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Health protective behavior following required arsenic testing under the New Jersey Private Well Testing Act

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ABSTRACT

Exposure to naturally occurring arsenic in groundwater is a public health concern, particularly for households served by unregulated private wells. At present, one of the greatest barriers to exposure reduction is a lack of private well testing due to difficulties in motivating individual private well owners to take protective actions. Policy and regulations requiring testing could make a significant contribution towards universal screening of private well water and arsenic exposure reduction. New Jersey's Private Well Testing Act (PWTA) requires tests for arsenic during real estate transactions; however, the regulations do not require remedial action when maximum contaminant levels (MCLs) are exceeded. A follow-up survey sent to residents of homes where arsenic was measured above the state MCL in PWTA-required tests reveals a range of mitigation behavior among respondents ($n = 486$), from taking no action to reduce exposure (28%), to reporting both treatment use and appropriate maintenance and monitoring behavior (15%). Although 86% of respondents recall their well was tested during their real estate transaction, only 60% report their test showed an arsenic problem. Treatment systems are used by 63% of households, although half were installed by a previous owner. Among those treating their water ($n = 308$), 57% report that maintenance is being performed as recommended, although only 31% have tested the treated water within the past year. Perceived susceptibility and perceived barriers are strong predictors of mitigation action. Among those treating for arsenic, perceived severity is associated with recent monitoring, and level of commitment is associated with proper maintenance. Mention of a treatment service agreement is a strong predictor of appropriate monitoring and maintenance behavior, while treatment installed by a previous owner is less likely to be maintained. Though the PWTA requires that wells be tested, this study finds that not all current well owners are aware the test occurred or understood the implications of their arsenic results. Among those that have treatment installed to remove arsenic, poor monitoring and maintenance behaviors threaten to undermine intentions to reduce exposure. Findings suggest that additional effort, resources, and support to ensure home buyers pay attention to, understand, and act on test results at the time they are performed may help improve management of arsenic water problems over the long term and thus the PWTA's public health impact.

1. Background

Arsenic is naturally occurring in groundwater across the United States and worldwide. Chronic exposure to arsenic through drinking water is associated with various adverse health effects including cancers, cardiovascular disease, lung disease, and diminished child IQ (Naujokas et al., 2013; National Research Council, 2014). Although users of public water systems benefit from the federal Safe Drinking

Water Act and its regulatory oversight ensuring their drinking water meets government standards for arsenic and other contaminants, the 45 million Americans who rely on private well water are excluded from these protections at home (Maupin et al., 2014; Nigra et al., 2017). Monitoring and maintaining the quality of drinking water remains the responsibility of individual well owners. The “private” designation of water sources supplying fewer than 25 people or 15 households spares individuals the regulatory burden of compliance (Safe Drinking Water

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Act, 1974), while forgoing equal assurances of safe drinking water. Exceptions for individual household water supplies from drinking water regulation appear to be the norm worldwide where such laws are enforced, despite consistent evidence of poor water quality and increased health risks from private sources (Vesterbacka et al., 2005; Said et al., 2003; Charrois, 2010).

The exact portion of the over 13 million U.S. households dependent on private well water (U.S. Census Bureau, 2013) who are affected by arsenic, or the health and economic costs associated with that exposure, is unknown without a regulatory monitoring system in place. However, the probability of arsenic occurrence at regional and local scales can increasingly be predicted by geostatistical modeling (Ayotte et al., 2006; Yang et al., 2012); a recent study estimates over 2.1 million Americans are drinking from wells with arsenic above the 10 µg/L federal standard (Ayotte et al., 2017). A likely greater number drink from wells above the more protective standard of 5 µg/L, in effect for the state of New Jersey since 2006. Nevertheless, high degrees of spatial heterogeneity mean the presence and concentration of arsenic in individual wells can only be determined by a specific water test. Therefore, every well must be tested.

In the absence of regulations, individual protective behavior is essential to exposure reduction, yet the reasons private well owners test or do not test their water are often complex, with additional challenges in the case of arsenic (Flanagan et al., 2015a; Flanagan et al., 2016a; Jones et al., 2006; Flanagan et al., 2016b; Hexemer et al., 2008). As a result, a majority of households, including those located in at-risk areas, have not tested their wells for arsenic and are unaware of their exposure risk (Flanagan et al., 2015a, 2016c; Shaw et al., 2005). Community campaigns to encourage private well testing often have limited success (Paul et al., 2015; Renaud et al., 2011; Severtson et al., 2004), and socioeconomic disparities in exposure likely arise from differing rates of testing participation (Flanagan et al., 2016a, 2016b). Given the challenges in motivating individual private well owners to act, there is potential for policy and regulations to make a significant contribution towards universal screening of private well water quality (Zheng and Flanagan, 2017).

With its Private Well Testing Act (PwTA), New Jersey is one of only two states in the United States, the other Oregon, to require testing of private well water for arsenic during real estate transactions (Zheng and Flanagan, 2017). Between September 2002 and April 2014 the PwTA has generated over 43,000 well tests for arsenic in the counties where it is required. However, testing only acts as a screening tool. The PwTA is a right-to-know law and has no requirement that protective action be taken, only that the test occur and that both parties certify at closing that they have received and reviewed the water test results (Flanagan and Zheng, 2018). Nevertheless, the law provides a model for practical and feasible state-level policy and regulatory action, in the absence of other regulations, to ensure that more private wells are tested for arsenic.

After arsenic is found in a well, a household must then decide on further action to reduce exposure – treatment, use of bottled water, or no action. Follow-up surveys to participants of voluntary well testing programs in other states find that a third to a half of households notified of high arsenic in their water may not be acting to reduce their exposure (Severtson et al., 2006; Flanagan et al., 2015b), suggesting that protective behavior even among informed well owners is not guaranteed. The specific effect of PwTA-required testing during home purchase, as compared to voluntary testing (Flanagan et al., 2016b), on subsequent protective actions among those with arsenic exceedances, is still unknown. Despite anecdotal stories that the pressure of the home sale prompts negotiations for installation of corrective treatment, there is no quantifiable evidence available to confirm this. Findings from a random sample survey of private well households in northern New Jersey suggest that owners of wells tested under the PwTA may frequently forget or misremember arsenic test results, are more likely to not know what kind of water treatment they are using, and do not report better

maintenance or monitoring of treatment than those who had voluntarily tested their well water (Flanagan et al., 2016c). This suggests challenges to reducing exposure remain even when testing is required.

A survey of well owners with arsenic above the NJ standard of 5 µg/L as identified through PwTA-required testing was conducted to estimate the proportion acting to mitigate arsenic exposure, the proportion appropriately monitoring and maintaining their treatment systems, and to investigate the factors that influence these mitigation behaviors. Understanding the arsenic-mitigation behavior among this population will help to evaluate the impact of the PwTA, aid the development of public resources to support well owners with their exposure reduction needs, and inform the design of future private well testing and treatment programs and policies.

2. Methods

2.1. Study population

Over one million people (11% of the population) in New Jersey rely on private well water for drinking (Maupin et al., 2014). Only 25% of private wells are estimated to have been tested through the PwTA in the years since 2002, due, in part, to the pace of housing turnover (Flanagan et al., 2016c). The PwTA requires testing untreated well water for arsenic in the 12 counties in the northern half of the state where arsenic concentrations as high as 250 µg/L are naturally occurring in the bedrock aquifers of the Newark Basin (Fig. 1) (Serfes et al., 2005). Of the private wells tested, 8.9% have exceeded the state arsenic standard for drinking water and arsenic has been found more frequently than any other contaminant (New Jersey Department of Environmental Protection, 2008). From September 2002 through March 2014, there were 3476 unique wells found with arsenic values greater than 5.0 µg/L. Public and commercial properties, based on property tax records, and several addresses which had been randomly selected for a previous mailed survey on arsenic testing and treatment in 2014 (Flanagan et al., 2016c) were excluded from selection. The final sample of 1500 addresses included all wells with ≥ 25 µg/L arsenic ($n = 175$), all wells with 10–25 µg/L ($n = 872$), and an approximately 20% random selection of all wells with 5–10 µg/L ($n = 453$). The median well arsenic value of the selected addresses was 12 µg/L, and median tax-assessed property value was \$456,650. Specific test results are maintained as confidential and are not publicly shared as a condition of the Act.

2.2. Data collection

Data were collected via self-administered mailed questionnaire, adapted from surveys used for arsenic-affected private well users in Wisconsin (Severtson et al., 2008) and Maine (Flanagan et al., 2015b) and reviewed by key stakeholders in New Jersey for content validity. Questions covered arsenic testing experiences, water treatment practices, and basic demographic information. A series of statements based on health behavior theory with Likert scale responses were included to explore the relative influence of psychological beliefs on mitigation behavior outcomes. Survey items were categorized into psychological constructs that may explain arsenic mitigation behavior (Table S1), as outlined by the Health Belief Model: Perceived Susceptibility – feelings of personal vulnerability to arsenic exposure; Perceived Severity – feelings on the seriousness of consequences of arsenic exposure; Perceived Benefits – perceived effectiveness of actions to reduce exposure; Perceived Barriers – feelings on the obstacles to reduce exposure; Self-efficacy – level of confidence in one's ability to reduce exposure; and Cue to Action – advice to reduce exposure from a local authority (Glanz et al., 2008). This model was modified with the additional factor of "Commitment," or the feeling of obligation to reduce arsenic exposure, taken from the RANAS model of integrated health and social psychology theories (Mosler, 2012) because it has been found to be a significant predictor of arsenic mitigation behavior in Bangladesh

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