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Arsenic in Private Well Water Part I: Impact of the New Jersey Private Well Testing Act on Household Testing and Mitigation Behaviors

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Abstract

Regularly ingesting water with elevated arsenic increases adverse health risks. Since September 2002, the NJ Private Well Testing Act (PWTA) has required testing untreated well water for arsenic during real estate transactions in 12 counties. Its implementation provides an opportunity to investigate the effects of policy intervention on well testing and treatment behavior. Here we analyze results of a survey mailed to 1,943 random addresses (37% response), including responses from 502 private well households who purchased their homes prior to PWTA commencement and 168 who purchased after. We find the PWTA has significantly increased arsenic testing rates in an area where 21% of wells contain arsenic above the 5 μg/L NJ drinking water standard. The PWTA has allowed identification of more wells with arsenic (20% of post-PWTA vs. 4% of pre-PWTA households) and more treatment for arsenic (19% of post-PWTA vs. 3% of pre-PWTA households). Such an Act is a partial answer to significant socioeconomic disparities in testing observed among households for whom it is not required. Additionally residents purchasing homes since 2002 are younger and disproportionately more likely to have children in their household (60% vs. 32%), a priority group given their particular vulnerability to effects of arsenic. Despite more wells tested under the PWTA, post-PWTA well owners forget or misremember arsenic test results more often, are more likely to report not knowing what kind of treatment they are using, and are not reporting better maintenance or monitoring of their treatment systems than pre-PWTA households. This suggests serious challenges to reducing arsenic exposure remain even when

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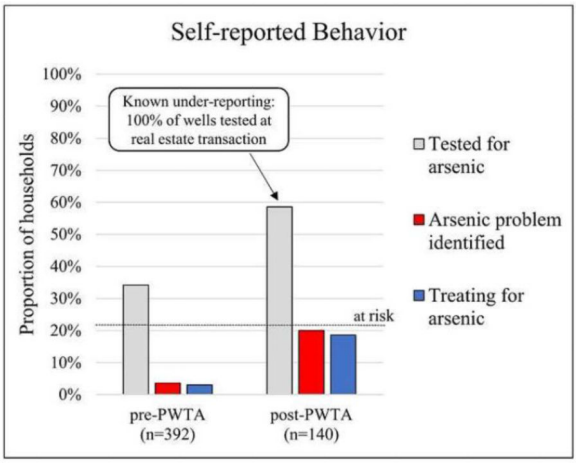
testing is a requirement. Furthermore, only a fraction of wells have been tested under the PWTA due to the slow pace of housing turnover. We recommend more public resources be made available to support private well testing among socially and biologically vulnerable groups.

Graphical Abstract



Keywords

private well testing; arsenic; drinking water; policy; New Jersey; behavior

1. INTRODUCTION

Arsenic is a toxic element known to increase the risks for adverse health effects in people who regularly drink water with elevated levels.[1] Arsenic in water is colorless, odorless, and tasteless and its presence can only be identified by specific testing. Naturally occurring concentrations in groundwater are generally below levels considered an acute risk for poisoning, but over time chronic exposure can have serious consequences. Dose-dependent relationships have been observed for a range of conditions including cancers of the skin, bladder, kidney, and lung,[2–4] as well as cardiovascular disease, pulmonary disease, diabetes mellitus and neuropathy.[5] Of great concern are the consequences of exposure that begins early in life or during pregnancy. Risks include reduced birth weight and impaired cognitive function, as well as significantly higher risks of impaired lung function, death from renal and lung cancer, lung disease, and acute myocardial infarction later in life.[6–10] For this reason families with pregnant women or young children who are at greater risk for developmental effects and adverse outcomes later in life should be more vigilant about the quality of their well water.

Evidence of health impacts from chronic exposure to arsenic led the United States Environmental Protection Agency (USEPA) to adopt a standard for arsenic in drinking water of 10 μg/L in 2001, replacing the old maximum contaminant level (MCL) of 50 μg/L.[11] Public water systems were given several years to comply and this “arsenic rule” became enforceable in 2006. In 2004 the state of New Jersey (NJ) updated the NJ Safe Drinking

Water Act by adopting its own more stringent standard of 5 μg/L, the most protective in the nation, which also became effective in 2006.[12] Although public water supply systems are regulated to meet these government drinking water standards for arsenic and other contaminants, private well water is not. Throughout the United States (U.S.) any regulation for arsenic testing of existing private wells is rare. States, aside from New Jersey and Oregon (ORS448.271), do not require arsenic testing of private wells during property transfer. New Jersey's Private Well Testing Act (PWTA, N.J.S.A. 58:12A-26 et seq.) commenced in September 2002 and requires testing of untreated groundwater for a variety of parameters prior to real estate transactions, including home sales and rentals. Arsenic testing is required in 12 counties in the northern and central part of the state (Figure 1) where naturally occurring arsenic concentrations as high as 250 μg/L occur in the bedrock aquifers of the Newark Basin.[13] About one million people (11% of population) in New Jersey rely on private well water for drinking.[14] Little has been known about the influence the PWTA has had on well testing and water treatment behavior for arsenic or other contaminants in New Jersey.

Laws, regulations, and guidelines, have the potential to improve public health. The ten great public health achievements of the 20th century in the United States identified by the Centers for Disease Control and Prevention (CDC) were each influenced by policy changes or regulations.[15] These include seat belt laws, workplace and food safety regulations, anti-smoking legislation and taxation, and fluoridation of drinking water. The quality of publicly-supplied drinking water in the United States is among the best in the world, in part because it is regulated by the USEPA.[16] There is increasing recognition that further changes in policy and the environment will be necessary to cultivate and maintain the individual-level behavior changes needed to combat chronic diseases.[17] Private well water in the U.S. is still widely unregulated, relying on individuals to be aware, willing, and capable to monitor, improve, and maintain the safety of their drinking water. Over 13 million, mostly rural, U.S. households regularly depend on private wells for their drinking water.[18] Local community engagement efforts to promote testing for arsenic are limited in scale and in success.[19,20] Policy-level intervention will be a required component of any strategy to eliminate exposure to arsenic from private well drinking water.[21] The implementation of the PWTA in NJ provides the opportunity to investigate the effects of a private well testing policy intervention on testing and water treatment behavior.

Here we present the findings from a mailed survey of private well households in 17 towns of northern New Jersey covered by the PWTA's requirement for arsenic testing. Addresses were selected randomly and then matched to PWTA records where available, allowing comparison of self-reported testing and treatment behavior between households who have faced the requirement to test and those who have not, in order to gain insight into the potential effectiveness of the regulation.

2. METHODS

2.1. Study area

The study area covers 17 towns in northern New Jersey (Table 1), selected for arsenic occurrence, based on the percentage of wells tested under the PWTA with greater than 5

µg/L arsenic, and majority private well water supply, based on the percentage of households using private wells in 1990.[22] The 2010 census shows a combined population of 144,132 and overall 76% of households in this area are estimated to rely on private well water.[22,23] PWTA records of 10,278 wells in these towns performed as of April 2014 show that 20.8% of wells tested exceed the New Jersey MCL of 5 µg/L and 7.1% exceed the federal MCL of 10 µg/L. Based on these numbers we estimate there may be 22,784 people in these towns drinking from wells with arsenic concentrations exceeding 5 µg/L, and 7,777 drinking from wells with arsenic concentrations over 10µg/L. The maximum arsenic concentration recorded under the PWTA was 254 µg/L from Hopewell, while the 75th percentile value was 4.6 µg/L and median value was 2.0 µg/L, using the Kaplan-Meier survival analysis approach for censored data.[24]

2.2. Survey instrument

Participants completed a 35 question survey on their water testing and treatment practices, preferences, and opinions, as well as basic demographic information. This questionnaire was a modified version of one developed for our previous study in Maine, with a similar section designed to measure the RANAS (Risk, Attitude, Norm, Ability, Self-regulation) factors[25] that may influence testing and treatment behaviors through a series of statements to which the respondent indicated agreement on a scale of 1 (strongly disagree) to 6 (strongly agree).[26] The primary addition was a question regarding the well owner's current thoughts on arsenic testing, i.e. their stage of testing behavior.[27] These stages were 1) never thought about it, 2) thought about it but decided against it, 3) undecided about testing, 4) plan to test for arsenic, and 5) test has been completed. The survey was offered on paper and participants were also given a URL with the option to complete it online using a unique code.

2.3. Survey implementation

Residential property parcels located within the 17 municipalities were selected using state Geographic Information System data. Properties overlapping known public water service areas were removed prior to selection in order to improve the return rate, but it was not possible to exclude all properties that may have a public water connection. A total of 2,000 surveys were mailed out to randomly selected addresses, 1,601 of which were selected using stratified random sampling by town in proportion to the estimated number of well-supplied households in the area. Approximately 6.3% of addresses available from each municipality were selected for the final representative sample. An additional 399 random addresses were selected for mailing from Alexandria and Kingwood Townships to increase statistical power to detect differences between groups of towns based on history of local testing promotion/intervention activities, with findings reported in a companion paper.[28] Selected addresses were matched to available PWTA records for confirmation of self-reported testing history.

Repeated contact by mail was used to increase response rate. Starting in June 2014 selected addresses were mailed a pre-survey letter, a survey with a cover letter and postage-paid return envelope, and thank you/reminder postcard about 1–2 weeks later. Also enclosed with the survey was a $2 cash incentive for participation, intended to improve response rates.[29]

The study protocol and survey instruments were approved by the Institutional Review Board of Columbia University.

2.4. Data analysis

Surveyed households were classified as being either “pre-PWTA” if they have resided in their home since prior to commencement of the PWTA, or “post-PWTA” if they bought or rented their home since 2002 and there was a record of the required well test occurring. Descriptive analysis, correlation, and regression analyses were employed using STATA IC v14. All statistical tests were two-tailed and p values less than 0.05 were considered significant. T-tests and ANOVA were performed to detect significant differences in group means, z-tests for differences in group proportions, and Mann-Whitney U-tests for significant differences in group distribution in Tables 2, 3, 5, 6, and 8. Spearman’s correlation rho coefficients (ρ) were calculated between dependent behavior variable and independent demographic variables in Tables 4 and 7. Behavior influencing factors were analyzed both as continuous (1–6) and dichotomized binary variables. Logistic regression analyses were conducted predicting binary testing behavior outcomes from dichotomized behavior influencing factor variables and demographic covariates. Linear regression analyses were conducted predicting continuous behavior factors from PWTA status adjusting for income and education in Tables 5 and 8. Completed surveys with partially missing data were only excluded from analyses requiring those variables of interest. Descriptive analyses (Tables 2, 3, and 6) were limited to surveys completed by households randomly selected proportionally by town to be the representative sample. Analyses of PWTA status associations with demographic and behavior influencing factors employed the full sample of surveys available in order to increase statistical power (Tables 4, 5, 7, and 8).

3. RESULTS

3.1 Sampled and general population characteristics

Out of the 2000 surveys mailed, several (n=57) were returned unopened as undeliverable. The survey response rate among delivered surveys (n=1,943) was 36.6%; 711 completed surveys (including 52 submitted online) were returned. Households on public water supply (n=22) and surveys received after August 1st (n=19) when a follow-up letter with more information on arsenic in NJ was mailed out were excluded from the analysis. In total 532 completed surveys from well households in the “representative” sample (excluding the extra surveys sent to Kingwood and Alexandria addresses) and 670 surveys from the full sample were suitable for analysis.

Although a comparison to only well water-supplied residents is not possible, census data for the area surveyed indicates that our respondents are slightly older, more likely to be male, and of higher income and education than the general population (Table 2). Respondents who purchased their homes after enactment of the PWTA are overall significantly younger, more likely to have children at home, and to have higher education and household income than those who have been residing in their homes prior to enactment of the PWTA.

3.2. Self-reported testing practices

Overall 82% of respondents reported that their well water has been lab tested for something (Table 3). This percentage is significantly higher among post-PWTA households, although not 100% indicating that there is either recall bias or misunderstanding of the question among those whose home purchase or rental agreement were required by law to include a well test. It is possible that a current well owner would answer no if the seller had taken responsibility for testing. Among wells that have been tested, half were tested in the past five years. This rate is significantly higher among post-PWTA households given that many homes may have been purchased during that time period, but the pre-PWTA rate suggests that well owners are still testing their water for reasons other than following the construction or purchase of a new home with a well.

Among most recent tests, post-PWTA households reported arsenic and lead as parameters that were included at a significantly higher rate than pre-PWTA households (Table 3). As a result, significantly more problems with arsenic have been identified among post-PWTA households; 23% of households who report their well has been tested and 20% of post-PWTA households overall identify an arsenic problem, very close to the estimated occurrence rate of 21% for the area. In comparison only 10% of pre-PWTA households who report their well has been tested and 4% of pre-PWTA households overall have identified an arsenic problem. If 21% of wells in this area are believed to have arsenic above 5 μg/L, but 4% of pre-PWTA households are reporting an arsenic problem, only 1 in 5 wells with arsenic problems are being detected by households for whom testing was not required, suggesting the majority of at-risk households remain unknowingly exposed. Post-PWTA households are significantly more likely to report that an arsenic test has been completed and less likely to report that they have never thought about testing for arsenic than pre-PWTA households. However, the 59% completed test rate among post-PWTA households indicates that many home buyers may not be involved with or aware of the well testing process that happens at the real estate transaction. Although testing for gross alpha is not required for every county in the survey area, there is a significantly higher rate of gross alpha testing among post-PWTA households as well.

There are clearly recall and reporting biases evident among post-PWTA households that may also affect pre-PWTA households, but self-reports can only be compared to actual testing history for post-PWTA households. Although we have confirmed that all 168 post-PWTA wells have been tested for arsenic and reported under the Act’s requirements, many of these households selected a testing stage other than “arsenic test has been completed” on their survey, most commonly that they have “never thought about arsenic testing” (Table 3). These respondents are significantly negatively predicted by knowing who to contact for a well test (Odds Ratio (OR)=0.23, 95% Confidence Interval (CI)=0.08–0.65) and reporting that local authorities have recommended they test (OR=0.16, 95% CI=0.03–0.83), indicating they may not have been aware that the required PWTA test took place. Furthermore, the majority of post-PWTA households (54%) do not recall what their arsenic results were, even if able to confirm that the test did take place, a higher rate of forgetting than among pre-PWTA households (41%) (Table 3). Specifically, 17 of 48 (35%) post-PWTA households known to have arsenic above 5 μg/L based on NJ State records did not report the exceedance

on their survey whereas 8 of 39 (21%) who reported a problem actually had no record of exceedance. Self-reporting of arsenic testing and identified problems result in both underestimation and misclassification of test results.

The reporting bias appears to be associated with income where higher-income post-PWTA households are more likely to correctly report that their well has been tested for arsenic (Table 4). When arsenic is indeed in compliance there is no harm done by forgetting a test, but 4 of 32 (13%) post-PWTA wells with respondents reporting to have "never thought about arsenic testing" do in fact have arsenic levels greater than 5 μg/L and none of them reported having an arsenic problem elsewhere on the survey, indicating these current well owners may still be unaware of their arsenic status. When asked the level of arsenic in their water two said they don't remember and two said they have never tested for arsenic. Post-PWTA households with records of arsenic exceedance appear much more likely to not remember or to misremember the results of their previous arsenic test than pre-PWTA households with self-reported problems. After testing water samples from 12 pre-PWTA wells self-reported to have an arsenic problem,[28] we found that only two well owners (17%) had misremembered the level of arsenic (options were <5 μg/L, 5–10 μg/L, 10–50 μg/L, 50–100 μg/L, and >100 μg/L) in their water on their survey. Among PWTA wells with confirmed arsenic problems, self-reports revealed that the majority of well owners (75%) have either forgotten or misremembered their arsenic levels, regardless of current mitigation behavior.

Among all households, a change in the taste, smell, or appearance of their water was the most commonly cited situation that would prompt a well test (80%), consistent across PWTA groups. Second was learning that their neighbors have contaminated water (74%), much higher than the next most common prompts of well testing available for free (46%) and learning that some wells in their town have contaminated water (40%).

3.3. Demographics are associated with behavior when testing is not required

Although homes bought after the PWTA were required to have their well tested at purchase, including for arsenic, reported testing has not been universal. This recall or misinformation bias is significantly associated with household income for both ever testing and arsenic testing (Table 4). Lower income households are less likely to report that their well has been tested despite falling under the requirements of the PWTA; reporting bias may be partly responsible for the significance of income to testing among pre-PWTA households as well. However, there are no other significant associations between demographic factors and reported testing behavior among post-PWTA households. Among pre-PWTA households which may have in fact never been tested before, having tested is significantly and positively associated with respondent's education and household income and negatively associated with living alone (Table 4). Education and household income are also highly significant to testing recently and having completed an arsenic test among households purchasing homes with wells prior to the PWTA. Households with children are more likely to report testing their well at home purchase. When all demographic variables are entered into fully adjusted logistic regression models predicting testing behavior among pre-PWTA households, only education remains significant for having ever tested, years lived in the home for testing at home purchase, and household income for completing an arsenic test. Each increase of

$25,000 in household income is associated on average with a 4% increase in likelihood that the well has been tested for arsenic (95% CI: 1–7%).

3.4. Perceptions and beliefs about testing vary by PWTA status

Mean (M) agreement (1=Strongly Disagree, 2=Moderately Disagree, 3=Slightly Disagree, 4=Slightly Agree, 5=Moderately Agree, 6=Strongly Agree) with all survey statements relevant to testing (n=34) are compared by PWTA status in Table 5. Overall post-PWTA households have significantly higher perceptions of vulnerability to water contamination risks, although only the risks from arsenic remain significantly predicted by PWTA status after controlling for age and household income to account for some of the demographic differences between the groups. On average post-PWTA households slightly agree with town risks for arsenic (M=3.61) while pre-PWTA households slightly disagree that there are risks for arsenic in their town (M=2.92)($p<.01$). Although rare overall, post-PWTA households are more likely to know someone with an arsenic problem (M=2.25 vs. M=1.82, $p<.01$), and they express greater personal obligation towards testing (M=3.85 vs. M=3.39, $p<.01$) and commitment to safe water than pre-PWTA households (M=5.48 vs. M=5.31, $p<.05$). There are no differences in self-efficacy and ability beliefs between the groups.

3.5. Self-reported treatment behavior

The majority of households in this area are treating their well water in some way (Table 6). Most are treating all the water in their home although many use point-of-use systems or pitcher/refrigerator filters, yet very few report use of a system capable of removing arsenic. Use of any treatment is significantly predicted by household income ($p<0.001$) overall, and among pre-PWTA households, but income is no longer significant to treatment use among post-PWTA households (Table 7). The rates of treatment and whole-house treatment are significantly higher among households purchasing their home post-PWTA compared to those pre-PWTA ($p<0.01$), even after adjusting for the effects of income in a logistic regression model. Water softeners and sediment filters are most commonly used, with no significant differences between groups; only the use of granular ferric adsorption and reverse osmosis systems, technologies known to be capable of removing forms of arsenic from water, are significantly higher among post-PWTA households ($p<0.01$), reflecting the much higher rate of arsenic testing and problem identification among this group (Table 3). Of the 140 post-PWTA households surveyed in the representative sample, 19% report that they are using treatment specifically to treat for arsenic, compared to only 3% of pre-PWTA households, $p<0.001$. However, post-PWTA respondents are significantly more likely to report that they are using some kind of treatment without knowing what it is (Table 6).

In our survey only 38% of pre-PWTA and 45% of post-PWTA households reporting using some kind of treatment say they have ever tested their treated water. Only 70% of pre-PWTA and 68% of post-PWTA treating households report that they perform maintenance on their systems as recommended. Neither of these differences are statistically significant.

Any use of treatment is significantly positively associated with household income and having children in the home, and negatively associated with age, years lived in the home,

and living alone, only among pre-PWTA households (Table 7). No associations between treatment use and demographic variables are significant among post-PWTA households.

Among 71 surveyed households with known (PWTA confirmed >5 μg/L n=48) or self-reported arsenic "problems" (n=23), 54% (n=38) report using some kind of water treatment for arsenic, 10% (n=7) report drinking bottled water only, but 37% (n=26) do not report using any strategy to avoid exposure to arsenic from their drinking water. Although this sample size is small, it is consistent with the rates we have seen from a much larger sample of private well households with arsenic above MCL in Maine (n=256), where 43% of households report installing treatment systems, 30% report taking another mitigation action such as drinking bottled water, and 27% report not taking action.[30] In New Jersey those with arsenic problems who report taking actions to reduce exposure believe more strongly than those who don't that their untreated water is not safe to drink (M=4.45 ±0.25 vs. M=3.0 ±0.40, $p<0.01$) and that their household is at risk of drinking arsenic contaminated water (M=4.58 ±0.28 vs. M=3.4 ±0.32, $p<0.01$). There are no significant differences in age, education and income between those taking action to reduce their exposure and those not. There are no differences in mitigation rate between pre-PWTA and post-PWTA groups, although pre-PWTA wells with arsenic have been identified only by self-reporting.

3.6. Beliefs about water treatment vary by PWTA status

Mean agreement (1=Strongly Disagree, 6=Strongly Agree) with all survey statements on treatment (n=17) are compared by PWTA status in Table 8. Pre-PWTA households perceive their untreated water to be safer (M=4.87 vs. M=3.79) and of higher quality (M=4.84 vs. M=4.00) than post-PWTA households. Post-PWTA households are more positive about the health benefits of treating and feel safer drinking treated water (M=4.88 vs. M=4.15) than pre-PWTA households. The significance of PWTA status towards these beliefs remains even after controlling for income and age of the respondent. Similar to beliefs relevant to testing, there are no differences in ability and self-efficacy beliefs regarding treatment and maintenance.

4. DISCUSSION

4.1. PWTA increases testing rate and reduces social vulnerability

The PWTA has significantly increased the number of private wells tested (10,278 wells in the 17 study towns during 2002–2014) and rates of testing for arsenic specifically, in an area of northern NJ where an estimated 21% of wells are known to be contaminated with arsenic above the NJ MCL. This has allowed more at-risk households to be identified (Figure 2, arsenic reported in 20% of post-PWTA wells vs. 4% of pre-PWTA wells) and to treat for arsenic (reported by 19% of post-PWTA households vs. 3% of pre-PWTA households), even when self-reported testing history is biased. When private wells have never been tested for arsenic then unaware households may continue drinking contaminated water indefinitely, unless they take initiative to test themselves. With the PWTA, new residents in New Jersey have the opportunity to become aware of the arsenic status of their well before they drink the water.

Importantly, the PWTA has significantly increased arsenic testing rates while closing socioeconomic gaps in testing status and treatment. For those private well owners with homes purchased prior to PWTA requirements, it is still entirely their responsibility to have their well water tested and to be aware, willing, and capable to perform the test and then complete any necessary follow-up actions like installing and maintaining water treatment equipment. Among these households who have had to make the decision and take action on their own, we find that education and household income are significantly and positively associated with testing behavior, likely both influencing awareness and understanding of risks and ability to manage those risks. Demographic patterns in testing observed among pre-PWTA households are not unique to New Jersey. We have observed similar trends in testing and treatment behavior in Maine where there are no testing requirements at real estate transactions.[26,30] Without an equal requirement for everyone to test, socioeconomic self-selection in protective health behaviors emerges. In pre-PWTA NJ and no-PWTA Maine, higher income, educated households are testing for arsenic at twice the rate of lower income and less educated households.[31] Here we find that higher income and higher educated households are more likely to have ever tested their well, to have tested their well at home purchase, to have tested their well in the past 5 years, and to have tested for arsenic (Table 4). In post-PWTA NJ the official testing rate is inherently equal, regardless of socioeconomic status, another achievement of regulation. Differences in testing behavior likely contribute to the significant positive association observed between income and any treatment use in pre-PWTA households (ρ=.214, $p<0.01$). This is not observed among post-PWTA households despite absence of regulation over treatment (Table 7).

4.2. PWTA helps to reduce risks for the biologically vulnerable

Although the PWTA did not intentionally target biologically susceptible groups such as pregnant women and families with children, such households are more likely to be buying homes, and in turn, the policy has an unintended benefit. Indeed, those who have purchased homes more recently are in general younger (median age 49 vs. 61, $p<0.001$), of higher income (median household income $125–150,000 vs. $100–125,000, $p<0.01$), and more likely to have children in the home than those who purchased their homes prior to the PWTA (60% vs. 32%, $p<0.001$). Although there is known underreporting for arsenic testing, 62% of post-PWTA households with children report having completed a test for arsenic compared to 42% of pre-PWTA households with children ($p<0.01$). More importantly, 26% of post-PWTA households with children report knowing their well has an arsenic problem compared to 7% of pre-PWTA households ($p<0.001$). Given an estimated arsenic occurrence rate of 21%, it appears that post-PWTA families are less at risk of unknowingly consuming arsenic contaminated water from their well. This is a significant achievement of the PWTA for the next generation of unborn children whose parents have recently purchased or have yet to purchase their home.

4.3. Post-PWTA well owners are more psychologically favorable toward testing and treatment

Well water risk awareness is higher among post-PWTA households than pre-PWTA households. Post-PWTA households express greater awareness of water contamination risks. Their greater awareness for arsenic risks specifically remains significant even after adjusting

for household income and age, suggesting that this may be a difference based on exposure to the PWTA rather than differences in the demographics of households purchasing homes more recently. Post-PWTA well owners have more negative perceptions about the quality and safety of their untreated water compared to pre-PWTA well owners, likely because they have been exposed to actual test results for their wells. Post-PWTA well owners express a stronger personal obligation to test, commitment to safe water quality, and a plan to test their well within the next year. It is possible that exposure to the PWTA and the experience of testing has made monitoring their well water more of a priority. But there is no difference in ability beliefs regarding both well testing and water treatment among PWTA groups; although risk perceptions and attitudes are more favorable towards protective actions among post-PWTA households, there is no advantage in action knowledge and self-efficacy.

Learning that friends or neighbors have tested their well water and found problems can be a strong prompt to test one's own well too; yet since only a minority of wells are likely to be contaminated it would be difficult to rely on social channels alone to boost testing rates. Nevertheless as testing rates improve the arsenic testing norm may become stronger; 25% of post-PWTA households report knowing someone with an arsenic problem compared to only 10% of pre-PWTA households ($p<0.01$). In our central Maine study area with higher arsenic testing rates, 36% of households report knowing someone with an arsenic problem. However, despite gains in social norms, testing for arsenic will continue to face particular challenges given that the majority (80%) of surveyed private well owners report they are looking for a change in the aesthetic quality of their water to justify testing, yet water users will not be able to see, taste, or smell arsenic in their water.

Although higher than pre-PWTA households, overall well water risk awareness is still lower among post-PWTA households in NJ than in a higher-risk area of Maine.[26] Yet the same optimistic biases are found; that is, well owners more strongly agree that there are risks for well contamination in their area vs. for their own well ($M=3.46 \pm 0.23$ vs. $M=2.89 \pm 0.24$, $p<.001$), and that there are risks for arsenic in their town vs. in their own well ($M=3.61 \pm 0.24$ vs. $M=3.13 \pm 0.25$, $p<.001$). Since post-PWTA wells have actually been tested this bias may be a more accurate assessment based on experience. However, these biases are mirrored in pre-PWTA households that have not all tested. Overcoming optimistic biases will continue to be a challenge; although 74% of households reported that their neighbor having a contaminated well would prompt them to test their own, only 40% would do so after hearing that wells in their town are contaminated. Awareness of town-level risks does not always translate into perception of personal risk among untested households.

4.4. Limitations of PWTA

Assuming a similar rate of housing turnover, we estimate that it will take about half a century for the PWTA to "reach" all private well households in Northern NJ; about 25% of homes (140 out of 532) in our randomly selected sample have faced a PWTA testing requirement since the PWTA became effective. The majority of wells in New Jersey have still not faced a requirement to test. For this reason it is important not to wait for the PWTA to "solve" the problem of arsenic exposure from drinking water. Although families purchasing homes currently are more likely to have children than not, at present, there are

more children living in homes purchased prior to the PWTA than those purchased after. In our sample 156 families with children purchased their home prior to PWTA requirements, compared to 95 families with children purchasing theirs since. To accelerate testing in consideration of biological vulnerability to arsenic, it would be helpful to expand the PWTA such that all wells supplying drinking water for pregnant women and children may be tested for arsenic, and if possible, for free with some innovative funding source.

The low reporting rate for arsenic testing among post-PWTA households is a concern despite the positive of more wells being tested and contaminated wells being identified and treated (Figure 2). While testing requirements like the PWTA remove important barriers to testing like well owner initiative and socioeconomic self-selection, a home buyer unengaged by the importance of well testing may not be engaged in the results and therefore not prepared or committed to the long-term responsibility of monitoring water quality and maintaining necessary water treatment systems. The PWTA's boost to arsenic testing rates may also lead to next stage challenges as new well owners are expected to follow-through with taking responsibility for their well water quality after the initial test, of which they may only be remotely aware.

As the PWTA generates more arsenic testing with housing turnover, more important to reducing actual exposure will be the protective actions taken after a contaminated well has been identified. Interestingly there are no differences in rate of reported mitigation between pre-PWTA and post-PWTA households with identified arsenic problems, suggesting that post-PWTA households are not more likely to take protective action, only that they are identifying more problematic wells in absolute numbers. Overall there are higher rates of arsenic treatment use among post-PWTA households (18% vs. 3%, $p<0.001$) reflecting the greater number of arsenic exceedances identified, but also a higher rate of unknown treatment use reported (7% vs. 2%, $p<0.01$). It is possible that these unknown systems were installed by previous owners, including at sale after a problematic well test. In fact, nearly a quarter (24%) of treatment systems in place in post-PWTA households were reported to be installed by a previous owner, more than double the rate in pre-PWTA households (10%, $p<0.001$). A treatment system installed by a previous owner and whose purpose is not understood by the current owner is at risk of becoming ineffective through improper maintenance.

The PWTA is a limited private well water testing law and does not address water treatment, which is still unregulated in New Jersey. The PWTA does not seem to have any influence on water treatment maintenance behavior. There are no significant differences in reported maintenance or monitoring of treated water quality between pre-PWTA and post-PWTA households. More than half (58%) of all treating households have never tested their treated water and only two-thirds (69%) report maintaining treatment systems as recommended. Once treatment is installed, either by the current well owner or a previous one, responsible maintenance behavior and regular monitoring of treated water quality are absolutely essential to ensuring treatment success. Treatment failure is a real risk and threatens to undermine all the effort made by the well owner and others in getting that household to the point of actually reducing arsenic exposure from their drinking water. In our water sampling in New Jersey (18% of n=22) and in Maine (15% of n=68) we have identified multiple

examples of incorrect or ineffective treatment systems failing to deliver water below the arsenic MCL arsenic at the tap,[28,30] and similarly ineffective treatment has been observed elsewhere by others.[32,33] Several NJ well owners who sent water samples believed they were treating for arsenic because there was a system in their basement, although they did not know what kind of system it was and had never performed any maintenance on it. The presence of tanks in the basement can give the false assurance of safe water leaving well owners unconcerned about monitoring the quality of their water. In Nevada, use of any treatment was found to increase consumption of tap water despite some treatments being ineffective at removing arsenic, either for being inappropriate, inefficient, or not maintained.[33]

Implementation of the PWTA results in more treatment systems being installed to remove arsenic from newly tested well water. It is important that the arsenic removal system chosen is appropriate for the water chemistry of that well and that the well owner is then fully aware and capable of handling the future maintenance responsibility, or that the treatment company be enlisted for a maintenance contract. Furthermore, when households depend on bottled water or point-of-use treatment to reduce their arsenic exposure, oftentimes due to the higher costs of a whole-house system,[30] consistent behavior change beyond regular maintenance and monitoring behavior is required. The occasional use of untreated water for drinking and cooking contributes to continuing arsenic exposure of affected families.[34,35] Alternative strategies like extending public water supply into the most arsenic-affected areas when feasible may ultimately be a more effective solution than relying on testing regulation or individual behavior change to eliminate arsenic exposure from drinking water within a population.[21] Unfortunately, given the diffuse nature of mostly rural private well households, this may not be an option in many locations.

4.5. Study limitations

We had to rely on self-reported testing and treatment behavior, which we've seen from matching to PWTA records can be problematic because of recall bias. As with any survey there is non-response bias, so although we randomly selected addresses for our sample the 37% response rate may suggest that our findings are not entirely representative of private well owners in this area. Furthermore some survey respondents declined to provide household income information, introducing more bias into the analyses requiring this demographic factor. The non-response also limits our final sample-size which reduces power for analysis, particularly among small sub-groups of interest. Finally, this was a cross-sectional survey conducted at only one point in time. We know which households have tested under the PWTA but we don't know what their testing behavior or psychological beliefs about testing would have been before their interaction with the PWTA or without the required test taking place. Also those purchasing houses in recent years may be different in unknown ways from those who purchased their homes prior to 2002, so it is difficult to attribute all the differences observed between groups to the influence of the PWTA policy alone. With this study design we are also not able to identify any spillover effects the PWTA has had on the behavior and beliefs of non-PWTA households; they may have also benefited indirectly from the greater number of arsenic tests being performed. Indeed, the building of the PWTA database of test results has permitted fine-scale spatial analysis of arsenic

occurrence in northern New Jersey and identification of the most at-risk areas. This may have contributed to greater testing promotion and generating more testing among pre-PWTA households as a result.

5. CONCLUSION

The PWTA in New Jersey has not only led to significantly higher well testing rates and testing for arsenic in at risk areas, but also closed the socioeconomic gaps in testing among new homeowners with an unintended benefit of reaching higher proportions of families with children. This has resulted in more at risk households being identified and treating for arsenic, and going forward several decades ensures that young households will be aware of their drinking water quality and that socioeconomically disadvantaged households will not fall further behind in testing behavior. These are significant effects that should lead all states to consider similar private well testing regulations, especially in areas where a large number of residents drink from groundwater but are unaware of common risks faced such as naturally occurring arsenic contamination. Yet given that the majority of current NJ private well households have resided in their homes since before 2002 and therefore drink from wells that have never faced a PWTA testing requirement, arsenic exposure from untested and untreated wells remains a serious public health concern and the need for other approaches to increase arsenic testing and mitigation is clear. Among these households unaffected by the PWTA there are still strong socioeconomic patterns in testing and treatment behavior, as well owners must be aware, willing, and capable to manage the protective actions of well water testing and treatment on their own. Providing more public resources to support private well testing while targeting interventions to socially and biologically vulnerable groups can help make up for the slow progress in housing turnover. Furthermore, the existence of the PWTA does not prohibit consideration of other policy tools that could complement these efforts and address shortcomings.

By design, the PWTA has only mandated the *testing* of private well water for arsenic, and indeed leads to more arsenic testing and identification of problematic wells. To capitalize on this progress in testing, public health efforts will need to shift emphasis to the actual behaviors that protect health, which include reducing exposure to the arsenic through consistent avoidance or water treatment. Testing is just the screening process; effectively reducing exposure is necessary to mitigate the health effects of arsenic. Therefore the observed disconnect between post-PWTA well owners and their arsenic test results is concerning. New home owners that are not engaged in the PWTA-required water testing at sale may be unprepared for the responsibilities that arise with having an arsenic-contaminated well. Once treatment is in place, regular maintenance and monitoring are critical. For those well owners who do face arsenic problems, the decisions to test a well or treat water are no longer one-off actions; maintenance and monitoring will be required ongoing behaviors for the long term. Studies of households living with arsenic in their well water show that due to deficiencies in technology and behavior in practice, real elimination of arsenic exposure is elusive.[30,32,34] Once significant gains in arsenic screening are achieved, shifting resources to education and support for these households facing arsenic problems in their well water will be necessary.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

- The impact of NJ legislation on private well testing and treatment is investigated Randomly selected well owners purchasing homes before and after the Act were surveyed
- Without required testing only 1 of 5 wells exceeding the arsenic MCL is identified
- Required arsenic testing reduces socioeconomic disparities, benefits children
- To maximize PWTA benefits, more support for households after testing is necessary

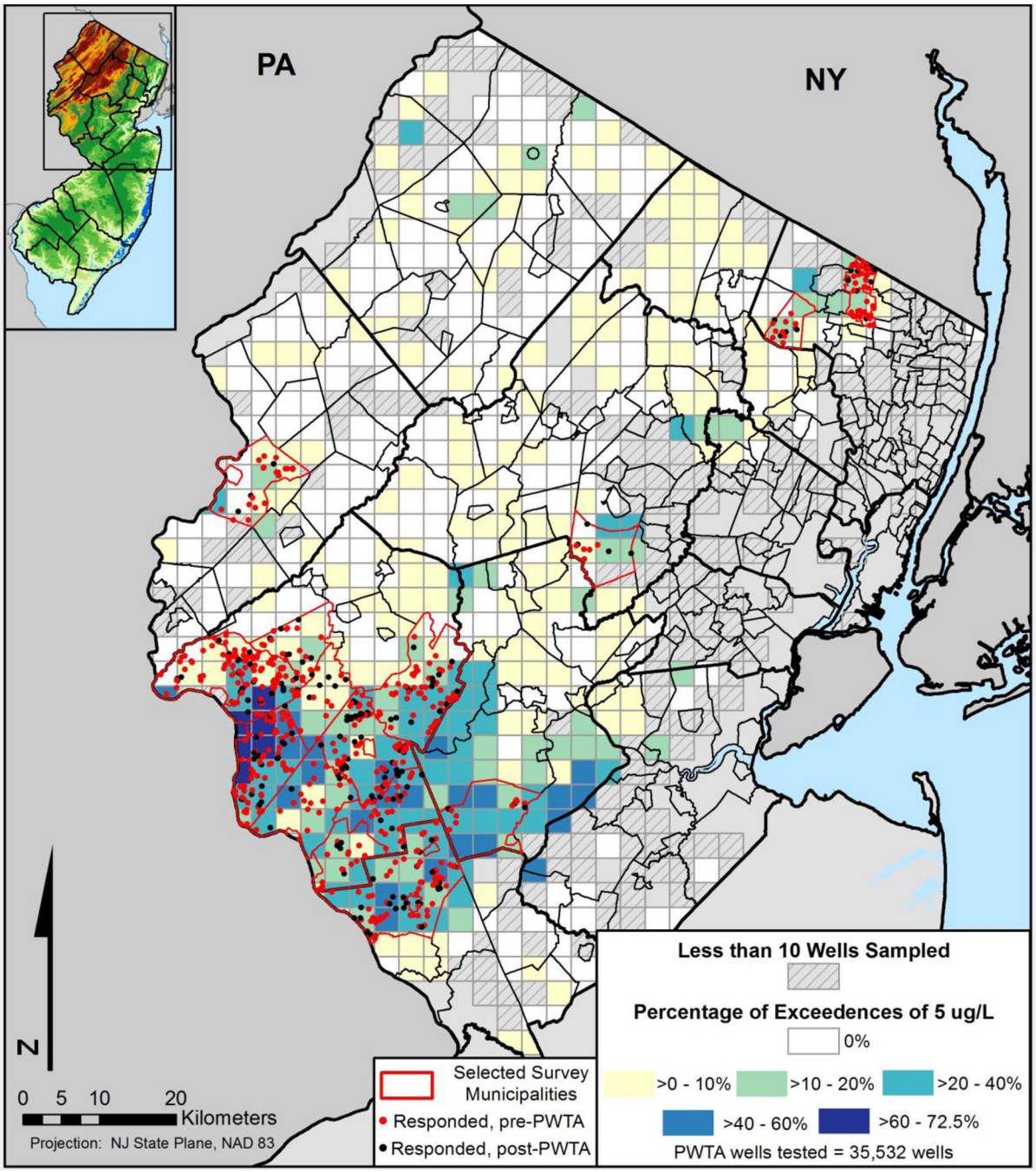

Figure 1.

Distribution of surveyed homes purchased prior to the commencement of the PWTA (pre-PWTA (n=502)) and those purchased after the PWTA (post-PWTA (n=168)) analyzed from 17 selected municipalities of New Jersey and rate of arsenic occurrence above the 5 μg/L MCL within 2×2 mile areas based on PWTA testing records as of April 2014 (colored boxes). Areas not covered by a box have no wells tested under the PWTA.

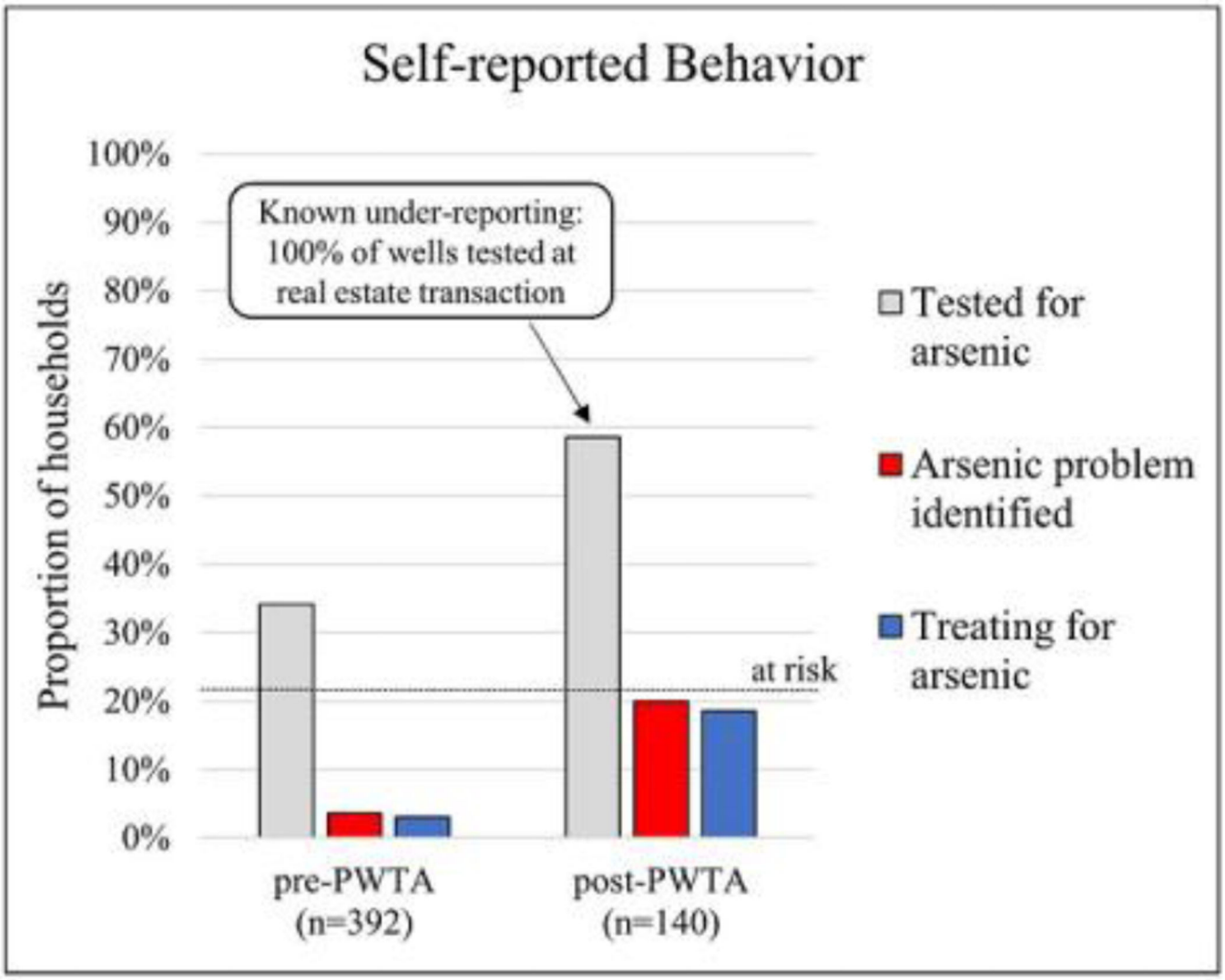

Figure 2.

Self-reported rates of testing for arsenic, finding an arsenic "problem," and treating for arsenic among pre-PWTA and post-PWTA households, compared with known rate (100%) of arsenic testing among post-PWTA households ("unreported") and the 21% of wells estimated to be contaminated with arsenic in this area ("at risk"). There is clear evidence of under-reporting among post-PWTA households as 100% of wells are known to have been tested for arsenic at real estate transaction.

Table 1

Selected towns for study area

Town	County	Population	Households with Wells	Tested Wells > 5 μg/L
Alexandria	Hunterdon	4,938	97%	24.2%
Delaware	Hunterdon	4,563	89%	20.5%
East Amwell	Hunterdon	4,013	99%	42.2%
Franklin	Hunterdon	3,195	99%	7.7%
Holland	Hunterdon	5,291	83%	8.3%
Kingwood	Hunterdon	3,845	99%	42.6%
Raritan	Hunterdon	22,185	54%	24.6%
Readington	Hunterdon	16,126	83%	18.8%
Union	Hunterdon	5,908	67%	5.3%
West Amwell	Hunterdon	3,840	99%	18.4%
Franklin Lakes Boro	Bergen	10,590	57%	8.7%
Saddle River Boro	Bergen	3,152	98%	10.1%
Upper Saddle River Boro	Bergen	8,208	94%	12.9%
Harding	Morris	3,838	67%	12.3%
Hopewell	Mercer	17,304	93%	26.5%
Montgomery	Somerset	22,254	60%	33.6%
White	Warren	4,882	83%	7.3%
Total		144,132	76%	20.8%

Table 2

Demographic characteristics of source population and survey respondents in 17 towns of New Jersey, and by homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA) and those who purchased after commencement of the PWTA (post-PWTA).

Demographic characteristic	Area population[a]	Representative sample (n=532)	pre-PWTA (n=392)	post-PWTA (n=140)
Median age (years)[b]	51	58	61	49
Sex ratio (M/F)	49/51%	54/46%	55/45%	51/49%
Median household income[c]	$121,095	$125,000–150,000	$100,000–125,000	$125,000–150,000
% Bachelor's degree[d]	56%	71%	68%	79%
Households with children[e]	38%	38%	32%	60%
Living alone[e]	19%	8%	10%	4%
Median (Range) Years in Home	--	17 (1–73)	24 (12–73)	7 (1–12)

[a] 2012 American Community Survey

[b] The survey respondents were required to be at least 18 years old, the median age for the area is estimated for population ≥18. 25th and 75th percentile ages for sample are 50 and 67, respectively. Median age is significantly different between PWTA groups ($p<0.001$)

[c] 30% of survey respondents chose not to report income data, distribution of survey income is significantly different than general population ($p<0.01$), and the distribution of income is significantly different between pre-PWTA and post-PWTA groups ($p<0.01$)

[d] Census data is for population 25 and older only; survey respondents could have been as young as 18 but the youngest reported age was 26. Proportions significantly different between PWTA groups ($p<0.05$).

[e] Households with children and living alone significantly different between PWTA groups ($p<0.001$).

Table 3

Self-reported testing history for all surveyed households and by homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA) and those who purchased after commencement of the PWTA (post-PWTA). Percentages reflect positive responses.

Survey Question	Responses	Representative Sample (n=532)	Pre-PWTA Households (n=392)	post-PWTA Households (n=140)
Have you ever had your well water tested by a lab?	Yes *	82%	80%	88%
	No	16%	19%	10%
	Don't know	1%	1%	2%
Approximately when was your well last tested?[a]	In the last 12 months *	15%	13%	20%
	1 to 5 years ago **	36%	32%	50%
	More than 5 years ago **	47%	54%	28%
	Don't know	2%	2%	1%
What was your water tested for the last time it was tested?[a]	Bacteria	60%	58%	64%
	Arsenic **	44%	30%	53%
	Hardness	42%	41%	44%
	Nitrates	40%	38%	46%
	Iron	40%	38%	42%
	Lead *	39%	35%	48%
	Manganese	27%	26%	29%
	Gross Alpha	18%	16%	23%
	Other[b]	10%	10%	9%
	Don't know	32%	32%	34%
Has a test of your water ever shown a problem with any of the following?[a]	Hardness	32%	34%	25%
	Iron	11%	11%	13%
	Arsenic **	10%	4%	23%
	Bacteria	9%	9%	8%
	Manganese	3%	4%	2%
	Nitrates	3%	3%	3%
	Lead	2%	1%	2%
	Gross Alpha	1%	1%	3%
	Other	4%	4%	2%
	Don't know	18%	18%	19%
If your well was tested for arsenic, what was the highest arsenic level measured?[a]	5 μg/L or less	15%	14%	18%
	between 5 and 10 μg/L	4%	3%	7%
	between 11 and 50 μg/L	1%	1%	2%
	between 51 and 100 μg/L	0%	0%	1%
	greater than 100 μg/L	0%	0%	0%

Survey Question	Responses	Representative Sample (n=532)	Pre-PWTA Households (n=392)	post-PWTA Households (n=140)
	don't remember*	44%	41%	54%
	never tested for arsenic**	34%	41%	18%
What are your thoughts about testing your well water for arsenic?	Never thought about it**	30%	34%	21%
	Undecided about testing*	13%	14%	8%
	Decided not needed	7%	8%	4%
	Plan to test for arsenic	9%	9%	9%
	Test has been completed**	41%	35%	59%
What are your thoughts about testing your well for gross alpha?	Never thought about it	59%	59%	58%
	Undecided about testing	10%	12%	5%
	Decided not needed	6%	7%	4%
	Plan to test for gross alpha	6%	6%	4%
	Test has been completed**	19%	16%	29%
Was well tested at home purchase?	Yes**	68%	62%	86%

*Significant at 0.05 level, difference between pre-PWTA and PWTA groups

**Significant at 0.01 level, difference between pre-PWTA and PWTA groups

[a]N=441, 314, and 123 wells reported tested, respectively among the Representative Sample, Pre-PWTA, and Post-PWTA groups.

[b]Such as pH, VOCs, sulfates, copper, mercury, hydrocarbon, calcium, sodium, chloride, uranium, pesticides

Table 4

Associations (ρ) between demographic variables and testing behaviors for homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA, n=502) and those who purchased after commencement of the PWTA (post-PWTA, N=168)

Demographic Variable	Ever Tested		Tested at Home Purchase		Tested Recently (past 5 years)		Arsenic Test Completed	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Age	−0.009	−0.002	−0.164**	0.014	−0.049	−0.100	−0.092*	−0.004
Years Lived in Home	−0.058	0.067	−0.245**	0.049	−0.090	−0.306**	−0.069	−0.090
Education	0.171**	0.040	0.117**	0.030	0.120**	−0.027	0.097*	0.017
Household Income	0.119*	0.178*	0.114*	0.119	0.143**	0.089	0.148**	0.194*
Live Alone	−0.104*	0.077	−0.079	0.085	−0.052	−0.057	−0.091*	−0.014
Children in the Home	0.037	0.034	0.106*	0.025	0.034	0.049	0.084	0.063

*Significant at the 0.05 level

**Significant at the 0.01 level.

Spearman's correlation coefficients were calculated between dependent behavior variable and independent demographic variable. Years in home and age are continuous variables; income and education are ordinal categorical variables (<$25,000; $25,000-$50,000; $50,001-$75,000; $75,001-$100,000; $100,001-$125,000; $125,001-$150,000; >$150,000)(some high school or less, high school/GED, some college, technical/community college, bachelor's degree, some graduate school, graduate degree), live alone and children in the home are binary variables.

Table 5

Mean agreement with survey statements on testing among homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA, n=502) and those who purchased after commencement of the PWTA (post-PWTA, n=168)

Survey Statement (1/Strongly Disagree --- 6/Strongly Agree)	**pre-PWTA Mean (SD)**	**post-PWTA Mean (SD)**
I. Risk		
a. Vulnerability		
Wells in this area are at risk of being contaminated **	3.05 (1.58)	3.46 (1.48)
My family is at risk for drinking contaminated water **	2.39 (1.48)	2.89 (1.56)
There is a considerable risk that wells in this town are contaminated with arsenic ** a	2.92 (1.46)	3.61 (1.53)
Our household is at risk of drinking arsenic-contaminated well water ** a	2.57 (1.44)	3.13 (1.54)
b. Severity		
Adverse health effects from drinking well water are overblown	3.07 (1.49)	2.89 (1.34)
Arsenic-related health effects are likely to be serious	4.57 (1.39)	4.73 (1.31)
The health risks from arsenic exposure are overblown	2.73 (1.31)	2.68 (1.36)
c. Knowledge		
My well water quality can change overtime *	4.59 (1.21)	4.85 (1.08)
We can be exposed to arsenic from our well water	4.49 (1.38)	4.64 (1.44)
Years of exposure increases our arsenic-related health risks	4.80 (1.30)	4.86 (1.20)
Children/pregnant women especially vulnerable to arsenic-related health risks	4.78 (1.35)	4.94 (1.20)
II. Attitude		
a. Instrumental		
Water testing results are helpful to protect the health of my family **	5.01 (1.15)	5.28 (0.90)
Regularly testing my well water is too expensive	3.91 (1.64)	3.89 (1.40)
Regularly testing my water takes too much time	2.63 (1.39)	2.73 (1.36)
I am concerned that a bad water test result will hurt my property value	3.59 (1.74)	3.57 (1.66)
b. Affective		
I feel safer having my well tested by a lab **	4.72 (1.32)	5.04 (1.07)
I feel better not knowing what is in my well water a	1.94 (1.38)	1.78 (1.27)
III. Norms		
a. Descriptive		
I believe most of my neighbors regularly test their well water	2.64 (1.20)	2.61 (1.22)
My relatives have recently tested their well water	1.85 (1.22)	1.96 (1.23)
My friends have recently tested their well water	2.16 (1.32)	2.19 (1.28)
I know someone with an arsenic well problem **	1.82 (1.56)	2.25 (1.85)
b. Injunctive		
I think most of my neighbors expect me to regularly test my water	1.91 (1.14)	2.06 (1.18)
Local authorities have recommended I test my well water	2.68 (1.69)	2.81 (1.70)

Survey Statement (1/Strongly Disagree --- 6/Strongly Agree)	**pre-PWTA Mean (SD)**	**post-PWTA Mean (SD)**
c. Personal		
I feel personally obligated to test well my water ** [a]	3.39 (1.76)	3.85 (1.68)
It is my responsibility to have my water tested	4.92 (1.34)	5.10 (1.24)
IV. Ability		
a. Action Knowledge		
I know who to contact to have my water tested	4.04 (1.81)	4.23 (1.78)
b. Self-efficacy		
Finding a well testing service is too difficult	2.71 (1.51)	2.83 (1.51)
I am confident I can manage regularly testing my water	4.58 (1.33)	4.36 (1.45)
There is nothing I can do about the arsenic level in my well water	2.15 (1.24)	1.99 (1.18)
V. Self-regulation		
a. Action Planning		
I have never thought about having my well water tested **[a]	2.46 (1.65)	2.06 (1.40)
I plan to have my well water tested within the next year [a]	3.69 (1.67)	3.95 (1.61)
b. Remembering		
I would like to get my well tested, but I keep forgetting to	3.05 (1.73)	3.20 (1.71)
c. Commitment		
I am committed to monitoring the quality of my well water	3.94 (1.52)	4.19 (1.44)
I am committed to drinking safe water *[a]	5.31 (0.95)	5.48 (0.83)

* $p<.05$,

** $p<.01$ significant difference in PWTA group means

[a] Agreement is significantly predicted by PWTA status after adjusting for age and household income

Table 6

Reported treatment behavior among representative sample for all surveyed households and by homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA) and those who purchased after commencement of the PWTA (post-PWTA)

Use of treatment	Full sample (n=532)	pre-PWTA (n=392)	post-PWTA (n=140)
We don't use any treatment **	24%	28%	12%
Pitcher or refrigerator water filter	29%	28%	34%
Treat at point of use/under sink	17%	17%	16%
Carbon filter	10%	10%	8%
Reverse osmosis	6%	5%	9%
Treat all water in the home **	59%	55%	69%
Water softener	42%	40%	46%
Sediment filter	25%	24%	26%
**Granular ferric adsorption	4%	2%	7%
**Reverse osmosis	3%	2%	7%
Anion exchange	2%	2%	3%
Unknown type of treatment **	4%	2%	7%
Drink only purchased bottled water	11%	12%	10%
We treat in this way because a lab test for arsenic showed we needed to **	7%	3%	19%

** significant difference at 0.01 level between pre-PWTA and post-PWTA groups

Table 7

Associations (ρ) between demographic variables and treatment use for homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA, n=502) and those who purchased after commencement of the PWTA (post-PWTA, n=168)

Demographic Variable	Any Treatment Use	
	Pre-PWTA	Post-PWTA
Age	−0.146**	−0.035
Years Lived in Home	−0.219**	0.030
Education	0.050	−0.041
Household Income	0.214**	0.057
Live Alone	−0.094*	−0.089
Children in the Home	0.112*	−0.053

* p<0.05,

** p<0.01

Table 8

Mean agreement with survey statements on treatment for homeowners who purchased prior to the commencement of the PWTA (Pre-PWTA, n=502) and those who purchased after commencement of the PWTA (post-PWTA, n=168)

Survey Statement (1/Strongly Disagree --- 6/Strongly Agree)	**pre-PWTA Mean (SD)**	**post-PWTA Mean (SD)**
I. Risk		
My untreated water is perfectly safe to drink ***a**	4.87 (1.42)	3.79 (1.89)
The overall quality of my untreated water is good ***a**	4.84 (1.48)	4.00 (1.79)
II. Attitude		
a. Instrumental		
Treating my water is good for my health ***a**	4.64 (1.37)	5.19 (0.98)
Treating my well water reduces my risk for disease ***a**	4.51 (1.38)	4.89 (1.15)
Treating my well water is too expensive	3.46 (1.62)	3.38 (1.57)
Treating my water is too much hassle	3.06 (1.47)	2.99 (1.41)
b. Affective		
I feel safer drinking treated water ***a**	4.15 (1.59)	4.88 (1.31)
I like my untreated well water (e.g. taste, smell, looks) ***a**	4.83 (1.59)	4.10 (1.76)
III. Norms		
a. Descriptive		
I believe some of my neighbors treat their water ***a**	3.47 (1.53)	3.87 (1.40)
My relatives treat their water	2.30 (1.45)	2.83 (1.64)
b. Injunctive		
My neighbors would expect me to treat if my water did not meet standards	3.71 (1.72)	3.78 (1.66)
Local authorities would advise not to drink my water if it did not meet standards	4.40 (1.59)	4.27 (1.53)
c. Personal		
If my water did not meet standards I would feel a personal obligation to treat it	5.25 (1.03)	5.31 (0.97)
IV. Ability		
a. Action Knowledge		
I know where to get information about water treatment options	4.21 (1.68)	4.08 (1.84)
I know how to find a company to install a treatment system	4.54 (1.57)	4.63 (1.57)
b. Self-efficacy		
I am confident I could choose a water treatment system if necessary	4.77 (1.36)	4.56 (1.56)
I am confident I can maintain a treatment system, even if additional costs	4.66 (1.33)	4.70 (1.39)

** $p<0.01$ significant difference in group means

[a] Agreement is significantly predicted by PWTA status after adjusting for age and household income