Natural Disaster Emergency Response to Private Well User Needs: Evaluation of a Pilot Outreach Approach

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Abstract **After a flood, private well users are recommended to disinfect their well to eliminate potential microbial contamination but research gaps exist on user implementation of recommended procedures. This study evaluated a distance education class on well disinfection after severe flooding that was piloted by the Texas A&M AgriLife Extension Service. Participants submitted a well water sample for microbial analysis and completed pre- and post-class surveys. Water samples tested positive for total coliforms among 33% of well users with an income >$85,000, 85.7% with an income between $45,000 and $85,000, and 75% with an income <$45,000. Comparing participant responses on pre- and post-class surveys indicated 88% of participants improved knowledge of disinfection procedures and 46% improved well disinfection technical knowledge; however, 59% of participants who did not learn the technical steps reported increased confidence in independent well disinfection post-class. Online tools such as chlorine dose calculators could improve disinfection outcomes for those with a limited understanding of technical concepts. Evaluation of this education program provides a preliminary understanding of educational needs and highlights the potential value of distance education classes to facilitate well disinfection after natural disasters.**

Introduction

The drinking water quality of private wells is not included in the protections of the Safe Drinking Water Act, thereby leaving well users solely responsible for their water safety (Tiemann, 2017). Well stewardship comprises voluntary activities that involve water testing, treatment, and maintenance, and is generally minimal across the U.S. under both routine and emergency conditions (Gilliland et al., 2020; Malecki, Schultz, Severtson, Anderson, & VanDerslice, 2017; Pieper, Krometis, Gallagher, Benham, & Edwards, 2015; Ridpath et al., 2016). As a result, illnesses related to well water contamination have been observed (Auld, MacIver, & Klaassen, 2004; Craun et al., 2010; Wallender, Ailes, Yoder, Roberts, & Brunkard, 2014).

Microbial contamination can be introduced to private wells during flooding events, resulting in unsafe drinking water (Dai et al., 2019; Eccles, Checkley, Sjogren, Barkema, & Bertazzon, 2017; Van Biersel, Carlson, & Milner, 2007). With predicted increases in flooding risk and resulting contamination, it is imperative well users take actions to ensure their well water safety, especially in circumstances where access to recovery resources and/or well water services could be limited (Kohn et al., 2012; National Groundwater Association, 2019; Pieper et al., 2020). Knowledge of maintenance and treatment protocols is recognized as a precursor to stewardship actions (Kreutzwiser et al., 2011). A lack of information and resources has been reported to inhibit well user recovery actions postflood (Gilliland et al., 2020), but well water education has been found to motivate well users to test and conduct well maintenance (Bauder, 1993; Renaud, Gagnon, Michaud, & Boivin, 2011).

Well disinfection (also known as shock chlorination) is a commonly promoted well water recovery strategy for eliminating water microbial contamination (Pieper et al., 2020; U.S. Environmental Protection Agency [U.S. EPA], 2019). In brief, well disinfection includes the delivery of chlorine disinfectant into wells to inactivate pathogens that can cause illness upon consumption or exposure (U.S. EPA, 2019). This process usually

TABLE 1

Household Sociodemographics of Study Participants

Demographic Variable	# (%)
Household race (n = 46)	
White	42 (91.3)
Two or more races	4 (8.7)
Ethnicity (n = 46)	
Non-Hispanic or Latino	40 (87.0)
Hispanic or Latino	6 (13.0)
Household highest educational attainment (n = 45)	
<Bachelor's degree	15 (33.3)
≥Bachelor's degree	29 (64.4)
Prefer not to answer	1 (2.2)
Household income (n = 45)	
<$45,000	12 (26.7)
$45,000–$85,000	14 (31.1)
>$85,000	6 (13.3)
Prefer not to answer	13 (28.9)
Recruitment mode (n = 61)	
Neighbors or family	16 (26.2)
Radio or newspaper articles	15 (24.6)
Social media (Twitter, Facebook) or e-mail	10 (16.4)
Texas A&M AgriLife Extension Service (staff or website)	9 (14.8)
Federal Emergency Management Agency	3 (4.9)
Two sources	8 (13.1)
Neighbors or family and social media	3 (4.9)
AgriLife Extension and media	2 (3.3)
AgriLife Extension and people	1 (1.6)
AgriLife Extension and social media	1 (1.6)
Neighbors or family and media	1 (1.6)

requires user knowledge of well system characteristics, including well depth and diameter, static water level, and wellhead location. The essential technical knowledge required for well disinfection includes chlorine dose calculations and pH adjustments to ensure functional disinfection. Prior research has evaluated the effectiveness of well disinfection (Eykelbosh, 2013; Pieper et al., 2020), but research gaps exist on how well users implement published guidelines.

The aim of this study was to evaluate the impact of a pilot disinfection class on well user knowledge on where to access resources, knowledge and application of disinfection protocols in a classroom setting, and reported self-confidence of independently conducting well disinfection.

Methods

In response to extreme flooding in October 2018, the Texas Well Owner Network (TWON), part of the Texas A&M AgriLife Extension Service, coordinated a low-cost ($10) well water microbial screening event. This event was offered on November 5 and 6, 2018, at four AgriLife Extension county offices in flood-impacted, rural counties: Burnet, Llano, Mason, and San Saba. The event was promoted through the TWON and Texas Water Resource Institutes networks (e.g., websites, e-mail listservs, social media accounts) and through news media outlets (e.g., newspapers, television, and radio). Participants independently collected well water samples from a faucet as close to the well as possible after 2 min of flushing, and then brought samples to the local extension office. Samples were processed within 30 hr of collection and the presence of total coliforms and *E. coli* were detected using the IDEXX Colilert method.

Well Disinfection Class Description and Setting

On November 8, 2018, screening results were returned at a 1.5-hr class on well disinfection presented using a Web-conferencing platform at the AgriLife Extension county offices. This class was held approximately 19 days after flooding subsided (Lower Colorado River Authority, 2020) and 3 days after water sample screening. The class covered how to access well characteristics, flood-related microbial contaminants, and disinfection procedures. In addition, a variety of handouts were available for participants during the class. Personnel at each office were present to distribute sample results prior to the class, oversee and collect pre- and post-class surveys, and provide handouts after the class. In addition, staff assisted in answering attendee questions throughout the class.

Survey Design and Measures

Pre- and post-class surveys were given to all class participants to evaluate the class in improving knowledge of well disinfection. Evaluated areas included knowledge of where to access well maintenance resources, disinfection procedures, and perspectives on well disinfection. Survey information was also used to identify education needs and class structure preferences, as well as sociodemographic information. The surveys were developed in response to the flooding event and were not evaluated for validity and/or reliability prior to dissemination. The pre-survey was distributed after participants received their water screening results and before the presentation. The post-survey was distributed following the presentation. This work was conducted under Louisiana State University Health Sciences Center Institutional Review Board approval (IRB 9549).

TABLE **2**

Differences in Microbial Detection and Participant Information Needs by Annual Household Income

Variable	Annual Household Income			*p*-Value*
	<$45,000	$45,000–$85,000	>$85,000	
	# (%)	# (%)	# (%)	
Microbial detection	12	14	6	
Total coliforms detected	9 (75.0)	12 (85.7)	2 (33.3)	**.01**
E. coli detected	3 (25.0)	2 (14.3)	0 (0)	.1
Reported information needs	11	13	6	
Information about what to test well water for	6 (54.5)	5 (38.5)	4 (66.7)	.06
Well testing laboratories and contact information	3 (27.3)	5 (38.5)	2 (33.3)	.11
How to identify well issues after flood/disaster	3 (27.3)	5 (38.5)	1 (16.7)	.09
Information about well design and susceptibility	2 (18.2)	1 (7.7)	1 (16.7)	.16
Well maintenance providers and contact information	1 (9.1)	2 (15.4)	3 (50.0)	**.03**
Where to find information about your specific well (e.g., well depth, year of construction, etc.)	2 (18.2)	3 (23.1)	3 (50.0)	.05
How to disinfect well water	8 (72.7)	6 (46.2)	5 (83.3)	**.03**
How to prepare well before flood/other disaster	3 (27.3)	5 (38.5)	0 (0)	**.04**
Water treatment options	5 (45.5)	5 (38.5)	4 (66.7)	.06
Information about general well maintenance	6 (54.5)	8 (61.5)	3 (50.0)	.1

*Fisher's exact test. Bolded *p*-values indicate a statistically significant difference.

Statistical Analysis

Descriptive statistics were used to analyze measures collected from the pre- and post-class surveys. Wilcoxon sign-rank tests and McNemar's tests (exact McNemar's for small sample sizes) were used to evaluate class impacts on assessed outcomes. Chi-square tests of independence and Fisher's exact tests were used to identify associations between outcomes and sociodemographics. Significance level was defined as $\alpha < .05$. All statistical analyses were conducted using SAS version 9.4.

Results

A total of 138 participants attended the education class at the four county locations and 62 participants filled out at least one survey (44.9% response rate). Both a pre- and post-class survey were completed by 52 participants (37.7%). Survey question-specific response rates ranged from 62.3–98.4%, with only 14.8% of participants completing the free response question regarding suggestions for class improvement.

Sociodemographics and Study Recruitment

Class participants (n = 46) mainly self-reported as White (91.3%), with 13.0% identifying as Hispanic or Latino (Table 1). The majority of participants (n = 45) reported holding a bachelor's degree or higher (64.4%) and one third reported making an income between $45,000 and $85,000 (31.1%). Two participants reported a primary household language other than English.

Study participants (n = 61) reported learning about the education class through multiple outlets: 26.2% reported hearing from neighbors or family, 24.6% from radio or newspaper, 16.4% from Internet sources (e.g., Twitter, Facebook, or e-mail), 14.8% from the Texas A&M AgriLife Extension via its staff or website, and 4.9% from the Federal Emergency Management Agency. Almost one fifth (13.1%) of participants learned of the class through two or more sources, most commonly from neighbors or family and Internet sources (4.9%).

Water Sample Microbial Detection

Overall, 78.3% of wells (n = 60) tested positive for total coliforms and 18.3% were positive for *E. coli*. Water samples from well users who reported an income >$85,000 ($n$ = 6) were significantly less likely to test positive for total coliforms (33.3%), as compared with those with an income <$45,000 ($n$ = 12, 75.0%) or between $45,000 and $85,000 ($n$ = 14, 85.7%); p = .01; Table 2).

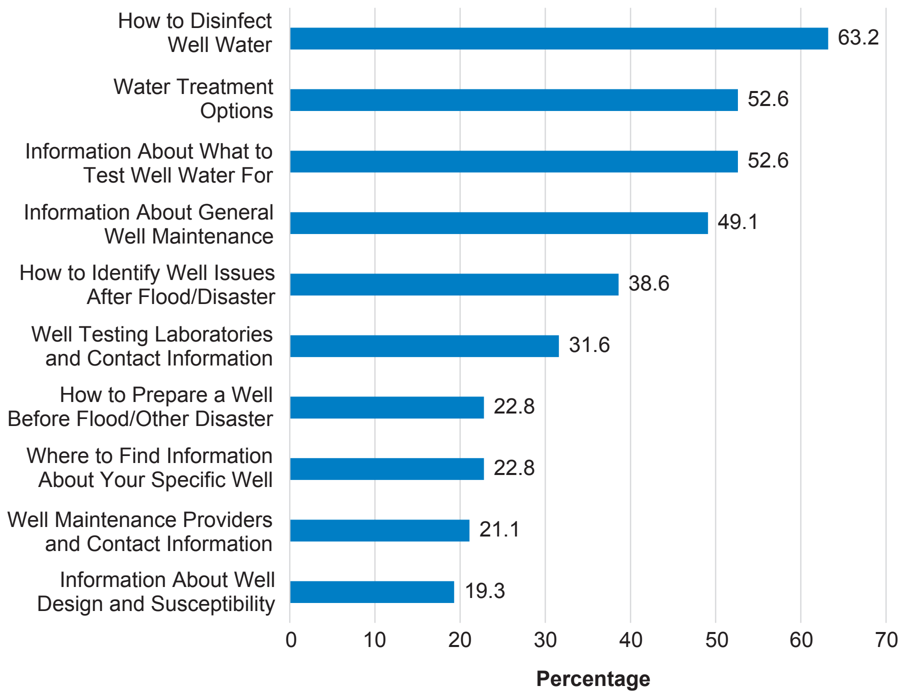
Class Content Preferences

Participants (n = 57) reported on topics they preferred to learn from the class. Most participants preferred to learn independent well disinfection (63.2%), what to test well water for (52.6%), water treatment options (52.6%), and general well maintenance information (49.1%) from the class (Figure 1).

Those with an income between $45,000 and $85,000 ($n$ = 13, 46.2%) were significantly less likely to report independent well disinfection as a class content preference compared with those who had an income <$45,000 ($n$ = 12, 72.7%)

FIGURE 1

Class Content Preferences of Class Participants (*n* = 57)



or >$85,000 ($n = 6$, 83.3%; $p = .03$; Table 2). Of the six participants who preferred to learn information on well maintenance providers, three reported an annual household income >$85,000 and one reported an annual household income <$45,000. Information requests on recommended well water tests and well treatment options were uniform across income brackets ($p = .06$ and $p = .06$, respectively).

Impact of the Class on Ability to Locate Resources

Before the class, 44.9% of participants ($n = 49$) perceived well recovery information and resources to have been available after the flood. Self-assessed participant ($n = 53$ for all but testing where $n = 52$) ability to locate well stewardship resources was limited: 32.1% of participants knew how to locate information on well system characteristics, while similar knowledge was reported by 26.4% about well treatment systems, 38.5% for well water testing, and 32.1% for disinfection procedures (Table 3). Reported knowledge of locating well water treatment and testing resources was observed to be higher post-class (92.0%; $n = 51$).

Impact of the Class on Well Disinfection Knowledge

Class attendees were asked two test questions on class content both pre- and post-class to evaluate knowledge gained.

Disinfection Protocols With Well Damage

Participants ($n = 43$) were asked, "Should you try to shock chlorinate your well system if you see damage to the well such as cracks or openings to the environment?" Prior to the class, 23.3% of participants correctly answered the question, 74.4% of participants marked "don't know," and one participant marked an incorrect answer (Table 4). The class presentation specified that well damage (e.g., cracks or corrosion in the well casing) should be fixed prior to disinfection.

After the class, 88.4% of the participants ($n = 43$) answered the question correctly, 7.0% reported "don't know," and 4.7% answered incorrectly (Table 4). Those who reported an incorrect answer or "don't know" response on the pre-class survey ($n = 33$) were significantly more likely to answer the question correctly after the class (12.1% incorrect versus 87.9% correct; $p < .0001$). Of those who marked "don't know" prior to the class ($n = 32$), 87.5% answered the question correctly after the class. One participant who answered the question correctly before the class responded with the incorrect answer to the same question after the class.

Calculating Well Disinfection Chlorine Dose

Participants' ability to calculate a chlorine dose for well disinfection was evaluated. Participants were given the following scenario: "Use the table below to determine the amount of chlorine bleach needed to shock chlorinate a 150-ft well with a 6-in. well casing and a static water level of 100 ft." A standard chlorine dose table was provided. Prior to the class ($n = 37$), only two participants (5.4%) answered this question correctly (Table 4). Specifically, 64.9% marked "don't know" and 29.7% answered the question incorrectly. Of those who answered incorrectly pre-class ($n = 11$), 27.2% used static water level as the water depth variable and 72.7% did not account for static water level when determining water depth.

The same scenario was given on the post-class survey ($n = 37$). After the class, 45.9% of participants correctly answered the question, 45.9% incorrectly answered, and 8.1% marked "don't know" (Table 4). Of those who answered incorrectly post-class ($n = 17$), 41.2% used static water level as the water depth variable and 58.8% did not account for static water level when determining water depth. One half (50%) of those who marked "don't know" on the pre-class survey ($n = 24$) correctly answered the question post-class. Overall, the post-survey ($n = 37$) reflected that 40.5% participants learned how to calculate a chlorine dose after the class. Those who reported an incorrect answer or "don't know" response on the pre-class survey ($n = 35$) were significantly less likely to correctly answer the question on the post-class survey (54.3% incorrect versus 43.2% correct, $p = .0003$).

Assessed Knowledge Compared With Self-Perceptions

Participants ($n = 51$) reported being significantly more comfortable independently disinfecting their well water after the class (45.3% before versus 74.5% after; $p < .0001$; Table 3). Comfort in ensuring drinking water safety postflood ($n = 50$) was significantly higher post-class (32.7% before versus 90.0% after; p

TABLE **3**

Participant Agreement With Well Maintenance and Class-Related Statements Ranked on a 5-Point Likert Scale

Statement	#	Disagree	Neutral	Agree	Don't Know	*p*-Value
		# (%)	# (%)	# (%)	# (%)	
Pre-class survey						
Information and resources were available to help address our well recovery needs after the flood.	49	2 (4.1)	8 (16.3)	22 (44.9)	17 (34.7)	–
I am comfortable shock chlorinating my well by myself.	53	17 (32.1)	2 (3.8)	24 (45.3)	10 (18.9)	–
I am comfortable ensuring the safety of my drinking water after floods.	52	14 (26.9)	8 (15.4)	17 (32.7)	13 (25.0)	–
I know where to find information about my specific well.	53	12 (22.6)	5 (9.4)	17 (32.1)	19 (35.8)	–
I know where to find information and resources related to well treatment systems.	53	13 (24.5)	9 (17.0)	14 (26.4)	17 (32.1)	–
I know where to find information for well testing.	52	9 (17.3)	10 (19.2)	20 (38.5)	13 (25.0)	–
I know where to find information about how to shock chlorinate my well.	53	14 (26.4)	8 (15.1)	17 (32.1)	14 (26.4)	–
Post-class survey						
This class made me more comfortable in shock chlorinating my well by myself.	51	3 (5.9)	8 (15.7)	38 (74.5)	2 (3.9)	**<.0001**[a]
I know where to find information and resources related to well water treatment and testing.	51	0 (0)	4 (7.8)	46 (90.2)	1 (2.0)	–
This class covered the information I came here for.	49	1 (2.0)	8 (16.3)	39 (79.6)	1 (2.0)	–
I would recommend this class to a friend or neighbor.	51	0 (0)	6 (11.8)	43 (84.3)	2 (3.9)	–
I would prefer to take this class online.	50	12 (24.0)	15 (30.0)	16 (32.0)	7 (14)	–
This class made me more comfortable ensuring the safety of my drinking water after floods.	50	0 (0)	4 (8.0)	45 (90.0)	1 (2.0)	**<.0001**[b]
I feel that this class changed my attitude on the importance of well maintenance.	51	0 (0)	10 (19.6)	38 (74.5)	3 (5.9)	–
I think the length of the class should be shorter.	51	10 (19.6)	32 (62.7)	4 (7.8)	5 (9.8)	–
I would like to have seen the disinfection process being conducted at a well.	50	6 (12)	23 (46.0)	20 (40.0)	1 (2.0)	–
I would have liked more handouts.	49	14 (28.6)	21 (42.9)	12 (24.5)	2 (4.1)	–
The question/answer session of this class is helpful.	51	1 (2.0)	10 (19.6)	38 (74.5)	2 (3.9)	–
The lecture presentation of this class is helpful.	51	0 (0)	6 (11.8)	43 (84.3)	2 (3.9)	–
I feel that this class could be improved.	50	12 (24.0)	22 (44.0)	11 (22.0)	5 (10.0)	–

Note. Disagree = Likert scale 1–2; Neutral = Likert scale 3; Agree = Likert scale 4–5. Bolded *p*-values indicate a statistically significant difference.

[a]Wilcoxon signed-rank test comparing the difference between "I am comfortable shock chlorinating my well myself" in the pre-class survey and "This class made me more comfortable in shock chlorinating my well by myself" in the post-class survey.

[b]Wilcoxon signed-rank test comparing the difference between "I am comfortable ensuring the safety of my drinking water after floods" in the pre-class survey and "This class made me more comfortable ensuring the safety of my drinking water after floods" in the post-class survey.

$< .0001$). Participants who correctly calculated a bleach dose after the class were significantly more likely to report an increased confidence in independent well disinfection as compared with those who did not correctly calculate a bleach dose (77.8% versus 59.1%; $p = .02$; Table 5). The majority of participants who were unsure or unable to calculate the correct bleach dose reported the class increased their comfort in independently disinfecting their well (59.1% agree versus 13.6% disagree, 22.7% neutral, 4.6% don't know; Table 5).

TABLE **4**

Changes in Assessed Participant Well Disinfection Knowledge From Class Content

Pre-Class Survey Answers of Content Knowledge Question	# (%)	Post-Class Survey Answer			*p*-Value[a]
		Don't Know	Incorrect	Correct	
		# (%)	# (%)	# (%)	
Disinfection with well damage present[b]	43	3 (7.0)	2 (4.7)	38 (88.4)	**<.0001**
Don't know	32 (74.4)	3 (9.4)	1 (3.1)	28 (87.5)	
Incorrect	1 (2.3)	0 (0)	0 (0)	1 (100)	
Correct	10 (23.3)	0 (0)	1 (10.0)	9 (90.0)	
Calculation of a chlorine bleach dose[c]	37	3 (8.1)	17 (45.9)	17 (45.9)	**.0003**
Don't know	24 (64.9)	3 (12.5)	9 (37.5)	12 (50.0)	
Incorrect	11 (29.7)	0 (0)	7 (63.6)	4 (36.4)	
Correct	2 (5.4)	0 (0)	1 (50.0)	1 (50.0)	

Note. Bolded *p*-values indicate a statistically significant difference.
[a]Exact McNemar's test, "don't know," and incorrect responses collapsed into one response.
[b]Answers to question asked in both pre- and post-class surveys: "Should you try to shock chlorinate your well system if you see damage to the well such as cracks or openings to the environment?"
[c]Answers to scenario given in both pre- and post-class surveys: "To the best of your knowledge, please use the table below to determine the amount of chlorine bleach needed to shock chlorinate a 150-ft well with a 6-in. well casing and a static water level of 100 ft." A standard chlorine dose table was provided.

Participant Class Preferences, Opinions, and Suggestions

Overall, participants agreed they would recommend the class to others (n = 51, 84.3%). Most reported the class covered their respective information needs (n = 51, 79.6%) and found the presentation and question/answer session helpful (n = 51, 84.3% and 74.5%, respectively; Table 3). Only 7.8% of participants (n = 51) preferred a shorter class (62.7% were neutral) and 24.5% (n = 49) would have liked more handouts (42.9% were neutral). A large portion of the class would have preferred a live demonstration of well disinfection (40.0%), but 46.0% were neutral about viewing the disinfection process at a well. Eleven participants (22.0%) felt the class could be improved. Suggested improvements included more handouts and fixing technical issues (e.g., larger screen, better sound quality).

Discussion

To our knowledge, this study is the first to evaluate a user education class on emergency well disinfection practices. This TWON education class aimed to develop an understanding of disinfection to mobilize knowledge needs and resources education to affected well users. Recommendations for how to improve class outreach, class content, delivery, and evaluation are discussed in the following sections.

Outreach

The findings of the evaluation of this pilot class suggest modifications to the recruitment strategy are necessary for emergency response preparation. Similar to previous findings, participants with low incomes had higher detection of microbial contamination (Smith et al., 2014), indicating this group would most benefit from well disinfection, and therefore this class. Difficulties in accessing the low-income population are compounded when in a rural area, as in this study (Texas Department of State Health Services, 2020). Previous research suggests increased advertising, especially sharing recruitment announcements with schools and churches, and including the low costs of participation on advertisements can help overcome recruitment barriers to accessing low income, rural populations (Friedman, Foster, Bergeron, Tanner, & Kim, 2015; Murimi & Harpel, 2010).

Class Content

Through this pilot class, participants reported learning well disinfection protocols and how to access resources. A lack of access to needed resources has been identified as a barrier to recovery efforts (Gilliland et al., 2020) and these results suggest that content included in this class could help to overcome this barrier. Increased knowledge of a technical skill needed for chlorine dose calculation was observed among 40% of participants; however, 50% of participants were not able to calculate a correct dose. One of the primary challenges for this particular class was simplifying the technical concepts behind dose calculation in such a way that it could be rapidly understood and correctly applied. In the pilot class, key terms (i.e., static water level, water depth in well, and total well depth) and the steps to find static water level were clearly defined. More than one half of study participants, however, still did not grasp this topic. Therefore, instead of well users relying on technical knowledge for postflood well disinfection, it might be advisable to use online tools and resources that simplify technical content. For example, instructors can demonstrate to well users how to look up best-estimate chlorine doses based on their specific (or estimated) well system characteristics using online calculators (Eykelbosh, 2013). Online videos can be used to reinforce

TABLE **5**

Participant Perceptions of Well Maintenance Ability Compared With Tested Knowledge Post-Class

Post-Class Tested Knowledge	#	Comfortable Independently Shock Chlorinating Well					Comfortable Ensuring Water Safety Postcontamination Event				
		Disagree	Neutral	Agree	Don't Know	*p*-Value[a]	Disagree	Neutral	Agree	Don't Know	*p*-Value[a]
		# (%)	# (%)	# (%)	# (%)		# (%)	# (%)	# (%)	# (%)	
Disinfection with well damage present[b]	43					.07					.05
Participant unable or unsure	6	0 (0)	1 (16.7)	4 (66.7)	1 (16.7)		0 (0)	1 (16.7)	4 (66.7)	1 (16.7)	
Participant able	37	3 (8.1)	7 (18.9)	26 (70.3)	1 (2.7)		0 (0)	3 (8.3)	33 (91.7)	0 (0)	
Calculation of a chlorine bleach dose[c]	40					**.02**					.16
Participant unable or unsure	22	3 (13.6)	5 (22.7)	13 (59.1)	1 (4.6)		0 (0)	3 (13.6)	18 (81.8)	1 (4.6)	
Participant able	18	0 (0)	3 (16.7)	14 (77.8)	1 (5.6)		0 (0)	1 (5.6)	17 (94.4)	0 (0)	

Note. Bolded *p*-values indicate a statistically significant difference.
[a]Fisher's exact test.
[b]Based on answers to question asked in post-class survey: "Should you try to shock chlorinate your well system if you see damage to the well such as cracks or openings to the environment?"
[c]Based on answers to scenario given in post-class survey: "To the best of your knowledge, please use the table below to determine the amount of chlorine bleach needed to shock chlorinate a 150-ft well with a 6-in. well casing and a static water level of 100 ft." A standard chlorine dose table was provided.

learning, although such services might be limited with disruptions to power and Internet access in the postdisaster period (Gilliland et al., 2020).

Recommendations for Improving Class Content and Delivery

Class content should meet the local population's knowledge needs, be delivered in a way that is succinct but thorough, and match the comprehension level of those attending (Morris, Wilson, & Kelly, 2016). In this study group, only one half of participants correctly calculated a bleach dose after the class, despite the higher education level of participants. There are a variety of reasons that could underlie this finding. The process of calculating a chlorine dose was the most challenging concept class participants were exposed to, and subsequently tested on, during the class. The identification of the correct chlorine dose for disinfection has been observed to be limited among lay persons (Levy et al., 2014).

Knowledge of well depth and casing diameter is important for well disinfection. One participant indicated they did not know their well depth, which is a barrier to well disinfection that has been reported in previous literature (Gilliland et al., 2020). One solution to this lack of knowledge is to hold a preclass workshop to help participants locate their well characteristics through various resources. Chlorine doses for each participant's well can then be calculated with help from proctors during class, thereby facilitating effective future well maintenance.

Recommendations for Improving Study Design and Class Evaluation

As with all education programs, future well disinfection classes should continue to be evaluated. Participants were given resource material highlighting all of the necessary steps to well disinfection to inform future use. Encouraging participants to use this information while completing the post-class survey will test if these resources can be accurately interpreted, and the content question results will more likely mimic participant behavior in the real world with access to these materials.

For the sake of brevity, this survey only evaluated two components of the entire lesson. To more thoroughly assess the clarity of different topics presented, questions targeting specific topics can be used to evaluate the class, which in turn would help fine-tune presentations and resource distribution on each topic. Reviewing answers to the questions with the participants will allow participants to inform class presenters as to why they did not understand specific material. In this way, one might be able to differentiate problems based on technical difficulties (e.g., sound difficulties) versus content presentation challenges.

Asking participants if they know their well depth can gauge previous knowledge of their well system. Restructuring survey questions to explicitly reflect positive changes, rewording potentially biasing questions, and adding questions to more completely assess learning will also be beneficial to future evaluations. Results from a question about participant perception of current well water quality was removed from analysis because participants viewed the results for their water sample before filling out the pre-survey. Revising the wording of some questions will reduce participant misinterpretation or clarify responses. For example, 74.5% of participants agreed the class changed their attitude on the importance of well maintenance; however, it was unclear whether the change was positive or negative.

Study Limitations

Possible bias within the study results might have arisen from selection bias from the study recruitment method and the nature of self-reported data. Reported information needs, perceptions, and content learning might have been biased due to the requirement of attending the education class to receive results, results being distributed before participants were surveyed, and for reasons inherent in the class improvement suggestions listed by participants (e.g., stand closer to the microphone, use a bigger viewing screen). Furthermore, low sample size and missing responses for some questions might have biased the results.

Conclusion

This pilot class on well disinfection education, developed rapidly as an emergency-recovery response to a flooding event, increased the resource access and disinfection knowledge of attendees. Results suggest class attendees learned information necessary to overcome flood recovery barriers. Technical components of well disinfection could be better implemented by using chlorine dose calculators that are available online. With improvements to the class content and delivery, this class can serve as a foundation for future education classes to reduce safe water access barriers within rural, flood-affected populations. These results underscore the importance of class evaluations to measure outcomes and assess knowledge gaps.

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References

Auld, H., MacIver, D., & Klaassen, J. (2004). Heavy rainfall and waterborne disease outbreaks: The Walkerton Example. *Journal of Toxicology and Environmental Health, Part A*, *67*(20–22), 1879–1887.

Bauder, J.W. (1993). Assessing extension program impact: Case study of a water quality program. *Journal of Natural Resources and Life Science Education*, 22, 138–144.

Craun, G.F., Brunkard, J.M., Yoder, J.S., Roberts, V.A., Carpenter, J., Wade, T., . . . Roy, S.L. (2010). Causes of outbreaks associated with drinking water in the United States from 1971 to 2006. *Clinical Microbiology Reviews*, *23*(3), 507–528.

Dai, D., Rhoads, W.J., Katner, A., Strom, L., Edwards, M.A., Pruden, A., & Pieper, K.J. (2019). Molecular survey of *Legionella* and *Naegleria fowleri* in private well water and premise plumbing following the 2016 Louisiana flood. *Environmental Science: Water Research & Technology*, *5*, 1464–1477.

Eccles, K.M., Checkley, S., Sjogren, D., Barkema, H.W., & Bertazzon, S. (2017). Lessons learned from the 2013 Calgary flood: Assessing risk of drinking water well contamination. *Applied Geography*, *80*, 78–85.

Eykelbosh, A.J. (2013). *Review of guidelines for shock chlorination in private wells*. Vancouver, Canada: National Collaborating Centre for Environmental Health, British Columbia Centre for Disease Control. Retrieved from https://ncceh.ca/documents/evidence-review/review-guidelines-shock-chlorination-private-wells

Friedman, D.B., Foster, C., Bergeron, C.D., Tanner, A., & Kim, S.-H. (2015). A qualitative study of recruitment barriers, motivators, and community-based strategies for increasing clinical trials participation among rural and urban populations. *American Journal of Health Promotion*, *29*(5), 332–338.

Gilliland, A.E., Pieper, K.J., Straif-Bourgeois, S., Rhoads, W.J., Dai, D., Edwards, M., . . . Katner, A. (2020). Evaluation of preparedness and recovery needs of private well users after the Great Louisiana Flood of 2016. *Journal of Public Health Management and Practice*. Advance online publication. Retrieved from https://pubmed.ncbi.nlm.nih.gov/32332488/

Kohn, S., Eaton, J.L., Feroz, S., Bainbridge, A.A., Hoolachan, J., & Barnett, D.J. (2012). Personal disaster preparedness: An integrative review of the literature. *Disaster Medicine and Public Health Preparedness*, *6*(3), 217–231.

Kreutzwiser, R., de Loë, R., Imgrund, K., Conboy, M.J., Simpson, H., & Plummer, R. (2011). Understanding stewardship behaviour: Factors facilitating and constraining private water well stewardship. *Journal of Environmental Management*, *92*(4), 1104–1114.

Levy, K., Anderson, L., Robb, K.A., Cevallos, W., Trueba, G., & Eisenberg, J.N.S. (2014). Household effectiveness vs. laboratory efficacy of point-of-use chlorination. *Water Research*, *54*, 69–77.

Lower Colorado River Authority. (2020). *Hydromet historical data by gauge; October 1, 2018–November 1, 2018*. Retrieved from https://hydromet.lcra.org/HistoricalData

Malecki, K.M.C., Schultz, A.A., Severtson, D.J., Anderson, H.A., & VanDerslice, J.A. (2017). Private-well stewardship among a general population based sample of private well-owners. *Science of the Total Environment*, *601–602*, 1533–1543.

Morris, L., Wilson, S., & Kelly, W. (2016). Methods of conducting effective outreach to private well owners—A literature review and model approach. *Journal of Water and Health*, *14*(2), 167–182.

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References *continued from page 23*

Murimi, M.W., & Harpel, T. (2010). Practicing preventive health: The underlying culture among low-income rural populations. *The Journal of Rural Health*, *26*(3), 273–282.

National Groundwater Association. (2019, March 25). *The National Ground Water Association reports thousands of wells potentially affected by Midwestern flooding* [Press release]. Retrieved from https://www.ngwa.org/publications-and-news/Newsroom/2019-press-releases/ngwa-reports-thousands-of-wells-potentially-affected-by-midwestern-flooding

Pieper, K.J., Krometis, L.-A.H., Gallagher, D.L., Benham, B.L., & Edwards, M. (2015). Incidence of waterborne lead in private drinking water systems in Virginia. *Journal of Water and Health*, *13*(3), 897–908.

Pieper, K.J., Rhoads, W.J., Saucier, L., Katner, A., Barrett, J.R., & Edwards, M. (2020). Improving state-level emergency well disinfection strategies in the United States. *Science of the Total Environment, 720,* 137451.

Renaud, J., Gagnon, F., Michaud, C., & Boivin, S. (2011). Evaluation of the effectiveness of arsenic screening promotion in private wells: A quasi-experimental study. *Health Promotion International*, *26*(4), 465–475.

Ridpath, A., Taylor, E., Greenstreet, C., Martens, M., Wicke, H., & Martin, C. (2016). Description of calls from private well owners to a national well water hotline, 2013. *Science of the Total Environment*, *544*, 601–605.

Smith, T., Krometis, L.-A.H., Hagedorn, C., Lawrence, A.H., Benham, B., Ling, E., . . . Marmagas, S.W. (2014). Associations between fecal indicator bacteria prevalence and demographic data in private water supplies in Virginia. *Journal of Water and Health*, *12*(4), 824–834.

Texas Department of State Health Services. (2020). *Definitions of county designations*. Retrieved from https://www.dshs.texas.gov/chs/hprc/counties.shtm

Tiemann, M. (2017). *Safe Drinking Water Act (SDWA): A summary of the act and its major requirements* (No. RL31243). Retrieved from https://fas.org/sgp/crs/misc/RL31243.pdf

U.S. Environmental Protection Agency. (2019). *Private drinking water wells*. Retrieved from https://www.epa.gov/privatewells

Van Biersel, T.P., Carlson, D.A., & Milner, L.R. (2007). Impact of hurricanes storm surges on the groundwater resources. *Environmental Geology*, *53*(4), 813–826.

Wallender, E.K., Ailes, E.C., Yoder, J.S., Roberts, V.A., & Brunkard, J.M. (2014). Contributing factors to disease outbreaks associated with untreated groundwater. *Ground Water*, *52*(6), 886–897.