

Household Water Disinfection in Hurricane-Affected Communities of Louisiana: Implications for Disaster Preparedness for the General Public

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In 2005, a record-breaking 14 hurricanes struck the Atlantic basin. Hurricane Katrina made landfall along the US Gulf Coast on August 29, 2005, and was responsible for more than 1600 deaths and an estimated US\$100 billion in property damage. Hurricane Rita struck the Texas and Louisiana coastlines on September 24, 2005, also causing extensive property damage, albeit with minimal loss of life. In the aftermath of the hurricanes, thousands of residents were left without basic municipal services, such as electricity and natural gas.¹ Direct physical damage and prolonged power outages greatly affected municipal treatment and distribution systems for drinking water, as well as wastewater treatment and collection.

In areas affected by Hurricane Rita, water systems that sustained a loss of electric power or loss of pressure in the distribution system placed customers on orders to boil water. Regional health authorities provided water system operators with sample text for use in their communications with consumers regarding boil water orders; operators were not mandated to use the text provided them (Figure 1). In addition, the Louisiana Department of Health and Hospitals updated an emergency news Web site with boil water order information every 24 hours.² Local media, such as radio and television, also carried boil water order details.

During the early posthurricane periods, power outages made communicating boil water orders by electronic media very difficult (Figure 2). Moreover, even if residents were aware of the boil water orders, lack of electricity and natural gas service may have prevented them from complying. We sought to examine the extent to which hurricane-affected residents in Louisiana were aware of boil water orders imposed on their communities, their compliance with the boil water orders, and knowledge of household water disinfection techniques other than boiling.

Objectives. Thousands of Louisiana residents were asked to boil water because of widespread disruptions in electricity and natural gas services after Hurricane Rita. We sought to assess awareness of boil water orders and familiarity with household water disinfection techniques other than boiling.

Methods. We conducted a cross-sectional survey in randomly selected mobile home communities in Louisiana.

Results. We interviewed 196 respondents from 8 communities, which had boil water orders instituted. Of 97 who were home while communities were still under orders to boil water, 30 (31%) were aware of the orders and, of those, 24 (80%) said the orders were active while they were living at home; of the 24, 10 (42%) reported boiling water. Overall, 163 (83%) respondents were aware of a method of water disinfection at the household level: boiling (78%), chlorination (27%), and filtration (25%); 87% had a container of chlorine bleach at home.

Conclusions. Few hurricane-affected respondents were aware of boil water orders and of alternate water disinfection techniques. Most had access to chlorine and could have practiced household chlorination if disruption in natural gas and electricity made boiling impossible. (*Am J Public Health.* 2007;97:S130–S135. doi:10.2105/AJPH.2006.094441)

METHODS

On the day after Hurricane Rita, approximately 80 community water systems in Calcasieu and Cameron Parishes in southwestern Louisiana placed customers on orders to boil water. We conducted a cross-sectional survey among residents of southwestern Louisiana mobile home communities during the week of November 7, 2005, approximately 6 weeks after the hurricane. We enumerated mobile home communities in Calcasieu and Cameron Parishes that were inhabitable after Hurricane Rita. Of 26 surviving communities, 4 had fewer than 20 mobile homes each and were excluded. A random-number generator was used to select 8 mobile home communities at random from the remaining 22 for inclusion in the survey. Trained interviewers attempted to interview 1 adult from each inhabited mobile home within the randomly selected mobile home communities. Respondents were eligible for participation in the survey if the following

criteria were met: she or he was aged 18 years or older at the time of interview, the interview location was the primary residence of the respondent at the time of interview, and the respondent had been a resident of Calcasieu or Cameron Parishes before Hurricane Rita made landfall on September 24, 2005. If no adult was home at the time of the interviewer's visit, 1 additional attempt was made to interview an eligible respondent.

The questionnaire addressed demographics, awareness of and compliance with boil water orders, knowledge of household water disinfection techniques, knowledge regarding waterborne and hand hygiene-related disease, and the use of waterless hand sanitizer for hand hygiene. No personal identifier information was captured on the survey instrument. Interviewers obtained verbal consent from each study participant and left an information sheet regarding the study with participants. All of the questions were read aloud by the interviewer, who recorded responses on the questionnaire.

BOIL ADVISORY

(Water Supply Name)

PWS_ID #

date

For Immediate Release to Water System Customers

The _____ has experienced problems with the water supply system.
Water supply Name

Because of these problems, the water produced by our water supply system is of questionable microbiological quality.

Therefore, as a **precaution**, we are issuing a BOIL ADVISORY effective immediately. This BOIL ADVISORY is to remain in effect until rescinded by your Water Supply owners.

It is recommended that all consumers disinfect their water before consuming it (including fountain drinks), making ice, brushing teeth, or using it for food preparation or rinsing of foods by the following means:

Boil water for one (1) *full* minute in a clean container. The one minute starts after the water has been brought to a rolling boil. (The flat taste can be eliminated by shaking the water in a clean bottle, pouring it from one clean container to another, or by adding a small pinch of salt to each quart of water that is boiled.)

Again, please be sure to disinfect your own water prior to consumption until you have been advised otherwise.

The Water Supply Providers will rescind this Boil Advisory upon notification from the Louisiana Department of Health and Hospitals - Office of Public Health that additional water samples collected from our water supply system have shown our water to be safe.

FIGURE 1—Boil advisory text recommended to water systems after Hurricane Rita, Louisiana, 2005.

RESULTS

We interviewed 196 respondents from 8 mobile home communities (designated communities A–H) randomly selected for inclusion in the survey. The median age of respondents was 46 years (range: 19–90 years); 64% were women, and 75% had completed high school. Electric stoves were used by 79%, and gas stoves were used by 21%. At least 1 television was present in 98% of homes, and 46% of respondents reported having access to the Internet at home before Hurricane Rita. A question about which diseases could be caused by drinking contaminated water yielded the following

responses: diarrhea (33%), parasites (7%), and skin infections (2%).

Nearly all of the respondents (97%) reported evacuating because of Hurricane Rita, with a median duration of evacuation of 15 days (range: 2–60). In preparation for the hurricane, 119 respondents (61%) reported purchasing items such as bottled water (92 of 119; 77%) and canned foods (73 of 119; 61%). There was no difference in self-reported use of waterless hand sanitizer before (63%) and after (61%) the hurricane. Before Hurricane Rita, the community water supply was the primary source of drinking water for 57% of respondents, and bottled water was the primary source for 43%. After

the hurricane, the community water supply was the primary drinking water source for 31%, and bottled water for 69%.

Boil water orders were put into place in all 8 of the mobile home communities on September 24, 2005, the day that Hurricane Rita made landfall; the duration of the boil water orders varied from 14 to 43 days (Table 1).² Overall, 39% of all respondents were aware that their community had been under orders to boil water after Hurricane Rita. The 77 respondents who were aware of the boil water orders reported obtaining that information through a variety of media: leaflets (32%), word of mouth (23%), television (21%), radio (15%), newspaper (5%), and the Internet (1%). Many residents of community H, where 77% of respondents were aware of the boil water orders, reported that the community manager walked from home to home to drop off leaflets and personally explained the need for boiling water. Information provided on leaflets, as reported by community members, varied from community to community.

There was no association between gender, age group, years of education, or access to the Internet at home and the awareness of boil water orders. Of the 196 respondents, all of whom were living in mobile home communities that had boil water orders in place for some time after Hurricane Rita, 77 (39%) were aware of the orders. Among the 77, 59 (77%) said they were home when the boil water orders were in place. Of those 59, 27 (46%) reported boiling water. Twenty-three (39%) reported being able to boil water but did not, and 9 (15%) reported being unable to boil water. Awareness of boil water orders varied significantly by mobile home community, ranging from 9% in community A to 77% in community H ($P = .0005$; Table 1). The rate of boiling water was highest in communities G and H at 100% and 63%, respectively; the difference in the rate of boiling water between the communities was not statistically significant. However, the number of respondents in each community was small, ranging from just 2 to 21. Bottled water was the primary water source after the hurricane for 59% of respondents who reported boiling water and 81% of respondents who reported not boiling water ($P = .07$). Thus, a total of 25 respondents, or



FIGURE 2—Communication of availability of water and sewer services by signboard adjacent to hurricane-affected community, Louisiana, 2005.

TABLE 1—Awareness of Boil Water Orders by Mobile Home Community: Louisiana, 2005

Community	No. of Respondents	Duration of Boil Water Orders (d) ^a	Median Duration of Evacuation (d)	Aware of Boil Orders, no. (%)	Boiled Water, no. (%) ^b
A	34	43	16	3 (9)	0 (0)
B	27	19	18	6 (22)	1 (33)
C	8	28	26	3 (38)	1 (50)
D	8	24	15	3 (38)	1 (50)
E	74	14	14	30 (40)	6 (29)
F	12	28	16	6 (50)	1 (20)
G	11	14	14	8 (73)	7 (100)
H	22	14	15	17 (77)	10 (63)
TOTAL	196		15	78 (40)	27 (47)

^aAll boil water orders became effective on September 24, 2005.

^bThis proportion was calculated by dividing the number of respondents who reported boiling water by the number of respondents who were aware of boil water orders and who believed that the boil water orders were in place while they were living in the community.

13% of the study population, consumed water that was not bottled or boiled.

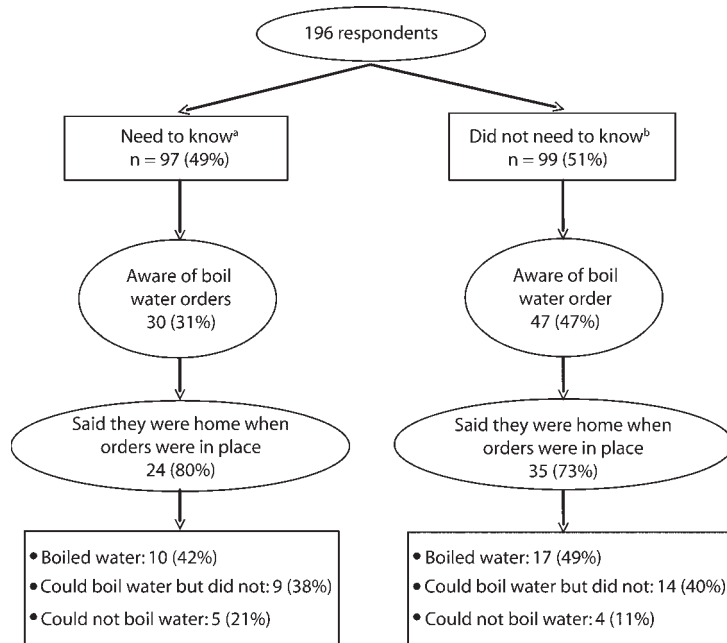
We defined “need to know” about the boil water orders as not having evacuated or having returned home while boil water orders were still in place. The determination of whether evacuees returned while orders were active was made by comparing the self-reported duration of evacuation to the number

of days that boil water orders were in place for the respective communities according to the Louisiana Department of Health and Hospitals. A total of 97 respondents (49%) had not evacuated or had returned to their homes while boil water orders were still active for their community, thus needing to know about the orders; 99 respondents (51%) returned only after boil water orders were lifted and,

thus, did not need to know about the orders (Figure 3) Awareness of boil water orders was lower among those who needed to know than among those who did not need to know ($P < .05$). A similar proportion of both groups believed that they were living in the community while boil water orders were active and, among those, a similar proportion reported complying with the orders.

Among the total of 27 persons who boiled water, 70% used a kitchen stove; 22% used another stove, such as a hotplate or crawfish boiler; 7% of respondents could not remember which stove was used; and 1% did not answer the question. When asked how long water was supposed to be boiled, 52% answered more than 5 min; 11% specified a duration between 1 and 5 min; 4% specified a duration less than 1 min; 7% answered 1 min; and 26% reported not knowing the proper duration for boiling. Boiled water was used for various purposes including cooking (46%), hand washing or bathing (42%), drinking (39%), brushing teeth (23%), or preparing drinks (12%). Other uses were reported by 26%, and these included washing dishes, preparing baby formula, and shaving.

Overall, 163 respondents (83%) reported knowing at least 1 method of water disinfection at the household level. The following techniques were specified by these respondents: boiling (78%), chlorination (27%), filtration (25%), and iodination (4%). Among the 44 respondents who suggested chlorination as a household disinfection technique, only 1 (2%) correctly named the dose of chlorine recommended by the Louisiana Department of Health and Hospitals (one-eighth teaspoon of commercial bleach per gallon of water); 21 (50%) stated a dose that was higher than recommended, 6 (14%) stated a dose that was lower than recommended, and 13 (31%) reported not knowing the recommended chlorine dose for drinking water disinfection. Ninety-two percent of respondents reported having a container of bleach at home before Hurricane Rita, and 87% said that they had bleach after Hurricane Rita. Seventeen percent of respondents reported having tincture of iodine or iodine drops at home before and after the hurricane.



^aNeed to know: Residents who had not evacuated or had returned while boil orders were still in place

^bDid not need to know: Residents who had returned after boil orders were withdrawn

FIGURE 3—Awareness of boil water orders among hurricane-affected respondents: Louisiana, 2005.

DISCUSSION

This study highlights the challenges of communicating to the public about drinking water issues during and after large-scale disasters. Awareness of boil water orders was low among hurricane-affected respondents and particularly low among those who needed to know because they had not evacuated or had returned before the orders were lifted. This finding reflects the need to identify effective and efficient means of mass communication during the early phase of a water emergency. Many who returned after boil water orders were lifted believed that the orders remained active, indicating the equal failure in adequately communicating the termination of the water emergency. Our findings also underscore the need to enhance the public's knowledge of the consequences of drinking contaminated water and alternative household water disinfection techniques given that prolonged and widespread disruptions in electricity and natural gas services may prevent boiling.

Previous studies have documented the difficulty of communicating to the public regarding

boil water orders in the context of known contamination or an outbreak of disease among consumers of municipal water supplies.^{3,4} The lack of accurate knowledge regarding boil water orders among our survey respondents has several possible explanations. Interruptions in electricity service may have prevented persons in hurricane-affected areas from accessing this information through usual media channels, such as television. Although not statistically significant, perhaps because of limited sample size, we found that, among persons aware of boil water orders, those who boiled water used bottled water for drinking less frequently than those who did not boil water. Residents may not have heeded announcements to boil water if they had purchased bottled water in preparation for the hurricane or if they received bottled water from emergency response teams after the hurricane. In disasters that occur without warning, residents may not be able to stock up on bottled water in advance and may be forced to use water from the tap or other sources, irrespective of its microbiologic quality.

The World Health Organization's Guidelines for Drinking-Water Quality recommend that

boil water orders be issued only if the responsible public health authority is convinced of an ongoing risk to the public's health that outweighs the risks associated with boiling, which include scalds and burns.⁵ The decision to issue boil water orders in Calcasieu and Cameron Parishes after Hurricane Rita was based on loss of electric power to the water treatment plants or loss of water pressure in the distribution system and not necessarily on the basis of confirmed microbiologic contamination. Perceptions of risk regarding the community water systems may have been low, because affected communities were not told of confirmed microbial contamination or of potential adverse health effects that might result from drinking the municipal water supply. Moreover, general awareness of the health consequences of drinking contaminated water was poor among survey respondents, which may have contributed to low risk perception. In an assessment of adherence to boil water orders in the context of cryptosporidial contamination of the municipal water supply in an English community, participants recommended that describing the health effects of drinking unboiled water would have been useful.⁴

Hundreds of community water systems were affected by the 2005 hurricane season. Although the water system companies were provided with sample text to address the boil water orders (Figure 1), they were not mandated to use the provided text. Because several weeks had elapsed since the time of the hurricane, we were unable to assess the exact messages delivered by each water system company supplying the mobile home communities in this study. Thus, we cannot know whether awareness of the boil water orders was hampered by a failure to deliver the messages or by use of unclear messages. Leaflets and word of mouth were the most commonly reported sources of information regarding boil water orders among hurricane-affected respondents. Such techniques may be most effective when usual media, such as television and radio, are rendered unavailable during emergency situations. However, these strategies may be difficult to scale up in the midst of very large disasters, in which hundreds of thousands of persons may be affected. Moreover, particularly when word of mouth is used as a

TABLE 2—Recommendations for Household Water Disinfection From Federal and Hurricane-Affected State Agencies: United States, 2005

Agency or State	Recommended Duration of Boiling	Disinfection With Liquid Chlorine			Chlorine Tablets	Tincture of Iodine	Iodine Tablets
		Type of chlorine recommended	Clear water	Cloudy water			
Environmental Protection Agency: www.epa.gov/safewater/faq/emerg.html	1 min	1% (nonscented, household chlorine bleach)	10 drops per quart; 40 drops per gallon	Double the amount	1 tablet per gallon	5 drops	1 tablet per gallon
		4–6%	2 drops per quart; 8 drops per gallon (1/8 teaspoon)	Double the amount			
		7–10%	1 drop per quart; 4 drops per gallon	Double the amount			
Centers for Disease Control and Prevention: http://www.bt.cdc.gov/disasters/foodwater.asp	1 min	Household chlorine bleach	1/8 tsp per gallon (approximately 0.75 mL)	1/4 tsp per gallon (approximately 1.50 mL)	Follow directions on label	...	Follow directions on label
Alabama ^a : http://www.adph.org/environmental	...	...	...	...	...	...	...
Louisiana: http://www.dhh.louisiana.gov/offices/faq.asp?ID=145	1 min	Unscented, liquid chlorine bleach	1/8 tsp per gallon	1/4 tsp per gallon	...	5 drops	...
Mississippi: www.health.ms.gov/msdhsite/index.cfm/23,0,148,html	1 min	Unscented, ordinary household chlorine bleach	1/8 tsp per gallon	...	...	...	...
Texas: http://www.dshs.state.tx.us/news/releases/20050926.shtm	1 min	Ordinary household bleach	1/8 tsp (approximately 8 drops) per gallon	...	...	Follow directions on label	...

^aThe Alabama Department of Health Web site has a link to the Centers for Disease Control and Prevention emergency hurricane health information.

communication tool or when each water system is left to produce its own communication materials, there may be a risk of passing along incomplete or inaccurate information. Managers of water systems would benefit from receiving communications materials, such as ready-to-post signs and letters, from public health officials regarding boil water orders. The text in such messages should be accessible to audiences of wide literacy skills and should contain information regarding alternatives to boiling for household water disinfection. Such pre-prepared materials may minimize the dissemination of misinformation about water safety issues.

A majority of survey respondents drank bottled water to meet their drinking water needs and, because of its availability, many who were aware of the boil water orders may not have felt the need to comply with those orders. Bottled water was commonly purchased by respondents in anticipation of Hurricane Rita, and many relief agencies carried out distribution efforts in the aftermath of the hurricane. Although bottled water distribution may have met the need for potable water in these communities, it is unlikely to have served residents very early in the posthurricane period. First, distribution centers must be established and stocked with necessary supplies. Next, the location of

centers must be communicated widely; as with the communication of boil water orders, the dissemination of such information might be significantly hampered when electricity services are disrupted and residents cannot access usual sources of information, such as television and radio. Because bottled water and other supplies are generally distributed at centralized locations, affected residents would have to be able to walk to the distribution center or have access to a functioning vehicle to collect necessary supplies. All of these potential barriers to procuring bottled water suggest that residents of disaster-prone areas should be aware of when and how to disinfect water at the household level.

Boiling water was the most widely recognized technique for household water disinfection among survey respondents. With electricity and natural gas services interrupted, it would have been nearly impossible for residents to comply with boil water orders in the immediate posthurricane period. Small-scale water purifiers, such as those available from sporting or camping stores, may be useful in the emergency context but are likely to be prohibitively expensive for some. The public should be aware of inexpensive emergency water disinfection techniques, such as chlorination or iodination. Only a minority of respondents was aware of these alternatives to boiling. Chlorination of water at the household level has been shown repeatedly to improve the microbiological quality of drinking water and to decrease the risk of diarrhea in the context of poorly functioning municipal water supply systems.^{6,7}

Among respondents who were aware that chlorine could be used to disinfect water, knowledge of the recommended dose of chlorine per gallon of water was poor. Guidance from federal and state public health and water safety authorities may be confusing to United States residents who are not in the habit of collecting water in containers and adding bleach to make it safe to drink (Table 2). The US Environmental Protection Agency provides guidance regarding 3 different concentrations of bleach, and other federal and state agencies refer to “household bleach.” Many US residents may not be aware that bleach can indeed be purchased in varying concentrations. Moreover, the common recommendation to use one-eighth teaspoon of bleach per gallon of water may be challenged by the absence of one-eighth teaspoons in sets of baking measures typically available in American homes. Notably, the overwhelming majority of respondents had a container of bleach at home and, thus, had the capacity to disinfect water by chlorination before and after the hurricane. Emergency preparedness plans should prioritize enhancing the public’s awareness of chlorination as a household disinfection technique and preparing user-friendly guidelines on appropriate doses of bleach for such disinfection.

This study faced some key limitations. The survey population was restricted to those whose homes were inhabitable and who had

returned to the area; hence, a potentially more vulnerable population of persons with greater property damage would not have been included in the survey. The survey was conducted 6 weeks after Hurricane Rita, which may have limited respondents’ ability to recall compliance with the boil water orders accurately. All of the practices were self-reported and, thus, the practice of boiling water may have been overestimated by respondents. Finally, the sample size within each mobile home community was small and prevented comparison of the boiling water practice between communities. Despite these important limitations, this study documented important deficiencies in communication regarding the initiation and cancellation of boil water orders and alternative techniques to boiling.

Hurricanes often present with several days of advance notice, allowing residents and government officials to prepare by stocking up on necessary supplies, disseminating important health information, or evacuating. Other natural disasters, such as earthquakes, do not afford this luxury of advance warning. With several seismically active regions within the country and forecasts of increasingly intense hurricane seasons to come, US residents and government agencies should be prepared to cope with disasters and with the consequences for drinking water supply. Enhancing awareness of household water disinfection strategies, including boiling and chlorination, may protect the public’s health in the aftermath of large-scale disasters. ■

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Contributors

P.K. Ram, M.R. Bonner, and E.D. Mintz originated the study. P.K. Ram developed the protocol, oversaw data collection and data analysis, and drafted the article. E. Blanton, D. Klinghoffer, and M. Platek

contributed to data collection, management, and analysis and reviewed the article. J. Piper and S. Straif-Bourgeois contributed to data analysis and article review. M.R. Bonner and E.D. Mintz contributed to interpretation of results and article revision.

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Human Participant Protection

This study protocol was deemed exempt from institutional review under CFR 46.101 (b)(2) by the social and behavioral sciences institutional review board at the University of Buffalo and the Human Research Protection Office of the Centers for Disease Control and Prevention.

References

- Centers for Disease Control and Prevention. Assessment of health-related needs after Hurricanes Katrina and Rita—Orleans and Jefferson Parishes, New Orleans area, Louisiana, October 17–22, 2005. *MMWR Morbid Mortal Wkly Rep* 2006;55:38–41.
- Louisiana Department of Health and Hospitals. *Boil orders related to Hurricanes Katrina & Rita*. Baton Rouge, LA: Louisiana Department of Health and Hospitals; 2005.
- Angulo FJ, Tippen S, Sharp DJ, et al. A community waterborne outbreak of salmonellosis and the effectiveness of a boil water order. *Am J Public Health* 1997;87:580–584.
- O'Donnell M, Platt C, Aston R. Effect of a boil water notice on behaviour in the management of a water contamination incident. *Commun Dis Public Health* 2000;3:56–59.
- World Health Organization. *Guidelines for Drinking-Water Quality, Third Edition*. Geneva, Switzerland: World Health Organization; 2004.
- Luby SP, Agboatwalla M, Hoekstra RM, Rahbar MH, Billhimer W, Keswick BH. Delayed effectiveness of home-based interventions in reducing childhood diarrhea, Karachi, Pakistan. *Am J Trop Med Hygiene* 2004;71:420–427.
- Semenza JC, Roberts L, Henderson A, Bogan J, Rubin CH. Water distribution system and diarrheal disease transmission: a case study in Uzbekistan. *Am J Trop Med Hygiene* 1998;59:941–946.