Water Resources Research

RESEARCH ARTICLE

10.1029/2021WR030669

Key Points:

- People perceived different authorities' credibility similarly, underscoring the need for them to provide compatible warning messaging
- Planning with multiple stakeholders and citizens before an incident is important to increase awareness and protective action compliance
- Water safety management must be integrated with a community's comprehensive emergency operations planning to ensure effective response

Correspondence to:

S. Arlikatti,
ahdus29@gmail.com

Citation:

Hyman, A., Arlikatti, S., Huang, S.-K., Lindell, M. K., Mumpower, J., Prater, C. S., & Wu, H.-C. (2022). How do perceptions of risk communicator attributes affect emergency response? An examination of a water contamination emergency in Boston, USA. *Water Resources Research*, *58*, e2021WR030669. https://doi.org/10.1029/2021WR030669

Received 22 JUN 2021
Accepted 18 DEC 2021

Author Contributions:

Conceptualization: Shih-Kai Huang, Michael K. Lindell, Jeryl Mumpower
Data curation: Shih-Kai Huang, Carla S. Prater, Hao-Che Wu
Formal analysis: Sudha Arlikatti, Shih-Kai Huang, Michael K. Lindell
Funding acquisition: Michael K. Lindell, Jeryl Mumpower
Investigation: Carla S. Prater
Methodology: Amy Hyman, Sudha Arlikatti, Michael K. Lindell
Resources: Amy Hyman, Jeryl Mumpower, Carla S. Prater, Hao-Che Wu
Supervision: Carla S. Prater
Validation: Michael K. Lindell

How Do Perceptions of Risk Communicator Attributes Affect Emergency Response? An Examination of a Water Contamination Emergency in Boston, USA

Amy Hyman[1], Sudha Arlikatti[2], Shih-Kai Huang[3], Michael K. Lindell[4], Jeryl Mumpower[5], Carla S. Prater[6], and Hao-Che Wu[7]

[1]Arkansas State University, Jonesboro, AR, USA, [2]Rabdan Academy, Abu Dhab, UAE, [3]Jacksonville State University, Jacksonville, AL, USA, [4]University of Washington, Seattle, WA, USA, [5]Texas A&M University, College Station, TX, USA, [6]Buddhist Global Relief, Seattle, WA, USA, [7]University of North Texas, Denton, TX, USA

Abstract A water main break that contaminated the Boston area's water distribution system prompted a four-day "boil water" order. To understand risk communication during this incident, 600 randomly sampled residents were mailed questionnaires, yielding 110 valid responses. This article describes how perceptions of different social stakeholders influenced whether respondents complied with the Protective Action Recommendation—PAR (i.e., drank boiled water), took alternative protective actions (i.e., drank bottled water or/and self-chlorinated water), or ignored the threat (i.e., continued to drink untreated tap water). Respondents perceived technical authorities (i.e., water utility, public health, and emergency management) to be higher on three social influence attributes (hazard expertize, trustworthiness, and protection responsibility) than public (i.e., news media, elected officials) and private (i.e., self/family, peers, and personal physicians) intermediate sources. Furthermore, respondents were most likely to comply with the PAR if they perceived authorities and public intermediates to be high on all three attributes and if they had larger households and lower income. Contrarily, they were more likely to take alternative actions if they were younger and had higher levels of income, risk perception, and emergency preparedness. These results underscore the need for technical authorities to develop credibility with their potential audiences before a crisis occurs.

1. Introduction

1.1. Safe Drinking Water in the United States of America (USA)

The Safe Drinking Water Act (SDWA) was passed by the US Congress in 1974, with amendments added in 1986 and 1996, to protect drinking water quality. Under the SDWA, the Environmental Protection Agency (EPA, 2021a) sets the standards for drinking water quality and monitors states, local authorities, and water suppliers who must comply with those standards (CDC, 2020). Further, the National Primary Drinking Water Regulations (NPDWR) (EPA, 2021b) protect public health by limiting contaminant levels in the public water system, while the National Secondary Drinking Water Regulations (NPDWR) (EPA, 2021c) are suggested guidelines to help public water systems personnel manage their drinking water quality for issues (other than health) related to taste, color, smell, clarity, etc. Despite these stringent regulatory standards and monitoring protocols, everyday people make conscious decisions whether to consume tap water directly, personally filter it before consumption, or drink bottled water.

The contributing factors that affect these decisions include reliability and quality of drinking water provided by public and private drinking water systems (Tanellari et al., 2015), consumer attitudes and perceptions toward taste, smell, color, cost, and convenience (Triplett et al., 2019), differences in concerns about water-related issues that are related to demographic characteristics (e.g., being single and childless, or old and poor), and social position (Haeffner et al., 2018). Although safety may be a rare concern for some (Merkel et al., 2012), for others health threats from water contaminants may influence their preference for bottled water despite its extreme cost disadvantage—nearly "240 times to 10,000 times more expensive than tap water" (Jakus et al., 2009, pg. 1). Specifically, the safety of tap water can be compromised by pipeline failure, which is a nontrivial concern given that drinking water utilities need $472.6 billion in infrastructure investments over the next 20 yr to maintain the nation's thousands of miles of pipelines (EPA, 2018b).

Writing – original draft: Amy Hyman, Sudha Arlikatti, Shih-Kai Huang, Michael K. Lindell
Writing – review & editing: Amy Hyman, Sudha Arlikatti

1.2. Water Distribution System (WDS) Contamination

Typically, when a WDS contamination is detected in a US community, water utility operators, local and state health authorities, emergency managers, and elected officials follow standard operating procedures to quickly assess the risk. The US EPA Response Guidelines and a Response Protocol Toolbox assists them in planning for drinking water contamination threats and responding to incidents (USA Environmental Protection Agency, 2003, 2004, 2018a, 2018b). For example, the Toolbox's Threat Evaluation Template is used to classify a threat as Possible, Credible, or Confirmatory by scanning the information source, evaluating the site, identifying the type of contaminant, and sending and receiving notifications on key response actions to provide alternative sources of water and start remedial procedures. Depending on the source from which the threat information is received (e.g., security breach/witness account/phone threat/written threat/unusual water quality/consumer complaints/public health notifications or other), the site or location of contamination, and the type of facility (e.g., source of water/treatment plant/pump station/ground storage tank/elevated storage tank/finished water reservoir/distribution main/hydrant/service connection), the contaminant is identified as known (chemical/biological/radiological), suspected, or unknown and the public is notified about actions to take. Response to a confirmed incident may require agencies to engage in a combination of actions including sample analysis, site characterization, isolation/containment, full Emergency Operations Center activation, public notification, provision of an alternate water supply, and initiation of remediation and recovery actions.

1.3. The 2010 Boston Water Contamination Emergency

Around 10:00 a.m. on May 1, 2010, a major water main break in Weston, Massachusetts produced contamination of the regional WDS. This event prompted Governor Deval Patrick and Boston Mayor Thomas Menino to declare a state of emergency, which triggered a sequence of notifications to affected community residents (Henry, 2010; Lindsay, 2010). First, the Massachusetts Water Resources Authority, together with the state's Emergency Management Agency and Department of Public Health, issued a warning addressing the causes of the emergency and advising residents of the affected area to boil water before drinking. The warning message also carried information on what to do for other water uses including cooking, washing fruits and vegetables, mixing infant formula, making ice, brushing teeth, washing hands, washing dishes, and bathing and showering. Additionally, residents were advised to consult their personal physicians, call Mass 211 for information and referral to critical health and human services support, or call the Commonwealth of Massachusetts Executive Office of Health and Human Services Department of Public Health for extended medical-related assistance (Executive Office of Health and Human Services [EOHHS], 2010).

Government entities distributed warning messages through multiple channels. Public safety officials used a Reverse 911 public alert system, sending recorded voice messages to landline telephones and registered cellphones within the geographical area, likely to be affected by the contaminated water. In addition, loudspeakers, fliers, and regular broadcasts by local news media transmitted repeated warnings so residents would hear and comply with the protective action recommendation (PAR) to boil water (Henry, 2010; Levenson & Daley, 2010; Lindsay, 2010). Some private entities such as Popular Mechanics, in an online newsletter, suggested self-chlorinating tap water instead of boiling it or using bottled water (Galvin, 2010). On the other hand, erroneous recommendations such as drinking filtered water, suggested by peer-to-peer communications, were also detected (Contreras, 2010). The Massachusetts Water Resources Authority repaired the pipeline by the evening of Sunday, May 2, and lifted the boil water order at 6:45 a.m. on Tuesday, May 4 after over 800 water quality samples from nearly 400 locations had been tested for purity and quality (Daley & Gil, 2010; LeBlanc, 2010).

1.4. Justification for This Study

In recent years, traditional hydrology studies have been criticized for their overly narrow focus on natural processes such as water quality, and failure to integrate social, cultural, political and economic values and processes, that shape water governance issues (Sivapalan et al., 2014). Hence, new socio-hydrological frameworks like the integrated Structure, Actors, and Water framework (Haeffner et al., 2018, pg. 665) have been developed and used to study perceptions of city leaders and the public at large (from Utah constituencies) on key water issues. Findings suggest these two groups differed in their views dramatically. While constituents were concerned about future water supply and price, leaders were concerned with deteriorating water infrastructure. They suggested that these differences in the perceptions, information, and experiences of individuals and organizational actors need to be understood in light of how they create impediments to a more sustainable water management system (Pg. 665).

In their research on the relationship between consumers' risk perceptions of arsenic exposure in tap water and the purchase of bottled water, Jakus et al., (2009) found that people systematically underestimated the "true risk" which was based on scientific estimates as a benchmark. They concluded that their population was not purchasing enough bottled water and suggested that this is a key finding. Policy makers need to decide if "consumer choice based on existing perceived risks is acceptable from a public perspective or if it is in the public interest to provide more information on the risks of tap water consumption and the choices available to customers" (pg.7). Their findings also revealed that more easily recognizable water quality characteristics like taste, smell had greater influence than the perceived risk in causing people to buy bottled water, However, all else being equal, those with greater risk perceptions were willing to spend more money on bottled water than those with lower perceived risk.

Price et al. (2015) tested attributes of water message structure and content (i.e., for potable recycled water) and found that complex messages and those that communicated about risk were most effective in positively affecting risk perceptions but not necessarily greater support for recycled water use. Risk information only influenced the risk perception of people residing in the area where the issue was more relevant. They highlighted the importance of understanding people's motivations to process information and suggested that repeated exposure to specific types of information would be useful. However, they called for finding ways "to inoculate people against counter claims of opposition groups" (pg. 2185).

In the past, the ultimate receivers of threat information (i.e., those in the risk area) were limited to one-to-one communications such as telephone and face-to-face communication to engage in the collective sensemaking process known as milling (Wood et al., 2018). Now, when people receive information from various public and private sector entities, they have access to social media such as Twitter that allow a single person to broadcast simultaneously to many others. This makes it possible for uninformed or malicious actors to have a much greater influence on the responses of the risk area population (Gao et al., 2020; National Research Council, 1989). Hence, scholars call for distinguishing the roles and functions between public and private intermediaries in the risk communication process (Kousky & Kunreuther, 2017; Steinberg et al., 2016).

In summary, the current study of water contamination incidents in Boston is unique as it leverages theories and findings from disaster sciences, specifically, the social-psychological theory of Protective Action Decision Model (PADM—Lindell, 2018; Lindell & Perry, 2004, 2012) to understand how individuals' perceptions of messages from community stakeholders (public and private influencers) affect their risk perceptions and thereby their decisions to comply with official PARs, or take an alternative protective actions, or take no action at all. The findings can guide policies to mitigate conflicts in messaging and reduce risks from future water contamination incidents, as well as to understand what water utility and emergency management officials can do differently to increase compliance with official PARs. It will also illustrate how individuals' demographic characteristics influence their preferences for bottled water over boiled water (the PAR) and why policy makers and urban hydrologists must consider a socio-hydrological perspective (Sivapalan et al., 2012) while making investments in water infrastructure and innovative designs for ensuring water quantity and quality, respectively.

Against this background, this article examines what attributes of information sources influenced the actions that residents took after receiving advisories regarding the water contamination and PAR. Specifically, it identifies eight types of stakeholders who served as risk communicators and classifies them into three categories, namely authorities (water utility, public health, emergency management, elected officials), public intermediate sources (news media), and private intermediate sources (risk area residents and their families, peers, and personal physicians). It also examines how these stakeholders' three key attributes—hazard expertize, trustworthiness, and protection responsibility—affected people's decisions to comply with the PAR (i.e., boil water), take alternative protective actions (i.e., drink bottled or self-chlorinated water), or ignore the threat. Additionally, the relationships of risk perception, preparedness, and demographic characteristics are explored as other predictors of households' responses to the water contamination threat.

The remainder of this article is divided into five sections. Section 2 discusses the study's theoretical foundation—the Protective Action Decision Model (PADM) and Communication Network Model (CNM)—and reviews research on the influence of community stakeholders' attributes on protective actions. The section concludes with a list of research objectives along with research hypotheses and research questions that guide this study. Section 3

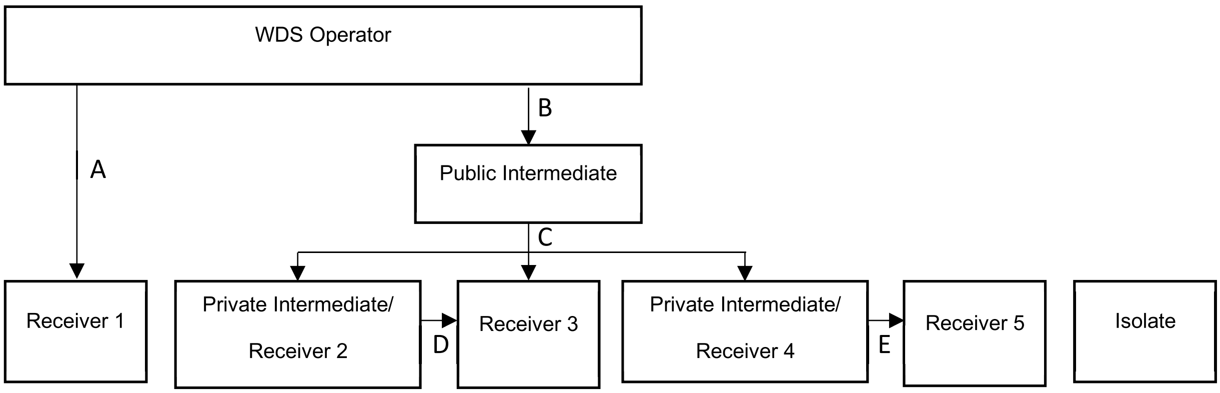


Figure 1. Communication Network Model (adapted from Lindell & Perry, 2004).

provides a description of the questionnaire items, sampling procedure, and data collection procedure. Section 4 presents the survey results and Section 5 discusses their theoretical and practical implications, as well as the study's limitations. Finally, Section 6 presents the study's conclusions.

2. Literature Review

2.1. Theories Framing Risk Communication

The Classical Persuasion Model proposed by Lasswell (1948) identifies five principal components of risk communication, namely, who (source), says what (message), in what medium (channel), to whom (receiver), and with what effect (effect). Further, the Shannon-Weaver model (Shannon & Weaver, 1949) focused attention on the linear relationship between message framing and transmission, from an information source to a receiver through a transmitter or a channel (Al-Fedaghi, 2012). Riley and Riley (1965) modified the Shannon-Weaver model by positing that mass communication occurs within a social system, between communicators and receivers, both of which are part of larger primary groups and are influenced by those groups. Thus, they viewed communication as influenced by multiple entities, with communication flowing between and within those social groups. Consistent with this framework, Katz and Lazarsfeld (1955) proposed the Two-Step Flow of Communication Model that highlights the importance of intermediate sources such as opinion leaders in disseminating a message from a communicator to receivers.

Lindell and Perry (2004) integrated these perspectives into the PADM, which describes the way that people process threat information and choose disaster responses. One important aspect of the PADM involves people's perceptions of information sources in terms of hazard expertize, trustworthiness in providing accurate information, and responsibility for protecting those at risk. In addition, as indicated in Figure 1, the CNM posits that an original source such as a WDS operator, can transmit messages directly to those at risk (Channel A) and to intermediate sources such as the news media (Channel B) who relay the messages to those at risk (Channel C) using a one-to-many broadcast process. In addition, there is a one-to-one contagion process in which message recipients exchange information with each other (Channels D and E), leaving very few isolates who fail to receive a warning (Lindell, 2018; Lindell et al., 2007; Rogers & Sorensen, 1988).

The message diffusion process relies on social connections in which ultimate receivers—including oneself and one's family, friends, relatives, neighbors, and coworkers—communicate information to each other about hazards and protective actions. Despite extensive research on the role of informal warning sources (e.g., Lindell et al., 2019), few studies based on the PADM and CNM have addressed the characteristics of these sources that influence people's warning responses.

2.2. Influence of Stakeholder Attributes

The impacts of communicator attributes in persuasion have a long history of study (Gass & Seiter, 2014) and, specifically, have been the subject of research on the effects of risk communicators' attributes on PAR compliance (Heath et al., 2018; Martin-Shields, 2019; Wang et al., 2018). Consistent with Petty and Cacioppo's (1986)

Elaboration Likelihood Model, scholars have found that communicator attributes can have direct or indirect effects on an individual's decision to take protective actions. A direct effect occurs if perceptions of the communicator's attributes directly influence the adoption of protective actions, whereas an indirect effect occurs if perceptions of the communicator's attributes alter how people interpret the communicator's message (i.e., perceive the risk), which in turn affects their decision to take protective actions (Arlikatti et al., 2007, 2014; Gladwin et al., 2001). This causal relationship may vary depending on the hazard, the information sources, and the situation. During high-stress situations, for example, people may rely on a heuristic process and focus more on an information source's characteristics than the message content itself (Kahlor et al., 2003; Reynolds, 2011).

Following French and Raven (1959), perceptions of stakeholders' expertize can be understood as beliefs about their possession of essential information about a situation (e.g., the concentration of a contaminant in parts per million) and about cause-and-effect relationships relevant to that situation (e.g., the probability of adverse health effects, given that contaminant concentration). People generally attribute higher levels of expertize to authorities and news media due to the belief that these stakeholders have relevant educational credentials and experience (Arlikatti et al., 2007; Lindell & Perry, 1992; Murphy et al., 2018; Perry & Lindell, 1990; Sager, 1994; Taibah, et al., 2017). Other studies have found that optimistic bias causes people to rate themselves as having higher expertize than their peers (Hatfield & Job, 2001; Klar & Ayal, 2004; Weinstein, 1989). Nevertheless, people tend to rate their own expertize somewhat lower than authorities and the news media (Arlikatti et al., 2007).

Perceptions of trustworthiness, a source's willingness to provide accurate information, are built on personal admiration (Eagly & Chaiken, 1998; French & Raven, 1959; Raven, 2008), as well as familiarity (Perry & Lindell, 1990), so, according to the *Onion Theory* (see, for example, Wu et al., 2020), people tend to trust those who are closer to them (Godschalk et al., 1994). Among all stakeholders, peers often receive the highest ratings of trustworthiness due to shared life experiences (Arlikatti et al., 2007; McGuire, 1985; Quarantelli, 1960; Taibah et al., 2017). Even though people rate their peers as less knowledgeable than themselves about a hazard, their high ratings of trustworthiness lead people consult those peers to confirm a warning (Wood et al., 2018) and sometimes heed peers' recommendations rather than those of authorities (Arlikatti et al., 2014).

Ratings of expertize and trustworthiness have been found to be strongly related (Arlikatti et al., 2007). Indeed, some studies have noted that a stakeholder's perceived expertize and trustworthiness combine to produce an overall perception of credibility (McCallum et al., 1991; Wei et al., 2018). Stakeholders perceived as credible can influence information acceptance and shape people's protective action decisions (Gauntlett et al., 2019; Lindell & Perry, 2012; Mileti & Peek, 2000). Conversely, studies highlighting the failed communication during Hurricane Katrina in 2005 found that messages received from non-credible sources were ineffective (Cole & Fellows, 2008). Hence it is important for risk communicators to develop credibility with their audiences during the continuing hazard (Lindell & Perry, 2004) or pre-crisis (Seeger, 2006) phase. Understanding how individuals evaluate stakeholder credibility can also assist risk communicators in tailoring messages and improving their perceived credibility among all population segments (Taibah & Arlikatti, 2015; Taibah et al., 2017).

Responsibility is a consequence of the rights and duties of a position within a social network (Eagly & Chaiken, 1998; French & Raven, 1959; Raven, 2008). Some studies have found that people believe in personal responsibility when it comes to protective actions (Garcia, 1989; Grothmann & Reusswig, 2006; Mulilis & Duval, 1997). However, other studies have found that people often believe authorities are responsible for protecting the public during an emergency (Arlikatti, et al., 2007; Giroux et al., 2009; Terpstra & Gutteling, 2008) because they are expected to plan and prepare for such events (Basolo et al., 2009). An explanation for the apparent inconsistency in these results is that people are more likely to attribute protection responsibility to government if they do not know any protective actions to take, if they consider the available protective actions to be insufficiently effective, or if those protective actions require resources that they lack (Lindell & Perry, 2000a, 2000b). Ultimately, people who believe preparedness is an individual's responsibility are more likely to take protective actions (Garcia, 1989; Lindell & Whitney, 2000).

2.3. Influence of Receiver Attributes

Some scholars have found that consumers' demographic characteristics can be linked to the purchase of bottled water (Merkle et al., 2012; Triplett et al., 2019). Affluent households with young children, and greater levels of education, those on a public water system, and those having concerns related to taste, smell and clarity were more likely to purchase bottled water while older adults were less likely than younger to consume bottled water (Jakus et al., 2009). In further trying to understand the willingness to pay for improvements to water systems, Genius and Tsagrakis (2006), found that both experiences with water shortages and drinking water from sources other than the tap were important determinants of Greek city residents' willingness to pay for a fully reliable water supply. Those not affected by water scarcity and already drinking tap water had a smaller willingness to pay, while those relying on bottled water had a higher willingness to pay. Willingness to pay increased with age up to a certain point (50 yr) and decreased, possibly because of the level of earnings going down and no young children in the household (pg. 8).

However, Tanellari et al. (2015) found that Washington DC suburban consumers' willingness to pay for water utility improvement programs was negatively affected by the cost of the proposed improvement. When asked which of three programs—water quality improvement, pinhole leak damage insurance, or public infrastructure upgrade, 44% respondents were not willing to pay into any program, but the highest support was for public infrastructure improvements.

2.4. Research Objectives, Questions, and Hypotheses

Objective 1: To examine how respondents rate each stakeholder's social influence in terms of expertize, trustworthiness, and protection responsibility.

1. RH1: There will be significant differences among the mean ratings of the stakeholders on the three social influence attributes (expertize, trustworthiness, and protection responsibility)
2. RH2: Stakeholders' attribute profiles on expertize and trustworthiness will be much more similar to each other than either one is to protection responsibility
3. RH3: Mean ratings and interrater agreement on hazard expertize will be highest for authorities (i.e., water utility, public health, emergency management, and elected officials), next highest for public intermediate sources (i.e., news media), and lowest for private intermediate sources (i.e., self/family, personal physician, and peers)
4. RH4: Mean ratings and interrater agreement on trustworthiness will be highest for private intermediate sources (i.e., family, personal physicians, and peers), next highest for public intermediate sources (i.e., news media), and lowest for authorities (i.e., water utility, public health, emergency management, and elected officials)
5. RH5: Mean ratings and interrater agreement on protection responsibility will be highest for self/family, next highest for authorities (i.e., water utility, public health, emergency management, and elected officials), and lowest for public (i.e., news media) and other private (i.e., peers and personal physicians) intermediate sources

Objective 2: To explore the mechanism of how stakeholders' social influence affects respondents' adoption of protective actions.

1. RH6: Stakeholders' overall social influence (the average of all three stakeholder attributes) will have positive correlations with risk perception and PAR compliance (i.e., drinking boiled water)

Finally, responses to three broader questions are sought. Namely,

1. RQ1: Do stakeholder perceptions have a direct effect on response actions or an indirect effect via their effects on risk perception?
2. RQ2: Do demographic characteristics, preparedness, experience, or risk perceptions affect the adoption of protective actions to water contamination as strongly as stakeholder perceptions?
3. RQ3: Are there differences in the predictors of the PAR compliance, the alternative protective actions, and ignoring the threat?

3. Methods

3.1. Data Collection

The data reported here is derived from a survey conducted by the Texas A&M University Hazard Reduction & Recovery Center (HRRC) six months after the May 1–4, 2010, Boston water contamination incident. The team randomly selected 600 households from the affected communities and, following Dillman's (1999) survey procedure, mailed the first wave of survey packets containing a cover letter, an informed consent form, a questionnaire, and a stamped return envelope to the selected households. This was followed by a reminder postcard and two more waves of survey packets at two-week intervals to those who had not returned a completed questionnaire. Of the 600 selected addresses, 102 were undeliverable. Of the remaining 498, 117 respondents returned questionnaires. Of these questionnaires, seven had over 25% missing items and were excluded from the data set. This yielded a final response rate of 22.4%, which is lower than contemporaneous HRRC surveys using the same procedure—39.9% from the Hurricane Katrina evacuation survey and 41.8% from the Hurricane Rita evacuation survey (Huang et al., 2017), 42.8% from the Christchurch earthquake response survey, and 55.3% from the Tōhoku earthquake response survey (Lindell et al., 2016).

The lower response rate might be the result of these other disasters causing substantial deaths, injuries, and economic losses, whereas the water contamination incident produced only minor disruption and, quite possibly, limited interest to most residents. By comparison, general population survey response rates currently average less than 10% (Leeper, 2019) and some hazards surveys have response rates this low (8% in Jiang et al., 2021) or lower (2% in Martin et al., 2020), so this water contamination survey's response rate is substantially above average. Of the valid responses, 46 respondents were from Boston, 23 from Brookline, and 41 from Somerville. Moreover, 61% of the respondents were female, 75% Caucasian, 39% married, and 48% were homeowners. The respondents had an average age of 48 yr, 16 yr of education, an annual average household income of US $67,057, and two members per household. Despite an over-representation of females, the sample was generally consistent with the 2000 Boston census data.

3.2. Questionnaire

The survey comprised multiple measures used to examine residents' PAR compliance, some of which were reported by Lindell, Huang, and Prater (2017) and Lindell, Mumpower, et al. (2017). This article focuses on portions of the questionnaire not previously analyzed in those studies. First, water contamination response was measured by three variables—*PAR compliance*, *alternative protective actions,* and *ignoring threat*—measured on a 1–5 scale (from *Not at all* = 1 to *Very great extent* = 5) of the extent to which they used boiled water, bottled or self-chlorinated water, and untreated tap water as their drinking water source, respectively. Each respondent's *risk perception* was measured by averaging the ratings of the likelihood of getting sick from 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) with the same 5-category extent scale, which yielded a measure with high internal consistency reliability (*Cronbach's* $\alpha = 0.83$). Measures of the eight stakeholder types on the three stakeholder attributes comprised ratings of WDS personnel, public health personnel, emergency management personnel, and elected officials; news media, personal physician; and peers, and self/family on hazard expertize, trustworthiness (only family was the referent on this attribute), and responsibility with the 5-category extent scale. This generated 24 *perceived stakeholder attribute* items. An overall *social influence* score was created for each of the three stakeholders by averaging the three attribute ratings for each stakeholder.

To measure households' *preparedness* levels, the reported number of stored bottles of water in a household was coded as *No stored bottled water* = 0 and *Yes stored bottled water* = 1 and having chlorine bleach at home was measured as a dichotomy (*No* = 0 and *Yes* = 1). An overall preparedness score was computed from the average of these two items. In addition, prior *experience* with falling ill from water contamination was measured as a dichotomy (*No* = 0 and *Yes* = 1). Finally, demographic variables included *age* (ratio scale), *gender* (*Male* = 0 and *Female* = 1), *ethnicity* (*Minority* = 0 and *White* = 1), *marital status* (*Unmarried* = 0 and *Married* = 1), *household size* (ratio scale), *education* years (*Some high school* = 9, High school/GED = 12, *Some college/vocational school* = 14, *College graduate* = 16, *Graduate school* = 18), *income* (*Less than $25,000* = 25,000, *$25,000–49,999* = 37,500, *$50,000–74,999* = 62,500, *$75,000–99,999* = 87,500, *More than $100,000* = 100,000), and *homeownershi*p (*Rent* = 0 and *Own* = 1).

Missing data analysis revealed that the highest rate was 28.2% and a test of missing completely at random revealed a non-significant result ($\chi^2_{1,434} = 1{,}444.9$, $p > 0.05$), indicating that the missing data occurred completely at random rather than a result of any specific variables. Hence, missing values were replaced by the Expectation-Maximization algorithm in SPSS 17.0.

3.3. Tests for Pseudo-Attitudes

Quantitative researchers face the problem of pseudo-attitudes when asking research participants to rate unfamiliar objects or concepts (Converse, 1970; Schuman & Kalton, 1985). Specifically, participants who want to avoid appearing ignorant might provide responses that are created in reaction to the questionnaire rather than ones that tap stable attitudes. One indication of pseudo-attitudes is that respondents check the scale midpoint, rather than leaving the answer blank, to indicate an opinion on topics to which they have given little or no thought. This leads to *central tendency bias* if this is the case for many respondents (Cascio & Aguinis, 2004). To test whether responses are due to central tendency bias, variable means can be tested to determine if they differ significantly from the scale midpoint (Cascio & Aguinis, 2004). A series of t tests revealed that, of the three behavioral and 25 psychological variables, 25% (7/28) of them have ratings that are not significantly different from the mid-point (3) of the 1–5 rating scale. However, a mean rating $M = 3.0$ could be the result of response distributions as dissimilar as, at one extreme, all respondents providing a rating of "3" and, at the other extreme, half providing a rating of "1" and the other half providing a rating of "5" (Lindell & Brandt, 2000). Since all respondents providing a rating of "3" is what would be expected with central tendency bias, it is also important to determine if there is a high level of interrater agreement, which can be measured by r_{WG}—an index that ranges $-1.0 \leq r_{WG} \leq +1.0$ and has a value of zero when the ratings have a uniform random distribution (LeBreton & Senter, 2008). None of the seven items whose means were nonsignificantly different from the midpoint had interrater agreement higher than $r_{WG} = 0.70$, a reasonable threshold for concluding the presence of pervasive central tendency bias. Hence, it is reasonable to conclude that the data are not significantly affected by pseudo-attitudes.

3.4. Analyses

The first objective (Examine how respondents would rate each stakeholder's attributes of expertize, trustworthiness, and protection responsibility) was examined using descriptive statistics and multivariate analysis of variance (MANOVA). Interrater agreement was tested using the Dunlap et al. (2003) table of statistical significance for r_{WG}. Differences among the three attribute profiles were calculated by computing the root-mean-squared (RMS) differences between each pair of attributes over all stakeholders. The second objective (Explore the mechanism of how stakeholders' social influence affects people's adoption of protective actions) involving RH6 and RQ1-RQ3 was tested using correlation and regression analysis.

In the analyses, that follow, there are $(8 \times 7)/2 = 28$ paired t tests for comparisons of the eight stakeholders on each of the three attributes for a total of 84 statistical tests. In addition, there are 199 tests on correlation and regression coefficients, so the total number of 283 statistical tests makes experiment-wise error rate a concern (Ott & Longnecker, 2015). Specifically, the expected number of false positive tests is $\text{FP} = \alpha \times n$, where FP is the number of false positive test results, α is the Type I error rate, and n is the number of statistical tests. If $\alpha = 0.05$ and $n = 283$, then $FP = 14$. Benjamini and Hochberg (1995), see, for a more recent discussion, Glickman et al., 2014 advocated that researchers', (a) specify a false discovery rate (d) for the entire study, (b) sort the p_i significance values for the individual tests in ascending order $1 \leq i \leq n$, and 3 classify each $p_i \leq d \times i/n$ as statistically significant. In the present study, the exact critical value of $p_i = 0.019$, which we rounded down to $p = 0.01$ for that only p-values less than this are classified as statistically significant.

4. Results

4.1. Profile and Cluster Analysis

The hypothesized classification of stakeholders (i.e., risk communicators) is mostly, but not completely, supported by the data. Specifically, the profiles in Figure 2 suggest that the hypothesized grouping of stakeholders into authorities, public intermediate sources, and private intermediate sources is generally supported, but elected officials tend to be rated more like news media rather than other authorities, whereas personal physicians tended to be rated differently from other private intermediate sources.

To further examine the hypothesized stakeholder groups, the profiles of the eight stakeholders were submitted to a hierarchical cluster analysis using squared Euclidean distances as the proximity measure and Ward's method as the clustering method. This analysis produced the dendrogram in Figure 3 that reveals three primary clusters, the first of which is defined by three of the authorities—water utility, public health, and emergency management.

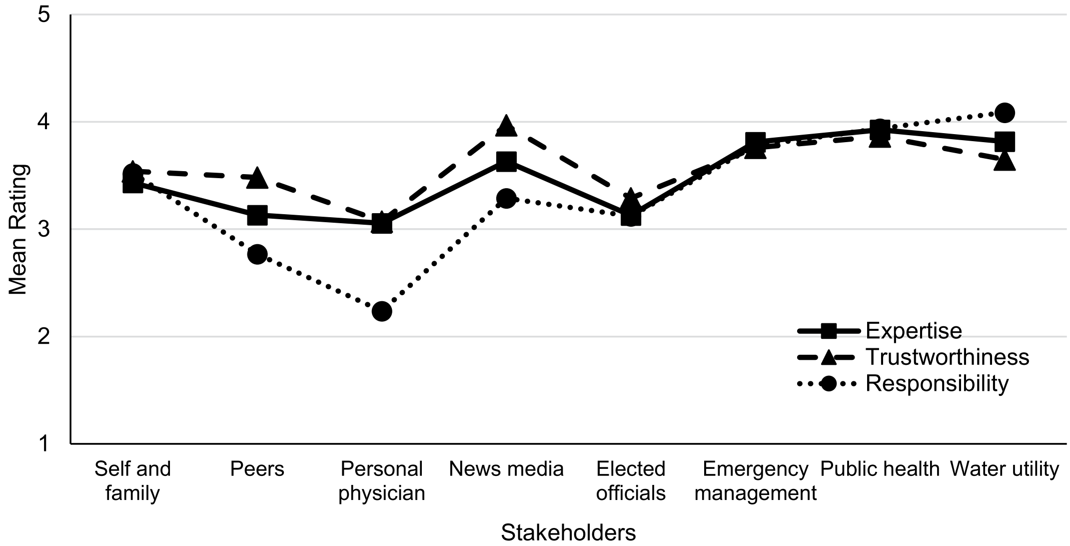


Figure 2. Mean ratings of social influence by stakeholder attributes—expertize, trustworthiness, and protection responsibility.

The second primary cluster is defined by peers and self/family, whereas the third primary cluster is defined by elected officials and news media. The second and third clusters merged with each other and then, much later, with personal physicians, after which all clusters merged. Based on these results, the categorization of stakeholders was revised to technical authorities (i.e., combining water utility, public health, and emergency management), public intermediate sources (i.e., combining elected officials and news media), and private intermediate sources (i.e., combining self/family, peers, and personal physicians).

4.2. Tests of RH1-RH5: Perceived Stakeholders' Social Influence Attributes

RH1 (*There will be significant differences among the mean ratings of the stakeholders on the three social influence attributes—expertize, trustworthiness, and protection responsibility*) is supported by a MANOVA that reveals significant effects for stakeholder (Wilks $\Lambda = 0.32$, $F_{7,103} = 30.75$, $p < 0.001$), and interaction (Wilks $\Lambda = 0.50$, $F_{14,96} = 6.88$, $p < 0.001$), but not attributes (Wilks $\Lambda = 0.94$, $F_{2,108} = 3.18$, *ns*). As indicated in Figure 2, the significant stakeholder effect is due to differences between the highest and lowest-rated stakeholders on each of the three attributes. These were largest for protection responsibility ($M_1 - M_2 = 4.15–2.13 = 2.02$, which is 50.5% of the 1–5 rating scale) followed by trustworthiness ($M_1 - M_2 = 3.95–3.08 = 0.87$—21.8% of the rating scale), and expertize ($M_1 - M_2 = 3.87–3.03 = 0.84$—21.0% of the rating scale). The interaction is due to differences among stakeholders in the differences among their ratings across attributes. Specifically, peers,

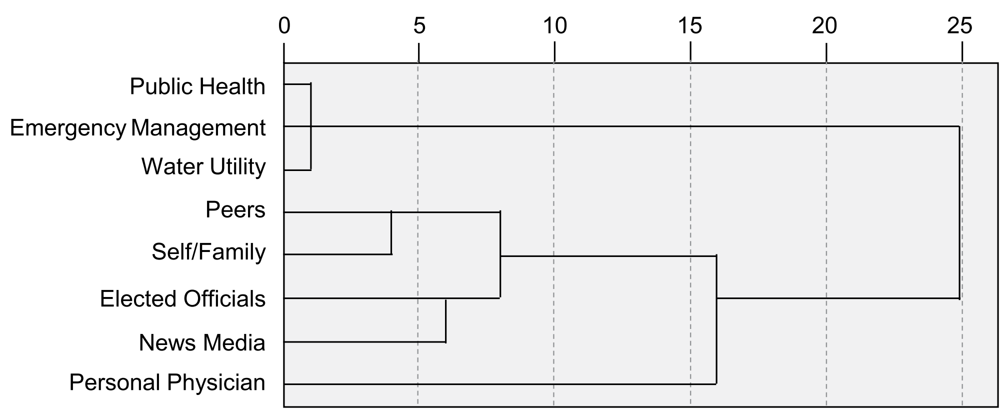


Figure 3. Cluster analysis of stakeholder profiles.

Table 1
Mean Ratings of Stakeholder Attributes

	Sf/Fam	Peers	PerPhy	NwMed	ElOff	EmMgt	PubHlth	WatUtil
Expertize	3.40[b]	3.05[c]	3.03[c]	3.58[b]	3.15[c]	3.73[ab]	3.87[a]	3.77[a]
Trustworthiness	3.61[b]	3.48[bc]	3.08[d]	3.95[a]	3.33[c]	3.76[ab]	3.83[ab]	3.59[b]
Protection responsibility	3.45[cd]	2.69[f]	2.13[g]	3.29[de]	3.05[e]	3.75[bc]	3.90[ab]	4.15[a]

Note. The superscript alphabet labels indicate means with common superscripts are nonsignificantly different from each other at $p > 0.01$. Sf/Fam, self/family; Peers, peers, PerPhy, personal physician; NwMed, news media; ElOff, elected officials; EmMgt, emergency management; PubHlth, public health; WatUtil, water utility.

personal physicians, and news media have their highest ratings on trustworthiness, followed by expertize and protection responsibility. By contrast, the ratings of the water utility differed slightly on the three attributes but in the opposite direction—highest on protection responsibility, followed by expertize and trustworthiness. Finally, the ratings for self/family, elected officials, emergency management, and public health are all equally high on all three attributes.

Consistent with RH2 (*Stakeholders' attribute profiles on expertize and trustworthiness will be much more like each other than either one is to protection responsibility*), the difference between the mean rating profiles of expertize and trustworthiness is RMS = 0.23, whereas the differences of the mean rating profiles of those variables with protection responsibility are RMS = 0.39 and RMS = 0.55, respectively.

Partly consistent with RH3 (*Mean ratings and interrater agreement of hazard expertize will be highest for authorities, next highest for public intermediate sources, and lowest for private intermediate sources*), a MANOVA reveals significant differences in expertize ratings among stakeholders (Wilks $\Lambda = 0.05$, $F_{8,102} = 251.60$, $p < 0.001$). As indicated in Table 1, technical authorities received the highest mean ratings (Public health $M = 3.87$, Water utility $M = 3.77$, and Emergency management $M = 3.73$). However, the lowest technical authority (emergency managers) has a nonsignificantly higher rating than news media or self/family ($M = 3.58$ and 3.40, respectively). In turn, these stakeholders received higher ratings than elected officials, peers, and personal physicians ($M = 3.15$, 3.05, and 3.03, respectively). Contrary to the hypothesis, there are no meaningful differences in interrater agreement on the ratings for most of the stakeholders. Specifically, respondents have moderately high agreement on the ratings of self/family ($r_{WG} = 0.47$, $p < 0.001$), followed by technical authorities ($\bar{r}_{WG} = 0.44$, $p < 0.001$), public intermediate sources ($\bar{r}_{WG} = 0.44$, $p < 0.001$), and peers ($r_{WG} = 0.40$, $p < 0.001$). However, there is virtually no agreement on personal physicians ($r_{WG} = 0.12$, *ns*).

Mostly contrary to RH4 (*Mean ratings and interrater agreement on trustworthiness will be highest for private intermediate sources, next highest for public intermediate sources, and lowest for authorities*), a MANOVA indicates significant differences in trustworthiness ratings between stakeholders (Wilks $\Lambda = 0.05$, $F_{8,102} = 251.24$, $p < 0.001$). As Table 1 indicates, news media ($M = 3.95$), a public intermediate source, received nonsignificantly higher ratings of trustworthiness than two of the technical authorities—public health and emergency management ($M = 3.83$ and 3.76, respectively), but the latter had nonsignificantly higher ratings than water utility, family, and peers ($M = 3.59$, 3.61, and 3.48, respectively). This latter group has significantly higher ratings than elected officials ($M = 3.33$), who have higher ratings than personal physicians ($M = 3.08$). However, partly consistent with the hypothesis, interrater agreement on trustworthiness is moderately high for news media ($r_{WG} = 0.45$, $p < 0.001$) and technical authorities ($\bar{r}_{WG} = 0.41$, $p < 0.001$), but is a bit lower for the other two intermediate sources—elected officials and peers ($r_{WG} = 0.31$ and 0.22, *ns*, respectively), and very low for self/family ($r_{WG} = 0.10$, *ns*) and personal physicians ($r_{WG} = 0.09$, *ns*).

Partially consistent with RH5 (*Mean ratings and interrater agreement on protection responsibility will be highest for self/family, next highest for authorities, and lowest for public and private intermediate sources*), a MANOVA revealed significant differences in protection responsibility ratings among stakeholders (Wilks $\Lambda = 0.04$, $F_{8,102} = 318.33$, $p < 0.001$). Table 1 shows that two technical authorities—water utility and public health ($M = 4.15$ and 3.96, respectively)—have significantly higher ratings than emergency management and self/family ($M = 3.75$ and 3.45, respectively), who have higher ratings than news media and elected officials ($M = 3.21$). In turn, these have higher ratings than peers and personal physicians ($M = 2.69$ and 2.13, respectively). Also, partly consistent with the hypothesis, technical authorities generally have the highest interrater agreement on protection responsibility ($\bar{r}_{WG} = 0.38$, $p < 0.001$), but there is significant variation among these stakeholders. Agreement is moderately high for the water utility ($r_{WG} = 0.49$, $p < 0.001$) and public health ($r_{WG} = 0.37$, $p < 0.001$), but lower for emergency management ($r_{WG} = 0.27$, *ns*), and extremely low for the public intermediate sources ($\bar{r}_{WG} = 0.10$, *ns*), personal physicians ($r_{WG} = 0.08$, *ns*), and private intermediate sources ($\bar{r}_{WG} = -0.09$, *ns*).

4.3. Tests of RH6, RQ1-RQ3: Effects of Stakeholders' Social Influence on Protective Actions

Table 2 displays the means, standard deviations, and intercorrelations among the variables in RH6 (Stakeholders' overall social influence will have positive correlations with risk perception and PAR compliance). Contrary to the hypothesis, risk perception has nonsignificant correlations with the overall social influence of all stakeholders. However, the overall social influence of authorities ($r = 0.25$) and public intermediate sources ($r = 0.28$) is positively correlated with PAR compliance, but none of the stakeholders' overall social influence variables has a significant correlation with taking the alternative protective actions or ignoring the threat.

RQ1 (*Do stakeholder perceptions have a direct effect on response actions or an indirect effect via their effects on risk perception?*) is first answered by the nonsignificant correlation of risk perception with PAR compliance. Specifically, in the absence of a significant correlation of risk perception with PAR compliance, stakeholder attributes cannot have an indirect effect on PAR compliance via their effects on risk perception. In addition, risk perception has nonsignificant correlations with the alternative protective actions and ignoring the threat.

RQ2 (*Do demographic characteristics, preparedness, experience, or risk perceptions affect the adoption of protective actions to water contamination as strongly as stakeholder perceptions?*) was first examined by the correlations in Table 2, which show that age has a negative correlation ($r = -0.41$) and income has a positive correlation with taking an alternative protective action ($r = 0.23$), whereas those having a higher preparedness level are more likely to ignore the threat ($r = 0.23$). Next, regression analyses for PAR compliance were conducted in the three stages displayed in Table 3. In Model I, PAR compliance was regressed onto the demographic variables, preparedness, and experience, whereas in Model II, compliance was regressed onto each stakeholder's overall social influence. After first entering all relevant variables into the regression model, backward deletion was used to discard nonsignificant predictors. Model I identified one statistically significant predictor, income ($\beta = -0.27$), with an adjusted $R^2 = 0.03$. Model II retained public intermediate sources ($\beta = 0.28$) and personal physician ($\beta = -0.34$) as the significant predictors with a significant adjusted $R^2 = 0.15$. It is noteworthy that Table 2 indicates that technical authorities and public intermediate sources' ratings were highly correlated ($r = 0.67$) and had approximately equal correlations with PAR compliance ($r = 0.25$ and 0.28, respectively), yet had been identified as distinct stakeholders. Thus, a re-estimated equation with both variables entering into Models II and III yielded regression coefficients of $\beta = 0.28$. Moreover, the results in Model III produced a statistically significant adjusted $R^2 = 0.28$ with significant coefficients for income ($\beta = -0.25$) and household size ($\beta = 0.26$), as well as for authorities and public intermediate sources ($\beta = 0.40$), and personal physician ($\beta = -0.47$).

The test of RQ3 (*Are there differences in the predictors of the PAR compliance, the alternative protective action, and ignoring the threat?*) regressed alterative protective action and threat-ignoring behavior onto all predictor variables followed by backward deletion of the nonsignificant predictors. Table 4 indicates that the analysis of alternative protective actions produced a statistically significant adjusted $R^2 = 0.31$ with significant coefficients for age ($\beta = -0.50$), income ($\beta = 0.24$), preparedness ($\beta = 0.27$), private intermediate sources ($\beta = -0.20$), and risk perception ($\beta = 0.26$). Analysis of ignoring the threat produced a model having a smaller but statistically significant adjusted $R^2 = 0.12$ with significant coefficient for preparedness ($\beta = 0.22$).

5. Discussion

The findings of the cluster analysis generally support the PADM and CNM proposition that stakeholders can be meaningfully divided into authorities, public intermediate sources, and private intermediate sources. However, the original classification requires some modification; respondents viewed elected officials as a public intermediate source like the news media rather than as one of the technical authorities. This suggests that elected officials are viewed simply as conduits for information from water utility, public health, and emergency management personnel rather than experts in their own right. In addition, despite frequently being mentioned in warnings as a supplemental source of health information, respondents viewed personal physicians as quite different from the

Table 2
Matrix of Means (M), Standard Deviations (SD), and Intercorrelations (r_{ij}) Among Variables

	Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Age	48.19	19.16																
2	Gender	0.62	0.49	−0.22															
3	White	0.75	0.43	0.08	−0.14														
4	HHsize	2.12	1.08	−0.23	−0.05	−0.28													
5	Education	16.06	2.59	−0.36	0.06	0.39	−0.12												
6	Income	67.78	30.31	−0.24	−0.20	0.30	−0.04	0.53											
7	HomeOwn	0.46	0.50	0.05	−0.24	0.23	0.12	0.22	0.53										
8	Preparedness	0.45	0.29	0.20	0.00	−0.14	0.16	−0.26	−0.13	0.08									
9	Experience	0.11	0.24	−0.06	−0.02	−0.04	−0.06	−0.04	−0.08	−0.06	0.08								
10	SI_AU	3.85	0.72	0.14	−0.07	0.12	−0.08	0.01	0.01	0.17	0.02	0.06							
11	SI_PBI	3.40	0.79	0.21	0.06	−0.09	0.01	−0.21	−0.18	−0.01	0.09	0.09	0.67						
12	SI_PVI	3.28	1.01	0.11	−0.01	−0.15	0.09	−0.22	−0.18	−0.15	0.12	0.01	0.34	0.52					
13	SI_PP	2.79	1.06	0.23	−0.04	−0.15	0.16	−0.21	−0.21	−0.12	0.04	−0.08	0.44	0.38	0.41				
14	RiskPerception	2.60	0.93	0.12	0.14	−0.13	0.16	−0.28	−0.22	−0.08	0.10	0.02	−0.05	0.19	0.14	0.20			
15	RecommAction	3.16	1.64	−0.02	0.16	−0.11	0.15	−0.08	−0.20	0.01	0.08	0.10	0.25	0.28	0.03	−0.15	0.07		
16	AlternatAction	3.62	1.40	−0.41	0.10	−0.13	0.06	0.12	0.23	0.11	0.14	−0.04	0.00	−0.01	−0.12	−0.03	0.18	−0.18	
17	ThreatIgnore	1.33	0.68	0.04	0.10	−0.03	0.15	−0.18	−0.22	−0.16	0.23	−0.13	−0.09	0.02	−0.01	−0.09	0.01	0.27	0.00

Note. *$r = 0.23$, $p < 0.01$; $r = 0.30$, $p < 0.001$. Age, age; Gender, female; White, white; HHSize, household size; Educ, year of education; Inc, income in $1,000 USD; HomeOwn, homeownership; Preparedness, level of preparedness; Experience, previous water contamination experience; SI_AU, authorities' social influence; SI_PBI, public intermediate sources' social influence; SI_PVI, private intermediate sources' social influence; SI_PP, personal physician's social influence; RiskPerception, risk perceptions; RecommAction, recommended action; AlternatAction, alternative action; IgnoreThreat, threat-ignoring behavior.

Table 3
Regression of Protective Action Recommendation (PAR) Compliance Onto Predictor Variables

	Model I			Model II			Model III			
	B	SE(B)	*β*	*B*	SE(B)	*β*	*r*	*B*	SE(B)	*β*
Age	0.00	0.01	−0.01							
Gender	0.49	0.35	0.15				0.16	0.41	0.28	0.12
White	−0.11	0.42	−0.03							
HHsize	0.19	0.16	0.13				0.15	0.39*	0.13	0.26*
Education	0.03	0.08	0.05							
Income	−0.00*	0.00	−0.27*				−0.20*	−0.00*	0.00	−0.25*
HomeOwn	0.59	0.39	0.18							
Preparedness	0.05	0.58	0.01							
Experience	0.71	0.65	0.10							
SI_AU				0.52	0.28	0.23 (0.28)	0.25*	0.91*	0.27	0.40*
SI_PBI				0.58	0.27	0.28	0.28*	0.27	0.24	0.13 (0.40)*
SI_PVI				−0.08	0.17	−0.05				
SI_PP				−0.52*	0.16	−0.34*	−0.15	0.72**	0.15	−0.47**
RiskPerception(Constant)	2.70	1.56		0.90	0.82			1.20	0.96	
R^2		0.11			0.18				0.32	
Adj R^2		0.03			0.15				0.28	
$df_{N,D}$		(9,100)			(4,105)				(6,103)	
F		1.40			5.92**				7.92**	

Note. $*p < 0.01$; $**p < 0.001$. *B* is the unstandardized regression coefficient**,** SE(B) is the standard error of that coefficient, *β* is the standardized regression coefficient, and *r* is the zero-order correlation coefficient. Age, age; Gender, female; White, white; HHSize, household size; Education, year of education; Income, income in $1,000 USD; HomeOwn, homeownership; Preparedness, level of preparedness; Experience, previous water contamination experience; SI_AU, authorities' social influence; SI_PBI, public intermediate sources' social influence; SI_PVI, private intermediate sources' social influence; SI_PP, personal physician's social influence; RiskPerception, risk perceptions.

other stakeholders, especially because of their low ratings on protection responsibility. More broadly, however, there was a nonsignificant level of agreement on the ratings of physicians on all three stakeholder attributes. This suggests that many people consider personal physicians to be largely irrelevant in a water contamination incident so, although there is no harm in identifying them as an information source, few people are likely to contact them for information.

5.1. Tests of RH1-RH5: Perceived Stakeholders' Social Influence Attributes

The findings in support of RH1 (*There will be significant differences among the mean ratings of the stakeholders on the three social influence attributes—expertize, trustworthiness, and protection responsibility*) are noteworthy because they indicate that respondents differentiate among water contamination stakeholders on these attributes. In turn, this underscores the importance of identifying the origins of these perceptions and the effects of those perceptions on PAR compliance, consumption of bottled or self-chlorinated water, and ignoring the threat. Possible origins of each of these perceptions are addressed below.

The findings in support of RH2 (*Stakeholders' attribute profiles on expertize and trustworthiness will be much more like each other than either one is to protection responsibility*) are important because they replicate findings from Arlikatti et al. (2007) and Wei et al. (2018), which suggest that these social influence attributes are not independent. Nonetheless, it is unclear if trustworthiness is inferred from expertize, expertize inferred from trustworthiness, or if both are inferred from other sources. The finding that authorities are viewed as having high trustworthiness aligns with other studies and is likely due to belief that they are more knowledgeable about hazards (Arlikatti et al., 2007; Lindell & Perry, 1992; Sager, 1994; Taibah et al., 2017). As summarized by Lewicki

10.1029/2021WR030669

Table 4
Regression of Alternative Action and Threat-Ignoring Behavior on Predictor Variables

	DV = Alternative action				DV = Threat-ignoring behavior			
	R	*B*	SD	*B*	*r*	*B*	SD	*β*
Age	−0.41**	−0.04**	0.01	−0.50**				
Gender								
White	−0.13	−0.46	0.28	0.14				
HHsize	0.06	−0.23	0.11	−0.18	0.15	0.08	0.06	0.13
Education								
Income	0.23*	0.00*	0.00	0.24*	−0.22*	0.00*	0.00	−0.25
HomeOwn								
Preparedness	0.14	1.32*	0.41	0.27*	0.23*	0.53*	0.22	0.22*
Experience	−0.04	−0.57	0.47	−0.10	−0.13	−0.50	0.26	−0.18
SI_AU								
SI_PBI	−0.01	0.22	0.17	0.12				
SI_PVI	−0.12	−0.27	0.13	−0.20				
SI_PP	−0.03	0.14	0.12	0.11	−0.09	−0.12	0.06	−0.19
RiskPerception	0.18	0.39*	0.13	0.26*				
(Constant)		3.62	0.80			1.73	0.29	
R^2		0.38				0.18		
Adj R^2		0.31				0.12		
Df.		(10, 99)				(5,104)		
F		5.99**				3.97**		

Note. $*p < 0.01$; $**p < 0.001$. *B* is the unstandardized regression coefficient, SE(B) is the standard error of that coefficient, *β* is the standardized regression coefficient, and *r* is the zero-order correlation coefficient; $N = 110$. Age, age; Gender, female; White, white; HHSize, household size; Education, year of education; Income, income in $1,000 USD; HomeOwn, homeownership; Preparedness, level of preparedness; Experience, previous water contamination experience; SI_AU, authorities' social influence; SI_PBI, public intermediate sources' social influence; SI_PVI, private intermediate sources' social influence; SI_PP, personal physician's social influence; RiskPerception, risk perceptions.

et al. (2006), expert power can be an important source of trustworthiness whereas position-based power defines the responsibility of a stakeholder and, in turn, control of the information.

The lack of complete support for RH3 (*Mean ratings and interrater agreement on hazard expertize will be highest for authorities, next highest for public intermediate sources, and lowest for private intermediate sources*) is somewhat surprising because respondents did rate authorities as having high expertize, but self/family, unlike other intermediate sources, received the second highest ratings on expertize. The higher ratings for self/family than for other private intermediate sources can be explained by *illusory superiority* (Hoorens & Buunk, 1992), which is people's tendency to regard themselves as being above the average and then estimate others in accordance with this anchor point (Alicke & Govorun, 2005; Goethals et al., 1991). However, this explanation only accounts for comparison to other private intermediates because self/family received lower expertize ratings than technical authorities and news media, a similar pattern to the one found for volcano (Perry & Lindell, 1990) and earthquake (Lindell & Whitney, 2000) hazards.

There is some evidence that people's familiarity with a hazard reduces the differences in perceived expertize among stakeholders because Lindell and Perry (1992) reported that respondents near the Mount St. Helens volcano rated themselves as more similar to authorities in hazard expertize (12 yr after the volcano erupted) than for two less familiar hazards—toxic chemicals transported along a nearby rail line and radiological hazard from a nearby nuclear power plant, a finding seconded by Wu et al. (2017) study of the Oklahoma earthquake. This suggests that Boston-area respondents considered water contamination to be a more familiar, and perhaps much more personally controllable, hazard than these other environmental hazards. Otherwise, news media but not elected officials are viewed as having high expertize and therefore an important channel from which to receive information. These results are consistent with previous studies on perceived stakeholder expertize, which suggest that technical authorities are thought to have high expertize due to their educational credentials, whereas news media are thought to have high expertize due to their close contact with scientists and other experts (Arlikatti et al., 2007; Latré et al., 2018).

RH4 (*Mean ratings and interrater agreement on trustworthiness will be highest for private intermediate sources, next highest for public intermediate sources, and lowest for authorities*) was only partially supported by the finding that news media (a public intermediate source) was rated highest of all the stakeholders, which can be explained by a *parasocial* relationship that develops between the local media and their audiences that can increase trust (Sherman-Morris et al., 2020). Contrary to the hypothesis, however, all private intermediate stakeholders were rated lower than technical authorities and news media. However, after excluding personal physicians, the differences among private intermediate stakeholders were not significant. One possible explanation for the differences among stakeholders with respect to trustworthiness is that respondents infer this attribute from a variety of sources. For example, Perry and Lindell (1990) reported that residents of areas near Mount St. Helens regarded the county Department of Emergency Services and County Sheriff as the most credible information sources because of their special skills (expertize) and past reliability (trustworthiness), which were attributable to relevant educational credentials, acceptance by currently trusted sources, and past job performance. Accordingly, the high mean ratings and levels of agreement regarding the trustworthiness of technical authorities and news media in the present study could be a result of their salient public image and trusting relationships with respondents.

Conversely, even though the ratings of family's and peers' trustworthiness are unexpectedly low, this finding is consistent with a study by Arlikatti et al. (2007). These relatively low trustworthiness ratings may be due to differential exposure to these stakeholders. Specifically, people generally see authorities and public intermediates on their best behavior, whereas they see their peers and their families along the entire range from their best to their worst behavior. Since negative instances, especially emotionally charged ones, are particularly memorable (Kensinger & Ford, 2020), this might account for the relatively low ratings of these two types of stakeholders.

The lack of complete support for RH5 (*Mean ratings and interrater agreement on protection responsibility will be highest for self/family, next highest for authorities, and lowest for public and private intermediate sources*) is also somewhat surprising because technical authorities, rather than self/family, received the highest ratings for protection responsibility. This might be due to differences among hazards because Arlikatti et al. (2007) and Lindell and Whitney (2000) found that self/family had *higher* ratings than authorities for earthquake protection responsibility, whereas Wei et al. (2018) and Wu et al. (2017) reported that self/family had *lower* ratings than authorities for Oklahoma human-induced earthquake and seasonal influenza protection responsibilities, respectively. One possibility is that authorities are perceived to have substantially more control over water contamination than earthquakes, whereas another possibility is that people attribute protection responsibility to authorities when they themselves lack knowledge about effective protective actions which, in turn, arises from their lack of disaster experience or hazard education. For example, Krasovskaia et al. (2007) found that respondents who attributed responsibility for flood prevention to authorities also had a passive attitude toward flood risk due to a false sense of security that came from never having experienced a flood.

The finding that the public intermediate sources were rated next highest on protection responsibility, but with a nearly uniform distribution of protection responsibility ratings, can be attributed to disagreements about their roles as information sources. For example, the state of emergency declared by the Boston Mayor was simply a repetition of the message given by the State Governor, retransmitting incident information and PARs originated by the Massachusetts Water Resources Authority. Hence, the respondents may rate the protection responsibility of public intermediates in accordance with perceptions of these stakeholders' social functions.

5.2. Tests of RH6, RQ1-RQ3: Effects of Stakeholders' Social Influence on Protective Actions

Regarding RH6 (*Stakeholders' overall social influence [the average of all three stakeholder attributes*] will have positive correlations with risk perception and PAR compliance), Models II and III in Table 3 reveal that the social influence of authorities and public intermediate sources (both $\beta = 0.40$) together with personal physicians ($\beta = -0.47$) has direct effects on PAR compliance. These findings are consistent with some findings of direct effects of stakeholder attributes on protective actions (Heath et al., 2018; Lindell & Whitney, 2000) but not

Arlikatti et al. (2007), who found evidence of both direct and indirect effects. One explanation is that the PAR in the water contamination incident was for a protective action (boiling tap water) that was perceived to be no more effective than the alternative protective actions (bottled water and self-chlorinated water) but required more time and effort.

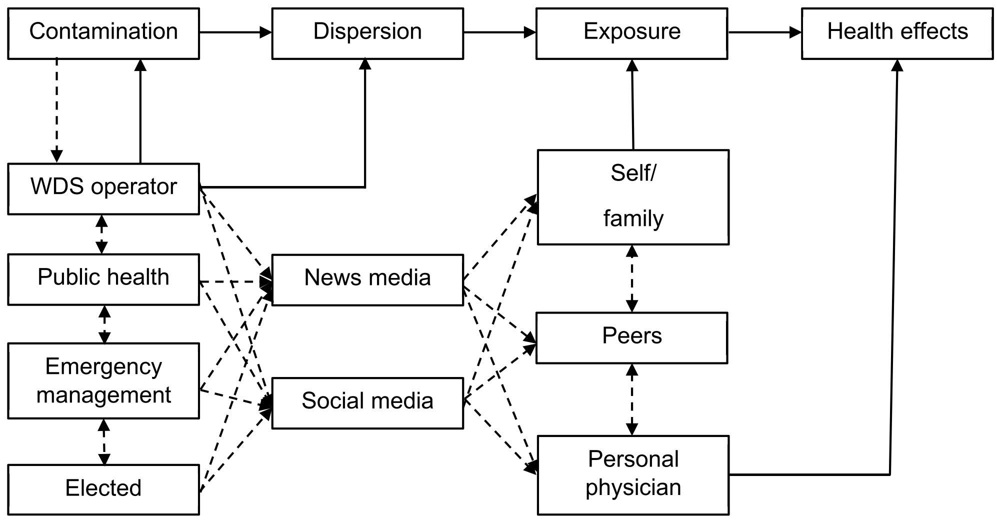
Moreover, the equal weights for authorities and public intermediate sources in Models II and III imply that these sources could substitute for each other in communications with the public. However, PAR compliance is more likely if they are communicating the same message and thus have additive effects. Conversely, authorities and public intermediate sources will tend to cancel each other if their messages conflict. Thus, the consistency of messaging by authorities and public intermediate sources can be expected to have a major effect on PAR compliance in future water contamination incidents.

There was a negative answer to RQ1 (*Do stakeholder perceptions have a direct effect on PAR compliance or an indirect effect via their effects on risk perception?*) because a mediation effect for stakeholders' social influence on response actions via risk perceptions was precluded by the finding that risk perception itself was not significantly correlated with any of the response actions. This negative result is not completely contrary to Lindell and Perry's (2004) assertion that stakeholders' social influence could elicit direct compliance via Petty and Cacioppo's (1986) peripheral route, rather than via their central route because Lindell and Perry (2004) acknowledged the possibility of both routes. Thus, given that only a direct effect was found in this study, it remains to be determined which personal characteristics and incident conditions favor a direct effect and which favor an indirect effect.

Regarding RQ2 (*Do demographic characteristics, preparedness, experience, or risk perceptions affect the adoption of protective actions to water contamination as strongly as stakeholder perceptions?*), the effect size changes of household size and social influence of personal physician, from a nonsignificant correlation to a significant regression coefficient require an explanation. One possibility is that the significant effect of household size on PAR compliance is due to concern about children's health. Specifically, whereas single people or childless couples might be willing to take chances with untreated tap water, parents are unlikely to take similar chances with their children's health. On the other hand, the significant negative effect of personal physician social influence can be explained as an artifact of collinearity among the stakeholder ratings because Table 2 indicates that these variables (Variables 10–13) have an average intercorrelation of $r = 0.46$. Consequently, the standardized regression coefficient for authorities increases from its correlation (from $r = 0.25$ to $\beta = 0.40$), public intermediates decreases from its correlation (from $r = 0.28$ to $\beta = 0.13$), and personal physician becomes more negative (from $r = -0.15$ to $\beta = -0.47$).

The results for RQ3 (*Are there differences in the predictors of the PAR compliance, the alternative protective action, and ignoring the threat?*) indicate that there are distinctly different predictors for these three dependent variables. One possible explanation for the significant effects of age ($\beta = -0.50$), income ($\beta = 0.24$), and preparedness ($\beta = 0.27$) on the adoption of alternative protective actions is that these are proxies for respondents' routine drinking water sources, especially bottled water. As Lindell et al. (2017a) found in other data from this incident, people who routinely drank bottled water before the incident would be more likely to continue to drink it during the boil water order. The nonsignificant effect of stakeholders' overall social influence, together with the significant effect of risk perception on the adoption of alternative protective actions, is noteworthy. As one respondent indicated that “I was very sensitive about this water contamination because I was 7 months pregnant at that time. If I was not, I could have drunk boiled tap water more, but I did not.” This comment implies that the reason why some people drank bottled or self-chlorinated water was not to reject compliance with authorities' PARs, but rather a personal risk perception that indicates an alternative protective action would yield the same level of protection (Lindell et al., 2017b).

The positive effect of preparedness on threat-ignoring behavior is somewhat puzzling because it suggests that optimistic bias misleads households into believing they are well-prepared, causing them to overlook their risk exposures (see, for example, Lo & Cheung, 2015). However, this finding needs to be tested further to see if it can be replicated and explained in future research.



Note: Dashed lines indicate information flow; solid lines indicate physical control.

Figure 4. Chain of Events Model (adapted from Lindell & Perry, 1992). Note: Dashed lines indicate information flow; solid lines indicate physical control.

5.3. A Conceptual Diagram Explaining Information Flow for a Water Contamination Incident

In summary, judgments of stakeholder attributes, especially protection responsibility can be explained by a process that integrates the CNM in Figure 1 with the Sociotechnical Systems Model in Ehsan Shafiee et al. (2018) and the Chain of Events Model from Lindell and Perry (1992). According to the chain of events at the top of Figure 4, *contamination* enters a WDS and *disperses* throughout the system, producing *exposures* if people drink the contaminated water, and adverse *health effects* depending on the contaminant's toxicity and the quantity consumed. The second chain of events involves the events in the social system that respond to the environmental chain of events. Specifically, people consider WDS operators responsible for detecting contaminant intrusion by carefully monitoring the system (indicated by dashed line) and taking corrective action to eliminate that contamination from the WDS (indicated by the solid lines to contamination and dispersion).

In addition, the WDS operator is responsible for promptly notifying public health and emergency management agencies, elected officials, and news media (also indicated by dashed lines), as well as transmitting warnings to those at risk indirectly via the news media (e.g., TV, radio, and newspapers) and directly via their Internet and social media sites (e.g., Facebook and Twitter). To the degree that there has been an absence of contamination incidents in the past, people are likely to consider WDS operators to be expert and trustworthy. However, if there is a contamination incident, people hold WDS operators responsible for conducting interventions that terminate the intrusion of contaminants into the system and preventing further dispersion by flushing the contaminants that have already entered.

Unlike the WDS operators, who have information about the system and physical control of it, public and private intermediates only have information about WDS contamination. In addition to information that the WDS operator provides about the state of the system, public health and emergency management agencies have specialized expertize about the effects of that contamination on public health and the appropriate PARs that should be issued. Self and family are ultimately responsible for deciding whether to comply with authorities' PARs but can consult with peers and personal physicians to confirm the warning and discuss the logistics of protective action—the process of *milling* (Wood et al., 2018). Elected officials and news media are perceived to have protection responsibility only to the extent that people consider it to be their role to disseminate prompt and accurate information about the incident to the public, whereas peers have protection responsibility only to the extent that they are expected to provide such information to their friends, relatives, neighbors, and coworkers. Finally, personal physicians are considered to have low levels protection responsibility because their role is to provide advice on their patients' personal health rather than public health. However, they can implement remedial actions to minimize the adverse health effects to those who get sick. In summary, the interpretation of protection responsibility is complex because the various stakeholders differ in the actions that they can take at successive stages in the environmental chain from contamination through dispersion and exposure to health effects.

5.4. Study Limitations

It is important to acknowledge that this study has its limitations. The response rate was only 22%, which raises concern that the respondents may not be truly representative of the population affected by this water contamination incident. However, a low response rate does not necessarily imply response bias because the latter occurs only if demographic characteristics are significantly correlated with questionnaire response, which they are not (Groves & Peytcheva, 2008; Tourangeau, 2017). Moreover, a low response rate does not seem to bias central tendency estimates such as means and proportions (Keeter et al., 2000). Finally, when testing path models, the issue of generalizability from the sample to the population most directly concerns whether the sample's correlation and regression coefficients for the psychological and behavioral variables—not their means and proportions—are representative of those in the population to which the results will be generalized. This generally means that the issue is whether there is adequate variation in the variables to avoid bias in those correlation and regression coefficients. Thus, even if there is bias in the estimated means and proportions on the psychological and behavioral variables, there will be little effect on correlation coefficients unless there are *ceiling* or *floor effects* that cause these coefficients to be systematically underestimated (Lindell & Perry, 2000a, 2000b; Nunnally & Bernstein, 1994).

It is also important to point out that, since the respondents' rating of trustworthiness were quite similar to their ratings of expertize, an anchor effect might have occurred in which respondents made judgments based on an initial value (Furnham & Boo, 2010). However, it cannot be determined for certain if an anchor effect occurred since expertize and trustworthiness ratings differed in their similarity to protection responsibility ratings. Moreover, as a cross-sectional design, this study is also limited in its ability to determine definite causal inferences (Lindell, 2008). A longitudinal study might reveal more informative findings on the cause-and-effect relationships among residents' ratings of stakeholders' attributes, especially if there is an event that changes those ratings.

6. Conclusions and Future Work

To understand risk communication and PAR compliance during the 2010 Boston water contamination incident, 600 randomly sampled residents were mailed questionnaires, yielding 110 valid responses. The findings from this study have some important implications for other water contamination incidents. First, water from alternate sources, although untreated, was later found to be safe and did not cause any detectable negative health effects. This may have been perceived by some people as excessive caution by government health authorities that could lead to a *cry wolf* effect (Breznitz, 1984). However, it usually takes repetitive false alarms warning the public to take protective actions, but the threat not materializing, to cause the public to lose faith in official warning systems (LeClerc & Joslyn, 2015; Ripberger et al., 2015; Simmons & Sutter, 2009). Although false alarms can lead to noncompliance when a real threat strikes (Atwood & Major, 1998; Jauernic & Van Den Broeke, 2016; Rigos et al., 2019; Sharma & Patt, 2012), the Boston water contamination was a single incident rather than a repetitive series, so it is unclear if any local residents considered the incident to be a false alarm that should be ignored in the future.

Second, the comparable levels of perceived expertize, trustworthiness, and protection responsibility of authorities from agencies such as water utilities, public health, and emergency management means that they need to communicate the same message—or at least compatible messages. Additionally, these findings suggest that using public intermediate sources to support warning message dissemination will also increase compliance. Since people are prone to seek additional information after receiving a message, especially if there is ambiguity (Lindell, 2018; Lindell et al., 2019; Wood et al., 2018), a larger number of sources disseminating the same message—or clearly compatible messages—will confirm the initial message and influence those at risk to comply with PARs more rapidly. Third, authorities need to plan, long before an incident occurs, how to warn people about water contamination through multiple channels to increase PAR compliance (Lindell & Perry, 2004). They are undoubtedly familiar with disseminating warnings through conventional channels such route alert, broadcast media, social media, and emergency notification systems (Arlikatti et al., 2014). However, another possibility is to inject food grade dye into the water main systems to alert the population to stop drinking tap water and trigger an appropriate response action (Rasekh et al., 2014). The advantage of food dye is that it would provide an immediately recognizable environmental cue that a household's tap water is unsafe to drink.

Fourth, water contamination incidents need to be taken seriously by the public as they can be caused by security breaches and vandalism as well as accidental pipe breaks. Even though a majority of the direct threats received by water distribution operators are hoaxes intended to receive media attention or settle a personal grudge, WDS operators must take each event seriously by adhering to the USEPA (2004) Response Protocol Tool Box. Specifically, Module 5: Public Response Guide outlines public health response measures that can potentially minimize public exposure to contaminants; and Module 6: Remediation and Recovery Guide, outlines the remedial and recovery process once the contamination incident is confirmed. Various organizations that are likely to be involved and their roles are also listed. The public needs to be made aware that these procedures have been established to increase their confidence that the technical authorities are executing a planned, rather than improvized, response.

In 2010, when this water contamination incident unfolded in Boston, the State of Massachusetts website did not have specific information related to drinking water health and safety. However, following this incident they added a section, titled "Drinking water boil orders and public-health orders", for people to learn how public health orders protect them from contaminated water supplies (Mass.gov, 2022). Detailed information about the following topics—water-borne illness, general precautions during a boil order, tips for water use during a boil order, what to do after the order is lifted—is followed by a short quiz at the end of each section. However, the link to access this information is a bit obscure and the contents on the webpage rather tedious to read without pictures or videos. Other state governments such as Michigan (https://www.youtube.com/watch?v=AkU6U8-5ztk), nonprofit organizations such as Boil Water Watch (https://www.youtube.com/watch?v=3zoojollIBA), and private entities are posting instructional videos with water experts. These YouTube videos present facts and animations (https://www.youtube.com/watch?v=REiMJ5iLZRs) related to water contamination and boil water orders. Other states may want to provide similar content on their websites, especially if they make these resources more accessible and understandable to consumers of different demographic segments.

Finally, water safety management needs to be integrated with the rest of a community's comprehensive emergency operations planning (Lindell & Perry, 2007). To ensure an effective and timely water incident response, training on crisis communications should be provided to water utility personnel, as well as other technical authorities, hospitals/clinics, regional poison control centers, and news media. These can be in the form of charettes at town hall meetings or tabletop exercises, drills, and full-scale exercises. The USEPA has developed an SRS Exercise Development Toolbox to support the design and development, implementation, and evaluation of exercises for water contamination scenarios. The roles and responsibilities of all parties should be understood as promulgated by the whole community approach described in the National Response Framework (FEMA, 2019). In this way, water contamination events will be taken seriously and the public health and safety protected.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The data set used to generate the results of this study can be accessed at, https://www.researchgate.net/publication/352639734_Water_Contamination_project_Dataset upon request.

Acknowledgments
This work was supported by the US National Science Foundation under Grant CMMI-0927739. None of the conclusions expressed here necessarily reflects views other than those of the authors.

References

Al-Fedaghi, S. (2012). A conceptual foundation for the Shannon-Weaver model of communication. *International Journal of Soft Computing*, *7*(1), 12–19. https://doi.org/10.3923/ijscomp.2012.12.19

Alicke, M. D., & Govorun, O. (2005). The better-than-average effect. In M. D. Alicke, D. A. Dunning, & J. I. Krueger (Eds.), *The self in social judgment* (pp. 85–106). Psychology Press.

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.

Arlikatti, S., Taibah, H. A., & Andrew, S. A. (2014). How do you warn them if they speak only Spanish? Challenges for organizations in communicating risk to Colonias residents in Texas, USA. *Disaster Prevention and Management*, *23*(5), 533–550. https://doi.org/10.1108/dpm-02-2014-0022

Atwood, L. E., & Major, A. M. (1998). Exploring the "cry wolf" hypothesis. *International Journal of Mass Emergencies and Disasters*, *16*(3), 279–302.

Basolo, V., Steinberg, L. J., Burby, R. J., Levine, J., Cruz, A. M., & Huang, C. (2009). The effects of confidence in government and information on perceived and actual preparedness for disasters. *Environment and Behavior*, *41*(3), 338–364. https://doi.org/10.1177/0013916508317222

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B Methodological*, *57*(1), 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Breznitz, S. (1984). *Cry wolf: The psychology of false alarms*. Lawrence Erlbaum Associates.

Cascio, W. F., & Aguinis, H. (2004). *Applied psychology in human resource management* (6th ed.). Prentice Hall.

Centers for Disease Control and Prevention (CDC). (2020). *Drinking water standards and regulations*. Retrieved from https://www.cdc.gov/healthywater/drinking/public/regulations.html

Cole, T., & Fellows, K. (2008). Risk communication failure: A case study of New Orleans and Hurricane Katrina. *Southern Communication Journal*, *73*(3), 211–228. https://doi.org/10.1080/10417940802219702

Contreras, R. (2010). *Group files complaint over water crisis*. Associated Press. Retrieved from http://archive.boston.com/news/local/massachusetts/articles/2010/05/20/group_files_complaint_over_water_crisis/

Converse, P. E. (1970). Attitudes and non-attitudes: Continuation of a dialogue. In E. R. Tufte (Ed.), *The quantitative analysis of social problems* (pp. 168–189). Addison-Wesley.

Daley, B., & Gil, G. (2010). *Tests confirm it—Water was OK to drink all weekend*. The Boston Globe. Retrieved from http://archive.boston.com/news/local/massachusetts/articles/2010/05/05/turns_out_water_was_ok_to_drink_after_all/

Dillman, D. A. (1999). *Mail and internet surveys: The tailored design method*. Wiley.

Dunlap, W. P., Burke, M. J., & Smith-Crowe, K. (2003). Accurate tests of statistical significance for r_{WG} and average deviation interrater agreement indexes. *Journal of Applied Psychology*, *88*(2), 356–362. https://doi.org/10.1037/0021-9010.88.2.356

Eagly, A. H., & Chaiken, S. (1998). Attitude structure and function. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (4th ed., pp. 269–322). McGraw-Hill.

Ehsan Shafiee, M. E., Berglund, E. Z., & Lindell, M. K. (2018). An agent-based modeling framework for assessing the public health protection of water advisories. *Water Resources Management*, *32*(6), 2033–2059. https://doi.org/10.1007/s11269-018-1916-6

Executive Office of Health and Human Services (EOHHS). (2010). *Frequently asked questions: MWRA water break/boiled water*. Massachusetts Water Resources Authority. Retrieved from https://www.mass.gov/Eeohhs2/docs/dph/cdc/mwra_water_break/water_break_faq_boil.pdf

FEMA—Federal Emergency Management Agency. (2019). *National response framework*. U.S. Department of Homeland Security. Retrieved from https://www.fema.gov/sites/default/files/2020-04/NRF_FINALApproved_2011028.pdf

French, J. R. P., & Raven, B. H. (1959). The bases of social power. In D. Cartwright (Ed.), *Studies in social power* (pp. 150–167). Institute for Social Research.

Furnham, A., & Boo, H. C. (2010). A literature review of the anchoring effect. *The Journal of Socio-Economics*, *40*(1), 35–42. https://doi.org/10.1016/j.socec.2010.10.008

Galvin, J. (2010). *Lessons to learn from Boston's water-main break*. Popular Mechanics. Retrieved from https://www.popularmechanics.com/adventure/outdoors/tips/a5735/boston-water-main-safety-tips/

Gao, J., Zheng, P., Jia, Y., Chen, H., Mao, Y., Chen, S., et al. (2020). Mental health problems and social media exposure during COVID-19 outbreak. *PLoS One*, *15*(4), e0231924. https://doi.org/10.1371/journal.pone.0231924

Garcia, E. M. (1989). Earthquake preparedness in California: A survey of Irvine residents. *Urban Resources*, *5*, 15–19.

Gass, R. H., & Seiter, J. S. (2014). *Persuasion: Social influence and compliance gaining* (4th ed.). Routledge.

Gauntlett, L., Amlôt, R., & Rubin, G. J. (2019). How to inform the public about protective actions in a nuclear or radiological incident: A systematic review. *Lancet Psychiatry*, *6*(1), 72–80. https://doi.org/10.1016/s2215-0366(18)30173-1

Genius, M., & Tsagarakis, K. P. (2006). Water shortages and implied water quality: A contingent valuation study. *Water Resources Research*, *42*, W12407. https://doi.org/10.1029/2005WR004833

Giroux, J., Hagmann, J., & Cavelty, D. (2009). *Focal Report 3—Risk analysis: Risk communication in the public sector*. Center for Security Studies.

Gladwin, C. H., Gladwin, H., & Peacock, W. G. (2001). Modeling hurricane evacuation decisions with ethnographic methods. *International Journal of Mass Emergencies and Disasters*, *19*(2), 117–143.

Glickman, M. E., Rao, S. R., & Schultz, M. R. (2014). False discovery rate control is a recommended alternative to Bonferroni-type adjustments in health studies. *Journal of Clinical Epidemiology*, *67*(8), 850–857. https://doi.org/10.1016/j.jclinepi.2014.03.012

Godschalk, D., Parham, D., Porter Potapchuk, W., & Schukraft, S. (1994). *Pulling together: A planning and development consensus building manual*. Urban Land Institute.

Goethals, G. R., Messick, D. M., & Allison, S. T. (1991). The uniqueness bias: Studies of constructive social comparison. In J. Suls, & T. A. Wills (Eds.), *Social comparison. Contemporary theory and research* (pp. 149–176). Erlbaum.

Grothmann, T., & Reusswig, F. (2006). People at risk of flooding: Why some residents take precautionary action while others do not. *Natural Hazards*, *38*(1), 101–120. https://doi.org/10.1007/s11069-005-8604-6

Groves, R. M., & Peytcheva, E. (2008). The impact of nonresponse rates on nonresponse bias: A meta-analysis. *Public Opinion Quarterly*, *72*(2), 167–189. https://doi.org/10.1093/poq/nfn011

Haeffner, M., Jackson-Smith, D., & Flint, C. G. (2018). Social position influencing the water perception gap between local leaders and constituents in a socio-hydrological system. *Water Resources Research*, *54*, 663–679. https://doi.org/10.1002/2017WR021456

Hatfield, J., & Job, R. F. S. (2001). Optimism bias about environmental degradation: The role of the range of impact of precautions. *Journal of Environmental Psychology*, *21*, 17–30. https://doi.org/10.1006/jevp.2000.0190

Heath, R. L., Lee, J., Palenchar, M. J., & Lemon, L. L. (2018). Risk communication emergency response preparedness: Contextual assessment of the protective action decision model. *Risk Analysis*, *38*(2), 333–344. https://doi.org/10.1111/risa.12845

Henry, D. (2010). *Ruptured pipe cuts water in Boston*. The New York Times. Retrieved from https://www.nytimes.com/2010/05/03/us/03boston.html

Hoorens, V., & Buunk, B. P. (1992). Self-serving biases in social-comparison: Illusory superiority and unrealistic optimism. *Psychologica Belgica*, *32*, 169–194. https://doi.org/10.5334/pb.831

Huang, S.-K., Lindell, M. K., & Prater, C. S. (2017). Toward a multi-stage model of hurricane evacuation decision: An empirical study of Hurricanes Katrina and Rita. *Natural Hazards Review*, *18*(3), 05016008. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000237

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. https://doi.org/10.1029/2008WR007427

Jauernic, S. T., & Van Den Broeke, M. S. (2016). Perceptions of tornadoes, tornado risk, and tornado safety actions and their effects on warning response among Nebraska undergraduates. *Natural Hazards*, *80*(1), 329–350. https://doi.org/10.1007/s11069-015-1970-9

Jiang, Y., Li, Z., & Cutter, S. L. (2021). Social distance integrated gravity model for evacuation destination choice. *International Journal of Digital Earth*, *14*(8), 1004–1015. https://doi.org/10.1080/17538947.2021.1915396

Kahlor, L., Dunwoody, S., Griffin, R. J., Neuwirth, K., & Giese, J. (2003). Studying heuristic-systematic processing of risk communication. *Risk Analysis*, *23*(2), 355–368. https://doi.org/10.1111/1539-6924.00314

Katz, E., & Lazarsfeld, P. F. (1955). *Personal influence* (p. 309). The Free Press.

Keeter, S., Miller, C., Kohut, A., Groves, R. M., & Presser, S. (2000). Consequences of reducing nonresponse in a national telephone survey. *Public Opinion Quarterly*, *64*(2), 125–148. https://doi.org/10.1086/317759

Kensinger, E. A., & Ford, J. H. (2020). Retrieval of emotional events from memory. *Annual Review of Psychology*, *71*, 251–272. https://doi.org/10.1146/annurev-psych-010419-051123

Klar, Y., & Ayal, S. (2004). Event frequency and comparative optimism: Another look at the indirect elicitation method of self-others risks. *Journal of Experimental Social Psychology*, *40*(6), 805–814. https://doi.org/10.1016/j.jesp.2004.04.006

Kousky, C., & Kunreuther, H. C. (2017). *Defining the Roles of the Public and Private Sector in Risk Communication, Risk Reduction, and Risk Transfer*. Resources for the Future Discussion Paper 17-09, Available at SSRN: https://ssrn.com/abstract=3029630

Krasovskaia, I., Gottschalk, L., Ibrekk, S. A., & Berg, H. (2007). Perception of flood hazard in countries of the North Sea region of Europe. *Hydrology Research*, *38*(4–5), 387–399. https://doi.org/10.2166/nh.2007.019

Lasswell, H. (1948). The structure and function of communication in society. In L. Bryson (Ed.), *Communication of ideas* (pp. 43–71). Harper. p. 117.

Latré, E., Perko, T., & Thijssen, P. (2018). Does it matter who communicates? The effect of source labels in nuclear pre-crisis communication in televised news. *Journal of Contingencies and Crisis Management*, *26*(1), 99–112. https://doi.org/10.1111/1468-5973.12153

LeBlanc, S. (2010). *State vows to probe cause of MWRA water main break*. Metrowest Daily News. Retrieved from https://www.metrowestdailynews.com/x1195010352/State-vows-to-probe-cause-of-MWRA-water-main-break

LeBreton, J. M., & Senter, J. L. (2008). Answers to 20 questions about interrater reliability and interrater agreement. *Organizational Research Methods*, *11*(4), 815–852. https://doi.org/10.1177/1094428106296642

LeClerc, J., & Joslyn, S. (2015). The cry wolf effect and weather-related decision making. *Risk Analysis*, *35*(3), 385–395. https://doi.org/10.1111/risa.12336

Leeper, T. J. (2019). Where have the respondents gone? Perhaps we ate them all. *Public Opinion Quarterly*, *83*(S1), 280–288. https://doi.org/10.1093/poq/nfz010

Levenson, M., & Daley, B. (2010). *A "catastrophic" rupture hits region's water system*. The Boston Globe. Retrieved from http://archive.boston.com/news/local/massachusetts/articles/2010/05/02/a_catastrophic_rupture_hits_regions_water_system/?page=1

Lewicki, R. J., Barry, B., & Saunders, D. M. (2006). *Essentials of negotiation* (4th ed.). McGraw Hill.

Lindell, M. K. (2008). Cross-sectional research. In N. Salkind (Ed.), *Encyclopedia of educational psychology* (pp. 206–213). Sage.

Lindell, M. K. (2018). Communicating imminent risk. In H. Rodriguez, J. Trainor, & W. Donner (Eds.), *Handbook of disaster research* (pp. 449–477). Springer. https://doi.org/10.1007/978-3-319-63254-4_22

Lindell, M. K., Arlikatti, S., & Huang, S.-K. (2019). Immediate behavioral response to the June 17, 2013 flash floods in Uttarakhand, North India. *International Journal of Disaster Risk Reduction*, *34*, 129–146. https://doi.org/10.1016/j.ijdrr.2018.11.011

Lindell, M. K., & Brandt, C. J. (2000). Climate quality and climate consensus as mediators of the relationship between organizational antecedents and outcomes. *Journal of Applied Psychology*, *85*, 331–348. https://doi.org/10.1037/0021-9010.85.3.331

Lindell, M. K., Huang, S.-K., & Prater, C. S. (2017). Predicting residents' responses to the May 1–4, 2010, Boston water contamination incident. *International Journal of Mass Emergencies and Disasters*, *35*(1), 84–114.

Lindell, M. K., Mumpower, J. L., Huang, S.-K., Wu, H.-C., Samuelson, C. D., & Wei, H.-L. (2017). Perceptions of protective actions for a water contamination emergency. *Journal of Risk Research*, *20*(7), 887–908. https://doi.org/10.1080/13669877.2015.1121906

Lindell, M. K., & Perry, R. W. (1992). *Behavioral foundations of community emergency planning*. Hemisphere Press.

Lindell, M. K., & Perry, R. W. (2000a). Household adjustment to earthquake hazard: A review of research. *Environment and Behavior*, *32*(4), 461–501. https://doi.org/10.1177/00139160021972621

Lindell, M. K., & Perry, R. W. (2000b). Household adjustment to earthquake hazard: A review of research. *Environment and Behavior*, *32*(4), 461–501. https://doi.org/10.1177/00139160021972621

Lindell, M. K., & Perry, R. W. (2004). *Communicating environmental risk in multiethnic communities*. Sage.

Lindell, M. K., & Perry, R. W. (2007). Planning and preparedness. In K. J. Tierney, & W. F. Waugh, Jr (Eds.), *Emergency management: Principles and practice for local government* (2nd ed., pp. 113–141). International City/County Management Association.

Lindell, M. K., & Perry, R. W. (2012). The protective action decision model: Theoretical modifications and additional evidence. *Risk Analysis*, *32*(4), 616–632. https://doi.org/10.1111/j.1539-6924.2011.01647.x

Lindell, M. K., Prater, C. S., & Peacock, W. G. (2007). Organizational communication and decision making for hurricane emergencies. *Natural Hazards Review*, *8*(3), 50–60. https://doi.org/10.1061/(ASCE)1527-6988(2007)8:3(50)

Lindell, M. K., Prater, C. S., Wu, H.-C., Huang, S.-K., Johnston, D. M., Becker, J. S., & Shiroshita, H. (2016). Immediate behavioral responses to earthquakes in Christchurch New Zealand and Hitachi Japan. *Disasters*, *40*, 85–111. https://doi.org/10.1111/disa.12133

Lindell, M. K., & Whitney, D. J. (2000). Correlates of household seismic hazard adjustment adoption. *Risk Analysis*, *20*(1), 13–26. https://doi.org/10.1111/0272-4332.00002

Lindsay, J. (2010). *Catastrophic water main break leads to State of Emergency*. Metrowest Daily News. Retrieved from https://www.metrowestdailynews.com/x1195009824/Catastrophic-water-main-break-leads-to-State-of-Emergency

Lo, A. Y., & Cheung, L. T. O. (2015). Seismic risk perception in the aftermath of Wenchuan earthquakes in Southwestern China. *Natural Hazards*, *78*(3), 1979–1996. https://doi.org/10.1007/s11069-015-1815-6

Martín, Y., Cutter, S. L., & Li, Z. (2020). Bridging Twitter and survey data for evacuation assessment of Hurricane Matthew and Hurricane Irma. *Natural Hazards Review*, *21*(2), 04020003. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000354

Martin-Shields, C. (2019). When information becomes action: Drivers of individuals' trust in broadcast vs. peer-to-peer information in disaster response. *Disasters*, *43*(3), 612–633. https://doi.org/10.1111/disa.12349

Mass.gov. (2022). *Drinking water boil orders and public-health orders*. Retrieved from https://www.mass.gov/guides/drinking-water-boil-orders-and-public-health-orders

McCallum, D. B., Hammond, S. L., & Covello, V. T. (1991). Communicating about environmental risks: How the public uses and perceives information sources. *Health Education Quarterly*, *18*(3), 349–361. https://doi.org/10.1177/109019819101800307

McGuire, W. J. (1985). The nature of attitudes and attitude change. In G. Lindzey, & E. Aronson (Eds.), *The handbook of social psychology* (3rd ed., pp. 233–346). Lawrence Erlbaum.

Merkel, L., Bicking, C., & Sekhar, D. (2012). Parents' perceptions of water safety and quality. *Journal of Community Health*, *37*(1), 195–201. https://doi.org/10.1007/s10900-011-9436-9

Mileti, D. S., & Peek, L. (2000). The social psychology of public response to warnings of a nuclear power plant accident. *Journal of Hazardous Materials*, *75*(2), 181–194. https://doi.org/10.1016/S0304-3894(00)00179-5

Mulilis, J. P., & Duval, T. S. (1997). The PrE model of coping with threat and tornado preparedness behavior: The moderating effects of felt responsibility. *Journal of Applied Social Psychology*, *27*(19), 1750–1766. https://doi.org/10.1111/j.1559-1816.1997.tb01623.x

Murphy, H., Greer, A., & Wu, H. (2018). Trusting government to mitigate a new hazard: The case of Oklahoma earthquakes. *Risk, Hazards & Crisis in Public Policy*, *9*(3), 357–380. https://doi.org/10.1002/rhc3.12141

National Research Council. (1989). *Improving risk communication*. National Academies Press. Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK218586/

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.

Ott, R. L., & Longnecker, M. (2015). *An introduction to statistical methods and data analysis* (7th ed.). Duxbury.

Perry, R. W., & Lindell, M. K. (1990). *Living with Mt. St. Helens: Human adjustment to volcano hazards*. Washington State University Press.

Petty, R. E., & Cacioppo, J. T. (1986). *Communication and persuasion: Central and peripheral routes to attitude change*. Springer-Verlag.

Price, J., Fielding, K. S., Gardner, J., Leviston, Z., & Green, M. (2015). Developing effective messages about potable recycled water: The importance of message structure and content. *Water Resources Research*, *51*, 2174–2187. https://doi.org/10.1002/2014WR016514

Quarantelli, E. L. (1960). A note on the protective function of the family in disaster. *Marriage and Family Living*, *22*(3), 263–264. https://doi.org/10.2307/347652

Rasekh, A., Brumbelow, K., & Lindell, M. K. (2014). Water as warning medium: Food-grade dye injection for drinking water contamination emergency response. *Journal of Water Resources Planning and Management*, *140*(1), 12–21. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000322

Raven, B. H. (2008). The bases of power and the power/interaction model of interpersonal influence. *Analyses of Social Issues and Public Policy*, *86*(1), 1–22. https://doi.org/10.1111/j.1530-2415.2008.00159.x

Reynolds, B. J. (2011). When the facts are just not enough: Credibly communicating about risk is riskier when emotions run high and time is short. *Toxicology and Applied Pharmacology*, *254*(2), 206–214. https://doi.org/10.1016/j.taap.2010.10.023

Rigos, A., Mohlin, E., & Ronchi, E. (2019). The cry wolf effect in evacuation: A game-theoretic approach. *Physica A*, *526*, 120890. https://doi.org/10.1016/j.physa.2019.04.126

Riley, J. W., Jr, & Riley, M. W. (1965). Mass communication and the social system. In R. K. Merton, L. Brown, & L. D. Cottrell, Jr (Eds.), *Sociology Today* (Vol. 2, pp. 537–578). Harper and Row.

Ripberger, J. T., Silva, C. L., Jenkins-Smith, H. C., Carlson, D. E., James, M., & Herron, K. G. (2015). False alarms and missed events: The impact and origins of perceived inaccuracy in tornado warning systems. *Risk Analysis*, *35*(1), 44–56. https://doi.org/10.1111/risa.12262

Rogers, G. O., & Sorensen, J. H. (1988). Diffusion of emergency warnings. *Environmental Professional*, *10*(4), 185–198.

Sager, T. (1994). Power in a dialogue/technique perspective. In T. Sager (Ed.), *Communicative planning theory* (pp. 60–94). Avebury.

Schuman, H., & Kalton, G. (1985). Survey methods. In G. Lindzey, & A. Aronson (Eds.), *Handbook of Social Psychology* (3rd ed., Vol. 1, pp. 635–698). Random House.

Seeger, M. W. (2006). Best practices in crisis communication: An expert panel process. *Journal of Applied Communication Research*, *34*(3), 232–244. https://doi.org/10.1080/00909880600769944

Shannon, C. E., & Weaver, W. (1949). *The mathematical theory of communication*. University of Illinois Press.

Sharma, U., & Patt, A. (2012). Disaster warning response: The effects of different types of personal experience. *Natural Hazards*, *60*(2), 409–423. https://doi.org/10.1007/s11069-011-0023-2

Sherman-Morris, K., Poe, P. S., Nunley, C., & Morris, J. A. (2020). Perceived risk, protective actions and the parasocial relationship with the local weathercaster: A case study of Hurricane Irma. *Southeastern Geographer*, *60*(1), 23–47. https://doi.org/10.1353/sgo.2020.0003

Simmons, K. M., & Sutter, D. (2009). False alarms, tornado warnings, and tornado casualties. *Weather, Climate, and Society*, *1*(1), 38–53. https://doi.org/10.1175/2009wcas1005.1

Sivapalan, M., Savenije, H. H. G., & Bloschl, G. (2012). Socio-hydrology: A new science of people and water. *Hydrological Processes*, *26*(8), 1270–1276. https://doi.org/10.1002/hyp.8426

Sivapalan, M., Konar, M., Srinivasan, V., Chhatre, A., Wutich, A., Scott, C. A., et al. (2014). Socio-hydrology: Use-inspired water sustainability science for the Anthropocene, *Earth's Future*, *2*, https://doi.org/10.1002/2013EF000164

Steinberg, A., Wukich, C., & Wu, H.-C. (2016). Central social media actors in disaster information networks. *International Journal of Mass Emergencies and Disasters*, *34*(1), 47–74. http://www.ijmed.org/articles/692/download/

Taibah, H., & Arlikatti, S. (2015). An examination of evolving crowd management strategies at pilgrimage sites: A case study of "Hajj" in Saudi Arabia. *International Journal of Mass Emergencies and Disasters*, *33*(2), 188–212. http://www.ijmed.org/articles/677/download/

Taibah, H., Arlikatti, S., & Andrew, S. (2017). Risk communication for religious crowds: Preferences of Hajj pilgrims. *Disaster Prevention and Management*, *27*(1), 102–114. https://doi.org/10.1108/DPM-09-2017-0215

Tanellari, E., Bosch, D., Boyle, K., & Mykerezi, E. (2015). On consumers' attitudes and willingness to pay for improved drinking water quality and infrastructure. *Water Resources Research*, *51*, 47–57. https://doi.org/10.1002/2013WR014934

Terpstra, T., & Gutteling, J. M. (2008). Households' perceived responsibilities in flood risk management in The Netherlands. *International Journal of Water Resources Development*, *24*(4), 555–565. https://doi.org/10.1080/07900620801923385

Tourangeau, R. (2017). Presidential address: Paradoxes of nonresponse. *Public Opinion Quarterly*, *81*(3), 803–814. https://doi.org/10.1093/poq/nfx031

Triplett, R., Chatterjee, C., Johnson, C. K., & Ahmed, P. (2019). Perceptions of quality and household water usage: A representative study in Jacksonville, FL. *International Advances in Economic Research*, *25*(2), 195–208. https://doi.org/10.1007/s11294-019-09735-6

U.S. Environmental Protection Agency. (2003). *Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents. Contamination Threat Management Guide – Module 2*, EPA-817-D-03- 002. https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=76775

USEPA—U.S. Environmental Protection Agency. (2004). *Response Protocol Toolbox: Planning for and responding to drinking water contamination threats and incidents*. Retrieved from https://www.epa.gov/sites/production/files/2015-05/documents/drinking_water_response_protocol_toolbox.pdf

USEPA—U.S. Environmental Protection Agency (2018a). *Guidance for responding to drinking water contamination incidents*. Retrieved from https://www.epa.gov/sites/production/files/2018-12/documents/responding_to_dw_contamination_incidents.pdf

USEPA—U.S. Environmental Protection Agency (2018b). *Drinking water infrastructure needs, survey and assessment of sixth report to Congress, Office of Water (4606M)*, EPA 816-K-17-002, Retrieved from https://www.epa.gov/sites/default/files/2018-10/documents/corrected_sixth_drinking_water_infrastructure_needs_survey_and_assessment.pdf

USEPA—U.S. Environmental Protection Agency (2021a). *National Primary Drinking Water Regulations (NPDWR)*. https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

USEPA—U.S. Environmental Protection Agency (2021b). *National Secondary Drinking Water Standards: Guidance for Nuisance Chemicals (NSDWR)*. https://www.epa.gov/sdwa/secondary-drinking-water-standards-guidance-nuisance-chemicals

USEPA—U.S. Environmental Protection Agency (2021c). *Summary of the Safe Drinking Water Act (SDWA)*. https://www.epa.gov/laws-regulations/summary-safe-drinking-water-act

Wang, F., Wei, J., Huang, S.-K., Lindell, M. K., Ge, Y., & Wei, H.-L. (2018). Public reactions to the 2013 Chinese H7N9 influenza outbreak: Perceptions of risk, stakeholders, and protective actions. *Journal of Risk Research*, *21*(7), 809–833. https://doi.org/10.1080/13669877.2016.1247377

Wei, H.-L., Lindell, M. K., Prater, C. S., Wang, F., Wei, J.-C., & Ge, Y. (2018). Perceived stakeholder characteristics and protective action for influenza emergencies: A comparative study of respondents in the United States and China. *International Journal of Mass Emergencies and Disasters*, *36*(1), 52–70. http://ijmed.org/articles/739/download/

Weinstein, N. D. (1989). Optimistic biases about personal risks. *Science*, *246*(4935), 1232–1233. https://doi.org/10.1126/science.2686031

Wood, M. M., Mileti, D. S., Bean, H., Liu, B. F., Sutton, J., & Madden, S. (2018). Milling and public warnings. *Environment and Behavior*, *50*(5), 535–566. https://doi.org/10.1177/0013916517709561

Wu, H.-C., Greer, A., & Murphy, H. (2020). Perceived stakeholder information credibility and hazard adjustments: A case of induced seismic activities in Oklahoma. *Natural Hazards Review*, *21*(3), 04020017. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000378

Wu, H.-C., Greer, A., Murphy, H., & Chang, R. (2017). Preparing for the new normal: Students and earthquake hazard adjustments in Oklahoma. *International Journal of Disaster Risk Reduction*, *25*, 312–323. https://doi.org/10.1016/j.ijdrr.2017.09.033