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Journal of Water & Health

IWA PUBLISHING

Journal of Water and Health Vol 20 No 1, 1 doi: 10.2166/wh.2021.018

Evaluating the impact of free private well testing outreach on participants' private well stewardship in New Jersey

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ABSTRACT

Over 1 million people in New Jersey (NJ) are estimated to receive drinking water from private wells. The most commonly detected contaminants in NJ private well water are naturally occurring arsenic and gross alpha (8.3 and 10.9%, respectively). Between 2015 and 2018, three free and voluntary private well testing events tested a total of 571 at-risk wells and 226 (40%) were identified as having one or more contaminants exceeding drinking water standards. Participants were invited to complete a survey to evaluate household characteristics, participant experience, and private well stewardship behavior patterns. Of 529 delivered surveys, 211 (40%) participants completed surveys. Among respondents, 63% reported plans to test their private wells in the future. Among failed wells, 45% of households reported performing mitigative action in response to the event, either through the installation of water treatment system or switching to bottled water. The survey evaluation identified previous knowledge of well contamination risks and discussing test results with a third party as important factors for promoting self-reported stewardship behavior. The evaluation provides guidance for outreach organizers to develop effective testing events and further considers the private well owners' experience of the outreach events to identify information for 'best practices' and improvements of future programs.

Key words: health promotion, outreach, outreach evaluation, private well, water testing, well stewardship, well water contaminants

HIGHLIGHTS

- Less than half of participants report plans to perform mitigative action in response to exceeding contamination levels.
- This evaluation provides feedback and information which can be used to improve future voluntary private well outreach events.
- In addition, this study is one of the few to consider participants' experience toward free private well testing events.

INTRODUCTION

An estimated 1 million people in New Jersey (NJ) receive their drinking water from private wells (Flanagan *et al.* 2016). While public water supplies are protected under both the federal and state Safe Drinking Water Acts, private well owners are solely responsible for monitoring and maintaining the quality of their drinking water (Shaw *et al.* 2005; Zheng & Flanagan 2017). Chemicals from natural or anthropogenic origin occur in the environment and contaminate private well water supplies (DeSimone *et al.* 2009). More than 20% of tested wells in the US have one or more contaminants exceeding standards (Colley *et al.* 2019). Exposure to contaminants over the recommended drinking water standards (USEPA 2020) could result in acute and chronic health conditions including gastrointestinal illness, cancer, cardiovascular disease, and developmental or birth defects (Lewandowski *et al.* 2008; Cappello *et al.* 2013; Paul *et al.* 2015; Zheng & Flanagan 2017). The most commonly detected contaminants to exceed primary Maximum Contaminant Levels (MCLs) in NJ private well water are arsenic in Northern NJ and gross alpha in Southern NJ (8.3 and 10.9%, respectively) (NJDEP 2021), which naturally occur in the geologic formation.

In 2002, NJ passed the Private Well Testing Act (PWTA). This legislation requires private well testing for certain contaminants before the sale or lease of a property. Since the adoption of NJ PWTA over 100,000 wells have been tested, yet this represents only 25% of the total estimated number of wells in the state. Although this law has increased the number of private wells tested, it does not require owners to take mitigative actions such as installing and maintaining treatment and performing follow-up or regular testing to ensure water quality (Flanagan *et al.* 2016).

Private well water testing is the first step in which individuals can directly assess exposure and is the only way to determine the presence of many contaminants like arsenic and radioactive elements in water, which are odorless, colorless, and tasteless (NJDEP 2004; ATSDR 2007; Flanagan *et al.* 2016). Compliance with well testing guidance varies across regions and demographics but testing rates overall are low (Roche *et al.* 2013; Flanagan *et al.* 2016; Malecki *et al.* 2017; Seltenrich 2017; Munene & Hall 2019). Similar to testing practices, rates of subsequent mitigative action, including installing and maintaining water treatment (Kreutzwiser *et al.* 2011) are low. Studies have found that a quarter of participants reported taking no mitigative action when well water was found to have contaminants exceeding MCLs (Kreutzwiser *et al.* 2011; Flanagan *et al.* (2015a, 2016, 2018)).

Motivations and barriers to private well stewardship have been classified into four domains: knowledge, risk perception, convenience, and social norms (Malecki *et al.* 2017; Colley *et al.* 2019), and three major reasons cited for not testing include lack of perceived problem, no prior knowledge on how/what to test for, and not having pregnant women and children in the home (Paul *et al.* 2015; Malecki *et al.* 2017). Major motivations for treatment cited were organoleptic properties, such as hardness, presence of iron, and/or taste and smell of water. Studies have found that private well users additionally felt no need for treatment if they have been drinking water in the home for years without previous issues (Flanagan *et al.* 2015b; Malecki *et al.* 2017). Flanagan *et al.* (2016) found lower educational level, greater years lived in the home, and lower household income as significant factors which can negatively impact having ever tested or having tested during real estate transfer (Flanagan *et al.* 2015b, 2016; Munene & Hall 2019). Flanagan *et al.* (2016) also found that social norms play a role in testing, such that knowledge of friends or neighbors having tested increases the odds of individuals testing their own wells (Flanagan *et al.* 2016). Identifying the motivations and barriers to testing and treatment of private wells can be used to improve the implementation of future policies and interventions.

Besides legislation to require testing, studies suggest that planned interventions/programs can be effective at increasing private well screening/testing through means of addressing the barriers to the behavior (Renaud *et al.* 2011; Morris *et al.* 2016; Paul *et al.* 2015). One way to promote private well stewardship is through outreach events. Identification of population characteristics, attitudes, and behaviors can help in developing effective outreach events (Morris *et al.* 2016).

The NJ Departments of Health (NJDOH) and Environmental Protection (NJDEP) conducted three free and voluntary private well testing events across different communities in NJ during 2015–2018. The aim of the private well testing events was to increase private well testing and awareness of stewardship among owners by providing water testing results, mitigation recommendations, and educational resources. Following completion of the events, in 2019, event participants were given a survey to evaluate household characteristics, participant feedback regarding their experience with participation, and stewardship behavior patterns. This project presents the findings from the evaluation across the three private well outreach events with a focus on private well stewardship among the participants.

METHODS

The free private well testing campaigns occurred in different communities in NJ at high risk of private well water contamination from naturally occurring contaminants between the years of 2015 and 2018. Outreach methods, sample collection, testing strategies, and participation requirements for the campaigns/events differed (Table 1). Event A participants were recruited through a school-based program (methods published elsewhere – Rockafellow-Baldoni *et al.* 2020), wells were tested for arsenic and boron, and sample collection was performed by the participants who were given a sample collection bottle and instructions for collecting their water sample from their kitchen faucet. Participants from Event B and C were recruited from the community using flyers posted in community centers and on municipal websites. Both raw (untreated water) and treated water (when treatment was present) were tested for gross alpha and nitrates in Event B and gross alpha and other additional measures of radioactivity in Event C. For both Event B and C, sample collection was performed by an experienced well sampler, contracted for the projects, because the analysis for gross alpha must be performed within 24-hours of sample collection. Communication strategies for all three events were similar. All participants in either of the three

Table 1 | Event strategies and methods

Event characteristic	Event A	Event B	Event C
Recruitment strategy	School-based	Community-based	Community-based
Registration method	Paper	Online	Online
Partnerships	Environmental Commission, School partners	Environmental Commission	Township administration
Tested parameters	Arsenic Boron	Gross alpha Nitrates	Gross alpha Radionuclides
Sample location	Kitchen sink	Raw and treated	Raw and treated
Sample collection	Self-collected	Professionally collected	Professionally collected
Communication methods	Tailored letters	Tailored letters Public meeting	Tailored letters Public meeting

Other contaminants were tested for but were not considered in the survey analysis.

events were provided with a recruitment or informational flyer regarding event details including contact information for the event organizers. Tailored results letters were structured to be easy to understand and provide clear recommendations and outlined health risks associated with exposure to contaminated drinking water.

A total of 571 wells were tested. For each outreach event, water analyses were performed by a certified laboratory, and all participants received individualized letters through email or standard mail which included information regarding recommendations on future testing, water treatment, health effects, and additional resources. In early 2019, participants in the events were mailed the same self-administered survey – approximately 1–3 years following participation in one of the three outreach events. To encourage survey return, participants were mailed a tote bag which said 'Protect Your Family – Test Your Well water' upfront in appreciation of their time and a prepaid return envelope.

SURVEY

The survey contained three broad sections: household characteristics, event experience, and stewardship actions (see Supplementary Material). Household characteristic questions included open-ended and multiple-choice questions including whether a pregnant individual resided in the household at the time of participation in the event, number of adults in the home (coded as '1 to 2 adults' and 'greater than 2 adults'), number of children in home ('0 children' or '1 or more children'), number of children outside the household who use their tap water ('0 children' or '1 or more children'), the age of the youngest child living in the home (in years), residence status of the home (homeowner or renter), years lived in home ('1 to 10 years' and 'greater than 10 years'), frequency of using well water for drinking (coded as frequent 'mostly or always' or less frequent 'rarely, sometimes or never'), and discussion of test results with someone outside the home ('yes' or 'no'). The combined total number of children utilizing the tap water ('0 children' or '1 or more children') was calculated from survey responses and respondents were coded to the event they participated in (Event A, B, and C). If any of the tested contaminants described above exceeded their respective NJ MCL, the well test result was deemed as fail, and test results were coded as a binary variable (pass, fail).

Questions regarding event experience included participant feedback on communication during the event, satisfaction with their participation in the event, and prior knowledge before event participation. There were six questions pertaining to communication, three regarding satisfaction and three regarding knowledge prior to the event. The event experience questions were asked in a Likert scale range including 1 (disagree), 2 (neutral), and 3 (agree) and an additional 'not applicable' category was included for responses to communication questions when a respondent did not have a relevant communication experience ('not applicable' was coded as missing). The questions in each group (communication, satisfaction, and prior knowledge) were summed for a total score and the average score of each category was obtained. Additionally, the event experience variables were categorized as either 'agree' (equal to maximum total score) or 'disagree' (less than maximum total score).

The primary self-reported stewardship outcomes included multiple-choice responses to the following: having previously tested their well water before their participation in the event ('previous testing'), reporting plans to test their well water in the future ('future testing'), and performing mitigative action due to event recommendations defined as installing water treatment system or using bottled water as a source of drinking water ('performed mitigative action').

DATA ANALYSIS

Descriptive statistics and analyses were conducted using IBM SPSS statistical software (version 26.0). Pearson's Chi-square test, with a significance level of 0.05, was used to compare differences in proportions between Pass/Fail results of respondents and by each of the three event locations ('A', 'B', 'C') and Kruskal–Wallis test was used to compare differences in medians. Total scores, means, and standard deviation were calculated for event experiences (communication, satisfaction, and knowledge) and were analyzed by each event. Differences between event experience and event location were determined using one-way ANOVA, with significance < 0.05. Binary logistic regression was performed to estimate the association between dichotomized household participant characteristics and dichotomized event experience ('agree' v. 'disagree') on stewardship behavior outcomes ('future testing' and 'performed mitigative action').

RESULTS

Participant characteristics

Among the 571 mailed surveys, 34 (6%) of surveys were unable to be delivered (return to sender, unable to forward, or vacant), and 8 (1%) participants moved since their participation in the outreach event for a remaining total of 529 eligible households. A total of 211 (40%) completed surveys were returned and included in the analysis (five surveys were unable to be paired with private well test results and their event location and excluded from analysis). While survey responses cannot be compared between respondents and non-respondents, there was no significant difference between percentage of failed wells between survey respondents and non-respondents (data not shown). Between the three events, Event A participants had the lowest response rate at 28% ($n = 105$ out of 376), while Events B and C had comparable response rates of 58% ($n = 58$ out of 100) and 50% ($n = 47$ out of 94), respectively (Table 2). There was not a significant difference between the percentage of survey respondents with passing water results versus failed (p-value $= 0.18$) Event C had the highest rate of failure (81%), followed by Event B (56%), and Event A (30%) (Table 2).

The following results are summarized in Table 2. Survey respondents were mostly homeowners (91% ($n = 192$)) with 16 years as the median years in residence (range 0–70). More than half of the households had children living in the home (56% ($n = 118$)) with a median age of the youngest child being 11 years old (range 0–19) and 27% ($n = 56$) of respondents reported that additional children, besides their own, use their well water. Most households (67%) reported using well water for drinking purposes 'mostly' or 'always.' There were no significant differences between these characteristics among respondents with failing water results compared with those with passing results. The only significant difference was the frequency results were discussed with someone outside the home, with 74% of households with failing results reported discussing results with someone outside of the home compared with 60% of households with passing results ($p < 0.05$) (Table 2). Of the respondents who reported discussing their results with another person, most reported discussing their test results with either a friend/relative (25%) or a neighbor (23%), while another 33% ($n = 66$ out of 202) of survey participants did not discuss results with anyone (results not shown).

Participant event experience

A majority of the participants reported that communication of results (83%), risks (72%), and recommendations (70%) were clear. Participants also reported high satisfaction regarding the event, with 84% reporting that the events were easy to participate in, 85% were glad they participated, and 84% reported that they would participate again. Prior to participating in the event, 12% of participants reported having no prior knowledge of possible private well contamination, 7% reported not knowing they should test their private wells, and 17% reported not knowing their wells were vulnerable to contaminants (data not shown).

There was not a significant difference in respondents' overall experience with communication across the three events ($p = 0.13$) (Table 3). However, respondents who participated in Event C reported having lower trust that event organizers would keep them up to date with any changes compared with higher levels of reported trust among Event B respondents (p-value < 0.05). Satisfaction with participation in the event was generally positive but there was a significant difference between the events, as Event C had the lowest levels of satisfaction ($p < 0.001$). Although not indicative of event experience, participants were asked to rate their prior level of knowledge pertaining to private well water risk. Event C participants also reported significantly lower levels of prior knowledge compared to the other two events ($p < 0.001$) (Table 3).

Table 2 | Household characteristics of survey respondents by test results and event location (*n* (%)) ($n = 211$)

Household characteristic	Overall	'Passed' results	'Failed' results	*p*-value	Event A	Event B	Event C	*p*-value
Pregnant	4 (1.9)	3 (2.8)	1 (1.0)	0.34	2 (1.9)	1 (1.7)	1 (2.1)	0.99
Children in home	118 (55.9)	62 (59.6)	56 (55.4)	0.55	73 (70.9)	22 (38.6)	23 (51.1)	< 0.001**
Average age of youngest child (yrs.)	Median 11, Range 0–19	Median 10, Range 0–19	Median 9, Range 2–17	0.78	Median 10, Range 0–19	Median 9 Range 2–17	Median 12, Range 1–19	0.51
Children outside of home	56 (26.5)	31 (32.6)	25 (26.3)	0.34	27 (28.4)	21 (38.9)	8 (19.5)	0.12
Children using tap	140 (66.4)	76 (70.4)	71 (68.9)	0.74	83 (78.3)	38 (65.5)	26 (55.3)	0.01*
Adults living alone	9 (4.3)	7 (6.6)	2 (2.0)	0.10	4 (3.8)	5 (8.6)	0 (0)	0.09
Residence type				0.29				0.18
Own	192 (91.0)	95 (91.3)	97 (95.1)		91 (90.1)	55 (94.8)	46 (97.9)	
Rent	14 (6.6)	9 (8.7)	5 (4.9)		10 (9.9)	3 (5.2)	1 (2.1)	
Years in residence	Median 16, Range 0–70	Median 15, Range 0–60	Median 18, Range 1–55	0.20	Median 15, Range 0–60	Median 18, Range 1–55	Median 17, Range 0–70	0.19
Frequency of drinking well water				0.06				0.30
Mostly or Always	141 (66.8)	74 (70.5)	67 (65.0)		75 (72.8)	37 (63.8)	29 (61.7)	
Sometimes	27 (12.8)	17 (16.2)	10 (9.7)		12 (11.7)	9 (15.5)	6 (12.8)	
Rarely or Never	40 (19.0)	14 (13.3)	26 (25.2)		16 (15.5)	12 (20.7)	12 (25.5)	
Discussion of Test Results*	133 (63.0)	59 (60.2)	74 (74.0)	0.04*	57 (60.0)	47 (82.5)	29 (63.0)	0.01*
Survey Participation	211 (39.9)	108 (51.2)	103 (48.8)	0.18	106 (28.2)	58 (58.0)	47 (50.0)	< 0.001**
Test Results								< 0.001**
Pass	108 (51.2)	N/A	N/A		74 (69.8)	25 (43.1)	9 (19.1)	
Fail	103 (48.8)	N/A	N/A		32 (30.2)	33 (56.9)	38 (80.9)	

p-value calculated from Pearson's Chi-squared test for categorical variables. *p*-values for continuous variables calculated by Kruskal–Wallis test.
**p*-value < 0.05.
***p*-value < 0.001.
N/A, not applicable.

Stewardship behavior

Most respondents reported testing their private wells prior to participation in the event (79%, $n = 161$). With the option to select multiple responses, the most common reasons given for previously testing wells included real estate transaction (52%, $n = 106$), participation in a prior community event (19%, $n = 38$), and concern for water quality (26%, $n = 53$); 21% ($n = 43$) of participants reported not having previously tested their well (Supplementary Material, Table 1). A total of 130 out of 205 (63%) survey respondents reported that they plan to test their private wells in the future; reasons for testing included: to confirm recent test results (16%), to confirm the effectiveness of a water treatment system (9%), and general plans to test in the future (48%). There is no significant difference in reported plans of future testing between household with passing or failing test results (Supplementary Material, Table 1).

Among survey respondents with failed test results who responded either 'Yes, now drink bottled water' or 'Yes, installed a treatment system' ($n = 93$), 42 (45%) reported taking action in response to the event, with 18% ($n = 17$) reported using bottled water as a drinking source and 29% ($n = 27$) reported installing a water treatment system. Of the participants reporting that they will perform no action due to having safe water ($n = 70$), 26% had failed test results. Of the people who reported having

Table 3 | Mean agreement (standard deviation) with survey statements regarding event communications, satisfaction and prior knowledge ($n = 211$)

Survey statement (1/Disagree–3/Agree)	Event A Mean (Sd)	Event B Mean (Sd)	Event C Mean (Sd)	*p*-value
Overall Communication	14.73 (3.52)	15.61 (2.48)	14.32 (4.02)	0.132
The results of the letter were clear and understandable	2.82 (.49)	2.93 (.26)	2.74 (.54)	0.106
I learned about the health risks associated with contaminants in my well water	2.76 (.54)	2.79 (.46)	2.63 (.70)	0.368
Recommendations were clear and helpful	2.68 (.61)	2.80 (.45)	2.55 (.71)	0.118
I knew who to reach out to if I had questions	2.62 (.64)	2.73 (.56)	2.46 (.82)	0.118
My questions were answered clearly	2.61 (.62)	2.66 (.57)	2.43 (.78)	0.225
I trusted event organizers would keep me up-to-date with any changes	2.60 (.62)	2.80 (.48)	2.36 (.77)	0.004*
Overall Satisfaction	8.29 (1.30)	8.91 (0.34)	7.96 (1.65)	< 0.001**
Participation in the event was easy and straightforward	2.79 (.48)	2.97 (.18)	2.62 (.65)	< 0.001**
I am glad I participated	2.77 (.49)	2.97 (.18)	2.74 (.54)	0.010*
I would participate in an event like this again	2.77 (.47)	2.98 (.13)	2.65 (.67)	< 0.001**
Overall Prior knowledge	8.32 (1.20)	7.24 (1.85)	6.41 (2.15)	< 0.001**
Did you know there could be contaminants that are harmful to your health in your well water	2.78 (.44)	2.36 (.74)	2.04 (.82)	< 0.001**
Did you know you should have your well water tested for contaminants	2.81 (.44)	2.55 (.68)	2.35 (.82)	< 0.001**
Did you know wells in your area are vulnerable to naturally occurring contaminants	2.73 (.58)	2.33 (.83)	2.02 (.80)	< 0.001**

Each question was asked utilizing Likert scale 1–3 with 1 – disagree and 3 – agree. Six questions for communication, with the highest possible score of 18. Three questions for satisfaction, with the highest possible score of 9. Three questions for prior knowledge, with the highest possible score of 9. Higher values indicated greater communication, satisfaction with event or more prior knowledge before the event.
Overall means for each event are highlighted.
p-value calculated from Pearson's Chi-squared test.
**p*-value < 0.05.
***p*-value < 0.001.

treatment installed prior to private well testing event ($n = 53$), 28% had failed test results. Among the events, Event A participants reported a higher percentage of the previous testing due to participation in a prior event (Supplementary Material, Table 1). Overall, 54% ($n = 114$ out of 211) of survey participants reported some type of water treatment system already installed or which they installed following event participation, while 21% ($n = 44$ out of 211) of households utilized bottled water as a drinking water source prior to and after event. In total, 59% of households reported utilizing some form of mitigation before or after event participation (Supplementary Material, Table 1).

Survey respondents who reported discussing their private well test results with someone have greater odds of planning future well testing by a factor of 2.33 (95% CI: 1.26–4.30) compared to individuals who did not report discussing results (Table 4). Individuals who had prior knowledge of well water risks were 1.99 times (95% CI: 1.12–3.55) more likely to plan future well testing compared to those who had no prior knowledge. There were no significant differences between the household characteristics and whether a household reported plans to test their private well again in the future.

Among the wells with failed test results, survey respondents who reported discussing their results had higher odds of reporting taking mitigative action, when compared to those who did not discuss by a factor of 2.91 (95% CI: 1.02–8.32). Perception of the event experience was not found to be significantly associated with taking recommended mitigative action (Table 4). There were no significant differences between household characteristics or event experience and whether a household reported taking mitigative action due in response to recommendations (when results were restricted to failed households).

DISCUSSION

These voluntary private well testing events helped to increase the number of wells tested in NJ and raise awareness of potential risks of private well contamination. Overall, households reported a positive experience from participating in the water

Table 4 | Proportion and unadjusted odds ratio of survey respondents reporting plans to test private well in the future and taking mitigative action by household characteristics, test results and event experience

Variable	Future private well testing ($n = 211$)				Taking mitigative action ($n = 103$)			
	N (%)				*N* (%)			
	No Plans to test	Plans to test	*p*-value	OR (95% CI)	No Action	Action	*p*-value	OR (95% CI)
Adult			0.06				0.75	
>2 Adults	13 (25.5)	38 (74.5)		1.94 (0.98–4.04)	11 (52.4)	10 (47.6)		1.17 (0.44–3.11)
1–2 Adults	62 (40.5)	91 (59.5)		Reference	40 (56.3)	31 (43.7)		Reference
Children			0.36				0.88	
≥1 Child	50 (36.2)	88 (63.8)		1.37 (0.70–2.67)	35 (54.7)	29 (45.3)		1.08 (0.41–2.81)
0 Child	21 (43.8)	27 (56.3)			13 (56.5)	10 (43.5)		Reference
Residence			0.30				0.21	
Rent	7 (50)	7 (50)		0.56 (0.19–1.67)	1 (25.0)	3 (75.0)		3.95 (0.40–39.46)
Own	68 (36.0)	121 (64.0)		Reference	50 (54.3)	38 (43.2)		Reference
Years in home			0.80				0.22	
>10 Years	57 (37.3)	96 (62.7)		0.92 (0.47–1.78)	37 (51.4)	35 (48.6)		1.89 (0.68–5.24)
1–10 Years	18 (35.3)	33 (64.7)		Reference	14 (66.7)	7 (33.3)		Reference
Frequency of well water use			0.13				0.61	
Less frequent	29 (43.9)	37 (56.1)		1.59 (0.87–2.89)	18 (51.4)	17 (48.6)		0.80 (0.35–1.86)
More frequent	46 (33.1)	93 (66.9)		Reference	33 (56.9)	25 (43.1)		Reference
Previously tested			0.11				0.97	
Yes	53 (33.1)	107 (66.9)		1.76 (0.89–3.48)	40 (55.6)	32 (44.4)		0.98 (0.36–2.65)
No	20 (46.5)	23 (53.5)		Reference	11 (55.0)	9 (45.0)		Reference
Discussed results			**0.006****				**0.04***	
Yes	40 (30.1)	93 (69.9)		**2.33 (1.26–4.30)**	33 (47.8)	36 (52.2)		**2.91 (1.02–8.32)**
No	32 (50.0)	32 (50.0)		Reference	16 (72.7)	6 (27.3)		Reference
Test result			0.93				0.52	
Fail	37 (36.3)	65 (63.7)		1.03 (0.58–1.81)	20 (60.6)	13 (39.4)		0.75 (0.31–1.80)
Pass	38 (36.9)	65 (63.1)		Reference	30 (53.6)	26 (46.4)		Reference
Communication			0.61				0.27	
Agree	29 (39.7)	44 (60.3)		0.86 (0.47–1.56)	40 (58.8)	28 (41.2)		0.59 (0.23–1.51)
Disagree	44 (36.1)	78 (63.9)		Reference	11 (45.8)	13 (54.2)		Reference
Satisfaction			0.88				0.15	
Agree	56 (36.8)	96 (63.2)		1.05 (0.54–2.03)	22 (64.7)	12 (35.3)		0.53 (0.22–1.26)
Disagree	19 (38.0)	31 (62.0)		Reference	29 (49.2)	30 (50.8)		Reference
Prior knowledge			**0.02***					
Yes	30 (29.1)	73 (70.9)		**1.99 (1.12–3.55)**	35 (55.6)	28 (44.4)	0.84	1.09 (0.46–2.62)
No	45 (45.0)	55 (55.0)		Reference	16 (53.3)	14 (46.7)		Reference

Pearson's Chi-squared test used to evaluate categorical variables.
**p*-value < 0.05.
***p*-value < 0.01.

testing events, with a majority reporting that the communication throughout the event was timely and clear and that they would participate again in a similar event. This is encouraging as clear dissemination of results and recommendations can lead to a greater understanding of the issue and allow well owners to take action accordingly. Insight into the participants' opinions of the testing events can help strengthen future outreach programs.

A majority of participants discussed their results with individuals outside the home, with households with failing results having higher rates of discussion. Individuals who discussed the event's test results with someone reported significantly higher rates of planning future testing than individuals who did not discuss results. In addition, households who discussed test results were 2.9 times more likely to report taking mitigative action, similar to findings published by Flanagan *et al.* 2018. Among the events, Event B had the largest percentage of households who discussed their test results. Project coordinators strongly encouraged participants in Event B to share their results with friends and neighbors, and it is encouraging to learn that this behavior is associated with increased stewardship during these events. Several studies have previously reported an association between stewardship behavior and discussion, which could be due to social network influencing behavior (Renaud *et al.* 2011; Colley *et al.* 2019).

Although it is difficult to confirm if actual stewardship action occurred, it is encouraging to note that verbal acknowledgement of intentions can increase the likelihood of said behavior (Morris *et al.* 2016). Studies also indicate that social networks are an important factor for information dissemination, cues to action, and setting social norms for behavior (Colley *et al.* 2019). Discussion of the testing events could further encourage individuals who did not directly participate in the events to test their own wells, as studies have found that individuals are more likely to be concerned for health and test wells if they live close to wells, which have been found contaminated (Morris *et al.* 2016; Flanagan *et al.* 2020). Future private well outreach initiatives may consider offering free testing 'coupons' for participants to share with their neighbors to further take advantage of the impact of social networks on subsequent mitigative action. Respondents who reported previous knowledge of risks of well water contamination were almost twice as likely to report plans to test their private well in the future. Therefore, it is possible that community-level private well educational efforts may improve private well stewardship following private well testing outreach.

Of the households who participated, most respondents reported having more than one adult living in the home, having at least one child in the home, and having additional children living outside the home utilizing the well water. Therefore, the well testing events have the potential to reduce hazardous drinking water exposure to the whole family and other water users; especially as most participants reported using their private well water for drinking. Event A had the greatest number of well samples tested and the greatest number children in the home. This event used a school-based method to recruit participants allowing targeting of homes with children (Rockafellow-Baldoni *et al.* 2020). By having children deliver the invitation to participate in the well testing may have motivated well owners to participate. Furthermore, children are particularly vulnerable to the developmental effects of contaminants, including arsenic and gross alpha, making them an important target group for hazard reduction.

Respondents from Event B scored communication during the event more positively as compared to respondents from Event C. Although the survey tool cannot be used to assess why scores were higher, some differences in Event B implementation include relying largely on online sign-ups with email required, although mail-in registration and communication was also available. The online sign-up allowed for program organizers to more easily and frequently communicate with participants on a regular basis including registration confirmation, reminders and follow-ups, and invitation to a public meeting to provide an overview of results (presented at an aggregate level to maintain confidentiality) and answer questions regarding health effects and treatment. Unlike Event C, for which communication was scored the lowest, both Event A and B were co-sponsored by the local environmental health commissions which may have provided a community contact in which some participants may have more trust.

Most survey respondents (79%) reported having previously tested their private well. This rate is comparable between the event locations and with previous studies, where overall testing rates in high-risk areas were above 82% in New Jersey and 78–89% in Maine (Flanagan *et al.* 2016; Malecki *et al.* 2017). Of those who reported previously testing, almost half (52%) did so due to a real estate transaction, indicative of the effectiveness of NJ PWTA increasing testing rates. Of the individuals who reported previously testing their private wells, 39% failed the recent test results. This could suggest either previous testing did not include testing for contaminants targeted in the outreach events or lack of subsequent installation and/or maintenance of an effective treatment system. It is also possible that contaminant levels have changed over time, which highlights the importance of regular private well testing (Flanagan *et al.* 2016; Malecki *et al.* 2017).

Over half of participants reported plans to perform future testing (63%), regardless of the test result from the private well testing events. This means that individuals may continue to monitor private wells and thus reduce the risk of exposure, although the intention is not a guarantee that they will follow through on their plan. Individuals who reported having previous knowledge of private well risks also had a greater likelihood of reporting plans to perform future testing. Several studies have demonstrated that knowledge is an influencing factor, with lack of knowledge being negatively associated with well testing (Colley *et al.* 2019).

When asked if any action was performed due to recommendations of the event, 42 of the 93 (45%) failed households indicated either installing a water treatment system in the home (29%) or switching to drinking bottled water (17%). Additionally, 42 of the 119 (35%) failed households reported previously performing mitigative action prior to the testing event, with households reporting already having a water treatment system installed (28%) or utilizing bottled water as a drinking source (14%). In another survey of New Jersey residents, 54% of households with an identified problem installed a treatment system, while 10% reported resorting to drinking water bottles (Flanagan *et al.* 2016). While in Maine, 43% installed a treatment system and 27% switched to bottled water (Flanagan *et al.* 2016). Self-reported mitigation does not guarantee that households will install and maintain proper treatment systems (Flanagan *et al.* 2018).

Among those that reported having treatment installed prior to participation in the event ($n = 53$), 49% still had failed results, and among respondents who reported taking no action because they have safe water ($n = 70$), 26% had failing water results. This percentage of taking no action to reduce exposure is similar to rates seen in other studies which range from 27 to 40% (Flanagan *et al.* 2018). These results show that there are still individuals at risk of hazardous drinking water, due to either the inability to understand their results letter which explains that their water test failed, the mistaken belief that a failed water test is not a health risk, that they have an ineffective or unmaintained water treatment system, or they do not have the resources to obtain a treatment system. Studies indicate that individuals often inaccurately recall test results, and oftentimes downgrade problematic information (Malecki *et al.* 2017). Despite providing free water testing, communication regarding the need and maintenance of treatment is critical. Future outreach initiatives should seek to increase the comprehensibility of results and recommendations. Although the majority of participants felt the communication of results and recommendations were clear, there were households who disagreed with statements on clear communication (with 6% of households reporting unclear risks, and 7% reporting unclear recommendations). In addition, without results of the raw water, participants may not appreciate the underlying danger; and without results post-treatment, participants may have a false sense that they have effective treatment. Testing both raw and treated water may allow outreach organizers to communicate risk and provide recommendations more effectively.

This work is one of the first to evaluate subsequent private well stewardship behavior of participants participating in free and voluntary private well testing outreach in New Jersey. Several studies have published results from surveys of New Jersey private well owners' stewardship behaviors and attitudes, but these studies investigated the effectiveness of the PWTA (Flanagan *et al.* 2016, 2018). Similarly, some studies used mailed surveys to collect data on stewardship information after dissemination of test results, but these studies differ as they recruited participants from different populations, only focused on the behavior of households with failed results (with focus on arsenic), or acquired well test results from geological survey testing (Severtson *et al.* 2006; Flanagan *et al.* 2015a, 2015b; Malecki *et al.* 2017). Future direction can include further analysis of underlying demographic factors of the participants which could influence stewardship outcomes. Furthermore, future studies are needed to confirm if participants of private well testing events actually follow through on their self-reported plans to identify the effectiveness of programs.

LIMITATIONS

This study had a few limitations. First, an original questionnaire was developed to evaluate the effectiveness of private well testing events and results may not be comparable to previous studies. There is also the possibility of bias in the study, due to the nature of self-reporting. With differences in the time frame between the event and the survey, there is the possibility of recall bias which could differ among event respondents due to the date of survey and differing dates of participation. In addition, non-response bias could occur, as the response rate was 41% and may not be a representative sample of voluntary event participants. The non-response also limited the sample size, which reduces the power of analysis. The generality of the stewardship questions limited the amount of information gathered. For example, although over half of participants reported plans to test their private well in the future, no information was gathered on the type of testing in which they plan to perform. It is possible that the impact of recommendations to encourage participants to take mitigative action is underestimated since the questionnaire does not capture those that may still take action. Lastly, this survey captured data from participants from three different private well testing events. The difference between the events could influence results and interpretation, including the contaminant of concern tested for and treatment options. For instance, effective treatment for radium is a water softener, which is commonly installed for the treatment of water hardness and iron, a common problem in some areas, and is more affordable than the treatment for arsenic which is also more difficult to install and maintain (Spayd *et al.* 2015).

CONCLUSION

This study not only demonstrates that free and voluntary private well testing events increased the number of wells tested for contaminants of local risk, leading to the reduction of hazardous drinking water in some homes, but also identifies factors that influence self-reported stewardship behavior and can guide outreach organizers to develop effective testing events. This evaluation also provides a framework and baseline to evaluate the success of future free and voluntary private well outreach events and also considers the private well owners' experience of the outreach events, which could provide vital information toward the improvement of future programs including allowing online registration and email communication, co-sponsoring with local trusted partners, providing raw and treated water tests, and encouraging participants to discuss their participation and results with neighbors and friends. Successful outreach programs not only identify barriers to the behavior but incorporate the needs of the community in which they serve (Morris *et al.* 2016). Securing a sustainable funding stream through federal, state, and local budgets will be integral for the promotion and continuation of free private well testing programs.

DATA AVAILABILITY STATEMENT

Data cannot be made publicly available; readers should contact the corresponding author for details.

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First received 21 January 2021; accepted in revised form 8 November 2021. Available online 19 November 2021