Preventive Medicine Reports 20 (2020) 101209

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Private well water testing promotion in pediatric preventive care: A randomized intervention study

Carolyn J. Murray[a,b,*], Ardis L. Olson[c], Ellen L. Palmer[d,e], Qian Yang[d], Christopher I. Amos[d,f], Deborah J. Johnson[c], Margaret R. Karagas[a,g]

[a] Children's Environmental Health and Disease Prevention Research Center at Dartmouth, Dartmouth Geisel School of Medicine, 1 Medical Center Drive, Lebanon, NH 03756, USA

[b] The Dartmouth Institute for Health Policy and Clinical Practice, 74 College Street, Hanover, NH 03755, USA

[c] Dartmouth CO-OP Primary Care Research Network, Dartmouth Geisel School of Medicine, 46 Centerra Parkway, Lebanon, NH 03766, USA

[d] Department of Biomedical Data Science, Dartmouth Geisel School of Medicine, 1 Medical Center Drive, Lebanon, NH 03756, USA

[e] Department of Population and Quantitative Health Sciences, Case Western Reserve School of Medicine, Cleveland, OH, USA

[f] Department of Medicine, Baylor College of Medicine, Houston, TX, USA

[g] Department of Epidemiology, Dartmouth Geisel School of Medicine, 1 Medical Center Drive, Lebanon, NH 03756, USA

ARTICLE INFO

Keywords:
Water quality
Arsenic
Private wells
Well water testing
Pediatric environmental health

ABSTRACT

Over 43 million U.S. residents rely on private unregulated wells for their drinking water, raising public health concerns, particularly in regions like northern New England where widespread groundwater arsenic contamination is now recognized. Children are particularly vulnerable to adverse health effects from arsenic exposure. Despite AAP Guidelines, approaches to engage pediatric clinicians in promoting private well testing have not been previously described. We sought to determine the most effective practice approaches to achieve successful well water testing in routine pediatric care. 12 primary care clinics were block randomized to one of four study arms. Two intervention variables were assessed: (1) test results access (parent only vs. parent and clinic) and (2) follow up approaches (yes/no). Parents of children under 12 months using a private well were eligible. Prepaid water tests were provided. Primary outcome was parental water test completion. Eleven clinics successfully implemented processes identifying well users. 240 testing kits were dispensed. Completion rates averaged 29% (range 10 to 61%). The study arm with both clinic results access and staff follow up system was 2.3 times more likely to achieve test completion than other arms (95% CI 1.12–4.86, p = .03). Kit distribution by clinicians versus nursing staff, irrespective of study arm, had 2.4 times greater completion (95% CI 1.13–5.11, p = .02). Systematic drinking water source screening can be improved in pediatric care. Higher testing completion was found in practices randomized to reminders and structured follow up versus single visit discussion, but clinician involvement was the most predictive factor.

1. Introduction

The exposure of children in Flint, Michigan to lead from the public water system has raised awareness of inequities in enforcement of existing environmental regulations and the key role of community health care professionals in exposure identification and advocacy (Hanna-Attisha et al., 2016). However, the absence of regulatory protection of drinking water for the over 43 million U.S. residents dependent on private wells (Dieter et al., 2018) is largely unrecognized by the health care delivery system. This disparity in environmental protection and the resultant public health vulnerability are exemplified in northern New England where 40–50% of the population relies on unregulated private water systems, and widespread contamination of bedrock wells with naturally occurring arsenic is now recognized (Ayotte et al., 2012).

Abbreviations: AAP, American Academy of Pediatrics; CDC, U.S. Centers for Disease Control and Prevention; USGS, U.S. Geological Survey; Dartmouth CO-OP, Dartmouth CO-OP Primary Care Practice-based Research Network; EPA, U.S. Environmental Protection Agency

* Corresponding author: Children's Environmental Health and Disease Prevention Research Center, HB 7999, Dartmouth Geisel School of Medicine, 1 Medical Center Drive, Lebanon, NH 03756, USA.

E-mail addresses: Carolyn.J.Murray@Dartmouth.edu (C.J. Murray), Ardis.L.Olson@Dartmouth.edu (A.L. Olson), elp76@case.edu (E.L. Palmer), Qian.Yang@Dartmouth.edu (Q. Yang), Chris.Amos@bcm.edu (C.I. Amos), Deborah.J.Johnson@Dartmouth.edu (D.J. Johnson), Margaret.R.Karagas@Dartmouth.edu (M.R. Karagas).

https://doi.org/10.1016/j.pmedr.2020.101209
Received 10 May 2020; Received in revised form 2 September 2020; Accepted 5 September 2020
Available online 12 September 2020

Inorganic arsenic, a tasteless and odorless metalloid, has known cancerous and non-cancerous health effects (Naujokas et al., 2013) and like lead, poses unique health risks to children (Smith et al., 2006; Vahter, 2008; Rahman et al., 2010).

While the American Academy of Pediatrics (AAP) recommends routine periodic water testing for a range of contaminants including arsenic for families with children using private wells (Rogan et al., 2009), a review of the literature found no studies that addressed compliance with these recommendations in clinical settings, nor specific strategies for promoting this screening activity as part of routine pediatric preventive care. In 2014, NH added specific questions regarding drinking water source and arsenic testing to the annual U.S. Centers for Disease Control and Prevention (CDC) Behavioral Risk Factor Surveillance Survey. Over forty percent of respondents comprising a representative sample of NH residents indicated they used a private well, with 56% reporting no testing for arsenic in the prior three years and 15% reporting never having tested their well for arsenic (NH Private Well Water Summary, 2015). Given the high regional prevalence of private wells, low compliance with periodic testing (Malecki et al., 2017), and the potential health risks from exposure to arsenic in drinking water, we engaged regional pediatric clinicians in a primary care initiative to promote well water testing in their practices and determine the most effective approach to achieve successful water test completion. We conducted the study within the Dartmouth CO-OP Primary Care Practice-based Research Network (Dartmouth CO-OP), a 250-member voluntary research organization of primary care practitioners located in the states of Vermont, New Hampshire and Maine with whom we have successfully engaged in previous intervention studies (Glowa et al., 2016; Olson et al., 2009).

2. Patients and methods

2.1. Setting

A total of twelve practices were recruited from the Dartmouth CO-OP network in New Hampshire (NH) and Vermont (VT). To raise awareness of arsenic groundwater contamination and stimulate interest in study participation, we first created a GIS map to visually represent all Dartmouth CO-OP clinic locations in relation to U.S. Geological Survey (USGS) probability estimates of groundwater arsenic exceeding 5 mcg/L (Fig. 1). We sought practices that likely served a higher proportion of patients dependent on private wells for drinking water. The pediatric (n = 9) and family medicine (n = 3) practices selected were primarily rural and varied in size from 3 to 8 full time equivalent clinicians. Clinicians included physicians, nurse practitioners, and physician assistants. Reflecting the underlying demographics of northern New England, patient populations served by these clinics were predominantly (> 90%) white and English-speaking.

2.2. Study design

The interventions used for our study were designed to integrate clinician and staff education with new resources to enhance both screening for private well contamination and counseling about arsenic exposure, with the overall goal of optimizing parental completion of well water testing. Practice approaches used for our intervention study were conceptualized from current pediatric approaches related to fluoride and lead screening. Fluoride supplementation needs are based on the fluoride status of the individual child's drinking water. After counseling, this process entails the parent being asked to test their private well for fluoride, with the responsibility for requesting the water test, with receipt and interpretation of testing results resting solely on the parent. Office follow up methods were derived from observations in primary care of 1) fluoride drinking water assessment where follow up did not occur or was an ad hoc inquiry at later visits, and 2) blood lead screening procedures that require test ordering, completion and appropriate follow up by clinician or staff.

We compared the effectiveness of practice implementation approaches to promote well water screening that varied by two factors; 1) who received the screening results, and 2) follow up method. The first factor tested differences in testing completion when water analysis results were provided solely to the parent versus analysis results provided to both parent and clinical practice (Parent only vs. Parent and Clinic). The second factor tested the effectiveness of different levels of after-visit parental reminders to complete testing versus no systematic follow-up reminders (No Follow up vs. Follow up). Thus, there were 4 combinations of interventions used.

Individual practices were blindly randomized to one of four blocks and then these four blocks were blindly randomized to one of the four intervention arms. The office had no direct access to test results in the Parent only/Follow up arm, thus the parent received clinician reminders at their next visit, but not the more systematic approach by clinic staff provided in the Parent and Clinic/ Follow up arm. The four arms of the intervention also varied in the level of clinical practice change required, with the Parent only with No Follow up arm involving the least change in practice procedures and the Parent & Clinic with Follow Up arm requiring the most practice change and staff resources. The Parent only approach is similar to what is typically used with drinking water testing for fluoride. The Parent and Clinic approach is similar to procedures for completion of blood lead testing. A summary of the intervention components in each arm is provided in Table 1.

All clinicians and staff at all participating practices also received an on-site one-hour educational session that included an assessment of current knowledge and practice related to well water testing. Session content included education about health-related drinking water contaminants, the absence of regulatory protection of private wells, the high regional prevalence of arsenic groundwater contamination, and the potential pediatric health effects of exposure to arsenic and other water contaminants. (Training materials available upon request.) All practices were provided counseling messages, exam and waiting room posters, and informational resources for use if water testing revealed the presence of contamination. Materials were aimed at simplifying the process of well testing and providing guidance if subsequent action was needed (i.e., if an elevated arsenic level or other contaminant was detected via testing). These resources were developed with input from NH and VT state public health authorities and included contacts to agency personnel in the event of test result concerns.

Practices were instructed to perform an initial parental inquiry about the source of household drinking water as part of all preventive health visits of children less than one year of age. Those parents indicating private well use were then counseled about potential exposure to arsenic from well water and the importance of well water testing. The parents of children who identified a private well as their primary drinking water source and who had not tested their well in the prior year were eligible to participate. After obtaining informed consent, the parents were provided free water testing kits that encompassed a basic panel of drinking water contaminants consistent with recommendations of the NH and VT state health departments and the AAP for households with private wells (Rogan et al., 2009; AAP Council on Environmental Health et al., 2019). This included testing for nitrates, nitrites, fluoride, coliforms, *Escherichia coli (E. coli)* and arsenic. A pre-addressed, postage paid overnight mailer was provided for shipping water testing kits. Testing kits were identified by an assigned number to protect well owner identity. The research office received all water testing results from the accredited laboratory, matched test number to subject, and then distributed results by mail to parents and by facsimile to office sites per the randomization protocol. In the case of abnormal test results, written interpretation and specific guidance were provided to parents along with the results.

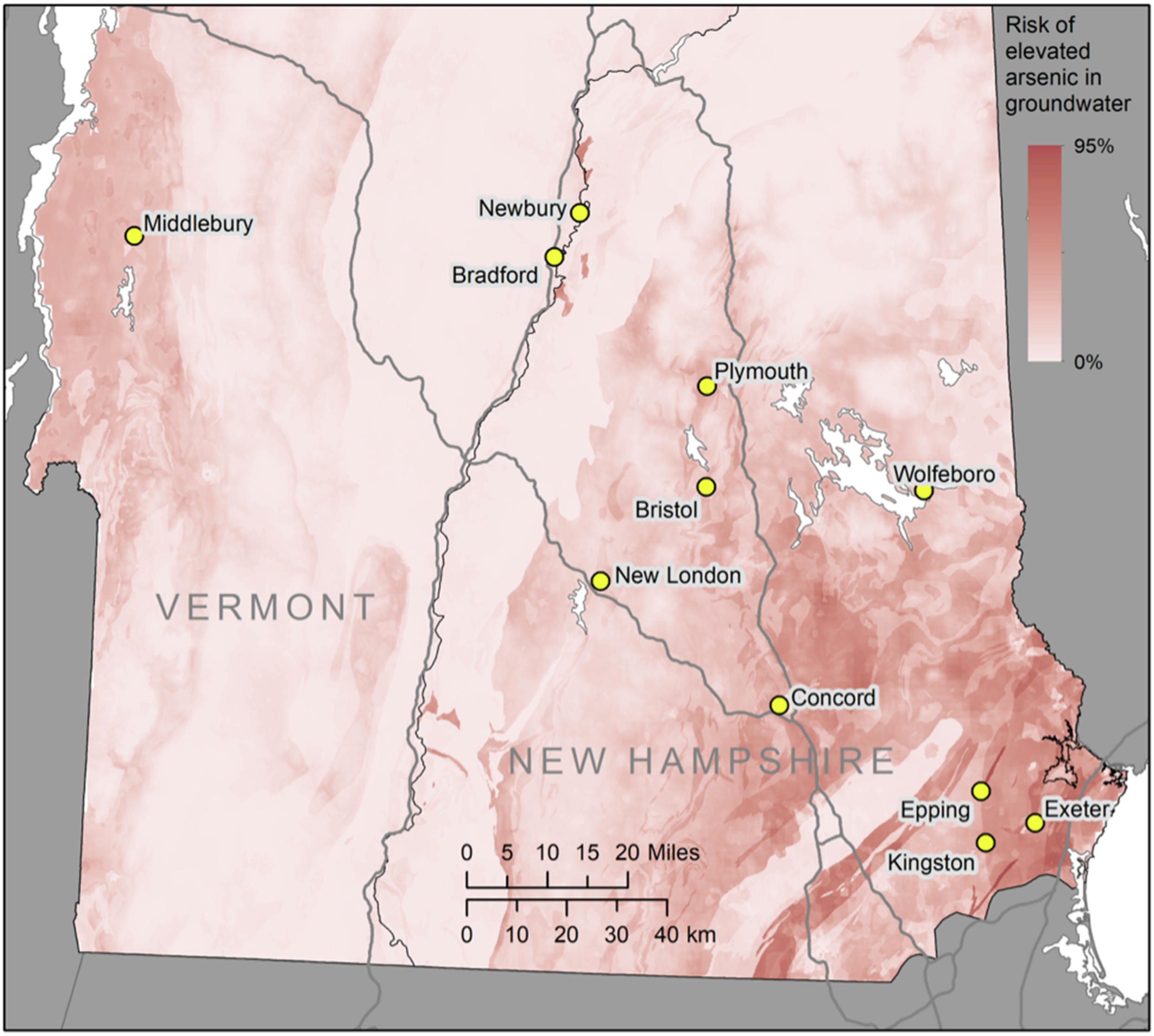

Fig. 1. Locations of participating practices in NH and VT, with estimated probability of arsenic exceeding 5 mcg/L in groundwater, based on the model in Ayotte et al. (2006). Map in Fig. 1 courtesy Jonathan W. Chipman, Citrin GIS/Applied Spatial Analysis Lab, Dartmouth College.

Table 1
Intervention components for each of 4 study arms; Access to Results vs. Follow-up After Visit.[1]

		Access to Well Water Testing Results	
		Parent Only	Parent and Clinic
Follow-up after visit	No planned follow-up	Parent mailed results and guide to interpret Single visit discussion **PARENT ONLY with NO FOLLOW-UP**	Parent mailed results and guide to interpret Results faxed to clinic Single visit discussion No specific follow-up system, follow up of results determined by individual clinician **PARENT and CLINIC with NO FOLLOW-UP**
	Office follow-up	Parent mailed results and guide to interpret Clinician inquiry about test results at next well child visit within 2 months, encourage testing if not yet done **PARENT ONLY with FOLLOW-UP**	Parent mailed results and guide to interpret Results faxed to clinic Designated staff to monitor if testing done, contact family if positive or testing not done **PARENT and CLINIC with FOLLOW-UP**

[1] All clinical sites were provided initial advice and received information/resources to respond to parental questions about well testing and guidance if positive test results received, including state-specific web sites regarding well water arsenic and remediation.

2.3. Data collection

Prior to initiation of the study, a retrospective medical record review of 30 consecutive pediatric preventive care visits was performed at each practice to assess for baseline documentation of drinking water source, and when applicable, advice about well water testing. Data on staff roles and workflow initiated to provide water test kits, and the follow up systems established were collected at each practice. From this we determined whether the clinician or their nursing staff directly provided the water testing kits to the parent. This study was reviewed and approved by the Committee for Protection of Human Subjects (CPHS) at Dartmouth College.

2.4. Data analysis

We assessed the variables related to the factorial study design for relationships with the main outcome (water kit returned) using mixed effects models, controlling for block randomization by study site by treating it as a random effect. Variables assessed under this model assumption, individually and in combination, were clinic follow up and receipt of test results by parent only versus both parent and clinic. For our primary outcome, water kit returned in each arm in our factorial study, we again used mixed effects models using the R package "lme4" (version 1.1–10) (Bates et al., 2015) and also completed a logistic regression model. Results were similar between models, so we report on the logistic regression model for the main effect. Post-hoc analyses using logistic regression evaluated kit return by type of staff dispensing the test kit (clinician vs. nursing staff). From the models, the estimated proportion of water tests completed for each of the study arms was calculated. All statistical analyses were completed in R studio (version 0.99.486, R version 3.2.2) (RStudio Team, 2015).

3. Results

At baseline, from chart audits in each participating clinic, drinking water source was documented in only 18% of preventive care visits. For those families identified as private well users, specific water testing recommendations were present in fewer than 10%, and these were focused on fluoride only. None of the practices addressed well water testing for other water contaminants, including arsenic.

One of the 12 practices (Parent and Clinic with No Follow Up arm) dropped out of the study due to unfilled key nursing staff positions, leaving 11 practices in the final analyses. The remaining practices screened for drinking water source at preventive care visits for children under age 1 and dispensed kits to eligible consented households for 3 months. A total of 240 kits were provided to parents from all practices combined. Parental completion of water testing varied by practice and ranged from 10% to 61% of kits dispensed with an overall completion rate of 29%. Table 2 shows the water testing completion rates and test results by study arm. The proportion that found elevated arsenic levels above the U.S. Environmental Protection Agency (EPA) regulatory limit (> 10 mcg/l) was 14.3% (n = 10) and was consistent with USGS estimates of well water arsenic contamination of 10–20% in our region (Ayotte et al., 2012).

In our analyses, there was no statistically significant difference in water testing completion between the Parent only (26.7%) and Parent & Clinic (31.7%) access to water test result arms (OR of returning kit 1.17, 95% CI 0.49–2.8, p = .76). We did detect differences in water testing completion by Follow up versus no Follow-up. Practices where follow-up occurred achieved a 37.2% completion rate whereas practices without follow up had a 22% completion rate (OR 2.22, 95% CI 1.03–4.78, p = .04). Practices with both implementation factors (water test results to both the parent and clinic and with follow-up) had the highest rate of water test completion of 45.1%. Our main effect model found that in practices with this combination of clinic access to results and a tracking system, the odds that parents would complete water testing were 2.3 times greater than in practices without these intervention strategies (95% CI 1.12–4.86, p = .03). (Table 3). Because of substantial variation in whom the practice had dispense the water kits, a post-hoc logistic regression model including member of the practice who distributed the testing kit was performed (Table 4). In this logistic regression model, while the clinic test access with staff tracking was still the arm with the most impact, kit distribution by the clinician (versus nursing staff) was the only statistically significant predictor of parental completion of water testing (OR 2.40, 95% CI 1.13–5.11, p = .02). There was no interaction effect between study arm and staff distribution method.

4. Discussion

4.1. Main findings

This study is unique in that it evaluated different primary care implementation approaches aimed at influencing parental compliance with testing of their private well, an activity that traditionally has fallen on the public health system with limited success given the absence of regulatory authority. All clinical sites in this study were able to implement a screening system to identify families using private wells. While there was a wide variation in test completion across the study arms (17.2%–45.1%), the average rate of 29.1% was on par with results achieved with extensive community-based well water testing promotion efforts that did not use prepaid kits (Zheng and Flanagan, 2017), suggesting that other parental barriers to water test completion need to be identified. While the overall well testing completion rate was lower than expected, all participating practices successfully implemented a system to identify private well users, which occurred infrequently prior to the intervention study and without consistent well testing recommendations. A key component likely to improve test completion across sites was our practice-wide training at all participating sites to heighten clinician and staff awareness of the previously under-recognized public health risk of arsenic and the potential health impact on children in their practice. Another important aspect of this program

Table 2
Proportion of parents completing well water testing and water test results.

	Intervention Access/Follow- Up	Testing kits Dispensed N	Water testing done N (%)	Abnormal test results N (%)	> 10 mcg/L Arsenic N (%)	Coliforms[a] N (%)
				Proportion of completed tests		
Parent Only with No Planned Follow-up	−/−	69	18 (26.1%)	8 (44.4%)	5	3
Parent Only with Office Follow-up	−/+	51	14 (27.4%)	4 (28.6%)	1	3
Parent and Clinic with No Planned Follow-up	+/−	28	10 (17.2%)	2 (20.0%)	0	2
Parent and Clinic with Office Follow-up	+/+	62	28 (45.1%)	6 (21.4%)	4	2
Totals (%)		240	70 (29.1%)	20 (28.5%)	10 (14.3%)	10 (14.3%)

[a] 1(10%) of Coliform positives was also positive for *E. coli.*

Table 3
Logistic Regression of Intervention model to enhance well water testing completion.

Study Arm	Intervention: Access/Follow Up	Odds Ratio	95% CI	p Value
Parent Only with No Planned Follow-up	−/−	1.00		
Parent Only with Office Follow-up	−/+	1.07	0.47–2.43	0.09
Parent & Clinic with No Planned Follow-up	+/−	0.59	0.25–1.41	0.23
Parent & Clinic with Office Follow-up	+/+	2.33	1.12–4.86	0.03

Table 4
Logistic Regression of the predictors of well water test completion.

Study Arm	Odds Ratio	95% CI	p Value
Parent Only with No Planned Follow-up	1.00		
Parent Only with Office Follow-up	1.07	0.48–2.52	0.83
Parent and Clinic with No Planned Follow-up	0.90	0.34–2.37	0.84
Parent and Clinic with Office Follow-up	1.61	0.72–3.58	0.24
Provider dispensed test kit to parent	2.40	1.13–5.11	0.02

was that the public health agencies in both states (NH and VT) provided input into practice-based informational materials and provided direct access to agency personnel in the event of test result concerns- an example of a unique public health-health care partnership to address a shared health concern.

An unexpected finding was the dominant influence on completion rates when the clinician dispensed the testing kit to the parent. While other staff members may have provided the education, having the clinician dispense the testing kit to the parent was likely to have served as a stronger endorsement of well water testing. Thus, our study informs us that an activated practice with clinician and staff education combined with an active clinician role in providing testing kits is important beyond the factors of who receives the test results or follow up methods. This aspect of our intervention merits further study on a larger scale.

In the environmental public health literature, lack of concern about water quality, confusion about what contaminants to test for, difficulties with lab access, and financial cost of testing have been cited as reasons for poor compliance with recommended periodic private well testing (Chappells et al., 2015; Flanagan et al., 2015; Munene et al., 2020; Imgrund et al., 2011). Testing prices vary depending on the tests selected, with a typical basic panel ranging in cost from $60- $100 and arsenic testing alone costing $15- $30. In our study, the use of prepaid standardized testing kits with prepaid mailing removed the barriers of parental confusion regarding test selection and the costs of testing and shipping. Following conclusion of the intervention study, practices were offered customized water testing kits supplied by the NH state public health laboratory, which included an option for an "arsenic only" test of $15.00 as well as the more comprehensive standard analysis for $85 to help sustain the engagement of these practices in drinking water source screening and well water testing promotion.

4.2. Limitations

This study had several limitations. First, it is a small randomized controlled intervention study in a predominantly rural region with a high prevalence of private well users, and a predominantly non-Hispanic white population. Still, our results would be applicable to other regions where patients obtain their drinking water from non-regulated sources. Our study design did not include descriptive data of families in the study, which limited analysis of individual factors that may have influenced test completion. While we utilized a two by two factorial randomized design, we had to make modifications to implement four arms that were realistic approaches in a clinical setting. Thus, follow up clinician inquiry at the next well child visit was used instead of research staff tracking results and contacting parents in the Parent Only/Follow up arm. In the absence of data on the number of eligible private well users at each practice, testing rates could not be calculated. Our study design also deliberately allowed each practice to customize their approach to water source screening, parental education and dispensing of testing kits based on their practice style and workforce. We were unable to study the actual content or delivery of counseling within the practice setting, although all practices were provided identical resources and talking points about the importance of private well testing for their child's health.

5. Conclusion

This study is an example of integration into the pediatric outpatient setting of a screening process to identify household drinking water source and promote comprehensive well water testing which, aside from fluoride assessment, has traditionally been viewed as more of a public health responsibility. Simply routinely asking the question in the clinical setting, "Have you had your well water tested?" serves as an endorsement of the importance of environmental health determinants within a primary care practice, which appeared to be amplified when the clinician had an active role in provision of the well water testing kit. Future studies should explore the role of clinical information systems to systematize the identification of drinking water source and testing reminders to promote parental action to assure "healthy water" in their household. Jointly identifying and addressing barriers to water test completion with public health partners is crucial to a water testing program, as illustrated by a recent healthcare system and health department partnership to promote well water testing in a region of New Jersey known to be a hot spot for natural arsenic contamination (Flanagan et al., 2020).

This disparity in drinking water safety between regulated public water systems and private wells would ideally be addressed by universal screening requirements (Zheng and Flanagan, 2017). However, the absence of federal regulatory authority and the lack of consistent state and local governmental policies to ensure regular screening of private wells underscores the important role of the "medical home" in patient education. In this era of increasing threats to our sources of drinking water and heightened awareness of water quality and human health, we recommend continued collaborative efforts between public health entities and primary care to address important environmental health determinants in our communities of practice.

Author contributions

Drs. Murray and Olson conceptualized and designed the study, carried out the initial analyses, drafted the initial manuscript, and reviewed and revised the manuscript. Ms. Johnson designed the data collection instruments, coordinated and supervised data collection and reviewed and revised the manuscript. Dr. Amos, Ms. Palmer and Ms. Qian Yang conducted the statistical analyses and reviewed and revised the manuscript. Dr. Karagas contributed to data analysis and critically reviewed the manuscript for important intellectual content. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments:

This publication was made possible by U.S. Environmental Protection Agency (US EPA) grant RD83544201 and National Institute for Environmental Health Sciences (NIEHS) grant P01ES022832. Data analysis reported in this publication was supported by The Dartmouth Clinical and Translational Science Institute, under award number UL1TR001086 from the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health (NIH). The content is solely the responsibility of the author(s) and does not necessarily represent the official views of the NIH. Study data were collected and managed using REDCap electronic data capture tools hosted at Dartmouth College.

We would like to thank the clinicians and staff of the following Dartmouth CO-OP Primary Care Research Network practices for their commitment to this study: Newbury Health Clinic, Newbury, VT; Core Physicians, Exeter, Epping, and Plaistow, NH; Wolfeboro Pediatrics, Wolfeboro, NH; Upper Valley Pediatrics, Bradford, VT; New London Pediatric Care Center, New London, NH; Newport Health Center, Newport, NH; Concord Pediatrics, PA, Concord, NH; Middlebury Pediatric and Adolescent Medicine, Middlebury, VT; Mid-State Health Center, Bristol and Plymouth, NH.

References

AAP Council on Environmental Health, 2019. Drinking water. In: Etzel, R.A., Balk, S.J. (Eds.), Pediatric Environmental Health, 4th ed. American Academy of Pediatrics, Washington, DC, pp. 277–302.

Ayotte, J.D., Cahillane, M., Hayes, L., Robinson, K.W., 2012. Estimated probability of arsenic in groundwater from bedrock aquifers in New Hampshire, 2011. U.S. Geological Survey Scientific Investigations Report 2012–5156, 25 p. http://pubs.usgs.gov/sir/2012/5156/.

Ayotte, J., Nolan, B., Nuckols, J., Cantor, K., Robinson, G., Baris, D., Hayes, L., Karagas, M., Bress, W., Silverman, D., Lubin, J., 2006. Modeling the probability of arsenic in groundwater in New England as a tool for exposure assessment. Environ. Sci. Technol., ES & T 40 (11), 3578–3585. https://doi.org/10.1021/es051972f.

Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. J. Stat. Softw. 67 (1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Chappells, H., Campbell, N., Drage, J., Fernandez, C., Parker, L., Dummer, T., 2015. Understanding the translation of scientific knowledge about arsenic risk exposure among private well water users in Nova Scotia. Sci. Total Environ. 505, 1259–1273. https://doi.org/10.1016/j.scitotenv.2013.12.108.

Dieter, C.A., Maupin, M.A., Caldwell, R.R., Harris, M.A., Ivahnenko, T.I., Lovelace, J.K., Barber, N.L., Linsey, K.S., 2018. Estimated use of water in the United States in 2015. U.S. Geol. Survey Circ. 1441, 65 p. https://doi.org/10.3133/cir1441.

Flanagan, S.V., Braman, S., Puelle, R., Gleason, J.A., Spayd, S.E., Procopio, N.A., Prosswimmer, G., Navas-Acien, A., Graziano, J., Chillrud, S., 2020. Leveraging health care communication channels for environmental health outreach in New Jersey. J. Public Health Manag. Pract [published online ahead of print, 2020 Jan 30]https://doi.org/10.1097/PHH.0000000000001121.

Flanagan, S., Marvinney, R., Zheng, Y., 2015. Influences on domestic well water testing behavior in a Central Maine area with frequent groundwater arsenic occurrence. Sci. Total Environ. 505, 1274–1281. https://doi.org/10.1016/j.scitotenv.2014.05.017.

Glowa, P., Olson, A., Johnson, D., 2016. Screening for adverse childhood experiences in a family medicine setting: a feasibility study. J. Am. Board Family Med. JABFM 29 (3), 303–307. https://doi.org/10.3122/jabfm.2016.03.150310.

Hanna-Attisha, M., Lachance, J., Sadler, R., Champney Schnepp, A., 2016. Elevated blood lead levels in children associated with the flint drinking water crisis: a spatial analysis of risk and public health response. Am. J. Public Health 106 (2), 283–290. https://doi.org/10.2105/AJPH.2015.303003.

Imgrund, K., Kreutzwiser, R., De Loe, R., 2011. Influences on the water testing behaviors of private well owners. J. Water Health 9 (2), 241–252. https://doi.org/10.2166/wh.2011.139.

Malecki, K., Schultz, A., Severtson, D., Anderson, H., Vanderslice, J., 2017. Private-well stewardship among a general population based sample of private well-owners. Sci. Total Environ. 601–602, 1533–1543. https://doi.org/10.1016/j.scitotenv.2017.05.284.

Munene, A., Lockyer, J., Checkley, S., Hall, D., 2020. Exploring well water testing behaviour through the health belief model. Environ. Health Insights, 14, 1178630220910143–1178630220910143. https://doi.org/10.1177/1178630220910143.

Naujokas, M., Anderson, B., Ahsan, H., Aposhian, H., Graziano, J., Thompson, C., Suk, W., 2013. The broad scope of health effects from chronic arsenic exposure: update on a worldwide public health problem. Environ. Health Perspect. 121 (3), 295–302. https://doi.org/10.1289/ehp.1205875.

NH Private Well Water Summary, 2015. 2014 Behavioral Risk Factor Surveillance System, NH Environmental Public Health Tracking Program, Bureau of Public Health Statistics & Informatics, Division of Public Health Services, NH Department of Health and Human Services.

Olson, A., Gaffney, C., Hedberg, V., Gladstone, G., 2009. Use of inexpensive technology to enhance adolescent health screening and counseling. Arch. Pediatr. Adolesc. Med. 163 (2), 172–177. https://doi.org/10.1001/archpediatrics.2008.533.

Rahman, H., Persson, H., Nermell, H., El Arifeen, H., Ekström, H., Smith, H., Vahter, H., 2010. Arsenic exposure and risk of spontaneous abortion, stillbirth, and infant mortality. Epidemiology 21 (6), 797–804. https://doi.org/10.1097/EDE.0b013e3181f56a0d.

Rogan, W.J., Brady, M.T., Committee on Environmental Health, Committee on Infectious Diseases, 2009. Drinking water from private wells and risks to children. Pediatrics 123 (6), e1123–e1137. https://doi.org/10.1542/peds.2009-0752.

RStudio Team, 2015. RStudio: Integrated Development for R. RStudio, Inc., Boston, MA. http://www.rstudio.com/.

Smith, A., Marshall, G., Yuan, Y., Ferreccio, C., 2006. Increased mortality from lung cancer and bronchiectasis in young adults after exposure to arsenic in utero and in early childhood. Environ. Health Perspect. 114 (8), 1293–1296. https://doi.org/10.1289/ehp.8832.

Vahter, M., 2008. Health effects of early life exposure to arsenic. Basic Clin. Pharmacol. Toxicol. 102 (2), 204–211. https://doi.org/10.1111/j.1742-7843.2007.00168.x.

Zheng, Y., Flanagan, S., 2017. The case for universal screening of private well water quality in the U.S. and testing requirements to achieve it: evidence from arsenic. Environ. Health Perspect. 125(8) 085002–085002. https://doi.org/10.1289/EHP629.