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Arsenic in Private Well Water Trilogy II: Who benefits the most from traditional testing promotion?

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Abstract

Arsenic, a toxic element naturally found in groundwater, is a public health concern for households drinking from wells. Private well water is not regulated to meet the federal drinking water arsenic maximum contaminant level (MCL) of 10 μg/L, or the more protective 5 μg/L New Jersey state MCL. In the absence of consistent private well regulation, public health efforts have relied on promoting testing in affected communities to various degrees of success. Few interventions publish results, and more often focus on the outcome of tested wells rather than *who* completed a test, and more importantly, *who* did not. Through our survey of randomly selected addresses (n=670) in 17 NJ towns we find higher rates of arsenic testing in areas with a history of testing promotion. However, we also see a stronger correlation of testing behavior with income and education in high promotion areas, suggesting that community engagement activities may be exacerbating socioeconomic status (SES) testing disparities. Well owners with a bachelor's degree had ten times greater odds of participating in our direct mail testing intervention than those with less education when tests cost $40. After all households (n=255) were offered free tests to overcome many of the usual testing barriers – awareness, convenience, and cost – only 47% participated and those who chose to return water samples were of higher income and education than those who did not. Our findings highlight that while efforts to promote and provide arsenic testing succeed in testing more wells, community testing interventions risk increasing SES disparities if those with more education and resources are more likely to take advantage of testing programs. Therefore, testing interventions can benefit by better targeting socially vulnerable

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populations in an effort to overcome SES-patterned self-selection when individuals are left alone with the responsibility of managing their drinking water quality.

Graphical abstract

Keywords

private well; arsenic; drinking water; testing promotion; socioeconomic status; New Jersey

1. INTRODUCTION

Arsenic is a toxic element naturally occurring in the Earth's crust that can be released into groundwater at unsafe levels for human consumption. Arsenic is a known carcinogen and long-term exposure is associated with multiple adverse health effects, including various chronic diseases as well as negative pregnancy and child development outcomes.[1] Water users cannot see, taste, or smell arsenic in groundwater drawn from wells; its presence can only be known through specific testing. Over 13 million, mostly rural, U.S. households regularly depend on private wells for their drinking water.[2] Unlike public water, private well water is unregulated by the Safe Drinking Water Act and is not required to meet the U.S. EPA's Maximum Contaminant Level (MCL) for arsenic of 10 μg/L or, in New Jersey, the more stringent state MCL of 5 μg/L. The safety of private well water is the responsibility of each individual owner to ensure. Through its Private Well Testing Act (PWTA) New Jersey is one of only two states that requires testing of private wells for arsenic at real estate transactions. Even though more than 35,000 private wells have been tested for arsenic through the NJ PWTA since 2002, approximately 160,000 wells in the arsenic-vulnerable northern part of New Jersey remain to be tested,[a] and the slow turnover of property means that the majority of private well households in NJ, like most private well households nationally, have not faced any requirement to test their water.

In the absence of federal and state regulations, private well testing is an individual well owner's responsibility. Public health efforts typically rely on testing promotion in communities susceptible to arsenic contamination. Often municipal governments or community organizations may sponsor regular testing days or information campaigns, especially if an area is particularly at risk for specific types of contamination like arsenic. Results from most of these efforts are not evaluated, or at least not made publically

[a]Estimate based on county population, percent on domestic supply in 2005 (US Census County Database), and 2.7 people per home (US Census Data).

available, and the few that have been published focus more on the outcome of tested wells or why well owners completed a test through the program, rather than *who* completed a test, and more importantly, *who* did not. Through our surveys of private well households in central Maine and northern New Jersey we have identified significant socioeconomic-related vulnerability to arsenic exposure due to lower rates of arsenic testing and treatment behaviors.[3] Here we first investigate the association between arsenic testing status and residence in a town with past arsenic testing promotion activities, and whether there is any effect on known disparities in testing behavior by socioeconomic status (SES). Second we examine the results of a direct-mail free well test intervention for evidence of an SES-effect on participation to help interpret findings of the survey.

2. METHODS

2.1. Household survey data

In June 2014 we implemented a mailed household survey of randomly selected addresses in 17 arsenic-affected towns of northern New Jersey with high private well water use and received responses from 670 private well households, a 37% response rate (Figure 1). The study area and survey implementation have been described elsewhere.[4] The survey instrument was adapted from one previously used in Maine[5] and included questions on well testing and treatment practices and opinions (n=20) as well as basic demographic information (n=11) and psychological factors that may influence behavior (n=48). Questions allowed differentiating between whether a well has been “ever tested,” that is whether the water has been tested by a laboratory for anything, and “arsenic tested,” specifically for arsenic. Self-reported education level and household income are used as measures of socioeconomic status, although 30% of households declined to provide income information thereby reducing the sample sizes for these analyses. Household income was reported categorically on the survey: < $25,000; $25,000-$50,000; $50,000-$75,000; $75,000-$100,000; $100,000-$125,000; $125,000-$150,000; > $150,000; and treated in regression analyses as either continuous (Table 5) or categorical with 4 values: < $50,000; $50,000-$100,000; $100,000-$150,000; and > $150,000 (Table 7).

2.2. Local arsenic occurrence data

PWTA summary records through March 2014 of arsenic test results within 2×2 mile areas were obtained and matched to addresses participating in the survey to estimate local arsenic occurrence or arsenic rate. This is defined as the percentage of wells with an arsenic concentration greater than 5 μg/L within the address’s assigned 2×2 mile area.

2.3. Intervention level classification

The 17 surveyed New Jersey towns have been classified into 3 groups based on previous efforts made locally to motivate well testing and treatment for arsenic. Public meetings, free testing, newsletters, and school events are example activities implemented by local governments that may lead to different testing rates between towns. Two towns were considered high intervention because of their more intensive recent (2010) activities to motivate arsenic testing: Alexandria and Kingwood Townships (see Appendix A). Five more towns have had some kind of arsenic testing initiatives before 2010 and so were classified as low intervention towns. The remaining 10 towns were classified as non-intervention towns because no known testing promotions occurred within them. Although 532 surveys were received from addresses selected using stratified random sampling to form a representative sample of the 17 towns overall, an additional 138 surveys were received from addresses oversampled from the two high intervention towns in order to detect differences between town groups based on history of local testing promotion. It is important to note that although these surveyed households are categorized as belonging to high, low, or non-intervention towns, it is not known whether these specific households were actually exposed to the town promotion activities or whether they may have been affected by other factors unknown to us.

2.4. Water sampling intervention

As a follow-up to the 2014 survey, 255 households who participated were shipped sample bottles in June 2015 with an offer to test their well water for arsenic and other parameters through Columbia's laboratory. These households were selected based on 1) arsenic concentrations >4μg/L in their well as known from PWTA records (n=55), 2) households without PWTA data who self-reported arsenic problems in their well (n=23), and 3) households without PWTA data who self-reported that they had "never tested for arsenic" (n=177). The first two groups were offered free testing, the third untested group was randomized to receive either an offer for free testing or a testing offer with a $40 fee. Sample bottles were shipped to all houses with sampling instructions (Appendix B), bottles for sample collection at the kitchen tap and at the basement pressure tank (if present), and a pre-paid return FedEx box. The deadline for shipping samples was July 1, after which all households were sent a reminder letter extending the deadline by 3 weeks. For the paid test households this reminder notified them that testing was now being offered for free if they returned their samples. Both the initial and reminder letters notified residents of the risks for arsenic from well water in their area, provided links to online resources and guidance regarding arsenic, and strongly encouraged them to take advantage of the testing opportunity. Results were mailed to participants in August 2015 and included their returned check if payment had been sent with samples.

2.5. Water sample analysis

Water samples were acidified to 1% HNO_3 (Optima Grade) and allowed for dissolution for at least a week before analysis by high resolution inductively coupled plasma-mass spectrometry (ICP-MS) by Columbia University. Repeated analyses of the standard solution 1643e (n=7) with 60.5 μg/L of arsenic and a check sample (n=12) with 16.9 μg/L of arsenic revealed an accuracy within 6.3% and a precision within 4.0%. The detection limit for arsenic was <0.02 μg/L. Also analyzed and reported were: aluminum, antimony, barium, beryllium, boron, cadmium, chromium, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, sodium, strontium, uranium, and zinc.

2.6. Statistical Analysis

Descriptive analysis, correlation, and regression analyses employed STATA IC v14. All statistical tests were two-tailed and p values less than 0.05 were considered significant. For Tables 1, 2, 4, and 6 chi-square tests were performed to examine bivariate associations between participant groups and variables of interest, and pairwise z-tests and Mann-Whitney

U-tests were performed to detect significant differences in group proportion and distribution, respectively. Spearman rank correlations (ρ) were used to detect significant associations between testing behavior and demographic covariates in Table 3. The relationships of binary testing and participation behavior outcomes with SES and other covariates were analyzed by multiple logistic regression in Tables 5, 7, and 8. In Table 5 the significance of income as a predictor for arsenic testing was tested by adjusting for education in model 1, intervention level in model 2, local arsenic rate in model 4, and intervention level and local arsenic rate in model 5; model 3 tested the significance of intervention level as a predictor of arsenic testing after adjusting for local arsenic rate. Completed surveys with partially missing data were only excluded from analyses requiring those variables of interest.

3. RESULTS

3.1. History of promotion associated with higher testing

Intervention towns show higher rates of arsenic testing and lower rates of having "never thought about arsenic testing" than non-intervention towns, although it is important to note that level of intervention activities is not the only difference between the groups (Table 1). The percentage of tested wells exceeding the NJ MCL for arsenic is also significantly associated with intervention level, with more recent promotion in higher arsenic areas. Despite the significance of income and education to arsenic testing behavior,[3] high intervention town households have the highest rate of arsenic testing (41%) among those who purchased homes before the PWTA's requirements, while overall being less educated than households in the other groups (Table 1).

In addition to the higher testing rate among intervention town households, we find significant associations between intervention level and several psychological factors that may influence testing behavior among residents who purchased homes before the PWTA (Table 2). Comparing survey responses, we find there is no association between area history of arsenic testing promotion and perceptions of area risk for well contamination in general, but when the statement is specific to arsenic the association becomes significant. There are higher rates of agreement about risks for arsenic in areas with a history of testing promotion. Similarly there are significant associations between promotion history and belief that finding a well testing service is difficult. This belief is less common in high promotion towns, while knowing someone else with an arsenic problem is more common in high promotion areas (Table 2).

3.2. Promotional activities may exacerbate SES testing disparities

Within groups significant associations between demographic variables and testing behavior are shown in Table 3. Despite small sample sizes, households in high intervention areas show stronger correlations between education and testing history, and household income and arsenic-specific testing, than in the full sample. Although arsenic testing rates are higher in intervention towns, including among lower income households, the testing gap between higher and lower income households is even more apparent within the high intervention group (Table 4). Overall, household income remains a stronger predictor of arsenic testing behavior than town intervention level (Table 5).

The most significant known difference between intervention groups is that intervention towns are also much more likely to have arsenic in their wells than in other areas, based on PWTA records (Table 1). Although the mechanism is not clear, local arsenic occurrence seems to be a significant predictor of arsenic testing behavior, dominating the effect of testing promotion alone (Table 5, Model 3). Yet when local arsenic occurrence and town intervention level are further adjusted for household income, only household income remains a significant predictor of arsenic testing status (Table 5, Model 5).

3.3. Greater participation among higher SES households in direct mail testing intervention

A total of 119 households mailed in water samples by the final extended deadline, a participation rate of 47%. This includes 74 households who had previously never tested for arsenic. Overall the distribution of education and household income was significantly higher among the group participating in the sampling program than those not participating, with no significant differences in age (Table 6). A greater majority of participants had a bachelor's degree (73%) and household income over $100,000 (70%) than those who did not participate (54% and 53%, respectively).

Among those households selected for the sampling program who reported in their survey that they had not yet completed an arsenic test, participation in the first phase of sampling was significantly different by offer group; 12% of those offered paid tests (n=93) and 42% of those offered free tests (n=84) sent samples by the first deadline ($p<0.0002$). The reminder letter generated an additional 15% response from the originally free group, and an additional 14% response from the originally paid group, maintaining the significantly different overall response rate despite an eventual free offer to all households.

Among previously untested households, overall participation was significantly predicted by both income and education, despite the free test eventually being available to all (Table 7). A well owner with a bachelor's degree had 2.67 times the odds of participating as one without, even after adjusting for income (95% CI=1.15–6.23). Although local arsenic rate was found to be a significant predictor in past arsenic testing behavior (Table 5), it was not significantly associated with prospective sampling program participation (Table 7). Among those (n=51) giving reasons for why they had never tested for arsenic before on a short survey included with their samples, 61% reported they did not know arsenic was a problem in their area; 20% reported that it was because testing is too expensive.

Only 10 households selected to receive the paid test offer participated in the early phase of the program, which required mailing in a payment of $40 with their water samples for analysis. Paid participation was significantly associated with education; 19% participation among those with at least a Bachelor's degree (n=47) and only 2% participation among those with less than a Bachelor's degree (n=46). A well owner with at least a bachelor's degree had 10.66 times the odds of paid participation (95% CI=1.29–87.96) than a well owner with less education. The effect of education on free participation over the same initial time period was not significant (OR=1.33, 95% CI=0.55–3.21). Although it is not a statistically significant finding, it may be interesting to note that 0 out of 11 households with known incomes <$50,000 (~20% of those receiving offers) paid for a well test, while 3 out of 10 in this lower income bracket that were offered a free test did send samples during this initial period.

3.4. Water quality results

Arsenic was the second most common standard exceeded in our tap water samples (25 of 119 samples), and was found over 5 μg/L in 38% (42 of 111) of raw well water samples (Table 8). Four of the tap water exceedances were in homes where the owner reported use of an arsenic-removal system indicating a high rate of treatment failure among the 22 participants that reported using treatment. Among previously untested wells, there were no significant associations between raw well water arsenic level and education or household income.

Sodium was the most common standard exceeded at the tap, in 32 of 119 samples (Table 8). Comparison of raw and treated water samples revealed that in 19 of 29 (66%) homes reporting use of a water softener, it had increased the concentration of sodium in raw well water from below the federal secondary standard of 50 mg/L to much higher concentrations at the tap, over 200 mg/L in several cases. After sodium and arsenic, lead exceeded the action level in 15 (14%) raw water samples but only in two tap water samples, suggesting that the pressure tank sampling point may not have been flushed adequately. Furthermore, iron was found at concentrations exceeding standards in 5% of raw water samples, strontium in 4% of raw water samples, and boron in 2% of raw water samples.

Among the 29 wells with PWTA arsenic records (tests between 2002–2014) that were sampled, the majority of 2015 ICP-MS raw water sample measurements from this study were consistent with the former tests. Overall there was a spearman correlation of $\rho=0.807$ ($p<0.001$) between arsenic measurements (Figure 2). A Wilcoxon rank-sum test found that the distribution of arsenic concentrations was not significantly different between tests ($p=0.213$). However, three out of every four measurements in this study were lower than the corresponding PWTA record and the average absolute difference in arsenic concentration between test results was 2.8 μg/L. Three wells flagged to have arsenic >5 μg/L in the PWTA records tested below 5 μg/L in this analysis; this may be a result of either slight changes in the water chemistry or improper sampling from the pre-treatment pressure tank.

4. DISCUSSION

4.1. Potential of community promotion and events to boost testing

Although our survey did not test the effect of any specific community testing promotion activity, we did find a significant difference in arsenic testing rate by history of town promotion. While the PWTA regulation has reached more well households overall, the differences in arsenic testing rate by town promotion history are still significant among the majority of households that have not yet been affected by the Act's testing requirements. There is a higher rate of testing for arsenic in the high intervention town group (Table 1), and a higher rate of testing at all income levels compared to non-intervention towns (Table 4). Although it is difficult to separate the effect of promotion activity from the effect of higher arsenic occurrence (Table 5), we do know that the proportion of estimated wells directly tested through town interventions is significantly different across the groups: 16%, 10%, and 0% of wells in the high, low, and non-intervention areas respectively (Table 1). The higher rates of arsenic in these intervention towns means that more problematic wells will be identified as wells are tested. Knowing someone else with an arsenic problem is a significant predictor of arsenic testing, and it is conceivable that testing interventions in higher arsenic areas will result in a greater amplification of effect as more wells are subsequently tested based on social connections. We do see greater perceived risks for arsenic and lower perceived difficulty for testing among residents in high-intervention towns, perhaps as a result of past promotional activities and events in these areas (Table 2). Our own sampling program resulted in 119 wells being tested for arsenic, and 74 for the first time. Of those 74, 20% were found to have arsenic above the New Jersey state MCL of 5 μg/L.

Periodic community testing events can be an effective trigger for those already thinking about arsenic testing, or for those most receptive to the behavior of well testing but unaware of local arsenic risks. Community interventions in Bangladesh have had success in motivating arsenic testing in severely affected areas, especially when coupled with household education.[6] A 2005 community-based intervention in the Quebec region succeeded at motivating more people to test for arsenic than a mass media campaign; however, while the proportion of well owners who had their water tested increased by four times, the total testing rate was only 16%.[7] Quebec residents who were already aware of problems related to drinking water (such as the need for microbiological analysis) were more likely to test for arsenic too. A 2000 arsenic well testing program in 19 towns within an arsenic advisory area of Wisconsin which was sponsored by public health and natural resources agencies offered reduced testing fees and succeeded in getting about one-third of residents to test through the program. A follow-up survey suggested that another third may have tested privately.[8,9] Offering the Wisconsin arsenic well test program in a community every year led to lower arsenic safety thresholds (the highest arsenic level an individual thinks is safe) among participants compared to those in a community where arsenic was highly publicized but the testing program was offered only once over 3 years.[9] Ongoing testing efforts may be more effective than publicity alone, but sustainability at the local level remains a challenge. More recently a 2012–2013 information campaign and test kit distribution in Tuftonboro, New Hampshire, (population approximately 2,500) prompted 275 arsenic tests, triple the number of samples from that area tested at the state laboratory in the previous six years, although it is not clear how many were first-time tests.[10] Such community testing efforts remain small-scale and limited in success. Based on our observations in New Jersey, we suspect that many promotional activities, while resulting in more tested wells, may preserve or exacerbate testing disparities among socioeconomic groups.

4.2. SES disparities in participation

Among surveyed households, income remained a significant predictor of past arsenic testing behavior even after alternately and simultaneously adjusting for local arsenic occurrence and history of town intervention activities (Table 5). Correlations between income and arsenic testing were stronger in the high intervention towns than among all households overall

(Table 2). Since we grouped the households from several towns together by history of intervention, the specifics of any one intervention are less important, though there may be unknown reasons why these particular activities resulted in SES disparities in participation. The two high intervention towns primarily focused on reduced cost testing events through the school system and resulted in 375 wells tested, importantly reaching families with children that are more biologically vulnerable to the adverse effects of arsenic. The low intervention towns held free or reduced cost testing events along with public meetings, and notices. Although our surveyed households' exposure to these specific past interventions was unknown, we find a similar significant association between SES and prospective arsenic testing behavior based on our test offer to previously untested households. Among those who had never previously tested for arsenic, well owners with at least a bachelor's degree had over 10 times greater odds of participating in a sampling program as one with less education when testing costed $40. When testing was offered to everyone for free, more educated well owners still had over 3 times greater odds of program participation (Table 7). Our free testing intervention demonstrates that even when an intervention aims to overcome many of the usual barriers to testing – awareness, forgetting, convenience, cost – getting majority participation is a challenge and those with higher SES are more likely to take advantage of the opportunity. Overall, well owners sending water samples for the free test were of higher income and education than those who chose not to participate (Table 6).

Health promotion efforts not targeted at lower income families have the tendency to increase SES disparities because those with more resources tend to more actively participate.[11] More highly educated well owners have been found to use more external sources of information after receiving arsenic test results above the MCL.[8] Participants in workplace health promotion programs tend to be better paid, more educated, healthier, and more motivated to change their health habits than nonparticipants.[12,13] Similarly, traditional efforts to promote well testing within a community such as testing events, notices mailed with tax bills, public meetings, sample bottles and flyers sent home with schoolchildren, etc., all may succeed in boosting overall testing numbers while at the same time exacerbating SES disparities because higher income and higher educated families are more likely to participate.

4.3. Cost as a testing barrier

Our testing intervention had a participation rate of 47%, the same rate of participation achieved in a study of private well owners in Ontario, Canada that delivered well water information kits and sampling bottles directly to well owners for free nitrate and bacteriological testing.[14] Our participation rate also aligns very closely to the 46% of well households we surveyed in NJ who reported that no-cost well testing would prompt them to test their well.[15] Interestingly, this self-reported survey did not match actual behavior when offered free-testing a year later; rates of participation in our sampling program were the same regardless of whether a respondent had earlier reported that free testing would prompt them to take action. Although these participation rates for free testing are mediocre, our pricing experiment demonstrated that a $40 charge can reduce demand for testing by over 70%. The effect of price on participation was observed in the town interventions as well; although programs in the high intervention towns were held in similarly sized schools, a discounted rate of $10 in Alexandria generated double the number of well tests (n=250) as the higher discounted rate of $25 in Kingwood (n=125). As reported in our surveys[3] and demonstrated by our intervention, cost can be a significant testing barrier and offering free water tests can be a significant motivator, but complete screening likely will still not be achieved.

4.4. Limitations

Our survey relies on self-reported testing history which is vulnerable to recall bias. We were not evaluating the effect of any specific past community intervention, instead we classified and combined towns into groups for analysis. Our intervention level analysis was necessarily an ecological study based on geography of residence, we do not know whether any of the surveyed households were actually exposed to the intervention activities in their area. Additionally, this was a cross-sectional analysis performed years after the activities and we do not have survey data to compare testing rates in these areas with those prior to testing promotion. Therefore we cannot assume that the testing differences we see are attributable to differences in testing promotion alone. Given the influences of social networks on testing behavior, a higher frequency of arsenic exceedances from an originally similar rate of testing could conceivably increase arsenic testing in a community through social connections independent of organized promotion activities. Retrospectively, it is difficult to disentangle the effects of promotion versus other factors associated with the increased risks for arsenic contamination in those areas. However, our own intervention demonstrated that new arsenic testing behavior was independent of local arsenic occurrence while remaining significantly associated with socioeconomic status, lending support to our interpretation of the observed relationships in our survey data.

5. CONCLUSION

Various efforts to promote and provide arsenic testing can succeed in achieving more wells tested. This was evident in our direct mail intervention and in our survey findings. Residents of New Jersey towns with a history of arsenic testing promotion have tested their wells at higher rates than residents of areas where there has been no promotion. However, health promotion at the community level may contribute to SES disparities in testing since those with more education and more resources are more receptive to risk information and far more likely to take advantage of testing programs. For this reason it is important that testing promotion and community engagement be better targeted to more socially vulnerable populations.[3] Additionally, community engagement should not be relied on alone to achieve universal screening and reduction of arsenic exposure. Policy changes at the state and local levels may be necessary to overcome the SES-patterned self-selection seen when individuals are left alone with the responsibility of monitoring, improving, and maintaining the quality of their drinking water.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- Local efforts to reduce arsenic exposure tend to rely on well testing promotion
- Arsenic testing rates are higher in areas of New Jersey with a history of promotion
- Testing and SES socioeconomic status are more strongly correlateed in areas with of high promotion
- Only 47% of households accepted a free test; participation was associated with SES
- Community testing promotion may exacerbate SES disparities in arsenic testing

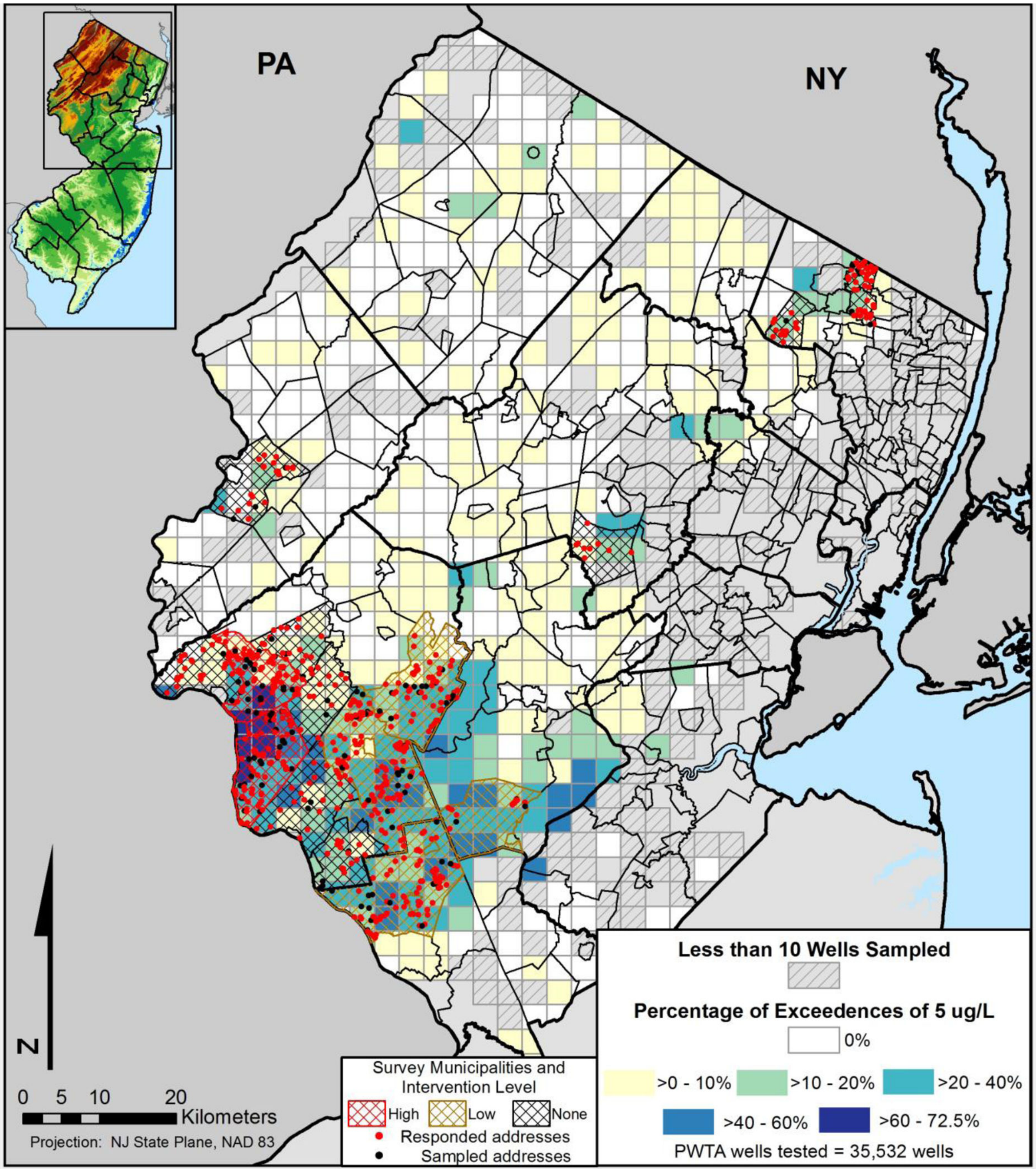

Figure 1.

Location of the private well households who completed the survey but did not have their well sampled through our promotion (red dots, n=551) and the subset of respondents who submitted water samples (black dots, n=119). A total of 670 households were included in survey analyses. Arsenic exceedance rates are presented for 2×2 mile areas based on PWTA testing records through March 2014 (colored boxes). Areas not covered by a box have no wells tested under the PWTA.

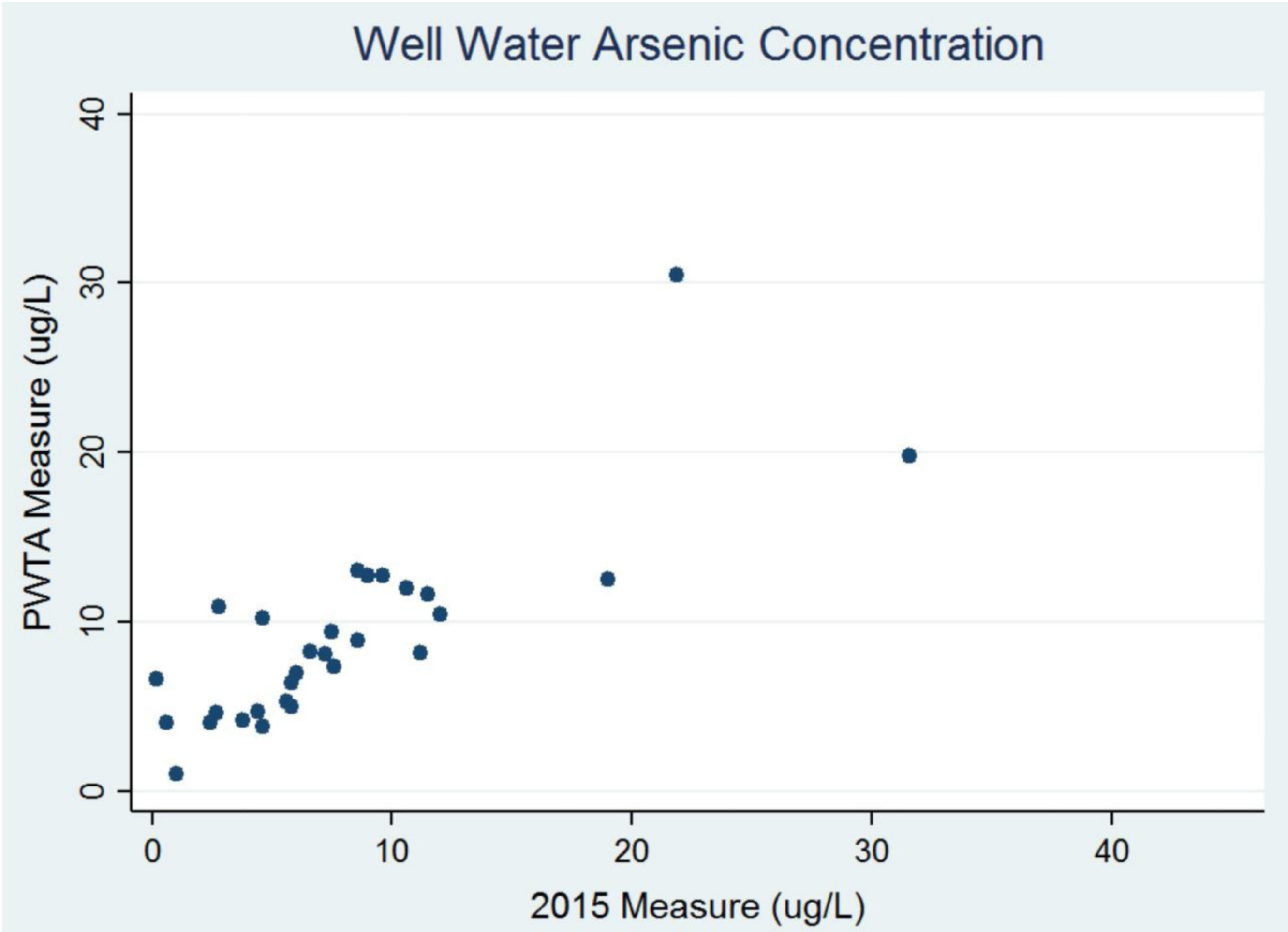

Figure 2.
Scatterplot of 2015 arsenic measurement from the current study and PWTA record (2002–2014) of arsenic level, ρ=0.807 p<0.001.

Table 1

Key characteristics of intervention groups. Pre-PWTA households are those where respondents moved into their homes prior to PWTA testing requirements.

	High (2 towns)	Low (5 towns)	None (10 towns)
Estimated (est.) number of wells in survey towns	2,355	11,800	11,071
PWTA tests through Apr. 2012 (% of est. wells)[a]	954 (41%)	5,222 (44%)	4,102 (37%)
Known tests through interventions (% of est. wells)[a]	375 (16%)	1,159 (10%)	0 (0%)
Percent PWTA well tests exceeding 5 μg/L arsenic[a]	32.4%	26.1%	11.3%
Surveyed households	186	284	200
Median age	57	58	59
Median income[b]	\$100,001–125,000	\$125,001–150,000	\$125,001–150,000
% Bachelor's degree or higher[c]	60%	75%	72%
Children in home	37%	41%	38%
Ever testing rate	82%	83%	83%
Arsenic testing rate[d]	49%	43%	37%
"Never thought about arsenic testing"[c]	21%	25%	41%
Pre-PWTA surveyed households	150	200	152
Pre-PWTA median age	60	61	61
Pre-PWTA median income	\$100,001–125,000	\$100,001–125,000	\$100,001–125,000
Pre-PWTA % Bachelor's degree[c]	59%	72%	68%
Pre-PWTA children in home	33%	33%	31%
Pre-PWTA wells ever testing rate	79%	82%	81%
Pre-PWTA wells arsenic testing rate[d]	41%	38%	30%
Pre-PWTA "Never thought about arsenic testing"[c]	24%	29%	44%

[a]Source: NJ DEP. Proportions significantly different between all groups $p<0.001$

[b]Distribution of income in high intervention group significantly lower than others combined, based on Mann-Whitney test $p<0.05$.

[c]Significantly different between groups by Pearson chi-square test, $p<0.05$

[d]High group and combined intervention groups both significantly different from no intervention group, $p<0.05$

Table 2

Percentage of pre-PWTA households agreeing with survey statements[a] by town promotion level. Pre-PWTA households are those where respondents moved into their homes prior to PWTA testing requirements.

Statement	High (n=150)	Low (n=200)	None (n=152)
Wells in this area are at risk of being contaminated	38%	38%	46%
There is a considerable risk that wells in this town are contaminated with arsenic**	42%	35%	23%[b]
Finding a well testing service is too difficult*	23%	26%	36%[b]
Know someone with a well arsenic problem*	19%	18%	7%[b]

* $p<0.05$

** $p<0.01$ by Pearson chi-square test

[a] Of 30 survey statements on testing, only the last 3 shown are significantly associated with intervention group. The first non-significant statement is also included to contrast with the second statement that is specific for arsenic.

[b] Significantly different from other group proportions based on pairwise tests

Table 3

Associations (ρ) between demographic variables and testing behaviors among pre-PWTA well owners in high intervention towns (n=150), low intervention towns (n=200), nonintervention towns (n=152), and the full sample (n=502). Pre-PWTA households are those where respondents moved into their homes prior to PWTA testing requirements.

Demographic Variable	Ever Tested				Arsenic Test Completed			
	High	Low	None	All	High	Low	None	All
Age	0.139*	−0.082	−0.068	−0.009	−0.176***	−0.008	−0.102	−0.092*
Years Lived in Home	−0.018	−0.054	−0.108	−0.058	−0.267***	−0.042	−0.063	−0.117***
Education	0.234***	0.116	0.178***	0.171***	0.053	0.123*	0.149*	0.097***
Household Income[a]	0.116	0.054	0.179*	0.119***	0.207***	0.072	0.186*	0.148***
Live Alone	−0.080	−0.076	−0.161*	−0.104***	−0.093	−0.097	−0.083	−0.091***
Children in the Home	−0.077	0.081	0.097	0.037	0.067	0.059	0.134	0.084*

* p<0.10

** p<0.05

*** p<0.01

[a] Income data only available for n=110, n=126, n=108, and n=344 in the high, low, none, and all groups, respectively

Table 4

Rate of arsenic testing among pre-PWTA households by town intervention level and household income. Pre-PWTA households are those where respondents moved into their homes prior to PWTA testing requirements.

	<$100,000	>$100,000	Overall
High intervention (n=110)	28%[a]	46%[ad]	38%
Low intervention (n=126)	27%[b]	43%[b]	38%[c]
No intervention (n=108)	22%	32%[d]	28%[c]

[a]Pairwise difference in arsenic testing rate between groups $p<0.05$

[b,c,d]Pairwise difference in arsenic testing rate between groups $p<0.10$

Table 5

Unadjusted and adjusted odds ratios (ORs) and 95% confidence intervals (CI) for outcome of completing an arsenic test among pre-PWTA households (n=502). Pre-PWTA households are those where respondents moved into their homes prior to PWTA testing requirements.

Explanatory variable	**Unadjusted ORs (95% CI) p-value**	**Model 1 (95% CI) p-value**	**Model 2 (95% CI) p-value**	**Model 3 (95% CI) p-value**	**Model 4 (95% CI) p-value**	**Model 5 (95% CI) p-value**
Household income ($25k increase)	**1.21 (1.06–1.38) 004**	**1.19 (1.03–1.36) 015**	**1.22 (1.07–1.39) 003**		**1.23 (1.07–1.40) 003**	**1.23 (1.07–1.40) 003**
Bachelor's degree	**1.56 (1.04–2.36) 033**	1.25 (0.75–2.11) .393				
Intervention Group						
High	**1.63 (1.01–2.63) 044**		1.69 (0.94–3.01) .078	1.27 (0.75–2.15) .373		1.33 (0.70–2.52) .383
Low	1.43 (0.91–2.25) .122		1.57 (0.89–2.75) .117	1.18 (0.73–1.91) .507		1.30 (0.72–2.37) .385
None (reference)	1.00		1.00	1.00		1.00
Local arsenic rate (5% increase)	**1.08 (1.03–1.14) 003**			**1.07 (1.01–1.13) 020**	**1.08 (1.01–1.14) 015**	1.06 (0.99–1.13) .073
area under ROC curve		0.5942	0.6133	0.5849	0.6221	0.6233

Significant ORs ($p<0.05$) in bold. Model 1 tests the significance of income as a predictor for arsenic testing by adjusting for education, Model 2 adjusts for intervention level, Model 4 adjusts for local arsenic rate, and Model 5 adjusts for both intervention level and local arsenic rate. Model 3 tested the significance of intervention level as a predictor of arsenic testing after adjusting for local arsenic rate. Local arsenic rate (% of wells exceeding 5 μg/L) was divided into increments of 5% to ease interpretation and treated as a continuous variable.

Table 6

Comparison of sampling participants vs. non-participants

Demographic characteristic	Participants (n=119)	Non-participants (n=136)
Median age (years)	59	60
Sex ratio (M/F)	59%/41%	55%/45%
% Household Income >$100,000[a]	70%	53%
% Bachelor's degree or higher[b]	73%	54%
Households with children	33%	35%
Living Alone	9%	14%
Median Years in Home	18 (range 2 to 73)	21 (range 2 to 65)

[a]Distribution of income significantly higher among participants based on rank-sum test p<0.05

[b]Distribution of education significantly higher among participants based on rank-sum test p<0.05

Table 7

Unadjusted and adjusted odds ratio (OR) of overall participation by education and income among households who had never previously tested for arsenic (n=123)[a]

Variable	Unadjusted ORs (95% CI)	Adjusted ORs (95% CI)
Household income		
<$50,000	1.00	1.00
$50,000-$100,000	2.99 (0.74–12.06)	2.52 (0.61–10.48)
$100,000-$150,000	**8.00 (1.91–33.54)**	**5.31 (1.20–23.51)**
>$150,000	**5.04 (1.24–20.43)**	2.98 (0.67–13.03)
Education		
Less than Bachelor's	1.00	1.00
Bachelor's degree or higher	**3.50 (1.62–7.57)**	**2.67 (1.15–6.23)**
Local arsenic rate (5% increase)	1.04 (0.93–1.16)	

CI=Confidence interval. Significant ($p<0.05$) ORs in bold. Local arsenic rate (% of wells exceeding 5 μg/L) was divided into increments of 5% to ease interpretation and treated as a continuous variable

[a]Analysis limited to those with income data available

Table 8

The number and percentage of raw well water (n=111) and tap water (n=119) samples exceeding standards

Element	Drinking water standard (µg/L)	Raw water exceedances (%)	Tap water exceedances (%)
Aluminum[a]	50 to 200	2 (2)	0 (0)
Antimony[b]	6	0 (0)	0 (0)
Arsenic[b]	5	42 (38)	25 (21)
Barium[b]	2,000	0 (0)	0 (0)
Beryllium[b]	4	0 (0)	0 (0)
Boron[c]	3,000	2 (2)	2 (2)
Cadmium[b]	5	0 (0)	0 (0)
Chromium[b]	100	0 (0)	0 (0)
Copper[d]	1,300	1 (1)	1 (1)
Iron[a]	300	5 (5)	1 (1)
Lead[d]	15	15 (14)	2 (2)
Manganese[c]	300	1 (1)	2 (2)
Molybdenum[c]	40	2 (2)	0 (0)
Nickel[c]	100	0 (0)	0 (0)
Selenium[b]	50	0 (0)	0 (0)
Silver[c]	100	0 (0)	0 (0)
Sodium[a]	50,000	6 (5)	32 (27)
Strontium[c]	4,000	4 (4)	2 (2)
Thallium[b]	2	0 (0)	0 (0)
Uranium[b]	30	0 (0)	0 (0)
Zinc[c]	2,000	0 (0)	0 (0)

[a]Secondary standard,

[b]MCL,

[c]Health advisory level,

[d]Action level