Final Report to New Jersey Water Resources Research Institute (NJWRRI)

Project title:

Reducing public exposure to common, harmful well water contaminants through targeted outreach to highly susceptible neighborhoods as a method of increasing likelihood of testing and treatment of water from private wells

Authors:

Kristi MacDonald and Mara Tippett

Raritan Headwaters Association (RHA)

P.O. Box 273

Gladstone, NJ 07934

www.raritanheadwaters.org

November 5, 2019

Executive Summary:

- While public water is required by state and federal law to be tested by water purveyors for a variety of contaminants, private well owners are responsible for testing and treating their own water.
- In the Upper Raritan region (WMA8) of New Jersey, 80% of the drinking water comes from private wells yet only a small percentage of well owners test their wells annually and many never test at all for common and potentially harmful groundwater contaminants.
- Finding effective ways to inform residents of the risks associated with their private well drinking water and promoting action to test and treat water for common contaminants is a challenge faced by agencies concerned with public health at the federal, state, and local level.
- In this study, several hypotheses were tested related to perceived risk and the health action of testing and treating well water that may vary with proximity and type of contaminant. Insights into whether a spatial model for predicting private wells at risk for contamination was explored based on rate of wells exceeding drinking water standards if a neighbor's well exceeded as compared to rate of wells exceeding in the general population of a region.
- Data from the Raritan Headwaters Association (RHA) Well Test Program (www.testmywell.org) collected from Raritan and Bethlehem townships in Hunterdon Co., New Jersey, USA were used to identify private wells that exceeded state and federal drinking water standards for 5 common, harmful contaminants of groundwater in our region: arsenic, radionuclides (radon and Gross Alpha), E. *coli*, and nitrates. Residents within 1,000 feet of the well address (n=2106) received notification that a nearby well had a specific contaminant(s) above the Maximum Contaminant Level (MCL) and a random sample of residents (n=491) received a letter that provided information on the regional rates of exceedances of the MCLs for the 5 contaminants. All were encouraged to test their well water through RHA's discounted well testing program.
- Overall, 10% (n=258) of people receiving letters responded and of these, 71% (n=183) tested their wells. Individuals who received specific letters that a contaminant in a neighbor's well had exceeded the MCL were more likely to test their well than were individuals who received a general letter about common contaminants in the region. Of those receiving letters regarding specific contaminant(s) in a local well, 8.2% (n=172) tested their well whereas of those receiving a general letter only 2.2% (n=11) tested. The likelihood of testing did not differ between townships or among the type of contaminants. Outreach that reports more localized, specific information on contaminants in well water results in an increased chance of testing as compared to more regional and generalized contaminant information.
- Of individuals who tested, 29% detected a contaminant above the MCL. A telephone survey of these participants was conducted to explore whether residents treated the water. Of the 22 survey respondents, 36% (n=8) treated their well water as a result of their test exceeding the drinking water standard. However, very few respondents (5%, n=1) reported switching their water source as a result of testing. Prior to testing, 36% (n=8) drank bottled water, 23% (n=5) drank unfiltered well water, and the rest drank filtered well water. Ninety-five percent of participants did not switch their water source after learning that their well exceeded the drinking water standard for one or more contaminants. Most respondents indicated that testing increased their confidence in their well water, even if they learned their water was exceeding the drinking water standard for a contaminant. In addition,

nearly all respondents planned to test their well again in the future. These results indicate that a large portion of well test participants are not treating contaminants that exceed the drinking water standards. In addition, it appears that initial testing and detection of exceedances promotes future testing.

- The likelihood of exceeding the drinking water standard for at least one of the 5 contaminants from a sample of 189 individual tests was 18% (n=34) for those receiving a letter about a specific exceedance locally whereas the likelihood of exceeding the MCL for one of those 5 contaminants in the two municipalities between 2012 and 2018 (n=1607) was 5% (n=86). None of the towns showed a higher likelihood for exceeding the MCL for arsenic or Gross Alpha if a neighbor exceeded for those contaminants, respectively. However, for Bethlehem Township and both towns combined, E. *coli* and nitrate had a higher likelihood of exceeding the MCL if a neighbor's well exceeded. Furthermore, for towns combined but not individual townships, radon had a higher likelihood of exceeding federal guidelines if a neighbor's well exceeded as compared to the combined township data from 2012-2018. This indicates that in some but not all cases, the likelihood of exceeding may be predicted to some degree based on existing well test data and outreach to residences may be targeted.
- While letters about local contaminants does help target residents and boost testing to some extent, more research is needed on how to get the majority of residents to respond with health actions of testing and treating their private well water. Further studies into how the originating source of outreach information impacts perceived reliability of data are needed. In addition, developing predictive models of likelihood of exceedances for contaminants will help to make outreach more efficient and successful in reaching those most at risk.

Keywords: Private wells, drinking water, groundwater quality, health actions, testing, treatment, arsenic, public health, E. *coli*, nitrate, uranium, Gross Alpha, radionuclides

Acknowledgements: This study was made possible through a grant from NJ Water Resources Research Institute (NJWRRI) at the NJ Agricultural Experiment Station Water Resources Program, Rutgers University and funds from Raritan Headwaters. For various contributions to the project we thank Kathy Katz and Deborah Hawkins (RHA), Chris Obropta, Elizabeth Pyshnik, and Rahman Rafique (NJ Agricultural Experiment Station Water Resources Program, Rutgers University), Kristina Gonzales (Raritan Scholars Program, Rutgers University). The map was produced by Melissa Mitchell Thomas (RHA).

Introduction/Background:

According to the 2009 American Housing Survey, about 15.8 million homes in the U.S. are served by a private well (U.S. Census Bureau, 2009), and the majority of these households are located in rural areas (Simpson, 2004). Unlike public water supplies which have federal and state requirements for regular testing and treatment, private well owners are largely responsible for the safety of their own water. The U.S. Geological Survey (USGS) reports that more than 20% of 2,100 private domestic wells sampled nationwide from 1991–2004 contained at least one contaminant at levels of potential health concern (DeSimone et al., 2009). About 13% of New Jersey residents or 1.15 million people get their drinking water from private wells. Of the roughly 300,000 private wells in NJ, only 20-25% of them have been tested at least once under the 2002 Private Well Testing Act (NJDEP, 2016), potentially leaving as many as 80% of the remaining wells in the state unmonitored for water quality. Thus, there is a critical need to better inform private well owners of the risks of contaminants exceeding drinking water standards in their well water in ways that will result in health actions including testing and treatment.

In the Upper Raritan Watershed Region (WMA8), eighty percent of residents rely on underground aquifers that supply their private wells with drinking water and nearly all of the remainder use groundwater from municipal or community wells (MacDonald and Thomas, 2016). Groundwater is used to irrigate much of the farmland in the watershed. Some of the groundwater remains underground in aquifers for hundreds or thousands of years but much of it is moving as it seeps from the ground into our streams and rivers. The streams that come from the headwaters region eventually flow into the Lower Raritan River that supplies drinking water to 1.5 million people outside our watershed. Finally, the water reaches Raritan Bay where it mixes with ocean water to form the lifeblood of the estuaries there. Groundwater matters to public health and the health of our ecosystems in far-reaching ways.

Contaminants including arsenic, nitrates, coliform bacteria, lead, radon, volatile organic compounds and pesticides, all of which pose threats to our health, are commonly found in drinking water from private wells in the region. Table 1 provides an overview of environmental sources, state and federal Maximum Contaminant Levels (MCLs), health impacts and testing requirements for the 5 common well water contaminants in this study. Sources of high levels of nitrate and E. *coli* include activities associated with urban, agricultural and industrial land uses (Naylor et al., 2018; Squillace et al., 2002; Swistock & Sharpe, 2005; Gonzales, 2008) whereas sources of arsenic, radon, and Gross Alpha are naturally occurring deposits in the bedrock (Ayotte et al., 2003; Brutsaert et al., 1981; Banning et al., 2013). Data from private wells in the region provided by Raritan Headwaters (RHA) Well Test Program indicate that about 16% of wells exceed the drinking water standard (5 ppb) for arsenic; 3.5% for Gross Alpha (15 pCi/L); 9.3% exceed the federal guideline of 4,000 pCi/L radon; 15% fail for coliform bacteria; and while less than 2% of wells fail for nitrate (NO_3;10 ppm) they often exhibit levels above the 1-2 ppm natural background levels and are at levels that may be harmful to pregnant women and infants (MacDonald and Thomas, 2016). The percentage of failures varies geographically with some municipalities having over 42% of wells fail for arsenic whereas others have only 1% (NJDEP, 2016). Furthermore, the levels of contaminants and the quality of drinking water from wells can change, which requires continual monitoring (MacDonald and Thomas, 2016).

Table 1. Health effects from exposure, sources, drinking water standards and recommendations for 5 common well water contaminants included in this study (USEPA 2016; NJDEP 2009).

Test	Reasons to Test	Possible Sources	EPA or NJDEP* MCL	Frequency of Testing
Arsenic (As)	Causes increased risk of cancers, gastrointestinal ailments, diabetes and cardiovascular impacts	Naturally occurring deposits, wood preservatives and historical application of arsenic-containing pesticides	5ppb*	Every 3-5 years; annually if arsenic detected at or near MCL
Gross Alpha	Can be ingested, or inhaled as gases that are released from the water into the air. Exposure to Gross Alpha emitters in drinking water can lead to lung cancer	Natural deposits of radioactive minerals (containing radium and/or uranium) may emit alpha radiation which can enter the home through well water	15 pCi/L; further testing recommended if Gross Alpha exceeds 5 pCi/L	At least once
Total coliform and E. *coli*	Indicative of potential fecal contamination and the potential presence of other harmful pathogens	Cracks in well casing, faulty seal or seepage near the well, septic system problems, improperly functioning septic systems, stormwater runoff, animal waste, seepage from fertilized land	no acceptable limit; should be absent from drinking water	Annually
Radon	Can be ingested or inhaled as gases are released from the water into the air. Exposure to radon in drinking water can lead to lung and other cancers	Naturally occurring, produced by the breakdown of uranium in soil, rock and water. Can enter the home through well water	There is no state or federal standard; EPA has proposed a standard of 4,000 pCi/L	At least once
Nitrate (NO_3^-)	High levels of nitrates are harmful to infants and pregnant women; alters ecological communities by favoring overgrowth of some organisms normally limited by nitrogen (e.g., algal blooms)	Cracks in well casing, faulty seal or seepage near the well, septic system problems, stormwater runoff, seepage from fertilized land	10 ppm	Annually

RHA has over 30 years of data from over 14,000 samples provided from private well owners in the watershed as part of our Well Test Program. Each municipality in the Upper Raritan region partners with RHA annually to provide reduced cost water testing through the RHA Community Well Testing Program. Despite partnering with local municipal governments to implement the

annual community well tests and varying levels of public relations leading up to the well test event, RHA has found that only 2-9% of residents on private wells participate each year. In a survey conducted by RHA (Tippett and MacDonald, 2017), 66% of residents indicated that they'd never tested their well water for arsenic. Seventy percent of respondents indicated more vulnerable members in the household including children under 12, senior citizens, and those with chronic illnesses or symptoms. This study confirmed that there is still a general lack of awareness and/or concern for this potentially health-threatening pollutant in our water supply. In addition, most residential private well owners test for only coliform bacteria and nitrate, which are also harmful, but not the other potential contaminants that pose serious threats. The survey also found that municipal involvement in publicizing the event and providing well test material through their municipal offices greatly boosts the percentage of residents participating (Tippett and MacDonald, 2017). Locally-generated awareness campaigns targeting arsenic-affected communities in Quebec, Canada have been found to be 4 times as effective as mass media campaigns at motivating water testing for arsenic. However, the testing rates in this area still remained a low 16% compared to the earlier 4% before intervention through targeted public outreach (Renaud et al., 2011). Residents in arsenic affected communities tend to underestimate the negative health impacts of arsenic despite the risks, either because they do not perceive a risk to themselves or because a combination of norm, ability, and attitude barriers influences their behavior (Flanagan et al., 2015). Despite low testing rates, analysis of survey data found that well owners in Quebec who said an acquaintance had already tested for arsenic were up to 11 times more likely to decide to test for arsenic themselves, demonstrating the power of social norms (Renaud et al., 2011). The explanations for why well owners are not testing are varied. Cost and convenience are known obstacles to regular well testing (Pyrch, 1999, Hexemer et al., 2008). Some are unaware of the health risks or choose to not test for other reasons. Water contaminants are generally odorless, colorless, and tasteless. Acute symptoms of contamination rarely occur and the specific causes of chronic illness are more difficult to determine. Often, an assumption is made that the water is safe and testing is unnecessary. People also tend to be optimistically biased, believing their risk to be lower than others (Weinstein, 1989).

Finding ways to better communicate to private well owners the health risks associated with well water and the need to test and treat for a variety of common contaminants is needed if we are to reduce exposures and illness. Targeting residents whose wells are most at risk for having levels of regulated contaminants above the drinking water standard is a potential way to efficiently reach individuals. Providing residents with warnings that wells close to their own property have failed to meet safe drinking water standards will potentially increase the perception of personal health risk and thereby lead to testing and subsequent treatment.

This study explored whether knowledge of nearby wells exceeding the drinking water standard for 5 common contaminants influences the likelihood to conduct water quality tests among residents. Additional questions included whether the likelihood to test varies depending on the contaminant of focus, whether follow-up treatment is initiated where well water exceeds drinking water standards, and whether well test data can be used to predict neighboring wells at high risk for contamination.

Our study questions include:

1) Does a direct mailing that includes information about potentially harmful contaminants in nearby wells increase the likelihood of residents' testing their private well for common, harmful contaminants (i.e., arsenic, radon, Gross Alpha, E. *coli*, nitrates)?
2) Does the rate of response vary among the contaminants based on the perception of risk or the communicated risk to health provided to them in a mailing?
3) Does the likelihood of treating a contaminant vary among individual contaminants?
4) Based on the well testing samples received and additional spatial data on the wells in the 2 townships from RHA's database, is it possible to develop a spatial model predicting probability of contaminant concentrations exceeding drinking water standards in the Upper Raritan in order to follow up with targeted, cost-effective public outreach?

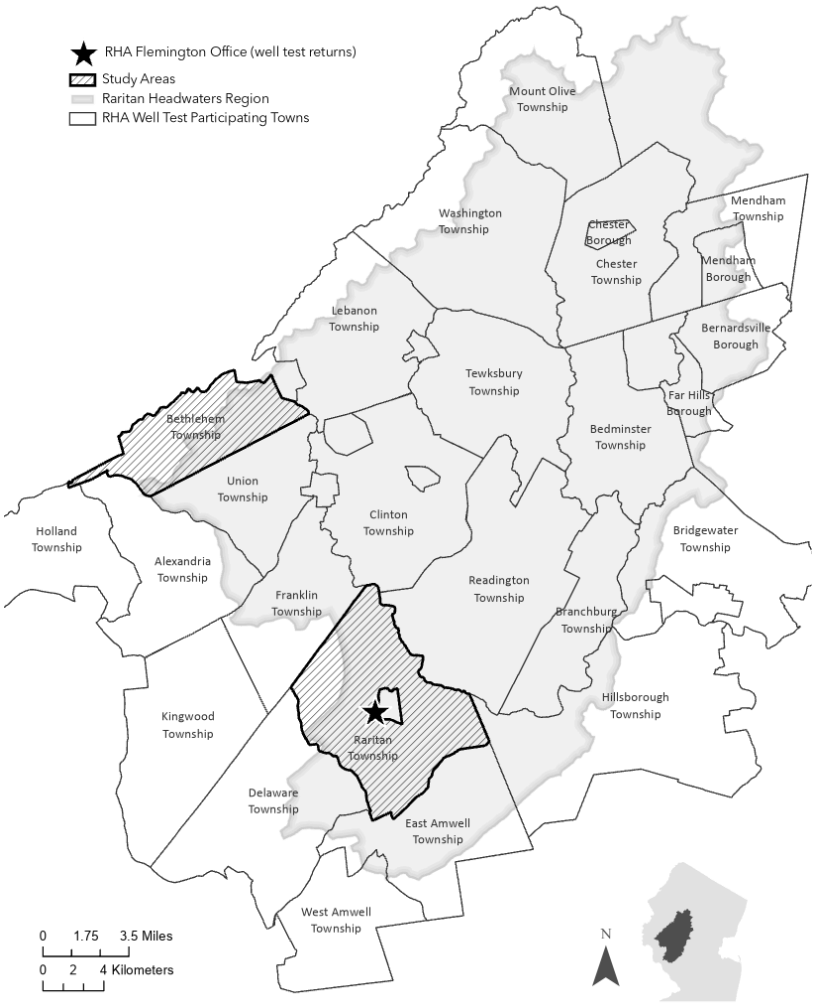
The findings will have broad applicability to local, regional, state, and federal policies pertaining to public outreach and regulations regarding testing and treatment requirements. Targeting residents whose wells are most at risk for having levels of contaminants above the drinking water standard is a potential way to efficiently reach individuals. Providing residents with warnings that wells close to their property have failed to meet safe drinking water standards could potentially increase the perception of personal health risk and thereby lead to testing and subsequent treatment.

Methods

Geographic Scope

The study focused on two of the region's townships, Bethlehem and Raritan, located in Hunterdon County in the Upper Raritan Region of New Jersey, USA (Figure 1). The Upper Raritan or North and South Branch Raritan Watershed Region (WMA8) is the largest watershed within the Raritan River Basin and the New Jersey Highlands Region and is the source of clean drinking water for more than half the state's population. The 1,217 km^2 (471 mi2) watershed provides well water to the residents of 38 municipalities in Hunterdon, Morris and Somerset counties and drinking water to more than 1.5 million residents that live beyond the watershed, in the densely populated towns and cities in northeastern New Jersey. The region includes the fractured bedrock aquifers of the Newark Basin including mainly the Brunswick aquifer, Lockatong and Stockton formations (Herman et al., 1998), along with some limestone aquifers and buried valley aquifers where glaciers deposited sand, gravel and clay materials. These resources are threatened by continued degradation caused by numerous stressors associated with human activities. There have been large-scale changes in land use in the watershed first with large-scale conversion of forest to agricultural land over the last century and in the past several decades with large-scale conversion of farmland and forestland to urban/suburban development (MacDonald and Thomas, 2016; RSRRI, 2016). These changes have likely influenced groundwater quality and drinking water from private wells.

Figure 1. Map of the Upper Raritan/North and South Branch Raritan Watershed Region (WMA8) showing Bethlehem and Raritan townships (study areas), the location of the RHA office in Flemington (well test return), and the towns that participate in the Community Well Test Program.



Data Collection and Analysis

For nearly six decades, RHA, a non-profit 501 c(3) environmental organization, has worked to protect clean water in the North Branch and South Branch Watershed Region of the Raritan River (Upper Raritan; WMA8). Its vision of a healthy future for this region includes a safe, clean water supply that can sustain healthy ecosystems and people. RHA has been testing water quality in private wells since 1974 as part of its Well Test Program (www.testmywell.org). This is the oldest community well test program in the country and currently tests up to 1,500 wells per year in the region. The wealth of groundwater data obtained from the program provides the opportunity to explore trends in water quality over time, geographic patterns, and also provide the public with

information on their private well drinking water supply. Private wells in Bethlehem and Raritan townships were selected from the program database if they exceeded the MCL for arsenic, Gross Alpha, E.*coli*, and/or nitrates or if radon was detected over the federal guideline of 4,000 pCi/L (there is no MCL for radon) for the period 2012 to 2018. Five hundred thirty two wells that exceeded one or more of the 5 contaminants of interest were identified. The number of wells in the database above the MCLs for each of the contaminants is outlined in Table 2.

Table 2. Wells tested by RHA in Bethlehem and Raritan that exceeded the MCL for at least one of the 5 contaminants of interest from 2012 to 2018. The addresses of these wells were used to generate a list of neighboring wells within 1,000 feet of the property boundary.

Contaminant	# of wells exceeding	MCL
Arsenic	344	5 ppb
Nitrates	53	10 ppm
E. coli	47	Should be absent
Gross Alpha	12	15 pCi/L
Radon	76	4,000 pCi/L*
Total	532	

*federal guideline

Well locations in Raritan and Bethlehem Townships that were identified as having one or more contaminants exceeding the drinking water MCL were geocoded and mapped in ArcGIS (ESRI, Inc.). All parcels within a 1,000 ft. buffer of each of the well points were selected. A spatial join (ArcMap function that joins tables based on location) of the parcels to the buffers was performed, creating a list of 2,909 parcels with potential wells within a 1,000 ft buffer. Parcel owners were joined to the Parcel IDs, government-owned and commercial properties were filtered out and a mailing list was created.

Institutional Review Board (IRB) approval for research utilizing human subjects was received from the Rutgers IRB Authority prior to mailing. In total, 2,597 letters were mailed (sample letter, Appendix A). This included 2,106 specific, local letters mailed to residents in Raritan and Bethlehem townships alerting them to the occurrence of elevated contaminant levels of arsenic, nitrate, Gross Alpha, radon, and/or E.*coli* in wells located within a 1,000 ft radius of

their property (Table 3). All letters included additional information about the specific contaminant(s) of concern-only but mentioned that testing options for other contaminants existed. In addition, 491 general, regional (control) letters were sent to randomly-selected residences in Raritan Township and Bethlehem Township informing the residents that wells in the region are at risk of contamination from coliform bacteria, E.*coli*, arsenic, nitrates, uranium, lead and/or radon (Table 3). Control letters included a general fact sheet on private well testing. All letters included an offer to test their well for a reduced rate through RHA's Well Test Program which utilizes a NJDEP-certified water testing lab (Garden State Labs, Hillside, NJ). An online survey was created and a link to the survey provided in all letters where residents could respond if they chose not to take advantage of the testing program (sample letter, Appendix B).

The residents' responses and specific test requests were recorded in a master spreadsheet of all letter recipients to monitor response rate and testing. Kits were assembled and placed in an easy to access pick up area, open 24 hours/day, at RHA's Main St., Flemington location (Figure 1). The kits included prepared sample bottles, detailed instructions, an information form and a chain of custody form for the state-certified water testing lab. Contact information for RHA's Well Test Program Manager was included so there was a point of contact for residents to use if they had questions. Participants were instructed to return well test samples to the Raritan Headwaters Flemington office on one of 6 designated mornings but accommodations were made for those who requested a different drop off day. Samples were then picked up the same morning by the state-certified lab for processing. Participants were notified of positive bacterial sample results within 2 days, and all other results were reported to the participant within 3 weeks of sample return via email (if one was provided) or by USPS (if an email was not provided). Results of the water quality tests were recorded and communicated to the resident once received back from the lab. In September 2019, a followup telephone survey (Appendix C) was conducted of all participants who had exceeded the MCL to determine if they were drinking their well water, if they had treated their water and why or why not, and if they were more or less confident that their water was safe as a result of testing.

In order to determine if rate of exceedances was higher in wells within 1,000 ft than randomly selected wells in the towns, results data from all well tests in Raritan and Bethlehem townships between 2012 to 2018 were pooled for each contaminant, respectively. Any residences in the study (those that received a mailing) were removed from the overall sample to avoid duplicating results.

Chi-square tests of independence were performed to determine if the likelihood of testing (yes, no) and treating (yes, no) was dependent on several categorical variables including type of letter (specific, general), municipality (Bethlehem, Raritan), number of specific contaminants (multiple, single), and type of contaminant (arsenic, E. *coli*, Gross Alpha, nitrate, radon). In addition, the likelihood of exceeding the MCL for neighbors of wells that exceeded was compared with likelihood of exceeding in all wells sampled through RHA from 2012-2018 by township and combined for each respective contaminant. The null hypothesis that the categorical variables were not related was rejected at p-values less than 0.05 for all tests.

Results

As of August 1, 2019, 258 (9.9%) of recipients of the letters responded to the letter by either calling in with questions and/or requesting a well test kit to test for the suggested, or additional, contaminants. Tables 3 and 4 provide a summary of the numbers of letters sent, the percent responding to the letter, and the percent testing. Eighteen of the kits that were requested were never picked up and 30 kits that were picked up were never completed and returned. There were only 4 responses to the online survey, all of which indicated that the reason they chose not to test their well at this time was that they'd recently done so and/or test regularly. A total of 183 wells (7.0%) were tested as a result of the mailing.

Table 3. Numbers of letters sent by category Specific/Local and single- or muli-contaminant and General/Regional, percent returned, percent tested.

Letter Type	# Letters	Total Responses	% Response	# Tested	% Tested
Specific/Local Letters	2,106	236	11.2	172	8.2
Single Contaminant	1915	213	11.1	155	8.1
Multiple Contaminants*	191	23	12.0	17	8.9
General/Regional Letters	491	22	4.7	11	2.2

*Specific/Local Letters included 38 arsenic and E. coli; 63 arsenic and nitrate, 5 arsenic, E. coli and nitrate; 11 Radon and arsenic; 20 Gross Alpha and arsenic; 7 radon and Gross Alpha; 45 radon and nitrate

Table 4. Numbers of letters sent for Specific/Local (single- and muli-contaminant) by contaminant type, percent returned, and percent tested. The concentrations of contaminants is for all tests resulting from all participants who tested as part of this study and includes mean, range and standard deviation (SD).

Contaminant Type	# Letters	Total Responses	% Response	# Tested	% Tested	Mean conc.	Range (min. - max.)	SD (+/-)
Arsenic	1,606	194	12.0	140	8.7	0.004 ppb	0-0.068	0.006
Nitrate	288	27	9.4	20	6.9	4.022 ppm	0-13.3	2.62
Gross Alpha	102	13	12.7	9	8.8	5.012 pCi/L	0-22.5	6.313
Radon	249	20	8.0	14	5.6	2,073 pCi/L	209 - 10,023	2,091
E. *coli*	57	6	10.5	4	7.0	0.042 (pres/abs)	0-1	0.201

More than half of the residents who received a letter for arsenic chose to test solely for this contaminant highlighted in their notice even though annual testing for bacteria and nitrate was recommended. Of the 140 wells tested for arsenic, 65 (46%) were also tested for bacteria and nitrates.

Results presented are presented by specific study questions.

Question 1. Does a direct mailing that includes information about potentially harmful contaminants in a well within 1,000 feet of a resident's property increase the likelihood of residents' testing their private well for common, harmful contaminants (i.e., arsenic, Gross Alpha, radon E. *coli,* nitrates)? Do the results differ by township?

a.Letter type (specific/local; general/regional) X Response Type (Test or Not Test)

A chi-square test of independence was performed to examine the relation between letter type (specific contaminant/local results or general contaminants/regional results) and decision to test. The relation between these variables was significant, Chi-square (1, N =

2,597) = 21.353, p <0.001. Individuals who received specific letters were more likely to test their well than were individuals who received a general letter.

b.How does this vary by township?

Even though there appeared to be a greater percentage of residents in Raritan Township (1-6 mile distance) who tested their wells than residents in Bethlehem Township (15-22 miles distance) there was no significant statistical difference. Raritan (7.3%) and Bethlehem (4.8%) did not demonstrate a statistically significant difference in percentage of residents who tested their wells for all letter types combined (Chi-square (1, N = 2597) = 2.623, p = 0.105). The two townships when analyzed separately demonstrated a similar pattern in that individuals that received the specific letters were more likely to test their well than individuals who received a general letter. For Bethlehem, the chi-square test of independence showed the relation between these variables was significant, Chi-square (1, N = 375) = 5.004, p = 0.025. For Raritan, a chi-square test of independence also showed the relation between these variables was significant, Chi-square (1, N = 2222) = 16.797, p <0.001.

Question 2. Does the rate of response vary among the contaminants based on the perception of risk or the communicated risk to health provided to them in a mailing?

a.Contaminant Type (Arsenic; bacteria; nitrate; Gross Alpha, radon) X Response Type (Test or Not Test)

An analysis of the responses to letters for individual, specific contaminants-only (multi-contaminants removed) revealed that the type of contaminant did not influence the likelihood of testing, Chi-square (4, N = 1,911) = 6.802, p =0.147).

b. Contaminant # (single; multiple) X Response Type (Test or Not Test)

A chi-square test of independence was performed to examine the relation between number of contaminants in specific letters (single and multiple) and decision to test. The relation between these variables was not significant, Chi-square (1, N = 2,106) = 0.101, p =0.750. Individuals who received specific letters reporting more than one contaminant were not more likely to test their well than were individuals who received a specific letter for one contaminant.

Question 3. Does the likelihood of treating a contaminant vary among individual contaminants?

Forty-five wells were at or exceeded the MCLs for the contaminants tested (see Table 3 for a breakdown among contaminants). Of these, 22 residents participated in a follow up survey (Appendix C) and the rest were either not reachable or declined to participate in the survey. The small sample size did not allow for comparison of treatment rates among contaminants. Thirty-six percent of the participants treated their well water as a result of their test exceeding the drinking water standard. The most common reasons for not treating were the belief that the contaminant was not a concern or that the existing treatment was sufficient, or that drinking bottled water

replaced the need to treat the well water. Prior to testing, 36% drank bottled water, 23% drank unfiltered well water, and the rest drank filtered well water. Ninety-five percent of participants did not switch their water source after learning that their well exceeded the drinking water standard for one or more contaminants. After testing, 55% reported that they were very confident and 36% reported that they were somewhat confident in their well water being safe to drink and a small percentage (9%) reported they were not confident. Testing and finding the water did not meet drinking water standards increased the confidence in 64% of respondents and decreased the confidence in 14%. Most respondents (77%) felt the information provided about treatment options along with their test results was helpful to them and 91% of respondents plan to test their well water again in the future.

Question 4. Based on the well testing samples received and additional spatial data on the wells in the 2 townships from RHA's database, is it possible to develop a spatial model predicting probability of contaminant concentrations exceeding drinking water standards in the Upper Raritan in order to follow up with targeted, cost-effective public outreach?

Likelihood of local wells being contaminated if a neighbor within 1,000 ft exceeded the MCL was explored for all 5 contaminants (Table 5). The likelihood of exceeding for at least one of the contaminants was 18% for those receiving the letter about a specific exceedance locally whereas the likelihood was 5% of those testing their wells in the two municipalities between 2012 and 2018. Likelihood of exceeding the MCL was compared between wells tested as a result of receiving a specific-local letter and the RHA community well test database for the 5 contaminants, respectively, for each township as well as for townships combined. For Raritan Township, none of the contaminants exhibited a greater likelihood of exceeding the MCL if a neighbor had failed as compared to the percentage in the RHA database for 2012-2018. None of the towns showed a higher likelihood for exceeding the MCL for arsenic or Gross Alpha if a neighbor exceeded for those contaminants, respectively. However, for Bethlehem Township and both towns combined, E. *coli* and nitrate had a higher likelihood of exceeding the MCL if a neighbor's well exceeded. [For Bethlehem, E. *coli* chi-square (1, N=112) = 17.493, $p<0.001$, and nitrate (1, N=115)=8.818, $p=0.003$ and for combined townships, E. *coli* chi-square (1, N=599)=23.387, $p<0.001$, and nitrate chi-square (1, N=604)=8.846, $p=0.003$]. Furthermore, for both towns combined, but not individual townships, radon had a higher likelihood of exceeding the federal guideline if a neighbor's well exceeded as compared to the combined township data from 2012-2017, Chi-square (1, N = 114) = 3.983, $p = 0.046$.

Table 5. For individual wells tested, percentage exceeding for contaminants for those receiving specific-local letter informing them that a neighbor had exceeded the MCL (% left) and percentage exceeding for all RHA Well Test data for the period 2012-2018 (% right). In addition, grey shading indicates cases where the likelihood of exceeding is greater for wells that are within 1,000 ft of a well that exceeded for a particular contaminant as compared to the general population of wells tested by RHA from 2012-2018 (based on Chi-square, $p<0.05$, see Appendix D for statistics).

Contaminant	Bethlehem Twp.		Raritan Twp.		Combined Towns	
	% Exceeding		% Exceeding		% Exceeding	
	Neighbor	RHA Data	Neighbor	RHA Data	Neighbor	RHA Data
Arsenic	No data	0	18.4	24	18.4	21.4
E. *coli*	50.0	1.8	0	0.6	25.0	0.8
Gross Alpha	0	0	16.7	6.9	11.1	5.1
Nitrate	40.0	5.4	0	0.4	10.0	1.4
Radon	33.3	21.4	0	4.2	26.7	9.0

Eight of the 20 wells tested for nitrates had elevated levels of nitrates at or over 8 mg/L (ppm) but only 2 were over MCL of 10 mg/L. While there were no radon fails in Raritan, one of the radon letter recipients also tested for Gross Alpha and failed.

Discussion/Conclusions

The central tenet of this study, that individuals receiving specific letters about contaminants in local wells are more likely to test their well than were individuals receiving a general letter about regional contaminants, was supported by the data. However, even though the targeted letters had a higher response rate (11.2%) than the general letters (4.7%) those numbers indicate in both cases that a large majority of residents are not responding with the health action of testing and treating when provided with information on potential contaminants in their private well water. This means there is more work to be done on effectively reaching the goal of private well owners taking the initiative to ensure the safety of their drinking water.

Possible explanations for the low numbers are many. Lack of understanding of the risks was indicated in that the type of contaminant did not influence the likelihood of testing. This suggests that residents perceived a similar risk (or lack thereof) among contaminants. It was also surprising that individuals who received specific letters reporting more than one contaminant were not more likely to test their well water than were individuals who received a specific letter for one contaminant. The number of contaminants did not seem to influence perceived risk, which indicates a possible lack of understanding.

Further explanations for why people are not testing came from the online survey for those opting out of the testing as well as the follow up telephone survey conducted of those who participated in testing their well. The 4 respondents to the online survey all indicated they were opting out of testing through RHA because they had already tested their well. From the telephone survey, it was learned that 36% of respondents treated their well water as a result of their test showing an exceedance in one or more contaminants while the remaining 64% did not. We learned that there is a certain level of optimistic bias that likely affects testing and treatment as evidenced by many saying the reason for not treating was the belief that the contaminant was not a significant health risk or that existing treatment was fine. Also, the survey brought to light that many people (36%) in the study were relying on bottled water prior to testing and continued to do so after testing, thus they did not see a need to treat the water. The number relying on bottled water is likely higher given that most residents did not respond to the letters. The tendency for residents to drink bottled water warrants further study as it indicates an assumption that local groundwater sources of drinking water are not trusted as being safe despite lack of scientific data to support this assumption. It is possible that people are afraid of learning about contaminants in their drinking water because they don't understand that they can treat the water and remove these contaminants. This seems to follow along the lines of the psychological phenomenon known as "catastrophe fatigue" whereby people receiving doomsday messages about environmental problems are not compelled to change their behavior to fix the problem. Positive messages that empower individuals with knowledge that they can do something to protect the health of their family by testing and treating their water should help to address this obstacle.

Another explanation for not testing is that cost and convenience are obstacles for some. Proximity of residents to RHA's Well Testing office (where kits were picked up and subsequently dropped off) and associated level of convenience may have been a factor in the level of response to the letter and subsequent testing. The potential effect of proximity was supported by a greater percentage of residents in Raritan Township (1-6 mile distance from the RHA office) that tested their wells than residents in Bethlehem Township (15-22 miles distance from the RHA office), although there was no significant statistical difference. Also, a number of residents responding to the letter by email or phone failed to pick up the well testing kits they ordered, which supports that convenience may have been a factor.

Still, 64% of residents who tested as part of this study were drinking filtered or unfiltered well water prior to testing, which means many do rely heavily on their private well water. Thus, a large population of people are in need of compelling scientific information on the risks associated with contaminants in their private well water and incentives for testing and treating their water. That testing was a positive experience was evidenced by reporting of increased confidence and the usefulness of the information provided in the letter as well as follow-up information on treatment. Testing tended to promote a tendency for residents to report they plan to test again in the future. However, targeting effective outreach to get the large majority to test

remains a challenge. Future studies might explore further how different sources of information will influence health actions. The letter in this study originated from RHA (a regional non-profit environmental group) and Rutgers University (a respected academic institution in the region). Future studies should explore other partnerships in providing information including municipal governments, schools, health departments, and healthcare providers and compare whether health actions are influenced by the source of information. In addition, direct mailings may not be the best route for reaching people. Of respondents who spoke with RHA's Well Test Program staff about the letters they received, many at first were skeptical about the letter; some believing it was intended to scare them into testing and that we were trying to sell them a product. However, after the conversation with RHA and Rutgers staff, most expressed a better understanding of the health risks of contaminants in their well water and the need to test and treat. Many indicated relief and gratitude for being informed of the risks. Furthermore, respondents who had received a letter indicating a local exceedance of one or more contaminants were more likely to test for additional contaminants if they spoke with a staff member than if they responded via email or left a voicemail to order a testing kit. In the latter case, they tested only for the specific contaminant even though USEPA guidelines recommend testing private wells for some contaminants (i.e., coliform/E. *coli* and nitrate) every year.

Outreach campaigns are expensive and the possibility of finding ways to be more efficient in targeting residents at greatest risk of exposure was explored. The results indicated that there is some potential to use wells that exceed an MCL to identify other wells at risk of exceeding in the geographic vicinity for E. *coli*, nitrates and radon but not for arsenic and Gross Alpha. Perhaps there are other variables other than contaminants in neighbors' wells that need to be explored including past and current land use, depth of well, well age and type, age of dwelling and septic systems, and well and septic service history for developing predictive models for use in identifying higher risk of exposure to contaminants.

Given that only a small percentage of private wells in the watershed are tested on a regular basis, there remains a critical need for education and outreach about where well water is coming from and what levels of contaminants it may contains. In addition, education and incentives to improve our practices on the land will go a long way toward protecting all of our water – groundwater and surface water. We also need to better inform residents that for the most part our groundwater is clean and can be relied upon as a source of safe drinking water as long as precautions are taken to test and treat on a regular basis; bottled water is not a good solution in many cases. This study indicates that better approaches are needed in order to encourage residents to respond with the desired health actions of testing and treatment of their private well water. While letters about local contaminants does help target residents and boost testing to some extent, more research is needed on how to get the majority of residents to respond. Further studies into how the originating source of outreach information impacts perceived reliability of data are needed. In addition, developing predictive models of likelihood of exceedances for contaminants will help to make outreach more efficient and successful in reaching those most at risk.

Literature Cited

Ayotte, J. D., Montgomery, D. L., & Flanagan, S. M. (2003). Arsenic in Groundwater in Eastern New England: Occurrence, Controls, and Human Health Implications. Environmental Science & Technology, 37(10), 2075–2083. https://doi.org/10.1021/es026211g

Banning, A., Demmel, T., Rude, T. R. & Wrobel, M. (2013). Groundwater Uranium Origin and Fate Control in a River Valley Aquifer. Environmental Science & Technology, 47(24), 13941–13948. https://doi.org/10.1021/es304609e

Brutsaert, W.F., Norton, S.A., Hess, C.T.,Williams, J.S., 1981. Geologic and hydrologic factors controlling radon-222 in ground water in Maine. Ground Water, 19, pp. 407-417

DeSimone LA, Hamilton PA, and Gilliom RJ., 2009. Quality of Ground Water from Private Domestic Wells. *Water Well Journal*. 2009 Apr:33–37.

Flanagan S.V., Marvinney R.G., and Zheng Y., 2015. Influences on domestic well water testing behavior in a Central Maine area with frequent groundwater arsenic occurrence, 2015. *Sci. Total Environ. 505*:1274–1281.

FlanaganS. V.MarvinneyR. G.JohnstonR. A.YangQ.ZhengY. 2015a Dissemination of well water arsenic results to homeowners in Central Maine: influences on mitigation behavior and continued risks for exposure. Sci. Total Environ. 505, 1282–1290.

Gonzales, T. R. 1. T. G. wa. go. (2008). The Effects That Well Depth and Wellhead Protection Have on Bacterial Contamination of Private Water Wells in the Estes Park Valley, Colorado. Journal of Environmental Health, 71(5), 17–23. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=gft&AN=35604987&site=ehost-live&scope=site

Herman, G.C., R. J. Canace, S. D. Stanford, R. S. Pristas, P. J. Sugarman, M. A. French, J. L. Hoffman, M. S. Serfes, and W. J. Mennel, 1998. *Aquifers of New Jersey. A publication of the New Jersey Geological Survey, New Jersey Department of Environmental Protection.* Retrieved from www.state.nj.us/dep/njgs/pricelist/ofmap/ofm24.pdf.

Hexemer, A.M., Pintar, K., Bird, T. M., Zentner S. E., Garcia, H. P., Pollari, F. 2008 An investigation of bacteriological and chemical water quality and the barriers to private well water sampling in a Southwestern Ontario Community. J. Water and Health 6 (4), 521–525.

MacDonald, K., and Thomas, M.M., 2016. A preliminary analysis of trends in contaminants in private well water in the North and South Branch Raritan Watershed (1984-2015). Published online at https://www.raritanheadwaters.org/wp-content/uploads/2016/08/2Final-2016-Trends-in-Groundwater-Contaminants-Report-6_8_2016.pdf

Naylor, E., Humphrey, C., Kelley, T., Easter, L., & Iverson, G. (2018). Evaluation of Nitrate Concentrations and Potential Sources of Nitrate in Private Water Supply Wells in North Carolina. Journal of Environmental Health, 80(9), 16–23. Retrieved from

http://search.ebscohost.com/login.aspx?direct=true&db=gft&AN=129386255&site=ehost-live&scope=site

NJDEP, 2009. Drinking Water Standards by Constituent. Retrieved from http://www.nj.gov/dep/standards/drinking%20water.pdf on February 21, 2016.

NJDEP, 2016. NJ Private Well Testing Act Data Summary (Sep. 2002 to Apr. 2014). Published online at http://njdep.maps.arcgis.com/apps/MapSeries/index.html?appid=826ec9fae77543caa582a787d5f088e7

NJDEP, 2016. *Drinking Water Facts: Private Wells.* (January 2016) Retrieved from http://www.nj.gov/health/ceohs/documents/eohap/pw_faq.pdf

Pyrch, L. A. 1999 Private Well Testing Pilot Education Project. Phase I: Knowledge, Attitudes, and Behaviors Associated With Private Well Testing in Three New Jersey Communities. Report of the New Jersey Department of Health and Senior Services, Division of Epidemiology, Environmental and Occupational Health, Consumer and Environmental Health Services, Trenton, NJ.

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 Promot Int. 2011* Dec; 26(4):465-75.

RSRRI (Rutgers Sustainable Raritan River Initiative), 2017. *State of the Raritan Report, Volume 1, December 2016*. Retrieved from http://raritan.rutgers.edu/wp-content/uploads/2017/01/SOR-Final-2017-01-30.pdf

Simpson H., 2004. Promoting the management and protection of private water wells. *J Toxicol Environ Health A. 2004*;67(20–22):1679–704.

Squillace, P. J., Scott, J. C., & Moran, M. J. (2002). VOCs, pesticides, nitrate, and their mixtures in groundwater used for drinking water in the United States. Environmental Science & Technology, 36(9), 1923–1930. https://doi.org/10.1021/es015591n

Swistock, B,R., & Sharpe, WE. (2005). The influence of well construction on bacterial contamination of private water wells in Pennsylvania. 7oi(i-iu(i o(Envinmmenuil HeaUh. 68(2), 17-22.

Tippett, M., and MacDonald, K., 2017. *Summary of Results from the Community Well Test Participant Pilot Study, Fall 2016*

U.S. Census Bureau, 2009. *American housing survey for the United States: 2009*. Retrieved June 2018 from < http://www.census.gov/prod/2011pubs/h150-09.pdf>.

USEPA, 2016. *Table of Regulated Drinking Water Contaminants.* Retrieved from https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations on June 27, 2018.

Weinstein, Neil D. "Optimistic biases about personal risks." Science, vol. 246, no. 4935, 1989, p. 1232+. Gale OneFile: Health and Medicine.

APPENDIX A.

a.Example of a Specific-Local Letter:

Dear Raritan Township resident,

This letter is to notify you that __arsenic__ has been detected in a private well in close proximity (within 1000 ft.) to your home. Of specific concern is that the level of contamination is above the NJ drinking water quality standard of __5__ug/L. More information on this contaminant is enclosed.

We strongly recommend that you test your well for __arsenic__and treat, if necessary. The cost of testing for this contaminant through Raritan Headwaters' Well Test Program is $ __35__. Samples are analyzed by a state-certified laboratory and results are confidential.

Wells in the Township are at risk of contamination from coliform bacteria, *E.coli*, arsenic, nitrates, uranium, lead and radon. Other testing options are available (see menu enclosed) and we'd be happy to discuss your concerns or explain any testing results you may have received in the past.

To take advantage of the Raritan Headwaters Well Test Program, please email welltesting@raritanheadwaters.org or call 908-234-1852 ext 401. **Please contact us to request your kit no later than April 12.** Your kit will then be available for pick up at your convenience at the RHA Well Test office located at 124 Main St., Flemington.

If you do not wish to participate, please fill out the 5-minute survey at the link below to better inform this public health initiative.

www.raritanheadwaters.org/survey/

Raritan Headwaters, a non-profit 501(c)(3) environmental organization and Rutgers University Cooperative Extension, Water Resources Program are conducting this public outreach and awareness initiative as part of a study to improve the health of rural communities. We ask your cooperation in evaluating your private well drinking water quality. We will provide results to you with additional information on recommendations for treatment if contaminants are found at levels above health standards.

Who we are: For 60 years, Raritan Headwaters Association (RHA) has made its mission to protect clean water in the North Branch and South Branch region of the Raritan River through our Community Well Test Program and other initiatives. To learn more visit www.raritanheadwaters.org

Sincerely,

Mara Tippett

Watershed Scientist, Groundwater

Raritan Headwaters

b. Example of a General-Regional Letter:

Dear Hunterdon County resident,

This letter is to notify you that private wells in the area have recently shown levels of certain contaminants above acceptable state and federal drinking water standards. We are advising all property owners who rely on private well water to test for contaminants and treat, if necessary. Affordable testing is available to residents through the Raritan Headwaters Well Test Program. Samples are analyzed by a state-certified laboratory and results are confidential.

Wells in the region are at risk of contamination from coliform bacteria, *E.coli*, arsenic, nitrates, uranium, lead and radon. Other testing options are available (see menu enclosed) and we'd be happy to discuss your concerns or explain any testing results you may have received in the past.

To take advantage of the Raritan Headwaters Well Test Program, please email welltesting@raritanheadwaters.org or call 908-234-1852 ext 401. **Please contact us to request your kit no later than April 12.** Your kit will then be available for pick up at your convenience at the RHA Well Test office located at 124 Main St., Flemington.

If you do not wish to participate, please fill out the 5-minute survey at the link below to better inform this public health initiative.

www.raritanheadwaters.org/survey/

Raritan Headwaters (RHA) a 501(c)(3) environmental organization and Rutgers University Cooperative Extension, Water Resources Program (RCE-WRP) are conducting this public outreach and awareness initiative as part of a study to improve the health of rural communities. We ask your cooperation in evaluating your private well drinking water quality. We will provide results to you with additional information on recommendations for treatment if contaminants are found at levels above health standards.

Who we are: For 60 years, Raritan Headwaters Association (RHA) – a non-profit organization has made its mission to protect clean water in the North Branch and South Branch region of the Raritan River through our Community Well Test Program and other initiatives. To learn more visit www.raritanheadwaters.org

Sincerely,

Mara Tippett

Watershed Scientist, Groundwater

Raritan Headwaters

APPENDIX B.

The following survey was provided in a link to SurveyMonkey.com in the mailing. It was included so that an assessment could be made of why some letter recipients opted not to test.

Informational Survey for Private Well Owners

Please help us to increase awareness about drinking water safety and better communicate with residents regarding the importance of regular well testing by completing this 4 minute, confidential survey. Your feedback is greatly appreciated. Thank you.

Q1 Why have you decided not to test your well water today? Please choose all that apply.

MULTIPLE CHOICE

I am not on well, I am on public water

I prefer not to know what contaminants are in my water

I'm not concerned about the safety of my drinking water

I do not drink the water from my well

My water is filtered

I tested my well water recently (within the last 3 years)

I test my well water regularly (every 1-2 years)

I prefer having my water tested with a company that comes to my home

I cannot afford to test at this time

I plan on selling my home in the next year and will test when I sell

Other

Q2 What type(s) of filtration systems do you use to treat your water? Check all that apply.

MULTIPLE CHOICE

Water softener

UV light

Arsenic (GFA) filter

Reverse osmosis

pH neutralizer

Granular activated carbon

Ion exchange

Not sure, there is filter equipment in my basement but I'm unsure what it does

Other

Q3 What is your primary source of drinking water?

MULTIPLE CHOICE

Unfiltered tap water

Filtered tap water (please specify type of filtration)

Bottled water

Other

Q4 Have you ever tested your well water?

MULTIPLE CHOICE

Yes

No

Q5 Have you tested your well water within the last 3 years?

MULTIPLE CHOICE

Yes, with Raritan Headwaters

Yes, with a private company

Yes, when I bought my home

Yes, my plumber tested my water

No, my well was tested in the year

Q6 Please check any tests you have done on your well in the last 3 years (if older, please note year in comments):

MULTIPLE CHOICE

Coliform bacteria

Nitrates

Arsenic

Lead

Volatile Organic Compounds

Gross Alpha

Radon

Iron

Manganese

Pesticides

Test kit from retail store

Not sure

Other

Q7 Would you be willing to share these results with Raritan Headwaters (all results are confidential and no personal information or specific addresses are ever published or shared with any other entity). Please email your results to welltesting@raritanheadwaters.org if you're willing to help us track contaminants in our groundwater.

MULTIPLE CHOICE

Yes

No

Yes, but I'm unable to email results

Q8 Please check off any of the following that apply to the occupants in your home.

MULTIPLE CHOICE

Children under 12

Senior citizens

Chronic illnesses or symptoms

None of these apply

Q9 Years spent in current dwelling?

MULTIPLE CHOICE

Lived in current home before 1986

Moved into current home between 1987 and 2002

Moved into current home between 2002 and present

Q10 I am aware of water quality problems in my:

MULTIPLE CHOICE

neighborhood

town

state

not aware of any water quality problems

APPENDIX C.

Follow Up Phone Survey On Treatment for Well Testing Participants with Samples Exceeding the MCL for one or more contaminants

Hello, this is _____ from Raritan Headwaters Association following up with you on your recent well water tests. Your well water was above the state drinking water standard for _____. Do you mind if we ask you a few questions about what you did to insure you have safe drinking water? It will only take 5 minutes to answer a few questions and it will help us develop ways of communicating water testing and treatment options in the future.

If NO say, "Thank you for your time and if you have any questions please don't hesitate to call us."

If YES……

1. What was your primary source of drinking water prior to testing?

Bottled water

Filtered well water

Unfiltered well water

Other (_____)

2. What is your primary source of drinking water now that you have tested?

Bottled water

Filtered well water

Unfiltered well water

Other (_____)

3. Did you already have a treatment system in your home when you tested?

Yes

No

4. Was the information on treatment options we provided with your test results helpful to you in making a decision about which treatment to choose?

Yes

No

5. Did you install a new or different treatment system after testing your water? (jump to corresponding Q)

If YES:

a. What type?

POU

whole house

Pitcher

Faucet mount

RO

Carbon

Sediment

Arsenic filter

Water softener

Other

Don’t Know

If NO:

b. Why not?

Planning on installing treatment in the future

I felt the treatment I had was sufficient

Expense

Lack of concern

Too busy

Didn’t know how to find treatment

Other

6. How confident are you today that your well water is safe to drink?

Very confident

Somewhat confident

Not at all confident

7. Did you retest after treatment?

Yes

No

8. Has testing increased the confidence in the safety of your water or decreased confidence?

increased

decreased

9. Do you plan to retest in the future?

Yes

No

At the end of the call say, “Thank you very much for your time. Please don’t hesitate to contact us with questions about your water, options for treatment, or for future testing.”

Voicemail message:

Hello, this is _____ from Raritan Headwaters Association following up with you on your recent well water tests. Your well water was above the state drinking water standard for _____. We are calling today to ask you a few questions about what you did to ensure that you have safe drinking water. It will only take 5 minutes to answer a few questions and it will help us develop ways of communicating water testing and treatment options in the future. Please call us back at 908-234-1852 ext 401

Thank you

Goodbye

APPENDIX D.

Chi-square results comparing likelihood of a contaminant exceeding the MCL in a well if a neighbor had exceeded versus likelihood demonstrated by all wells tested between 2012-2017, by township and combined.

Contaminant	Greater Likelihood of Exceeding if a Neighbor Exceeded by Geographic Area & Combined		
	Bethlehem	**Raritan**	**Combined Towns**
Arsenic	N/A (insufficient data)	chi-square (1, N=399) = 1.658, p=0.198	chi-square (1, N=431) = 0.505, p=0.478
E. *coli*	chi-square (1, N=112) = 17.493, p<0.001	chi-square (1, N=487) = 0.012, p=0.911	chi-square (1, N=599) = 23.387, p<0.001
Gross Alpha	N/A (insufficient data)	chi-square (1, N=487) = 17.493, p=0.012	chi-square (1, N=48) = 0.447, p=0.504
Nitrate	chi-square (1, N=115) = 8.818, p=0.003	chi-square (1, N=35) = 0.606, p=0.436	chi-square (1, N=604) = 8.846, p=0.003
Radon	chi-square (1, N=40) = 0.635, p=0.426	chi-square (1, N=489) = 0.064, p=0.801	chi-square (1, N=114) = 3.983, p=0.046