20% reported an older child or adult with diarrhea during the past month. Of note, only 42% of respondents had access to latrines, and 32% routinely used the river as a place for defecation (Table 2).

Families reported a median consumption of 3 gallons of water per day (range 0.5–15), and 57% collected water two or more times per day, spending a median of 20 minutes (range 2 to 240) per trip to collect water. Community water sources include natural springs, community taps, 2 wells, and the Laquinte River. Nearly two-thirds of households relied on spring water before and after the flooding. After the flooding, fewer households relied on community taps (13 vs. 23) and more used a well, river, and spring water (Figure 1). Some of the community taps were reportedly damaged after the flooding and were only semi-functional. All households had water storage vessels in the home. Approximately 81% of households use 5-gallon buckets; 91% of these buckets had lids. Eighteen percent of households use 5-gallon traditional clay containers, usually capped with a saucer.

Methods of water treatment in these communities included: boiling, chlorination with powdered (Clorox), solid (Aquatab) or liquid (Dlonet) hypochlorite, flocculation with "raket" (a local cactus), or sand and gravel filtration. Only 37% of households reported treating their drinking water by any method in the weeks before the flooding. By the study enrollment criteria, all study households had received and used PūR® at least once. Post-flood, PūR® was the predominant treatment method, 58%, followed by powder hypochlorite 16% (Figure 2).

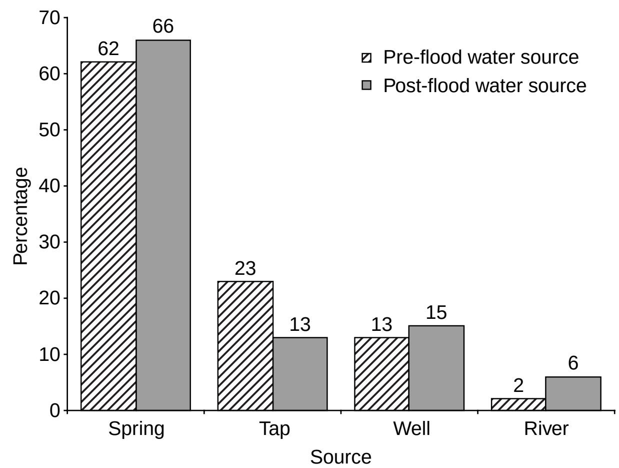

Figure 1 | Community water sources before and after flooding, Gonaives, Haiti, 2004.

Table 2 | Health and sanitation practices, Gonaives, Haiti, 2004

	Percent of households (*n* = 100)
Childhood diarrhea treatment	
Community clinic	73%
Homemade tea	21%
ORS	5%
Traditional healer	1%
Place of defecation	
Latrine	42%
River	32%
Bush	26%

Between PuR® distribution in late October and the survey in mid-November, 78% of respondents had used PūR® 1 to 5 times, 13% 6 to 10 times, and 9% 11 or more times. Ninety-two percent reported using PūR® sometime during the previous week.

Respondents heard about PūR® via multiple channels: 66 learned about PūR® from a community leader; 61 had attended a PSI demonstration; 38 heard a radio spot (60% of households had battery-powered portable radios), and 37 heard about it from neighbors.

Most respondents knew how to use the product correctly. Only 2% of the respondents reported trying to open the package with their teeth. Eighty-three percent correctly reported mixing one sachet with 2.5 gallons, 88% correctly answered the mixing time of 5 minutes, and 79% correctly reported waiting 20 minutes before drinking the PūR® treated water. Eighty percent threw flocculated waste into a latrine while 20% threw it into the bush. Seventy-eight percent answered all five knowledge questions correctly.

Ninety-seven percent of respondents reported that PūR®-treated water appears, tastes, smells, and is healthier, when compared with non-treated water. Eighty-one percent reported PūR® water is easy to prepare. All said that they

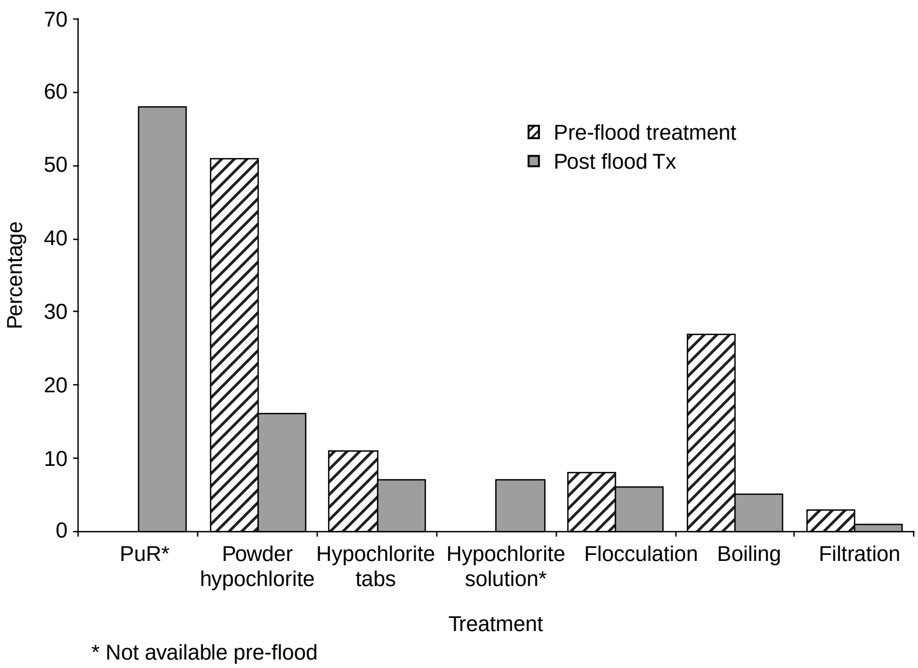

Figure 2 | Main water treatment method pre-flooding ($n = 37$) and post flooding ($n = 100$), Gonaives, Haiti, 2004.

would continue using PūR® if it was available in their communities. Respondents stated they would pay a median of 1 gourd (~0.027 USD) per sachet. Only 25% were willing to pay more than 2 gourds per sachet.

Environmental investigation

Only 22 households reported having PūR®-treated water in the home at the time of the interview. We tested samples of stored water in each of these 22 homes. The appropriate target range is 0.2 mg - <2 mg of free chlorine per liter of water. Of the 22 samples tested, ten were reported to have been treated >48 hours before testing; all of these had free chlorine levels <0.1 mg/l. Two other samples had a chlorine level <0.2 mg/l, nine samples had appropriate levels between 0.2 and 2 mg/l, and one had a level >2 mg/l.

All ten water sources tested were contaminated with coliform bacteria, although source water was visibly clear and all turbidity measurements were below 1 NTU (Table 3).

DISCUSSION

In the wake of devastating floods, an innovative campaign was launched employing local leaders to educate the residents of three communities about in-home water treatment and to distribute PūR® at no cost. PūR® was generally well-accepted in these communities, where survey respondents had good overall understanding of its proper

Table 3 | Water source fecal coliform counts, Gonaives, Haiti, 2004

Specimen #	Water source	Fecal coliform count/100 ml	Turbidity NTU[a]
1	Spring #1	77	0.1
2	Spring # 2	11	<0.1
3	Well # 1	17	<0.1
4	Spring # 3	91	0.45
5	Well # 2	85	0.26
6	Spring # 4	2	0.38
7	River	>200	0.96
8	Spring # 5	174	0.01
9	Tap # 1	1	0.54
10	Spring # 6	17	0.51

[a]NTU – Nephelometric Turbidity Units.

use, and reported liking the appearance, taste and smell, and the perceived health benefits of water treated with PūR®. No adverse events associated with PūR® use were detected. Although we were unable to conduct a study to identify health benefits that might have been expected from PūR® use, we did document levels of chlorine in some stored drinking water samples that would have been adequate to eliminate bacterial pathogens.

Data from our survey suggest that the PūR® adoption rate was sub-optimal. Less than one-fourth of households reported using PūR® more than five times over a 2 to 4 week period, and only 22% reported having PūR®-treated water in the home at the time of the interview. The short time period between the introduction of PūR® to the communities and our evaluation, and the informal distribution method, may have accounted in part for the low usage rate. Households may have received only a few sachets during the initial trial period, and not known how to access more after these were exhausted. A more regular distribution system, through markets and other traditional commercial sources, or through scheduled weekly visits to households, might have been more effective in increasing uptake. Additionally, many families collect and treat their water in the afternoon, while most interviews were conducted in the morning. Therefore, many households reported having no drinking water, treated or untreated, in the house at the time of the interview.

The residents of these resource-poor communities obtain their drinking water from a variety of untreated ground and surface sources. At the time of the survey, although these sources appeared clear and had low turbidity values, all were contaminated with fecal coliform bacteria. These findings highlight the high risk of waterborne disease and the need for in-home treatment. During the rainy season, or following flooding, the water is more turbid. At these times, the need for a flocculation-disinfectant product may be even greater. Only about one third of respondents reported treating their drinking water before the flooding, while all reported treating their drinking water after the tropical storm. Although muddier water after the storm may have prompted this change, repeated PūR®-related educational interventions and access to PūR® likely also played an important role.

Of note, these communities were aware of and concerned about health problems related to unsafe water. All of the respondents considered childhood diarrhea to be a significant health problem in their community. While other Haitian communities may not share such a high degree of awareness and concern, it suggests that linking perceptions about diarrhea prevention to specific safe water treatment messages could improve safe water behaviors.

Our evaluation had several limitations. Because education and distribution of PūR® did not begin until 4 to 6 weeks after the flooding, we were unable to examine uptake and improvements in household water quality during the time when water sources were turbid and the advantage of using PūR® would have been greatest. Because of the lack of experience using PūR® in an emergency response situation, PūR® was distributed in a non-systematic way. Areas of the communities were not equally covered and all households did not receive a set, equal number of PūR® sachets. This may have contributed to relatively lower usage rates at the time of the survey. The short time interval between the intervention and the evaluation may also have contributed to the discrepancy between the reported high acceptability of the product and the relatively low reported and observed usage rates, because even people that liked the product may not have acquired the habit of regularly obtaining and using it.

It is unclear whether PūR® will enjoy the same favor and widespread use in Haiti once free distribution ends. Less than 25% of those interviewed said they would be willing to pay 3 gourds, the intended sale price, for a sachet of PūR®.

CONCLUSIONS

Point-of-use water treatment is an essential measure to prevent waterborne disease in areas where source water is unfit for human consumption. For water sources that have been compromised by natural disasters point-of-use treatment approaches may be particularly valuable in helping to stem a “second wave” of morbidity and mortality from epidemic waterborne disease. However, the tools for point-of-use treatment must be disseminated quickly, be simple to use, and ideally should provide visual or other sensory cues about improvements in treated water quality.

In the future, it will be essential to collaborate with NGOs and other emergency relief organizations to get water purification products distributed quickly and effectively. NGOs should have prior familiarization with household water treatment products, and should establish teams of emergency responders to perform product demonstrations. Engaging local community leaders in education, promotion, and distribution efforts is feasible and may expand the reach of relief organizations. Acceptance by government officials is also important. They should understand that proven and licensed products, like dilute sodium hypochlorite bleach, calcium hypochlorite powder, and PūR® are safe for their communities, and offer effective and practical solutions for making water safe to drink following disasters.

In Haiti, community-based education and marketing techniques involving local leaders led to increased knowledge and acceptance of PūR® after the flood. Comprehensive, culturally-sensitive, and efficient delivery of safe drinking water programs post-disaster can be achieved when governmental and non-governmental organizations collaborate directly with community leaders to address the needs of affected communities. Better tracking of product distribution and earlier, more detailed evaluations of point-of-use water treatment programs in the post-disaster setting will help streamline future preparedness and response efforts.

In his evaluation of post-tsunami South Asia, Senate Majority leader William Frist described contaminated wells and destroyed water treatment plants, and highlighted the importance of assuring access to potable water as a critical priority to avoid a major epidemic (Frist 2005). PūR® has been distributed in tsunami-affected areas (Clasen *et al.* 2006), and in response to the recent earthquake in Kashmir. Further evaluations on how to maximize the usage and health benefits of point-of-use water treatment methods, including PūR®, in disaster response efforts can minimize the risks of waterborne disease in affected populations.

In summary, PūR® was well-accepted and properly used in remote communities where local leaders helped with distribution and education. More research is needed to determine the optimal use of PūR® and other safe water interventions following disasters. This highly effective water purification method can help protect disaster-affected communities from waterborne disease.

DISCLAIMER

The inclusion of trade names is for identification only and does not imply endorsement by CDC or the Department of Health and Human Services. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the funding agency.

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