Residents' Responses to the May 1-4 2010
Boston Water Contamination Incident

Michael K. Lindell

Shih-Kai Huang

and

Carla S. Prater

Hazard Reduction & Recovery Center
Texas A&M University
College Station TX 77843-3137

Abstract

This study examined local residents' warning sources, warning receipt times, message content, warning confirmation, risk perception, and consumption of untreated tap water, boiled water, bottled water, and personally chlorinated water during the May 1-4 2010 Boston water contamination incident. Most residents received their warnings from the news media and peers in a temporal process that followed a logistic curve with a very long tail. On average, warning messages mentioned 2.3 of the five recommended elements of a warning message—most commonly the threat and the recommended protective action. Consumption of untreated tap water declined, consumption of personally chlorinated water remained negligible, and consumption of boiled water and bottled water increased. Partially consistent with hypotheses, first warning source was significantly related to protective response but message content was not. Unexpectedly, risk perception was more strongly related to water consumption before the incident than after the incident. This finding calls attention to the need to recognize that, although increased risk perception can increase protective action, successful implementation of protective actions can decrease risk perception. Thus, as noted by Weinstein and his colleagues, hazards researchers need to use research designs that are capable of detecting this reciprocal effect over time.

Keywords: water contamination, warning response, boil water advisory, risk perception, warning messages, warning sources, warning channels

Introduction

When an emergency arises that threatens public health and safety, local officials must issue warnings to those at risk. Sorensen's (2000) review of hazard warning systems documented an extensive base of research that addressed people's response to warnings about a wide range of natural and technological hazards. However, his review did not address any studies of people's responses to water contamination incidents. Some of these incidents have relatively minor health consequences (e.g., Seydlitz, Spencer, Laska, & Triche, 1991; Seydlitz, Spencer & Lundskow, 1994), whereas others involve the possibility of long-term health effects (Jakus, Shaw, Nguyen & Walker, 2009).

There are a few water contamination studies in which an acute threat led authorities to warn people to drink bottled or boiled water instead of untreated tap water. A study of Calcasieu and Cameron parishes in the aftermath of Hurricane Rita found that only 39 percent of the respondents were aware of a boil water advisory six weeks after its initiation, but there was significant variation among the eight surveyed communities—ranging from 9-77 percent (Ram et al., 2007). Many of those who received a warning did boil water (46%), but almost as many who were able to boil water did not (39%) and 15 percent reported being unable to boil water due to loss of gas and electric power. Angulo et al. (1997) showed that in response to a salmonellosis outbreak in Gideon Missouri, all but ten percent of the households at risk heard about the event before ten days had passed and, of those who were aware, 31 percent did not comply—which the respondents attributed mostly to forgetfulness (44%). Similar findings emerged in an unidentified Oregon town that experienced *E. coli* contamination in its water system after a flood (Harding & Anadu, 2000). There, 90 percent of the residents were aware of the threat and took action, but only 57 percent of them boiled tap water as advised by the water utility, whereas 77 percent drank bottled water. Residents of that town and three others reported relying most on newspapers for information about city drinking water (75%), but also relied on mail or flyers from the water utility (58%), family or friends (56%), public health departments (51%), TV (36%), radio (34%), and personal physicians (25%). The researchers noted a 22 percentage point difference in the percentage of residents boiling water in a town that did (57%), and another that did not (35%), include a specific protective action recommendation in the warning message. Griffin, Dunwoody and Zabala's (1998) study of Milwaukee residents' media usage shortly after the 1993 Cryptosporidium outbreak found that people's continuing attention to information about Cryptosporidium hazard in the mass media (TV, radio, and newspapers) was significantly correlated with their routine exposure to those media but was also related to their worry about becoming sick from future consumption of contaminated tap water.

Although these studies are informative, they failed to report data on some important aspects of warning response that have been identified by disaster researchers (Drabek, 1986; Mileti & Peek, 2000). As summarized by the *Protective Action Decision Model* (Lindell & Perry, 1992, 2004, in press), this research has addressed issues such as the source of first warning, warning message content, channels of warning dissemination, sources of warning confirmation and additional information, risk perception, and compliance with protective action recommendations. One event that provides a particularly useful point of comparison to water contamination warnings is another very rapid onset event—the eruption of Mt. St. Helens (Lindell & Perry, 1987; Perry & Greene, 1982). In this event, more people in the area of greatest risk, Toutle/Silver Lake, were warned by authorities (44%) than by peers (37%) or news media (10%). By contrast, peers (28%) were more important in the area of lesser risk, Woodland, than were authorities (11%) or the news media (10%). Being warned first by an authority was important because it produced greater risk perceptions and immediate evacuation preparations. Similarly, the more specific the message was about the threat, the greater were people's risk perceptions and preparations to evacuate. Moreover, people sought confirmation from the news media (33% in Toutle/Silver Lake, 59% in Woodland), authorities (29% and 19%, respectively), and peers (18% and 8%, respectively). In addition, many people received warnings within one hour of the eruption (87% in Toutle/Silver Lake, 59% in Woodland) and most had been warned within four hours (96% and 97%, respectively).

Disaster research has also identified the elements of warning messages that are most important in getting people to take protective actions. These are the nature of the threat, the geographic areas that are expected to be affected and those that are expected to be safe, the recommended protective action(s), and sources of additional information and assistance (Lindell & Perry, 2004; Mileti & Peek, 2000; Sorensen, 2000). These message elements arouse protection motivation by identifying likely personal consequences of exposure. In addition, these elements provide guidance on appropriate responses to avoid the threat and how to obtain assistance in implementing those actions (Lindell & Perry, in press).

It is important to recognize that there have been many innovations in communications technologies since the Mt. St. Helens eruption. At that time, TV, radio, and newspapers were the only forms of electronic mass media and telephones were the only form of electronic peer communication. Now, emergency information can also be disseminated via email, Internet websites, and social media such as Twitter. Official agency websites—and even informal community websites (Novak & Vidoloff, in press)—have provided initial and continuing information about incidents. Similarly, social media have been found to provide a variety of different types of information about incidents in progress (Sutton, Palen & Shlovski, 2008). In particular, Twitter allows users to disseminate emergency information by forwarding ("retweeting") it to others (Hughes & Palen, 2009; Starbird et al., 2010; Vieweg, Hughes, Starbird & Palen, 2010). Moreover, these channels vary in their use by different user types (private, government, and media), ages, and ethnic groups (Vultee & Vultee, in press).

To date, most studies of innovative emergency communications technologies have used the message ("Tweet"), rather than the warning recipient, as the unit of observation. Although studies of social media usage can provide valuable information about the many aspects of these technologies, they cannot assess the relative extent to which these technologies are used in comparison to established technologies such as TV, radio, and newspapers. Nor can they assess the degree to which the use of different types of communications media is associated with the adoption of protective actions. Thus, there is a continuing need for surveys of risk area residents to address these issues.

Some indications of the extent to which different communications media are being used can be seen in research conducted over the past 25 years. Beatley and Brower (1986) found that most of their respondents (52.6%) named TV as their primary source of information about Hurricane Diana as it approached. A slightly smaller percentage named radio (41.8%) and many fewer mentioned newspapers (2.0%), environmental cues (2.0%), and peers (1.6%) as their primary sources of information. More recently, Lindell, Lu and Prater (2005) found that residents of the Lake Sabine area of Texas used local news media (mean rating of 4.27 on a scale from 1-5), national news media (M = 3.48), and local authorities (M = 3.08) much more than the Internet (M = 1.84) as sources of information about the approach of Hurricane Lili. Hayden et al. (2007) reported that nearly half of their respondents from Denver, Colorado and Austin, Texas named local TV stations as their most important source for weather information and most of the rest named local radio stations and environmental cues (each about 20%). Only about five percent named the Internet as their primary source, although reliance on this information channel rose to 40 percent when people were asked to report all of the places they obtained weather information. Cell phones and "other" channels accounted for only about five percent. When asked to identify the best way for officials to notify them about a flash flood, most people mentioned TV, sirens, and radio; less than 20 percent of the respondents named cell phones and less than 15 percent named email. However, the Lindell et al. (2005) and Hayden et al. (2007) studies collected their data in 2003 and 2004, respectively, which was before the emergence of Facebook and Twitter, so it is likely that the use of alternative communication channels has increased since then and needs to be re-examined.

The findings of previous research on emergency warnings lead to six research hypotheses and three research questions about risk area residents' responses to a water contamination incident.

H1: Authorities a) will be the most common first source of warnings about a rapid onset emergency and b) will transmit their warnings earlier than the news media and peers.

H2: The most common message content will be the nature of the threat, followed (in order) by affected areas, the recommended protective action, safe areas, and sources of additional information.

H3: Those who were first warned by sources other than authorities will use more channels to obtain additional information.

H4: The most common channels of additional information will be the broadcast media (TV and radio), followed (in order) by telephone calls, Twitter/other social media, email, official fliers, newspaper articles, and the Internet.

H5: Warning recipients' levels of routine access to TV and radio will be a) positively correlated with their receipt of additional information through those channels, b) positively correlated with their speed of warning receipt, and c) negatively correlated with the number of sources from which they seek additional information.

H6: Those who a) were first warned by authorities, b) received more specific warning messages, and c) had greater perceptions of risk will be more likely to adopt the recommended protective action.

RQ1: How rapidly was news of the incident disseminated to those at risk?

RQ2: Does warning message content and the number of message elements differ by warning source?

RQ3: Are time of warning receipt, first warning source, warning content, and additional information channels related to demographic characteristics (age, sex, ethnicity, marital status, household size, education, or income)?

Method

Incident Description

A major pipeline providing water to eastern Massachusetts broke in Weston about 10:00am on May 1, 2010. In response, Massachusetts Governor Deval Patrick declared a state of emergency and advised residents of the affected area to boil water before drinking it. Boston Mayor Thomas Menino also declared as state of emergency and initiated reverse 911 calls and police officers with bullhorns to notify people of the threat of water contamination. Boston news media outlets publicized information about appropriate response to different water exposure paths such as drinking, cooking, washing dishes, bathing and showering, tooth brushing, preparation of food (especially raw vegetables) and ice, as well as specific requirements for child care centers, schools, retail food establishments. They also provided information about locations where the Massachusetts National Guard was distributing free bottled water, and procedures for boiling water (one minute rolling boil) and personal chlorinating water (eight drops of household bleach to a gallon of water). The Massachusetts Water Resources Authority repaired the pipeline and, after water samples from nearly 500 locations had been tested, the Governor rescinded the boil water advisory at 6:45am on Tuesday, May 4.

Sample

The sample comprised 600 households in the Boston area (including Boston, Brookline, and Somerville) who experienced water contamination during 1-4 May 2010. Six months after the event, the Texas A&M University Hazard Reduction & Recovery Center (HRRC) conducted a survey following Dillman's (1999) procedure. Households were sent the first questionnaire and those who did not return a completed copy within two weeks were sent a reminder post card and as many as two replacement questionnaires mailed at two week intervals thereafter. The process ended when either the household had returned a questionnaire or the last questionnaire packet had been mailed. Out of 117 responses, 110 households returned valid questionnaires for a response rate of 22.4 percent, which was lower than other recent HRRC surveys following the same procedure—25.7 percent from the Hurricane Bret evacuation survey (Zhang, Prater & Lindell, 2004), 24.6 percent from Texas coastal evacuation expectations survey (Kang, Lindell & Prater, 2007), 50.7 percent from the Hurricane Lili evacuation survey (Lindell et al., 2005), 33.5 percent from the Katrina/Rita survey (Lindell & Prater, 2008), and 39.4 percent from the Hurricane Ike evacuation and reentry survey (Huang et al., 2010).

Among the respondents, 61 percent were female, the average age was 47.9, and 39 percent were married. Respondents identified themselves as African American (3.8%), Asian/Pacific Islander (10.5%), Caucasian (75.2%), and Hispanic (5.7%). There were 2.12 members per household, including .31 children and .34 elders per household. Forty seven percent of the respondents identified themselves as homeowners and they had an average of 16.1 years of education and US$ 67,057 annual household income. Other than over-representing women, the sample was generally consistent with the 2000 Boston census data.

Measures

Respondents were first reminded of the dates and times that the boil water advisory was issued and rescinded and then asked to report the day and time that they first found out about it. Next, they reported who was the source of their first information about the boil water advisory —authority; radio or TV announcer; friend, relative, neighbor, or coworker; or someone else (e.g., a stranger). However, only four respondents reported receiving warnings from strangers so this category was deleted from further analyses. Respondents then indicated what was the content of the information they received from that source—what was the threat (i.e., water contamination), which areas would be affected, which areas would be safe, what protective action to take (e.g., boil water), where to get additional information, and other. They were also asked to identify all channels through which they received additional information after the first warning—newspaper article, TV broadcast, radio broadcast, telephone call, email, official flier, Twitter/other social media, Internet or other. They were asked to report the extent (*Not at all* = 1; *Very great extent* = 5) to which they used each of four sources of drinking water *before* the boil water advisory (untreated tap water, bottled water, boiled water, and personally chlorinated water) and then the extent to which they used each of four sources of drinking water *during* the boil water advisory. To measure risk perception, they were asked to use the same five category extent scale to rate the likelihood that they would get sick from using untreated tap water through seven different exposure paths—have a glass of water to drink, rinse fresh vegetables such as lettuce, cook some spaghetti noodles, brew a pot of coffee, rinse their mouths after brushing their teeth, take a shower, and wash clothes.

They were asked to report how many quarts of bottled water they had and whether they had at least one cup of chlorine bleach at the time of the incident. In three separate questions, respondents were also asked to report the times at which they *usually*—that is, four or more times per week—watched local television news, listened to local radio news, and read local newspapers. Each respondent's number of news media access hours was summed separately for TV, radio, and newspaper to compute the three indexes of news media access. Finally, they were asked to report their age, sex (*Male* = 0, *Female* = 1); ethnicity (*Minority* = 0, *White* = 1); Marital status (*Unmarried* = 0, *Married* = 1); number of persons in the household under 18 years, 18-65 years, and over 65 years; education (*Some high school* = 1, *High school/GED* = 2, *Some college/vocational school* = 3, *College graduate* = 4, *Graduate school* = 5); household income (*Less than $25,000* = 1, *$25,000–49,999* = 2, *$50,000–74,999* = 3, *$75,000–99,999* = 4, *More than $100,000* = 5); and homeownership (*Rent* = 0, *Own* =1).

Results

Contrary to H1a (Authorities will be the most common first source of warnings about a rapid onset emergency), the first column of Table 1 (Var15-Var17) indicates that 42 percent of the respondents reported receiving their first information about the incident from peers, 41 percent from the news media, and only 13 percent from authorities. This difference in proportions is highly significant ($\chi^2_3 = 49.00$, $p < .0001$). Moreover, also contrary to H1b (Authorities will transmit their warnings earlier than the news media and peers), the differences among the warning sources with respect to respondents' times of warning receipt were not statistically significant ($F_{3, 81} = 1.97$, *ns*).

Partially consistent with H2 (The most common message content will be the nature of the threat, followed by—in order—affected areas, the recommended protective action, safe areas, and sources of additional information), the first column of Table 1 (Var18-Var22) shows that 82 percent of the respondents reported the content of their first warning included the nature of the threat, but only 52 percent reported it included affected areas. Most (76%) reported the first warning included the recommended protective action, but only nine percent reported it included safe areas, and only 16 percent reported it included sources of additional information. On average, respondents reported that their first warning contained information about 2.30 of the five recommended warning elements.

Contrary to H3 (Those who were first warned by sources other than authorities will use more channels to obtain additional information), Table 1 shows that the correlations between the sources of first warning (Var15-Var17) and the number of additional information channels used (Var32) were not statistically significant.

Partially consistent with H4 (The most common channels of additional information will be the TV and radio, followed by telephone, Twitter/other social media, email, official fliers, newspaper articles, and the Internet), the first column of Table 1 (Var24-Var31) shows that 66 percent of the respondents reported their most common channel of additional information was TV, but the Internet (34%) was more common than radio (21%) and telephone (25%), and the relative prevalence of the latter two was the reverse of that hypothesized. Moreover, reading newspaper articles (17%) was more frequent than receiving official fliers (7%), email (4%), or Twitter/other social media (3%). On average, respondents reported receiving information through 1.7 of the eight additional information channels.

Analysis of the percentages of respondents reporting TV, radio, newspaper, and total media access over the course of the typical day revealed a small peak in TV access from 6-8am, with a much larger peak from 5-7pm and a slightly smaller one at 10-11pm. Radio access had a more pronounced peak from 7-9am, another at noon, and a third peak from 4-7pm. Finally, newspaper access had a single major peak from 7-10am with another minor peak from 5-6pm. The first column of Table 1 (Var9-Var11) shows that the respondents routinely spent more hours watching TV (M = 1.74) than listening to radio (M = 1.23) or reading newspapers (M = .83).

Consistent with H5a (Warning recipients' levels of routine access to TV and radio will be positively correlated with their receipt of additional information through those channels), Table 1 show that routine TV access was significantly correlated with receiving additional information through that channel ($r_{9,27}$ = .25). In addition, routine radio access was significantly correlated with receiving additional information through that channel ($r_{10,25}$ = .47) and routine newspaper access was not significantly correlated with receiving additional information through that channel ($r_{11,24}$ = .16). Unexpectedly, routine TV access was positively correlated with receiving additional information by telephone ($r_{9,26}$ = .22) and official flyer ($r_{9,30}$ = .22), but negatively correlated with receiving additional information through the Internet ($r_{9,31}$ = -.22). None of the other correlations with routine news media access was statistically significant, in part because email and Twitter/Other social media were used too infrequently to make any meaningful comparisons.

Contrary to H5b (Warning recipients' levels of routine access to TV and radio will be positively correlated with their speed of warning receipt), Table 1 indicates that none of the correlations of Var9-Var11 with Var14 was statistically significant. Moreover, contrary to H5c (Warning recipients' levels of routine access to TV and radio will be negatively correlated with the number of sources from which they seek additional information), Table 1 indicates that routine newspaper access was positively correlated with the number of additional information sources sought ($r_{11,32}$ = .24) but the correlations of routine TV and radio access were not.

Column 1 of Table 1 (Var34-Var37) indicates that, before the incident, residents drank tap water (M = 3.50) more frequently than bottled water (M = 2.68), bottled water more frequently than boiled water (M = 1.98), and boiled water more frequently than personally chlorinated water (M = 1.22). During the incident, however, the means for Var38-Var41 indicate that consumption decreased for tap water (M = -2.31), remained unchanged for personally chlorinated water (M = -.03), and increased for bottled (M = 1.09) and boiled (M = 1.16) water. Consistent with H6a (Those who were first warned by authorities will be more likely to adopt the recommended protective action), Table 1 shows that there was a statistically significant correlation between first warning by an authority and consumption of boiled water during the incident ($r_{15,40}$ = .22).

Contrary to H6b (Those who received more specific warning messages will be more likely to adopt the recommended protective action), Table 1 shows there were no statistically significant correlations between the number of message elements in a warning message and the consumption of untreated tap water ($r_{23,38}$ = -.06), bottled water ($r_{23,39}$ = -.18), boiled water ($r_{23,40}$ = -.05), and personally chlorinated water ($r_{23,41}$ = .09). However, partially consistent with H6c (Those who had higher risk perception will be more likely to adopt the recommended protective action), risk perception was significantly correlated with consumption of bottled water during the incident ($r_{33,39}$ = -.18) but the correlations with untreated tap water ($r_{33,38}$ = -.12), boiled water ($r_{33,40}$ = .06), and personally chlorinated water ($r_{33,41}$ = .07) were not.

A more rigorous test of H6a-H6c is to predict the level of consumption of tap water, boiled water, and bottled water during the incident from the three predictors specified in those hypotheses (first warning by authority, number of message elements, risk perception) while holding constant the corresponding levels of consumption before the incident. In addition, it is important to hold constant the amount of bottled water available at the time of the incident because those with more bottled water are likely to consume it rather than boil water.

Table 2 shows that the prediction of boiled water consumption during the incident was statistically significant ($F_{5,\ 103}$ = 2.81, $p < .05$, *Adjusted* R^2 = .08) was significantly predicted by first warning by authority, even after controlling for the other predictor variables. Interestingly, the prediction of bottled water consumption during the incident ($F_{5,\ 103}$ = 5.76, $p < .001$, *Adjusted* R^2 = .18) was also significant; the only significant variable other than pre-incident consumption was the number of message elements and that variable had a negative sign. That is, as the number of message elements decreased, the consumption of bottled water increased. The prediction of tap water consumption during the incident from tap water consumption before the advisory, first warning by authority, number of message elements, risk perception, bottled water availability, and bleach availability was not significant ($F_{6,\ 69}$ = 1.04, *ns*).

In response to RQ1 (How rapidly was news of the incident disseminated to those at risk), Figure 1 shows the cumulative percentage of respondents who had received a warning in one hour intervals from noon on Saturday May 1 to 9:00pm on Sunday May 2. This figure is based upon the 89 respondents who had received a warning during that time period and excludes 15 respondents (14%) who reported receiving a warning before the time the advisory was issued and another three respondents (2.8%) who did not hear about the incident until after the advisory had been rescinded. This distribution of warning times follows the form of a logistic (S-shaped) function in which only about 20 percent of the respondents received a warning within the first five hours after the incident began but another 50 percent were warned within the next three hours. The most distinctive aspect of this distribution of warning times is the very long tail to the distribution. Only 10 percent of the respondents were warned in the next 15 hours between Hour 8 and Hour 24, probably because this time period includes the overnight hours. It took another 12 hours from Hour 23 to Hour 36 to warn the last 20 percent of the respondents who received a warning.

In response to RQ2 (Does warning message content and the number of message elements differ by warning source), Table 1 indicates that there were significant negative correlations between peer warning source and receipt of information about affected areas ($r_{16,19}$ = -.27) and sources of additional information ($r_{16,22}$ = -.27). Conversely, there were significant positive correlations between news media warning source and receipt of information about affected areas ($r_{17,19}$ = .36) and between authority warning source and sources of additional information ($r_{15,22}$ = .21). In addition, there was a significant negative correlations between peer warning source and number of message elements ($r_{16,23}$ = -.32) whereas there was a significant positive correlation between news media warning source and number of message elements ($r_{17,23}$= .31) .

In response to RQ3 (Are time of warning receipt, first warning source, warning content, and additional information channels related to demographic characteristics (age, sex, ethnicity, marital status, household size, education, income, or home ownership?), Table 1 shows that 29 (11%) of the 264 correlations of the eight demographic variables with the other 33 variables were statistically significant at $p < .05$. This is higher than would be expected by chance but not substantially. The correlations mostly involved age (9/29 = 31% of the significant correlations) and bottled water stocks (5/29 = 17% of the significant correlations). Specifically, older residents had higher routine TV access, more bottled water, were less likely to receive a warning from a peer, more likely to receive a warning from the news media, more likely to receive a warning that mentioned a protective action, more likely to obtain additional information from radio or an official flyer, less likely to obtain additional information from the Internet, and less likely to drink bottled water during the incident. Larger households had larger stocks of bottled water on hand, whereas White, and higher education and income respondents had smaller stocks of bottled water.

Discussion

Overall, there was mixed support for this study's hypotheses. Specifically, the data were consistent with H5a, partially consistent with H2, H4, and H6a, but contrary to H1a, H1b, H3, H5b, H5c, H6b, and H6c. Contrary to H1a (Authorities will be the most common first source of warnings about a rapid onset emergency), few of the respondents reported receiving their first information about the incident from authorities and approximately equal numbers of them were warned by peers and the news media. The low level of warning receipt from authorities contrasts with Ram et al. (2007) data, in which more people were warned by authorities (32%) than by peers (23%), although Ram et al. (2007) also showed that more people received their first warning from the news media (41%) than any other source. Indeed, the data from the Boston incident are more like Perry and Greene's (1982) Woodland data (the lower threat area) than the Toutle/Silver Lake (the higher threat area) data. The low level of warning receipt from authorities is surprising because, as noted earlier, accounts of the incident specifically mentioned the use of Reverse 911 and route alerting by officers with bullhorns. One possible explanation for this disparity is that the population at risk was simply too large to warn with the number of available emergency response personnel, although the low level of warning receipt from Reverse 911 is more difficult to explain. Another explanation is that authorities' warnings were rapidly relayed through peer networks, as noted by Lindell and Perry (1987, 2004) in their reviews of the literature on informal warning networks. Ultimately, the news media and peers seem to have been relatively successful in disseminating warnings because Figure 1 shows that 70 percent of the respondents received a warning within eight hours. However, the word "relatively" is an important qualification because it took more than a day (27 hours) for the remaining 30 percent of the risk population to receive a warning.

The lack of support for H1b (Authorities will transmit their warnings earlier than the news media and peers) might mistakenly be interpreted as meaning that people are warned with equal speed by all sources. However, the variances of the warning times differed significantly across warning sources ($\chi^2_3 = 34.4$, $p < .001$), with the standard deviations for the news media ($SD = 10.9$) and peers ($SD = 13.9$) being substantially larger than those for authorities ($SD = 2.7$) and strangers ($SD = .5$). The differences in the variances of the warning times, coupled with differences in the number warned by those sources—the sources with the smallest variances also had the smallest percentages of people warned (13% for authorities and 4% for strangers)—suggests that the estimates of warning times might be somewhat unstable. In turn, this raises the question whether these results will generalize to other water contamination incidents, let alone to other hazards. Unfortunately, none of the published water contamination incidents collected data on warning time distributions. Tornadoes are a logical source of data about the differences in warning times across sources but Lindell's (in press, b) review of this research found that some studies reported the prevalence of different warning sources and others reported warning times but none reported comparisons of different warning sources with respect to their warning times. Thus, further research is needed to determine if warning times are consistent within a particular hazard agent or reflect a more complex interaction between hazard type and characteristics of the community emergency management system—especially its warning systems.

The partial support for H2 (The most common message content will be the nature of the threat, followed, in order, by affected areas, the recommended protective action, safe areas, and sources of additional information) indicates that the nature of the threat is, indeed, the most common element of warning messages (80%). However, it might seem surprising that only 51 percent of the warning messages mentioned the affected areas because this is usually an essential element in conveying a perception of *personal* risk (Lindell & Perry, in press; Mileti & Peek, 2000; Sorensen, 2000). Table 1 indicates that affected areas were mentioned prominently in the news media warnings ($r_{17,19} = .36$), which are broadcast to thousands. By contrast, explicit mention of affected areas is not essential in personal warnings delivered either face-to-face or through telephone messages—whether by authorities ($r_{15,19} = .07$) or peers ($r_{16,19} = -.27$)—because the channel context (a one-to-one relationship between sender and receiver) itself makes clear that the message recipient is at personal risk. Moreover, as expected, 75 percent of the respondents reported that their first warning included a recommended protective action. This is usually an important feature of a warning message because it guides those at risk to engage in appropriate responses. In this case, it is unclear if the instruction to boil water was significant in itself or if it simply underscored the importance of avoiding untreated tap water. As Table 1 Column 1, Var34 indicates, many people already routinely drank bottled water so the boil water advisory might simply have been a cue to increase their consumption of bottled water. Although few warning messages mentioned safe areas (8%) or sources of additional information (16%), there are too few cases to examine differences among the information sources with respect to these message elements. On the whole, the warnings left much to be desired because the respondents reported that their first warnings averaged only 2.30 of the five recommended warning elements.

The lack of support for H3 (Those who were first warned by sources other than authorities will use more channels to obtain additional information) is significant because it suggests that none of the information sources listed was perceived to have a high enough level of expertise, trustworthiness, and protection responsibility to be considered as a completely sufficient information source. This result is a bit surprising because Lindell and Whitney (2000) and Arlikatti, Lindell and Prater (2007) found that multiple stakeholders, including local officials, were high on these dimensions. However, those studies only mentioned local officials in comparison with federal and state officials, as well as other broad categories of stakeholders. It is possible that judgments of abstract categories of stakeholders produces different results from judgments of specific officials during an actual incident. This possibility should be addressed in future research. In any event, there is a significant practical implication to the similarity in the number of additional sources sought, regardless of the initial information source. That is, authorities should expect those at risk to seek information from other sources and, perhaps, to find information that conflicts with that they are disseminating. Thus, authorities should try to incorporate a wide range of stakeholders into their crisis communication plans (Lindell & Perry, 2004). In the case of water contamination incidents, this should include representatives of the water utility, public health, emergency management, local physicians, and elected officials.

The partial support for H4 (The most common channels of additional information will be the TV and radio, followed by telephone, Twitter/other social media, email, official fliers, newspaper articles, and the Internet) indicates that TV continues to be the dominant channel for emergency information for almost two thirds of the respondents. This is consistent with both older (Beatley & Brower, 1986) and more recent (Hayden et al., 2007; Lindell et al., 2005) warning studies. However, it is interesting to find that the Boston residents used the Internet (34%) more than radio (21%) and telephone (17%) because previous studies reported that the Internet was a relatively unimportant source only 5-10 years ago (Hayden et al., 2007; Lindell et al., 2005). Thus, "new media" appear to be increasing in importance, the although importance of these channels should not be overestimated because newspaper articles (17%) and official fliers (8%) were more frequent than email (4%) and Twitter/other social media (3%) as sources of additional information. Nonetheless, the use of email and Twitter/other social media should be addressed in future surveys because they might increase in importance over the next ten years, just as the Internet has seemed to do over the past ten years. That is, these results underscore the importance of maintaining a balance between message-focused research (Starbird et al., 2010; Sutton et al. 2008; Vieweg et al., 2010) and recipient-focused research (Harding & Anadu, 2000; Perry & Greene, 1982; Ram et al., 2007). The two units of measurement and analysis provide very valuable, but distinctly different perspectives on emergency communication. Moreover, people seem to have been relatively satisfied with the information they received from the first few channels they used because, on average, respondents reported receiving information through only 1.7 additional information channels. Future research will need to examine whether increasing access to new media increases the number of information sources sought during emergencies or, more likely, substitutes for existing media. The present data, together with Ramirez, Dimmick, Feaster and Lin's (2008) work on media niche theory, suggest that patterns of media competition and complementarity might be especially complex in emergencies.

The support for H5a (Warning recipients' levels of routine access to TV and radio will be positively correlated with their receipt of additional information through those channels) shows that those who were high in TV access tended to continue to use that channel for receiving additional information. Interestingly, those who were high in routine TV access also tended to use the telephone more and the Internet less. However, those who were high in radio access were more likely to use TV than radio for additional information and those who were high in newspaper access were even more likely to use TV than newspapers for additional information. These results indicate that TV is most people's dominant channel for additional emergency information, but radio (47% among those who have high access to radio) and the Internet (44% among those who have high access to TV) are very important among some population segments. One practical limitation to the dissemination of emergency information via radio is that major metropolitan areas have dozens of radio stations, so distributing timely and accurate information to all of them could present a significant challenge for water utility personnel, emergency managers and public health officials. The significant degree of reliance on the Internet by those who are low in TV access provides an intriguing result that is, unfortunately, quite ambiguous. In retrospect, it seems obvious that researchers need to distinguish online newspaper sites from other types of Internet sites. In this particular instance, the *Boston Globe* website provided a wealth of information about the incident chronology and all five recommended elements of a warning message. Future research on emergency warnings should recognize that newspapers increasingly have online editions that can be updated just as rapidly as TV and radio broadcasts, so the relationship between newspaper print and online editions should be examined carefully.

The lack of support for H5b (Warning recipients' levels of routine access to TV and radio will be positively correlated with their speed of warning receipt) suggests that there is little advantage to being "plugged in"—at least at the levels observed in this study. Specifically, the highest levels of TV, radio, and newspaper access were 11, 11, and 9 hr/day, respectively. These durations correspond to 69, 69, and

56 percent of waking hours, respectively, but are substantially less than half of the entire day—46, 46, and 38 percent, respectively. Consequently, even the most connected individuals are out of contact with the news media for most of the day. An alternative explanation for the lack of a media access effect is that the incident occurred on a weekend, when people's schedules tend to be rather different from their normal weekday patterns of news media access. To address this possibility, additional research is needed to examine media access effects in another social context (e.g., a small town) in which warnings are initiated on a different day of the week (e.g., a weekday).

The lack of support for H5c (Warning recipients' levels of routine access to TV and radio will be negatively correlated with the number of sources from which they seek additional information) seems to indicate that people are satisfied with one or two additional sources, regardless of their usual information channels. Thus, these data suggest that water utility personnel, emergency managers, and public health officials can reach most of the risk area population by disseminating the essential elements of warning messages to local TV stations and ensuring that this information is posted on their own and newspapers' websites.

Even though there was a substantial decrease in consumption of tap water and corresponding increase in the consumption of bottled and boiled water, the results were only partially consistent with H6a (Those who were first warned by authorities will be more likely to adopt the recommended protective action) because those warned by authorities drank boiled water to a greater extent than those warned by the news media or peers, but not strangers. One would expect that the effect of a warning source would be explained by perceptions of that source's perceived expertise and credibility, but it is not obvious that strangers would be perceived to be high on either of these attributes. Perhaps the mere fact of a stranger initiating a social contact conveys a sense that the situation is so extraordinary that the person's message should be accepted and acted upon. On the other hand, there were only four cases of warnings by strangers so further research is needed to confirm this effect.

The lack of support for H6b (Those who received more specific warning messages will be more likely to adopt the recommended protective action) is rather surprising because it is contrary to the findings of research reviews on the effects of warning messages (Lindell & Perry, 2004; Mileti & Peek, 2000; Sorensen, 2000). Since there was such a dramatic reduction in the overall consumption of tap water (from 3.50 to 1.25 on a scale from 1-5), and there would have been no environmental (sights, smells, or tastes) or social (observations of others) cues for water contamination, the only plausible basis for this substantial change in consumption would have to be the content of warnings from social sources. Moreover, since there was no requirement for an immediate protective response—as would be the case in a building fire (e.g., Canter, Breaux & Sime, 1980)—one would expect little impact of deficiencies in the initial warning message if information about any missing warning message elements were readily available from additional sources. Thus, the question becomes how many recommended elements of a warning message had been received, either passively from a warning message or actively through seeking additional information, by the time residents needed to make a decision about whether of not to drink tap water. In other words, the hypothesis might have been better stated as "those whose warning *and information search* yielded more of the recommended elements of a warning message will be more likely to adopt the recommended protective action." Thus, future research should examine the distinction between the content of the initial warning message and the totality of the information available at the time that protective action is initiated.

Perhaps the most interesting finding regarding any of the hypotheses is the limited support for H6c (Those who had greater perceptions of risk will be more likely to adopt the recommended protective action) because risk perception is commonly considered to be a necessary precondition for protective action. Moreover, Griffin et al. (1998) found that worry, which is closely related to some measures of risk perception, was significantly related to continuing attention to mass media information about water contamination. However, there have been other studies that have found that short-term protective action or long-term hazard adjustment adoption was correlated with some aspects of risk perception but not others, as well as some studies in which these actions were completely uncorrelated with risk perception (Lindell, in press, b). One explanation for Table 1's nonsignificant correlations of risk perception (Var33) with tap water consumption (Var38) or boiled water consumption (Var 40) during the incident is based upon Weinstein and Nicolich's (1993) analysis (see also Weinstein, Rothman & Nicolich, 1998). They noted that if a) higher risk perception produces a higher level of protective action and b) a higher level of protective action produces a lower level of risk perception, the sign of the correlation we find will depend on the relative prevalence of respondents who are at each of these two stages in the process of hazard adjustment. Thus, if there are equal numbers of respondents in both stages of protective action, the correlation of risk perception with protective action will be zero. As Weinstein and Nicolich (1993) noted, hazards researchers need to use research designs that are capable of detecting this reciprocal effect over time. Ideally, this would involve the use of longitudinal data on the protective actions. Weinstein and Nicolich (1993) suggested, as an approximation, collection of data in which the respondents report data about two different points in time. However, the present data suggest that the retrospective pre-test (recalling the level of typical use of each water source before the incident) might be problematic because the correlation coefficients for Var34-Var37 (the "pre-test" data) have the same correlations as would be expected for the "post-test" data but are even stronger. One explanation for this pattern in Table 1 is that the respondents might have been affected by hindsight bias (Fishchhoff, 1975); when asked to report separate water consumption patterns before and during the incident, they had difficulty in discriminating between the two.

The problem with this explanation is that it fails to account for the fact there are significant stability coefficients for bottled ($r_{35,39}$ = .44) and boiled ($r_{36,40}$ = .26), but not tap ($r_{34,38}$ = -.01) water consumption. Instead, tap water consumption before the incident is significantly correlated with boiled water consumption during the incident ($r_{34,40}$ = .31). If the respondents were unable to distinguish between tap water consumption patterns before and during the incident, the stability coefficient for tap water consumption ($r_{34,38}$) should have been significant instead of the correlation between tap water consumption before and boiled water consumption during ($r_{34,40}$). The observed pattern of correlations between tap water consumption before and boiled water consumption during suggests that respondents' reports of their water consumption patterns at these two different times are valid, so it is the interpretation of risk perception that might be problematic. Thus, further research is needed to clarify the nature of the relationship between risk perception and *changes* in behavior over time.

The data addressing the research questions were also informative. In response to RQ1 (How rapidly was news of the incident disseminated to those at risk), Figure 1 shows that the cumulative warning time distribution function approximates a logistic function but there is a very long tail to the distribution. As noted earlier, there was little dissemination of the warning during the overnight hours. This is consistent with the data, described earlier, indicating that few of the respondents had TV, radio, or newspaper access during the time from midnight to 6:00am. Moreover, the overnight hours occurred on a Saturday night, which might well have an even lower level of news media access than weekday nights. However, the decreased overnight access to warnings is likely to be offset by reduced water consumption during that time period. As a result, the delay in receiving a warning might not result in an adverse health effect.

The rate of warning dissemination was significantly lower in the Boston water contamination incident than in the Mt. St. Helens eruption. As noted earlier, Perry and Greene (1982) reported that most people received warnings within one hour of the eruption (87% in the area of greatest risk, 59% in the area of lesser risk) and most had been warned within four hours (96% and 97%, respectively). However, the rate of warning dissemination seems to have been significantly higher in the Boston water contamination incident than in the water contamination incident reported in the Angullo et al. (1997) study, where only 10 percent of the respondents were aware of the incident after 10 days, and the Ram et al. (2007) study, where only 39 percent of the respondents were aware of the boil water advisory six weeks after the advisory was issued. The disparity could well be due in part to the difference in TV broadcast capacity between a major metropolitan area (Boston) and the rural areas studied by Angullo et al. (1997) and Ram et al. (2007).

In response to RQ2 (Does warning message content and the number of message elements differ by warning source), Table 1 indicates that there were some significant differences among warning sources in the message content they provided—especially their mention of sources of additional information and identification of affected areas. Nonetheless, all sources were quite *likely* to mention the threat and the recommended protective action and all sources were quite *unlikely* to mention safe areas. Moreover, peers were significantly less likely, and the news media were significantly more likely, to provide information about all aspects of message content except threat. This indicates that peers perform a function that is much like that of a siren—to interrupt normal activities by providing an ambiguous signal that "something is wrong" (Lindell & Perry, 1987). By contrast, the news media provide the detailed information about what is the threat, who is (and is not) at risk, what to do for protection, and where to obtain additional information.

In response to RQ3 (Are time of warning receipt, first warning source, warning content, and additional information channels related to demographic characteristics—age, sex, ethnicity, marital status, household size, education, or income), the number of statistically significant correlations between the demographic variables and the other variables was only slightly greater than chance. Specifically, older residents had higher routine TV access, more bottled water, were less likely to receive a warning from a peer, more likely to receive a warning from the news media, more likely to receive a warning that mentioned a protective action, more likely to obtain additional information from radio or an official flyer, less likely to obtain additional information from the Internet, and less likely to consume bottled water during the incident. The findings that older residents were less likely to receive a warning from a peer and more likely to receive one from the news media is consistent with other studies indicating that the elderly are more isolated than other age groups. Nonetheless, further studies are needed to determine if these correlations can be replicated in other research on water contamination incidents.

All studies have limitations and this one is no exception. First, the sample size was small and limited to a single incident. Thus, research is needed on other incidents to see if the results from the 2010 Boston incident generalize to other situations. In particular, it will be important to determine if there are systematic differences due to time of day/day of week and between time urban and rural areas. This study was also limited in the types of data collected. Thus, future research should ask respondents to list the diseases that could be caused by drinking contaminated water and describe the correct length of time to boil water (cf. Ram et al., 2007). In addition, since it seems likely that the respondents in this study continued to use tap water for some purposes, future research should ask respondents to describe the extent to which they used untreated tap water, boiled water, bottled water, and personally chlorinated water for activities such as drinking water, washing hands, washing vegetables, using ice from automatic ice makers, bathing, showering, washing dishes, washing kitchen/bathroom counters, washing clothes, and watering and eating vegetables from home gardens and local farms (Fox & Lytle, 1996).

Acknowledgment

This work was supported by the National Science Foundation under Grant CMM-0826401. None of the conclusions expressed here necessarily reflects views other than those of the authors.

References

Angulo, F.J., Tippen, S., Sharp, D.J., Payne, B.J., Collier, C., Hill, J.E., Barrett, T.J., Clark, R.M., Geldreich, E.E., Donnell, H.D., Jr. & Swerdlow, D.L. (1997). A community waterborne outbreak of salmonellosis and the effectiveness of a boil water order. *American Journal of Public Health,* 87, 580-584.

Arlikatti, S., Lindell, M.K., & Prater, C.S. (2007). Perceived stakeholder role relationships and adoption of seismic hazard adjustments. *International Journal of Mass Emergencies and Disasters,* 25, 218-256.

Beatley, T. & Brower, D.J. (1986). Public perception of hurricane hazards: Examining the differential effects of Hurricane Diana. *Coastal Zone Management Journal*, 14, 241-269.

Canter, D., Breaux, J. & Sime, J. (1980). Domestic, multiple occupancy and hospital fires. In D. Canter (ed.), *Fires and human behavior* (pp. 117-136). New York: Wiley.

Dillman, D.A. (1978). *Mail and telephone surveys: The total design method.* New York: Wiley.

Drabek, T.E. (1986). *Human system responses to disaster: An inventory of sociological findings*. New York: Springer-Verlag.

Fischhoff, B. (1975). Hindsight ≠ foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance,* 1, 288-299.

Griffin, R.J., Dunwoody, S. & Zabala, F. (1998). Public reliance on risk communication channels in the wake of a cryptosporidium outbreak. *Risk Analysis,* 18, 367-375.

Harding, A. & Anadu, E.C. (2000). Consumer response to public notification. *Journal of the American Water Works Association,* 92, 32-41.

Hayden, M.H., Drobot, S., Radil, S., Benight, C., Gruntfest, E.C. & Barnes, L.R. (2007). Information sources for flash flood warnings in Denver, CO and Austin, TX. *Environmental Hazards,* 7, 211–219.

Huang, S.K., Lindell, M.K., Prater, C.S., Wu, H.C. & Siebeneck, L.K. (2010). *Household Evacuation Decision Making in Response to Hurricane Ike*. College Station TX: Texas A&M University Hazard Reduction & Recovery Center.

Hughes, A.L. & Palen, L. (2009). Twitter adoption and use in mass convergence and emergency events. *Proceedings of the 6th International ISCRAM Conference*. Retrieved 10/05/11 at www.cs.colorado.edu/~palen/Home/Crisis_Informatics.html.

Jakus, P.M., Shaw, W.D., Nguyen, T.N. & Walker, M. (2009). Risk perceptions of arsenic in tap water and consumption of bottled water. *Water Resources Research*, 45, W05405, doi:10.1029/2008WR007427.

Kang, J.E., Lindell, M.K. & Prater, C.S. (2007). Hurricane evacuation expectations and actual behavior in Hurricane Lili. *Journal of Applied Social Psychology, 37*, 881-897.

Lindell, M.K. (in press, a). Response to environmental disasters. In S. Clayton (Ed.) *Handbook of*

environmental and conservation psychology. New York: Oxford University Press.
Lindell, M.K. (in press, b). North American cities at risk: Household responses to environmental hazards. In T. Rossetto, H. Joffe & J. Adams (Eds.). *Cities at Risk: Living with Perils in the 21st Century*. Dordrecht: Springer.
Lindell, M.K., Lu, J-C. & Prater, C.S. (2005). Household decision making and evacuation in response to Hurricane Lili. *Natural Hazards Review*, 6, 171-179.
Lindell, M.K. & Perry, R.W. (1987). Warning mechanisms in emergency response systems. *International Journal of Mass Emergencies and Disasters,* 5*,* 137-153.
Lindell, M.K. & Perry, R.W. (1992). *Behavioral Foundations of Community Emergency Planning.* Washington DC: Hemisphere Press.
Lindell, M.K. & Perry, R.W. (2004). *Communicating Environmental Risk in Multiethnic Communities.* Thousand Oaks CA: Sage.
Lindell, M.K. & Perry, R.W. (in press). The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Analysis.* DOI: 10.1111/j.1539-6924.2011.01647.x.
Lindell, M.K. & Prater, C.S. (2008). *Behavioral Analysis: Texas Hurricane Evacuation Study.* College Station TX: Texas A&M University Hazard Reduction & Recovery Center.
Lindell, M.K. & Whitney, D.J. (2000). Correlates of seismic hazard adjustment adoption. *Risk Analysis,* 20*,* 13-25.
Mileti, D. S., and Peek, L. (2000). The social psychology of public response to warnings of a nuclear power plant accident. *Journal of. Hazardous Materials*, 75, 181–194.
Novak, J.M. & Vidoloff, K.G. (in press). New frames on crisis: Citizen journalism changing the dynamics of crisis communication. *International Journal of Mass Emergencies and Disasters.*
Perry, R.W. & Greene, M.R. (1982). *Citizen Response to Volcanic Eruptions: The Case of Mt. St. Helens.* New York: Irvington Publishers.
Ram, P.K., Blanton, E., Klinghoffer, D., Platek, M., Piper, J., Straif-Bourgeois, S., Bonner, M.R. & Mintz, E.D. (2007). Household water disinfection in hurricane affected communities of Louisiana: Implications for disaster preparedness for the general public. *American Journal of Public Health,* 97, S130-S135.
Ramirez, A., Dimmick, J., Feaster, J. & Lin, S-F. (2008). Revisiting interpersonal media competition: The gratification niches of instant messaging, e-mail, and the telephone. *Communication Research,* 35, 529-547.
Seydlitz, R.J. Spencer, W., Laska, S. & Triche, E. (1991). The effects of newspaper reports on the public's response to a natural hazard event. *International Journal of Mass Emergencies and Disasters,* 9, 5-29.
Seydlitz, R.J. Spencer, W. & Lundskow, G. (1994). Media presentations of a hazard event and the public's response: An empirical examination. *International Journal of Mass Emergencies and Disasters,* 12, 279-301.
Sorensen, J. H. (2000). Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review*, 1, 119–125.
Starbird, K., Palen, L., Hughes, A. & Vieweg, S. (2010). Chatter on the red: What hazards threat reveals about the social life of microblogged information. *Proceedings of the ACM 2010 Conference on Computer Supported Cooperative Work.* Retrieved 10/05/11 at www.cs.colorado.edu/~palen/Home/Crisis_Informatics.html.
Sutton, J., Palen, L. & Shlovski, I. (2008). Back-channels on the front lines: Emerging use of social media

in the 2007 Southern California wildfires. *Proceedings of the 2008 ISCRAM Conference*. Retrieved 10/05/11 at www.iscram.org/index.php?option=content&task=view&id=2236.

Vieweg, S., Hughes, A., Starbird, K. & Palen, L. (2010). Supporting situational awareness during emergencies using microblogged information. *Proceedings of the ACM 2010 Conference on Computer Human Interaction*. Retrieved 10/05/11 at www.cs.colorado.edu/~palen/Home/Crisis_Informatics.html.

Vultee, F. & Vultee, D.M. (in press). What we tweet about when we tweet about disasters: the nature and sources of microblog comments during emergencies. *International Journal of Mass Emergencies and Disasters.*

Weinstein, N.D. & Nicolich, M. (1993). Correct and incorrect interpretations of correlations between risk perceptions and risk behaviors. *Health Psychology*, 12, 235–245.

Weinstein, N.D., Rothmann, A.J. & Nicolich, M. (1998) Using correlations to study relationships between risk perceptions and preventive behavior, *Psychology & Health*, 13, 479-501.

Zhang, Y., Prater, C.S., & Lindell, M.K. (2004). Risk area accuracy and evacuation from Hurricane Bret. *Natural Hazards Review,* 5, 115-120.

Table 1. Means, Standard deviations, and Intercorrelations Among Variables

Var	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	47.88	18.66																		
2	.61	.48	**-.26**																	
3	.75	.42	.08	-.16																
4	.39	.48	.11	-.04	-.11															
5	2.12	1.07	-.20	-.06	**-.28**	**.38**														
6	16.09	2.58	**-.35**	.04	**.38**	.03	-.13													
7	67.06	28.29	**-.21**	-.16	**.31**	**.24**	-.12	**.51**												
8	.47	.48	.10	**-.20**	**.28**	**.27**	.08	**.23**	**.52**											
9	1.74	1.91	**.32**	.08	.07	-.03	-.04	**-.32**	**-.38**	-.10										
10	1.23	2.00	.13	.12	.00	-.09	-.09	.01	.02	**.23**	**.25**									
11	.83	1.24	.04	-.15	.08	.03	.04	-.02	-.08	-.03	**.39**	.04								
12	3.08	2.97	**.21**	-.01	**-.24**	.04	**.25**	**-.30**	**-.32**	-.07	**.32**	.06	**.27**							
13	.20	.07	-.07	-.02	-.05	-.16	-.05	-.03	-.05	-.01	-.01	-.08	.05	.12						
14	9.99	11.63	-.12	.03	-.06	-.05	.00	-.02	-.10	-.15	-.07	-.02	.18	.06	-.07					
15	.13	.33	.00	-.18	.03	**-.20**	-.03	.07	.04	-.11	-.01	-.06	-.08	-.08	**.32**	-.18				
16	.42	.49	**-.26**	.10	-.04	.13	.16	-.09	-.07	-.09	-.06	-.10	.07	.12	-.05	**.23**	**-.34**			
17	.41	.49	**.29**	-.01	.11	.07	-.11	.00	.00	.12	.10	.13	.01	-.03	-.17	-.08	**-.32**	**-.71**		
18	.82	.38	-.04	.07	.08	-.04	.00	**.28**	.16	,04	-.03	.07	.03	-.06	-.15	-.17	.04	-.05	.03	
19	.52	.49	.03	.05	.06	.06	.09	.01	.16	.17	.07	.05	.08	.05	.09	-.05	-.07	**-.27**	**.36**	.09
20	.76	.42	**.24**	.02	.18	.01	.03	-.04	-.15	.18	.12	.08	.12	-.01	.12	**-.24**	.02	-.16	.14	-.03
21	.09	.27	.02	.04	.10	.04	-.11	-.01	.17	.09	-.04	-.04	.07	-.08	-.07	-.11	-.02	-.13	.17	.06
22	.16	.36	.06	-.01	.13	-.14	-.06	.09	-.02	-.07	-.04	.00	-.06	-.03	.16	-.08	**.21**	**-.27**	.17	-.06
23	2.25	1.17	.06	.02	**.19**	-.02	.05	.08	.14	.16	.08	.08	.09	-.07	.11	**-.26**	.07	**-.32**	**.31**	**.38**
24	.17	.37	.04	-.05	.08	-.03	-.01	.06	.07	.05	-.10	-.08	.16	-.13	-.03	-.01	.05	-.08	.04	.15
25	.21	.40	**.21**	.15	.06	.02	-.05	.11	.02	.12	.03	**.47**	.05	.14	-.03	.06	.01	-.06	.05	.04
26	.25	.43	.11	**.21**	-.07	.02	.04	-.04	-.15	-.16	**.22**	-.01	.15	.10	.03	.03	**.22**	-.02	-.09	-.02
27	.66	.47	.00	.15	-.15	.02	-.08	-.05	-.02	.10	**.25**	-.07	-.01	.01	.05	-.06	-.14	-.06	.14	-.06
28	.04	.19	-.06	.02	.11	.05	-.03	.15	.14	-.10	-.13	-.10	-.01	-.13	15	-.01	.07	.03	-.06	.10
29	.03	.16	-.11	.14	**-.31**	-.02	**.24**	-.14	**-.23**	-.11	.08	-.04	.11	**.23**	.06	**.24**	-.07	-.03	.09	.08
30	.07	.26	**.21**	-.10	-.01	.07	.03	-.04	-.03	.09	**.22**	.09	.04	.01	-.14	-.18	**.31**	**-.25**	.05	.04
31	.34	.47	**-.37**	-.18	.16	-.10	.04	.18	.19	-.02	**-.22**	-.06	.14	-.02	.10	.12	-.04	.09	-.05	.13
32	1.71	1.02	-.01	.11	.01	-.01	.05	.10	.04	.03	.15	.12	**.24**	.09	.09	.06	,12	-.12	.06	.14
33	2.61	.93	.08	.19	-.15	-.12	.17	**-.27**	**-.21**	-.03	.12	-.05	-.05	.16	.00	-.06	.13	.05	-.13	-.08
34	3.50	1.59	-.06	-.01	.20	.00	-.16	.15	.09	.13	-.17	-.01	.06	**-.21**	-.03	-.08	.08	.06	-.16	.13
35	2.68	1.38	-.16	.12	-.17	-.08	.06	-.13	.07	.00	.09	-.02	.10	**.29**	-.01	.18	-.07	.09	-.03	.01
36	1.98	1.48	.21	.14	**-.37**	.10	.16	**-.43**	**-.36**	-.16	**.27**	.06	.02	**.27**	.01	-.01	-.04	.03	.03	.05
37	1.22	.80	-.10	.14	**-.22**	-.11	-.07	.02	-.17	-.05	.03	.10	.06	.06	.08	.13	-.11	-.01	-.02	-.02
38	1.25	.74	.02	.16	.01	**-.23**	.09	-.10	-.19	-.19	**.25**	**.43**	.14	.16	-.13	.09	-.13	.08	-.05	-.07
39	3.82	1.33	**-.27**	.15	-.12	-.06	.06	.05	.13	.09	-.12	.12	-.06	.05	-.10	.14	-.11	.16	-.12	-.16
40	3.15	1.67	.01	.15	-.09	-.08	.08	-.07	-.15	.01	.00	-.02	-.16	-.06	.11	-.20	**.22**	-.08	-.18	.09
41	1.10	.53	-.20	.11	-.08	-.07	.16	.04	-.16	-.15	-.11	**.24**	-.08	-.07	-.04	**.26**	-.08	.21	-.15	-.16

Var	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
20	**.27**																					
21	**.23**	.17																				
22	.17	.19	.14																			
23	**.71**	**.61**	**.50**	**.50**																		
24	.08	.08	.04	.00	.15																	
25	.13	.16	.02	.18	.11	.02																
26	-.07	.12	-.10	.11	.00	.08	**.24**															
27	.10	-.18	-.08	-.14	-.05	-.11	-.08	.00														
28	.09	-.01	-.06	.05	.08	.04	.14	-.12	-.07													
29	-.06	-.04	-.05	.08	.01	.07	.05	**.29**	.00	-.03												
30	-.01	.16	-.08	-.03	.05	.16	-.06	-.09	-.10	.13	-.05											
31	.07	.02	**.22**	.02	.17	.00	-.11	-.18	-.14	.07	.12	**-.20**										
32	.15	.12	.00	.08	**.27**	**.44**	**.45**	**.49**	**.30**	**.25**	**.39**	.14	**.27**									
33	.04	.00	.00	.04	-.06	-.10	.03	.08	.14	.05	.05	.08	-.04	.09								
34	.01	.10	.07	-.06	.09	-.04	.08	**-.21**	**-.24**	.07	**-.24**	.20	.05	-.13	**-.25**							
35	**.23**	-.15	.11	-.03	.04	-.05	.06	**.21**	**.24**	-.14	.03	-.19	.09	.18	**.39**	**-.43**						
36	.00	-.11	.01	-.09	-.06	.01	-.07	.18	.01	-.11	.16	-.06	-.13	-.02	**.31**	**-.36**	**.30**					
37	**-.23**	-.01	-.08	-.13	-.18	-.09	.02	.21	.15	-.06	**.35**	-.06	.06	.20	-.03	-.21	.20	.01				
38	-.15	.09	-.12	.08	-.06	-.08	.13	-.10	**-.33**	.08	.05	.19	-.04	-.12	-.12	-.01	-.20	-.02	-.08			
39	-.03	**-.26**	.04	-.11	-.18	**-.22**	.15	-.02	.17	-.09	.02	-.13	.03	.02	**.20**	.08	**.44**	-.12	.11	.06		
40	-.16	.08	-.16	-.01	-.05	.07	-.06	.07	-.15	.06	-.06	.19	-.13	-.04	.06	**.31**	-.16	**.26**	.06	.21	-.13	
41	-.18	.02	-.06	.17	-.09	-.10	-.09	**-.11**	-.11	-.05	-.03	-.05	.15	-.12	.07	-.18	-.10	-.10	.04	**.59**	.15	.17

1=Age, 2=Sex, 3=White ethnicity, 4=Marital status, 5=Household size, 6=Education, 7=Income (x $1000), 8=Home ownership, 9=TV access, 10=Radio access, 11=Newspaper access, 12=Quarts of bottled water, 13=Contaminated water illness experience, 14=Time of warning receipt, 15=First source: authority, 16= First source: peer, 17= First source: news media, 18=Message: threat, 19= Message: Affected areas, 20= Message: Protective action, 21= Message: Safe areas, 22= Message: Additional information, 23= Number of message elements, 24=AddInfo: newspaper, 25= AddInfo: radio, 26= AddInfo: telephone, 27= AddInfo: TV, 28= AddInfo: email, 29= AddInfo: Twitter, 30= AddInfo: official flyer, 31= AddInfo: Internet, 32=Number of additional channels, 33=Risk perception, 34=Tap water before, 35=Bottled water before, 36=Boiled water before, 37=Chlorinated water before, 38=Tap water during, 39=Bottled water during, 40=Boiled water during, 41=Chlorinated water during; N ranges from 72-108 because of missing values, bolded values of r_{ij} are significant at $p \leqq 0.05$.

Table 2. Regression analysis results.

	Boiled water during				Bottled water during			
Variable	b	SE	β	t	b	SE	β	t
First Source: Authority	1.04	.44	.23	2.40*	-.29	.33	-.08	-.86
Number of Elements	-.07	.12	-.06	-.59	-.18	.09	-.17	-1.98*
Risk Perception	-.06	.16	-.04	-.39	.07	.13	.05	.51
Bottles of water	-.05	.05	-.09	-.96	-.04	.04	-.08	-.90
Pre-incident consumption	.32	.13	.28	2.65*	.41	.10	.42	4.36*
Constant	2.86	.54		5.32*	3.11	.59		7.54
Adjusted R^2	.08				.18			
F, df_n, df_d	2.81	5	103		5.76	5	103	

Figure 1. Cumulative Percentage of Respondents Who Received a Warning, by Time of Day