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Targeted private well outreach following a change in drinking water standard: Arsenic and the New Jersey Private Well Testing Act

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Abstract

Context: When the New Jersey Private Well Testing Act (PWTA) became effective in 2002, the maximum contaminant level (MCL) for arsenic in the United States was 50 micrograms per liter (μg/L). In 2006, the federal and New Jersey MCLs were lowered to 10 μg/L and 5 μg/L, respectively.

Objective: To notify and provide free arsenic water testing for homeowners who had a PWTA arsenic result that passed for the MCL in 2006 or earlier but would exceed under the more health protective MCL enacted in 2006, which is still in effect as of this publication date.

Design: About 1 200 homeowners with PWTA arsenic results between 5–50 μg/L were offered free arsenic water testing. Over 400 homeowners requested tests and 292 returned samples.

Setting: New Jersey, United States

Participants: Homeowners with a passing PWTA arsenic result before 2006 that would have failed under the NJ arsenic MCL enacted in 2006

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Conflicts of Interest:
The authors declare no conflicts of interest.

Main Outcome Measures: Return rate of testing kits; number of tests exceeding arsenic MCL; and participant survey results

Results: Untreated well water samples (n=279) were collected and 62.4% exceeded the NJ MCL. Treated well water samples (n=102) were collected and 11.8% exceeded the current NJ MCL. In all, about 40% of drinking water samples from the tap, including those with or without arsenic treatment, exceeded the NJ MCL. A survey of participants (n=69) found that although many (67%) respondents reported that they at least had some idea that wells in their area are vulnerable to naturally occurring contaminants, such as arsenic, many (68%) reported they had little or no idea that the NJ arsenic MCL had been lowered from 50 μg/L to 5 μg/L in 2006.

Conclusions: This effort further illuminates the necessity and significance of public health outreach for private well water users, especially after drinking water standards change.

Keywords

Arsenic; Drinking water; Private well outreach; Maximum contaminant level change

Introduction

Approximately one million New Jersey (NJ) residents receive their drinking water from private wells, representing about 11% of the state's population.[1] In 2001, the NJ legislature enacted the Private Well Testing Act (PWTA) to provide protection to purchasers and lessees of properties served by private potable wells and ensure awareness of the quality of their drinking water source. The Act became effective in September 2002. Between then and 2006, when the federal and NJ maximum contaminant levels (MCL) for arsenic were lowered, arsenic was a required test parameter in ten of the twelve counties in the bedrock region.[2]

Arsenic is a naturally occurring element that is found in the Earth's crust with trace concentrations ubiquitously found throughout the environment. In New Jersey, arsenic occurs in many geological formations and there are certain chemical and physical properties of local geology, especially pH and dissolved oxygen, that may cause arsenic to mobilize into groundwater.[3] Arsenic is released into bedrock groundwater through the oxidation of pyrite and desorption from hematite and clay minerals. There are two inorganic arsenic species that can be present in groundwater. These species include arsenic III (As III) and arsenic V (As V), which can co-occur.[4] Other ways in which arsenic mobility can be affected include natural and seasonal fluctuations in groundwater systems and human activities (such as pesticide use).[5] Although historically used in NJ fruit orchards,[6] golf courses, and crops,[7] arsenical pesticides are not particularly water soluble making them not a significant source in groundwater.[8] Many arsenic bedrock groundwater studies have been conducted; however, understanding the mechanisms of arsenic mobilization and distribution remains unclear due to the complex nature of groundwater chemical and physical properties.[9]

Chronic exposure to arsenic in drinking water has been attributed to a variety of health effects as nearly every organ can be affected by exposure.[10] Health effects include skin

lesions, cancer, diabetes, and lung disease,[10–12] with an increasing number of studies demonstrating a decrease in child IQ.[13] In utero and early life exposure are of particular importance as these can impair intellectual development and increase risk of health effects later in life.[14]

Ultimately, the NJ PWTA is a consumer information law which requires either the buyer or seller of a property with a potable well to test the untreated groundwater during a property transaction. NJ PWTA also requires landlords to test the well water every five years and provide tenants with the water test results. The NJ PWTA requires testing for a variety of water quality parameters, up to 44 of human health concern depending on the county. Treatment is not required. Public outreach efforts regarding PWTA data is in the local health authority's jurisdiction.[2] Unlike public water users, private well owners are solely responsible for the quality of their water.

Through 2018, over 100 000 private wells in NJ have been tested under the PWTA,[15] and among these, 49 000 wells have arsenic results. Initially, arsenic testing under the PWTA was only required in ten northern NJ counties. In 2008, arsenic testing was expanded to include all twelve northern counties. Most recently in 2018, arsenic testing became a statewide required parameter. Of all the wells tested in the twelve northern counties through the PWTA, 8.3% have been found to exceed the NJ arsenic drinking water MCL of 5 micrograms per liter (μg/L), making arsenic the second most common naturally occurring contaminant to exceed its MCL in NJ private well water. Overall, 2.8% of arsenic tests conducted in NJ's twelve northern counties are above the federal MCL of 10 μg/L. The Piedmont Physiographic Province of the bedrock region has been found to have the highest percentage of wells exceeding the MCL in NJ (17.3%) and the federal MCL (5.7%). A recent survey of residents with NJ PWTA arsenic tests above the NJ MCL found that most residents were not aware of high arsenic concentrations in their private well water.[16] When the NJ PWTA was enacted, the NJ MCL for arsenic was 50 μg/L. In 2006, when the federal arsenic MCL was lowered to 10 μg/L, New Jersey adopted a more health protective MCL of 5 μg/L. The decision to reduce the New Jersey MCL for arsenic to 5 μg/L was based on the review completed by the New Jersey Drinking Water Quality Institute (NJDWQI). They recommended the MCL be lowered to 3 μg/L, however the MCL ultimately was set at 5 μg/L due to the concern for the availability of a reliable removal technology.[17] At the time of implementation, NJ had the most health protective MCL in the country. Under the NJ PWTA between 2002 and 2006, residents whose wells tested below 50 μg/L, but above the NJ MCL of 5 μg/L may not be aware the MCL was lowered. These individuals may have a false sense that their well water meets health standards for arsenic based on messaging at that time. The misperception combined with a general lack of awareness of arsenic risks highlights a need for education and outreach. This outreach effort identified all NJ private well owners that had a NJ PWTA arsenic test result of 5–50 μg/L between 2002–2006 and offered free arsenic testing as an initiative to educate targeted well owners about the risk of arsenic in their drinking water.

Methods

Homeowner outreach

As required by the NJ PWTA, confidential testing data are submitted by certified laboratories to the New Jersey Department of Environmental Protection (NJDEP). A complete list of wells that tested between 5 and 50 μg/L prior to the MCL change but had not since been retested under the NJ PWTA was generated (see Map, Supplemental Digital Content 1, which shows previous PWTA results of homeowners who were eligible to participate in this outreach). With the support and collaboration from local health authorities, invitation letters offering free arsenic water testing were mailed to each identified resident. Interested residents were directed to sign up online through a Google Form. Registrants were mailed sample bottles with detailed sampling instructions for collection and return of water samples. Participation was voluntary, free, and confidential. The study protocol was approved as exempt by the Institutional Review Board of Columbia University.

Sample collection & drinking water exposure estimates

Registrants that reported having arsenic water treatment were asked to provide both untreated and treated (drinking water tap) water samples. Registrants that reported having no arsenic water treatment were asked to only provide a drinking water tap sample. For ease of test kit preparation, every registrant was mailed two bottles. Registrants who self-reported having arsenic treatment were asked during sign-up if they needed assistance with sample collection. Investigators assisted a small number of interested households (n=11). Once collected, registrants mailed their sample(s) back in a prepaid envelope. Registrants were asked to submit information about their water treatment system, if applicable, with their samples.

Minimum, maximum, median, and mean arsenic concentration values were calculated for both untreated and arsenic-treated drinking water tap samples. A "Drinking Water Exposure" category, which takes into account whether the home had arsenic treatment or not, was estimated. Specifically, if a home had arsenic treatment, we selected the treated water sample to represent the drinking water exposure at the tap. If the home did not have arsenic treatment, we used the untreated water sample to represent the drinking water exposure. This provides an estimate of the number of homes potentially exposed to arsenic in their drinking water.

Analytical methodology

Submitted water samples were acidified to 1% HNO3 (Optima Grade) in the Lamont-Doherty Observatory laboratory before analysis by high resolution inductively coupled plasma-mass spectrometry (ICP-MS) following previously established protocol.[18] The detection and reporting limits for arsenic were 0.02 μg/L and 0.1 μg/L, respectively. Repeated analyses of the standard solution NIST 1643e (n = 11) with 60.5 μg/L and a quality control sample (n = 11) with 64.7 μg/L revealed arsenic recoveries in the range of 94–101%.

Distribution of results

Result letters were mailed to the participants and included the recommendations on further action outlined in Table 1. Result letters included a printed copy of the New Jersey Geological and Water Survey Arsenic Water Treatment Guide.[19] Results letters were intended to be easy to understand with clear color-coding to indicate a passing or failing result in green or red font, respectively (see, Document, Supplemental Digital Content 5, which shows results letter that was mailed to each participant). Results letters were mailed between Fall 2019 and Winter 2020, just before the beginning of the COVID-19 pandemic in North America.

Follow-up survey

An online follow-up survey using the NoviSurvey platform was sent out to participants either by mail or email, depending on the availability of an email address. To encourage participation, the survey was anonymous, and results could not be linked back to individual participants. Survey questions included knowledge about registrants' wells prior to participation in this outreach, course of action after receiving test results, and satisfaction with how the outreach was conducted (see Document, Supplemental Digital Content 6, which shows survey sent to participants following this outreach with responses). The goal of this survey was to determine how effective our outreach effort was at informing participants who were at risk for arsenic exposure from their private well water and if they sought action towards lowering their exposure. Additionally, the survey allowed for participants to provide feedback on how the investigators can improve future outreach efforts. The survey was sent in Winter 2021, approximately one year following distribution of the results letters allowing sufficient time for people to take mitigation action, if necessary.

Results

Well owner participation

A total of 1 419 wells met the criteria for this outreach effort. While no local health authority disapproved, a few did not respond to our request for their support. Wells in those areas were not included because public outreach regarding the PWTA lies in the jurisdiction of the local health authority. A total of 1 199 households in areas with local health authority support of the outreach effort were mailed an invitation letter. Sample bottles were mailed to 448 (37%) homeowners; including 24 registrations from homeowners who did not receive invitation letters and heard about it through word-of-mouth. Free water tests were provided to the 24 individuals, but those results were not included in these findings because they did not fit the outreach criteria. Of the 424 eligible participants who were sent sample bottles, 292 (68.9%) returned their sample(s) for analysis.

Test results

Among the untreated well water samples (n=279) (either pre-arsenic treatment or from a home without arsenic treatment) collected, 62.4% were exceeding 5 μg/L (NJ MCL) and 17.9% were exceeding 10 μg/L (federal MCL) (Figure 1 & see Map, Supplemental Digital Content 2, which shows arsenic concentrations of untreated water samples), and

the remaining 37.6% (105) samples were below 5 μg/L. Although participants with arsenic water treatment were asked to provide both untreated and treated samples, 13 participants only provided a treated water sample. Despite approximately one-third of participants indicating some form of arsenic treatment (n=102), 11.8% of treated samples still exceeded the NJ MCL and 5.9% exceeded the federal MCL (Figure 2 & see Map, Supplemental Digital Content 3, which shows arsenic concentrations of post arsenic treatment water samples). Although not required, many (n=148) of the participants who indicated that they had no arsenic treatment present submitted two samples anyway. Several (n=20) participants indicated that they did not have arsenic treatment on their intake form, but results indicated that arsenic levels were largely reduced between the two samples submitted or participants indicated that their drinking water exposure sample was collected from a treated location (e.g., Reverse Osmosis tap). Among the samples that were representative of participants' drinking water exposure, (n=292) (either post arsenic treatment or from a home without arsenic treatment), 40% and 8.9% were exceeding the NJ and federal MCLs, respectively. (Figure 3 & see Map, Supplemental Digital Content 4, which shows arsenic concentrations of samples representative of drinking water exposures estimates).

The highest level of arsenic detected in an untreated water sample was 51.9 μg/L; its corresponding treated sample had a concentration of 0.1 μg/L (Table 2). The highest level of arsenic detected in a post-treatment sample was 37.6 μg/L; its corresponding untreated sample had a concentration of 42.0 μg/L. The highest arsenic drinking water exposure sample was 40.7 μg/L from a home without arsenic treatment.

Survey results

The anonymous follow-up survey had a 24% (n=69) participation rate. Although the majority of respondents (67%) reported that they had some idea that wells in their area are vulnerable to naturally occurring contaminants, such as arsenic; most (68%) reported they had little or no idea that the MCL for arsenic had changed from 50 μg/L to 5 μg/L in 2006 and 72% had little or no idea that it is recommended to test their well water for arsenic every five years (72%).

Of the survey participants who reported receiving results exceeding 5 μg/L (n=27), 63% indicated that they have since installed a new arsenic treatment system, serviced an existing system, or plan to do so soon based on the results they received from this outreach. To further assess the reach of this effort, participants were asked if they discussed their water test results with anyone. Nearly half (48%) indicated that they reached out to someone else regarding their results. Of those that discussed their results with someone else, water treatment professionals (48%), neighbors (48%), and friends (45%) were most common.

To evaluate the success of the communication and operation of the outreach, survey participants were asked about the outreach design. Most of the participants (97%) agreed that the results letter was clear and understandable. Most of the participants (94%) indicated that they were glad they participated and also indicated (94%) they would participate in a similar private well outreach in the future. Most participants (96%) agreed that participation in this event was easy and straightforward.

Discussion

When the NJ MCL was lowered in 2006 from 50 μg/L to 5 μg/L to be the most health protective arsenic standard in the country at that time, no official notification was sent out to homeowners, including those that had previously tested their private well under the NJ PWTA. Nearly 15 years later, many homeowners had little to no idea that the MCL had changed, and that their well water is no longer considered safe based on their previous PWTA results.

Value of NJ PWTA & testing frequency

Leveraging the NJ PWTA dataset has the potential to greatly improve public health outreach. This robust database provides insight on NJ groundwater quality and risk for private wells, which can be used to further protect the residents of the state. It must be recognized that this database, which is invaluable in our outreach efforts, is the result of a unique state law.[20] Most jurisdictions do not have access to such robust data, although some are diligently working towards compiling a private well database.[14] Using previous NJ PWTA results, targeted outreach has been conducted to households within proximity of a property with known high arsenic levels[21] and to vulnerable households with the assistance of local healthcare providers.[22] Since standards can be revised over time, a new benefit of having such an Act and large database is the ability to re-evaluate past tests against the revised standards and deliver these important updates to households already known to be at a high risk. This is especially important since this outreach demonstrated most homeowners were not aware of the lowered NJ arsenic MCL change, even 15 years later.

The 37.6% (n=105) of participants with a previous PWTA test above 5 μg/L who submitted an untreated well sample below 5 μg/L could be attributed to a few factors, including arsenic's temporal variability,[23] a change in analytical lab sensitivity from initial testing, or homeowner collection error. The previous PWTA tests were taken more than a decade prior to this outreach, therefore it is important that the homeowners were provided with more recent results so they can make informed decisions regarding their arsenic exposure. Due to arsenic's ability to mobilize through the groundwater and changing water chemistry over time, routine testing for arsenic is always recommended.[4] Although homeowners in this outreach were given testing frequency recommendations in their results letter based on their test results (Table 1), newer guidance that has since become available suggests more frequent testing intervals for arsenic. According to Mailloux et al.,[24] if the arsenic concentration of the well water is half of the MCL and above, testing should be completed every year. If the well water is below half the MCL, then testing should be completed every five years. Following this guidance, the NJ recommendation frequency for a well 2.5 μg/L and above, would be to test every year and if the well is below 2.5 μg/L, testing should be completed every five years.

Mitigation behavior

Among the tested households, several had already installed arsenic water treatment since their initial NJ PWTA test, but due to insufficient maintenance and monitoring they were not aware that the system was no longer effectively reducing arsenic levels in their water.

In this outreach, eight homes indicated that they were unsure if they had arsenic treatment. In addition, 20 participants indicated that they had no arsenic treatment but had a notable reduction in arsenic levels between their two submitted samples. This indicates that there was, indeed, some form of arsenic treatment present, or a treatment system installed for another purpose may also be effective at reducing arsenic. This raises concerns about the routine maintenance of such systems and homeowner knowledge of water treatment. More education on well water treatment and maintenance is needed to ensure arsenic exposure is reduced in private well users. The NJDEP recommends a point of entry (POE) dual tank, whole-house granular ferric adsorption system installed by a water treatment professional for the most effective removal of arsenic from private well water,[19] as described in more detail in a study conducted by Rockafellow-Baldoni et al. in 2018.[3] Although this outreach effort only focused on arsenic, it is recommended that private well owners test their wells for other contaminants as well. Without routine testing, private well owners may be exposed to contamination from their drinking water. Barriers to routine well water testing can include cost, ease of access to a certified laboratory, or low risk awareness.[14]

In a survey of protective behavior of 486 homeowners following a previous exceeding arsenic result from the PWTA-required test,[16] the majority of respondents (71.6%) indicated taking some form of mitigation action, including the installation of a water treatment system (63.4%), and switching to another source of drinking water (8.2%). Despite its low response rate, a similar proportion of respondents (63%) from our outreach effort also indicated that they took or plan to take mitigation efforts to lower their arsenic drinking water exposure within a year of receiving their results. Similarly, other surveys, for which participation is already self-selective, have found comparable rates of inaction among private well owners who received failing results for at least one contaminant, in New Jersey and elsewhere.[25–27]

Extensive guidance on treatment and financing options were included with the results letters (see Document, Supplemental Digital Content 5, which shows results letter that was mailed to each participant). Participants were provided with information about the New Jersey Potable Water Program provided by the New Jersey Housing and Mortgage Finance Agency. This program provides a no-interest, $10 000 loan to single-family homes that receive drinking water from a private well that exceeds a primary drinking water standard. The loan can be used to pay for the water treatment installation or connection to an alternative potable water supply.[28] Although participants were informed of loan financing options, four survey participants indicated that the COVID-19 pandemic affected their decision to install or service arsenic water treatment, citing the cost as the principal reason for not taking mitigation action. It is also possible the pandemic has affected priorities for health behaviors more generally, as a recent study by Latchmore et al., found a noticeable drop in well water testing behavior during the COVID-19 lockdown in Ontario, Canada.[29]

Limitations

Although this outreach effort had an overall participation rate of 24%, it must be noted that the education of homeowners about the MCL change was achieved from the mailed invitation letter, even if they did not participate in the offered testing. Both testing and survey participation were voluntary, so it may not be representative of the full sample of

eligible households. Regarding the test results, although detailed instructions for sample collection were provided, the samples were collected by homeowners themselves, which likely increased risk for errors. A common request on the follow-up survey was for assistance with finding a reputable water treatment company. Unfortunately, the NJDEP cannot make any recommendations as it is a conflict of interest for the State to endorse any company. This sentiment of a desire for more guidance was also echoed by Flanagan et al.[30] In addition, the follow-up survey had a low response rate and was anonymous; therefore, participants may not be representative the larger group in terms of failure rate, presence of treatment, geographic location, etc. In addition, the survey was sent about a year after the participants received their test results, which were sent just before the beginning of the COVID-19 pandemic in North America. This could have impacted the response rate and/or the participants' ability to recall the details of their experience with this outreach.

Conclusion

This outreach effort was made possible by using the robust NJ PWTA database to identify the targeted wells. The goal of this outreach was to educate homeowners of the revised NJ arsenic MCL, inform them of their current arsenic drinking water exposure, and provide helpful resources on mitigation. The low awareness of the arsenic MCL about 15 years following the change further demonstrates the need for outreach to private well owners in the event of future MCL revisions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Implications for Policy & Practice

- When drinking water standards are revised, state and local authorities should conduct timely notifications and outreach to private well owners regarding the revision of the standard and explain what implications that could have on the safety of their drinking water.
- More targeted outreach efforts, in conjunction with private well awareness, can help reduce homeowners' exposure to contaminants.
- Jurisdictions without a robust database of potable groundwater quality conditions should work towards the creation of a model similar to the NJ PWTA to assist with the protection of their residents' health through their drinking water quality.

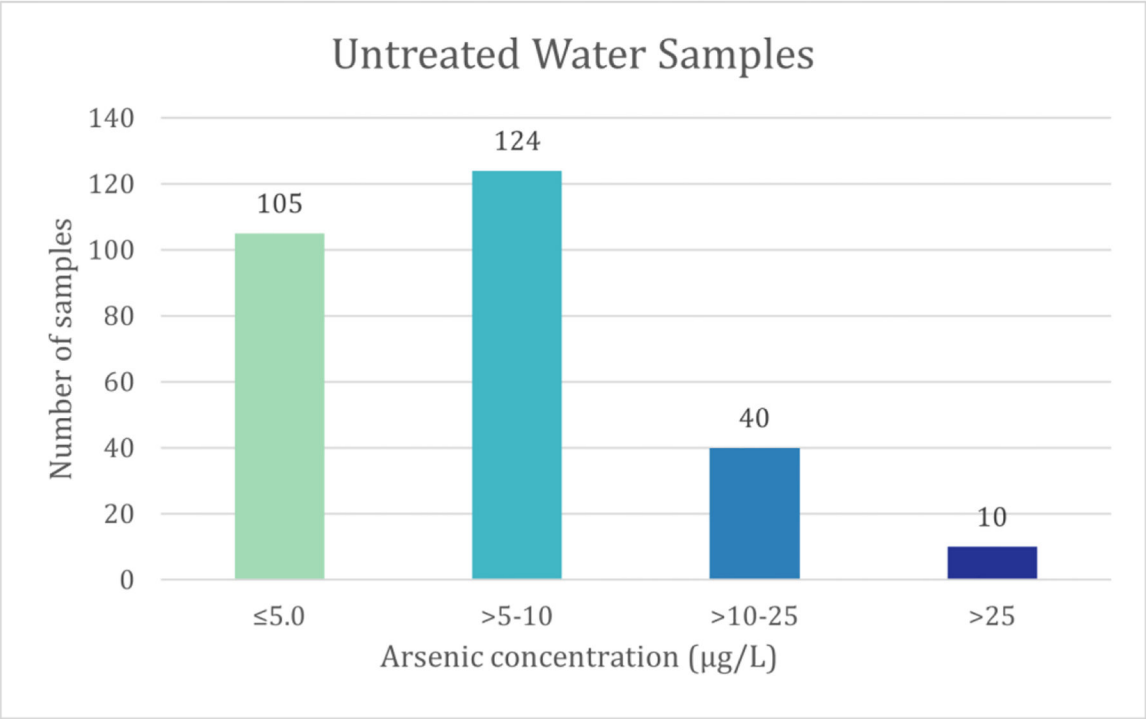

Figure 1:

Arsenic concentrations of untreated well water samples (n=279). The first bar represents samples less than or equal to the NJ MCL (5 µg/L). The combination of the first two bars is representative of samples less than or equal to the federal MCL (10 µg/L). These samples are representative of untreated well water, either pre-arsenic treatment or at the tap when no treatment is present.

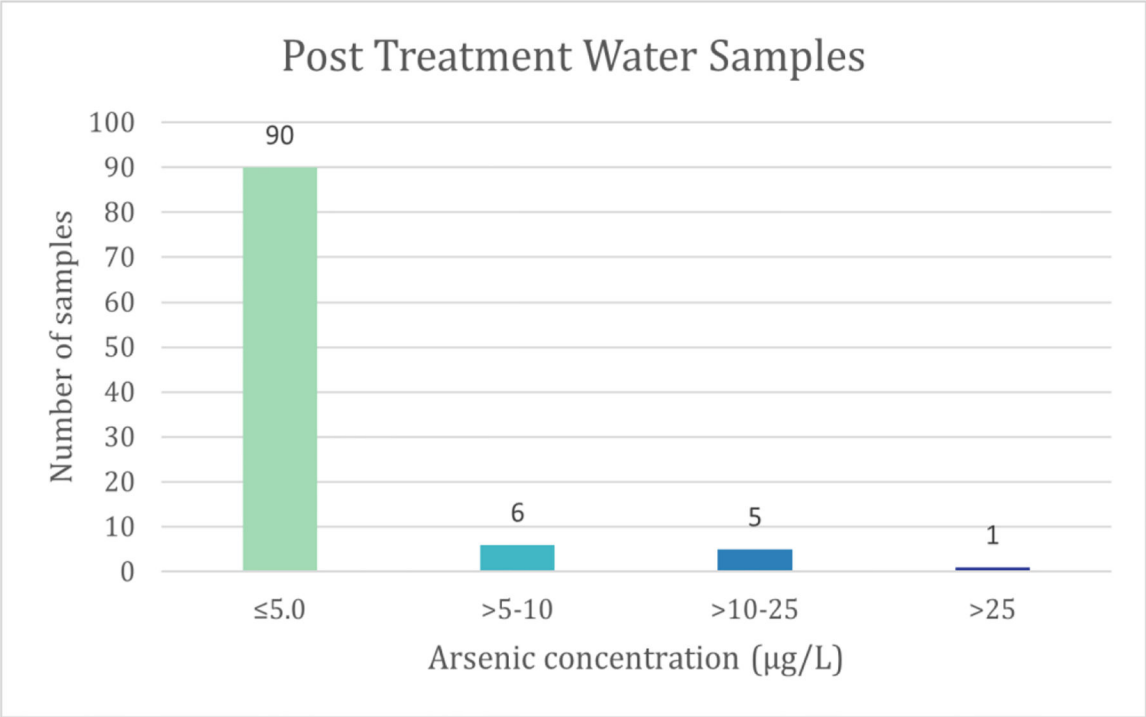

Figure 2:
Arsenic concentrations of post treatment water samples (n=102). The first bar represents samples that are less than or equal to the NJ MCL (5 µg/L). The combination of the first two bars represents samples that are less than or equal to the federal MCL (10 µg/L). These samples are post arsenic treatment.

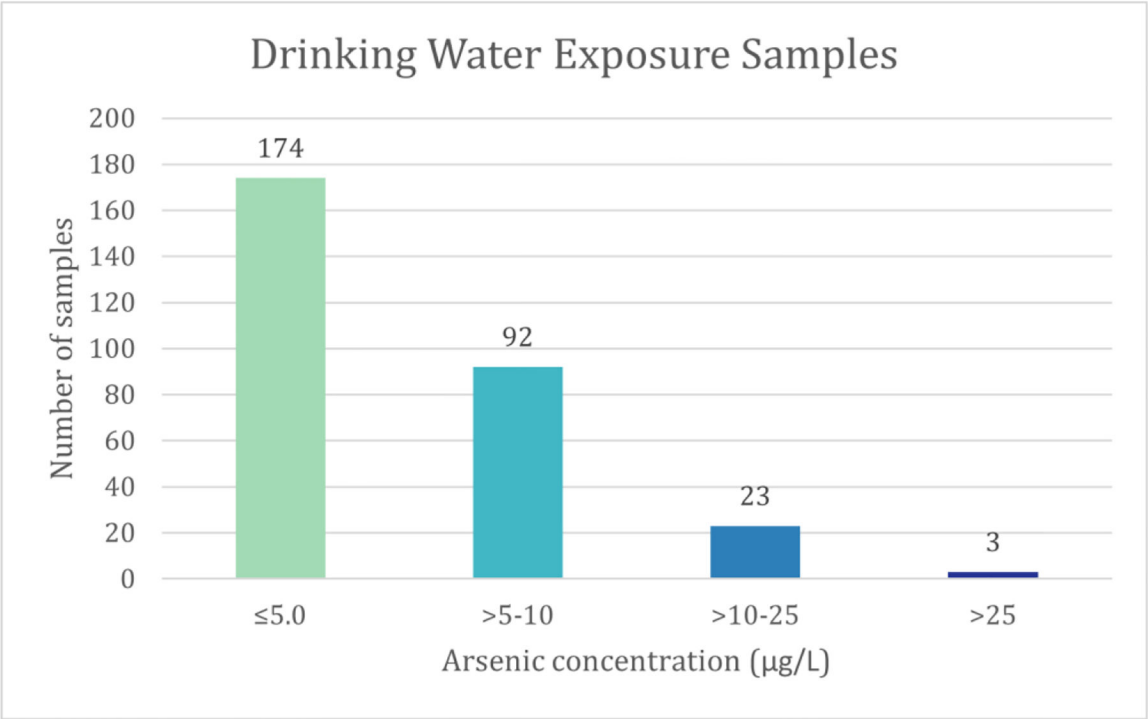

Figure 3:

Arsenic concentrations of samples representative of drinking water exposures estimates (n=292). The first bar represents samples less than or equal to the NJ MCL (5 µg/L). The combination of the first two bars represents samples less than or equal to the federal MCL (10 µg/L). These samples are at the tap; either post arsenic treatment or where no treatment is present to reflect the participants drinking water exposure to arsenic.

Table 1.

Recommendations given to homeowners based on different result scenarios

Scenario	Recommendation
Both untreated and treated tap samples were below MCL	Retest in five years
Drinking water tap sample was below MCL and no treatment was present	Retest in five years
Untreated sample exceeded MCL, but treated tap sample was below the MCL	Retest annually
Drinking water tap sample was above MCL with treatment present	Service or replace existing arsenic water treatment system
Drinking water tap sample was above MCL with no treatment present	Install arsenic water treatment system

Table 2.

Statistics for Untreated Well Water, Post Treatment, and Drinking Water Exposure Samples

	Untreated Well Water Sample (μg/L; n=279; Pre-Treatment or Untreated Tap)	Post Treatment Sample (μg/L; n=102; Treated Tap)	Drinking Water Exposure (μg/L; n=292; at the tap with or without arsenic treatment)
Minimum	<0.1	<0.1	<0.1
Maximum	51.9	37.6	40.7
Median	6.0	0.1	4.1
Average	7.8	2.1	4.7