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Science of the Total Environment 554–555 (2016) 113–118

Contents lists available at ScienceDirect

Science of the Total Environment

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

Meeting the public health challenge of protecting private wells: Proceedings and recommendations from an expert panel workshop

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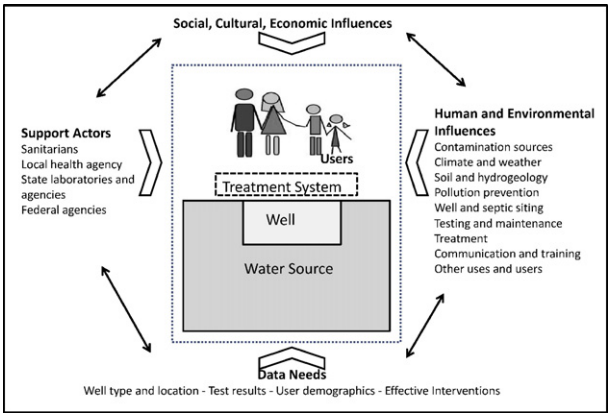
HIGHLIGHTS

- About 43 million Americans use federally unregulated private wells for drinking water.
- Private wells may be contaminated with naturally occurring and man-made chemicals.
- Protecting well water requires an "infrastructure for stewardship".
- Recommendations to advance private well protection are offered.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 23 December 2015
Received in revised form 2 February 2016
Accepted 18 February 2016
Available online 4 March 2016

Editor: D. Barcelo

Keywords:
Disease prevention
Emerging contaminants
Human health

ABSTRACT

Private wells serving fewer than 25 people are federally unregulated, and their users may be exposed to naturally occurring agents of concern such as arsenic and radionuclides, as well as anthropogenic contaminants. The Centers for Disease Control and Prevention's Clean Water for Health Program works to protect private wells and prevent adverse health outcomes for the roughly 15% of Americans who rely on them. To understand current and emerging challenges to the private drinking water supply, an interdisciplinary expert panel workshop on "Future and Emerging Issues for Private Wells" was organized to inform strategic planning for the Clean Water for Health Program. The panel assessed current conditions of ground water as a source for private wells, identified emerging threats, critical gaps in knowledge, and public health needs, and recommended strategies to guide future activities to ensure the safety of private drinking water wells. These strategies addressed topics of broad interest to the environmental public health community including: development of new methods to support citizen science;

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http://dx.doi.org/10.1016/j.scitotenv.2016.02.128
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Private wells
Unregulated drinking water

addressing contaminant mixtures; expanding capacity for well testing; evaluating treatment technologies; building an evidence base on best practices on well owner outreach and stewardship; and research and data needs.
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1. Introduction and approach

1.1. Unregulated drinking water and public health

Approximately 43 million Americans (about 15%) receive their household drinking water from groundwater drawn from private sources, such as wells, cisterns, and springs (United States Geological Survey, USGS, 2004; USEPA, 2012). These sources, unlike public drinking water systems, are not federally regulated and therefore are not required to undergo routine monitoring to ensure that water contaminants are present at concentrations below levels of health concern. A wide array of chemical and microbial contaminants of concern have been measured in private wells, including hormones, nitrates, nanomaterials, organic wastewater compounds, personal care product ingredients, pesticides, pharmaceuticals, and microbes such as Legionella and Campylobacter (Beer et al., 2015; Schaider et al., 2014 and Schaider et al., 2016; Squillace et al., 2002). Health effects associated with exposures to these contaminants can include endocrine disruption, cancer, liver and kidney problems, gastrointestinal illness, reproductive issues, and neurological disorders (Villanueva et al., 2014).

The population using private well water – and potentially at risk of exposure to contaminated water – is not well characterized (Vanderslice, 2011). The burden of disease attributable to use of water from contaminated private wells is also unknown; however, the wide-spread nature of various contamination concerns and the many potential health effects of these contaminants suggests that it could be significant. Sampling by the USGS found that 23% of private wells had at least one contaminant present at concentrations exceeding federal drinking water standards or other health-based levels of concern (DeSimone, 2009), and numerous emerging contaminants that lack health-based standards are detected in groundwater nation-wide (Barnes et al., 2005). Assessing the disease burden resulting from exposure to drinking water contaminants will be challenging and epidemiological studies are needed to better understand long-term low-dose exposures and risks (Villanueva et al., 2014).

1.2. Challenges to protecting private wells

There are a number of emerging threats to wells including the direct and indirect impacts of climate change such as drought and flooding or new agricultural practices, and the potential impacts of energy extraction, such as hydraulic fracturing (National Climate Assessment, 2014; USEPA, 2015; Vengosh et al., 2014). Assessments of how these emerging threats might impact private water supplies are limited.

The Safe Drinking Water Act (Public Law 93-523) that empowered EPA to set national health-based, enforceable standards for natural or man-made contaminants in drinking water excludes private wells serving fewer than 25 people. In absence of federal standards, many states and localities have regulations in place for construction of new wells and water testing, for instance requiring that wells are dug or drilled by a certified contractor or that the water from wells initially be tested for nitrate and coliform bacteria (DeSimone, 2009; Rogan et al., 2009). A few states and localities have gone further with regulations requiring that well water be tested upon resale of the property (e.g., State of New Jersey, 2001; State of Rhode Island Department of Health, 2015; Oregon Real Estate Transaction Law, 2013; Westchester County Private Well Water Testing Legislation, 2007). When testing is done, it is up to the private water well owners themselves to request and pay for the tests and to implement any necessary remediation. Private well testing in the US is a patchwork of varied requirements, and private well users are not afforded the same protections from contaminant exposure as public water supply users (DeSimone, 2009).

1.3. Addressing the public health challenge of protecting private wells

The Health Studies Branch of the CDC National Center for Environmental Health (NCEH), leads the Clean Water for Heath Program (CWH), created to understand and address the public health impact of drinking water sources that are not federally regulated. Specifically, CWH addresses non-infectious waterborne exposures by: 1) building the state and local epidemiologic capacity needed to prevent harmful non-infectious waterborne exposures; 2) advancing public health science to further our understanding of the health risks from non-infectious waterborne exposures; 3) translating science into effective interventions; and 4) responding to environmental health threats that impact drinking water (NCEH, 2012).

Considering the fragmented regulatory environment and new threats to water supply quality and safety such as climate events and changing technologies for energy and agriculture, the CWH Program sought expert advice to plan, assess and respond to emerging issues and improve outreach and interventions. An expert panel was organized by the Johns Hopkins Bloomberg School of Public Health that included persons with expertise in hydrology/hydrogeology, environmental engineering, environmental public health, exposure assessment, groundwater contamination and remediation, agriculture, and climate change. Agencies and organizations represented included the Alaska Native Tribal Health Consortium, US Department of Agriculture, US Geological Survey, New Jersey Department of Environmental Protection, the Rhode Island Public Health Laboratory, Garret County (Maryland) Health Department, Drexel University, Iowa State University, University of Utah, and University of Wisconsin. The panel convened in Baltimore, Maryland at a workshop in January 2015. The discussion and recommendations presented here were developed to inform future work of CWH as well as engage the environmental public health community to improve the evidence base and practice of private well protection.

2. Expert panel discussion

2.1. Discussion overview

The workshop discussion was centered on private well users/owners tapping into a water source. The private well user/owner is the steward, responsible for testing, treating (if necessary), and maintaining the well. In addition to the well user/owner there are a number of other support actors including sanitarians and other environmental public health practitioners involved in protecting private well water at the local, state, and national levels.

The many human and environmental factors and activities that may affect the water source and the private well include climate and weather, soil and hydrogeology, various sources of contamination, and other users or uses of the water source. Many data needs were identified including details of the well type and location, results of water sample analysis, user demographics, contaminant health effect information, and data on the effectiveness of treatments. Having these various types of data help inform the activities of the well user/owner and other actors. Collecting and analyzing the data, interpreting, communicating and responding to it occur in a dynamic social, cultural and economic context.

2.2. Current and emerging contaminants and mixtures in private well water

Contaminants in groundwater and private wells can range from pesticides and fertilizers, livestock waste, petrochemicals, and industrial chemicals to septic contaminants (USEPA, 2002, Phillips et al., 2015). For example, sampling of groundwater from large aquifers across the U.S. under the National Water-Quality Assessment found that 70% of samples had at least one volatile organic compound, pesticide or anthropogenic nitrate (Squillace et al., 2002). A basic set of private well water tests may include total coliform bacteria, nitrates and selected pesticides, arsenic, and radon depending on the area (Centers for Disease Control and Prevention, CDC, 2010; CDC, 2015a). The human health effects of these analytes have been characterized and reliable testing methods have been developed. On the other hand, numerous studies over the past two decades have found new classes of chemicals, biologics, and other emerging contaminants in groundwater and well water (USGS, 2015a). Examples include nanomaterials, personal care and domestic use products, plasticizers, pharmaceuticals, among others (Villanueva et al., 2014). For many emerging contaminants, health effects research, analytical methods development, and private well testing have been limited; thus measurement of these chemicals, and interpretation of sampling results in light of health relevance, can be complicated.

Experts warned that new contaminants and other threats to well water quality will vary by region. Contaminants will vary depending on anthropogenic and environmental factors such as the industrial and economic base of the area, as well as the geography, hydrogeology and climate. Similarly with regard to climate changes, for example, saltwater intrusion is a concern in coastal areas related to expected increased water withdrawals from aquifers exacerbated by sea-level rise (Kundzewicz et al., 2008). However, in the southwestern US, models show that climate change and related climate variability may influence groundwater recharge, discharge, and fluctuations in the water-table (Hanson et al., 2004).

Expert panelists also highlighted the need to shift focus away from considering single agents in isolation to recognizing the health relevance of exposures to contaminant mixtures. Work by the USGS has documented complex mixtures of volatile organic compounds, pesticides, nitrate, pharmaceuticals and other waste water contaminants in groundwater and drinking water wells; Squillace et al., 2002 reported that 33% of samples taken from 1255 private wells and 242 public water supply wells had at least three compounds. Schaider et al. (2014) sampled 20 public water supply wells on Cape Cod and found nine wells with multiple organic wastewater compounds. Considering contaminant mixtures, workshop participants discussed the need for identifying indicator chemicals that can be representative of classes of contaminants and the related issue of developing analytical methods for their screening and quantification. Existing chemical mixture assessment methods may be adapted for evaluating the potential health effects of chemical mixtures in private well water (e.g., USEPA, 2000; Agency for Toxic Substances and Disease Registry, 2004).

While scientists at the workshop expressed concern with the widespread prevalence of emerging contaminants in groundwater across the country, public health practitioner representatives felt that they lack capacity to shift much focus to addressing emerging contaminants, largely due to gaps in resources needed to address well-recognized contaminant issues. These concerns highlight the important role that the CWH and partner programs play in developing the knowledge for addressing emerging contaminants and in turn providing technical support to build that capacity for state and local health organizations.

2.3. Promoting private well testing

Engagement with private well owners around testing is the “foot in the door” as described by one participant; it is a first step and key to building a relationship. Outreach and education can be difficult but ultimately necessary for building trust within a community and to support effective well testing initiatives. Barriers to engagement discussed included the costs of testing and treatment, general mistrust of government, and perceptions about a water source, e.g., that well water is “natural” and therefore believed to be healthy. Similar issues were reported in a state-level survey. In Wisconsin, 82% of respondents had not tested their wells because the water did not have an unusual taste or appearance; this survey also found that 33% of families earning less than $20,000 per year had done testing compared to 71% of families with incomes over $75,000 (Knobeloch, 2011). There was an emphasis on the importance of making testing as simple as possible for the well owner, for example, by subsidizing costs or providing test kits and follow-up at community venues. A cautionary note was raised about simply providing test kits – such kits are best utilized within a program that supports the well owner in using the kit properly, interpreting the results, and providing follow-up or further assistance as needed.

Testing methodologies for many emerging contaminants have been developed (USGS, 2015b). However, it is unclear whether the nation's public health, agriculture or environmental laboratories have the capacity to implement emerging contaminant methodologies routinely. In a recent survey of these laboratories, 51% reported the quality of their instrumentation as only “fair” and about 30% lacked full capacity for environmental chemistry (Boulton et al., 2013). New testing technologies would also be welcome and may enhance the opportunities to engage and educate private well owners. Innovative technologies were discussed, such as sensors that can be placed in a well and retrieved later and sensors that automatically transmit data to a database.

2.4. Other data needs to characterize contamination in private wells

Managing private wells for public health protection requires data not just from well water sampling but also on well characteristics (type of well, depth of well, well integrity and maintenance) and the people using the wells (demographics, water uses, etc.). Continued efforts to increase the numbers and frequency of well testing are needed, but new data collection activities for wells and their users are also necessary.

Two strategies were discussed for developing a robust knowledge base on private wells: 1) promoting use of existing datasets; and 2) developing a data gathering template and data system that can be accessed throughout the country. One existing data resource highlighted at the workshop was developed under a collaboration between USGS and the New York State Department of Environmental Conservation. This dataset includes some well data (location, type, depth) and water analyses including physical properties, ions, nutrients, trace elements, dissolved gasses, volatile organics, pesticides, and radionuclides (USGS, 2014). Such databases and database systems can then facilitate the development of modeling efforts. Participants felt that modeling could become an important complement to more traditional means of testing in order to identify contaminants likely present in private wells. Two interrelated types of modeling efforts were discussed. Descriptive modeling efforts aim to increase understanding of geochemical as well as hydrogeological and land-use level factors that aid in prediction of private well contamination. By focusing on the important factors that drive different types of private well contamination from descriptive studies, there is a possibility of developing predictive models that will assist in identifying previously untested areas that may be vulnerable to certain types of contaminants. A review by Hrachowitz et al. (2013) may be a useful reference to inform a modeling strategy; the authors describe the 10-year effort to improve the science in support of modeling of surface water, outlining challenges, data needs and achievements.

2.5. Characterizing the population at risk, strengthening stewardship and outreach

A key theme of the workshop was the promotion of well stewardship which is closely tied to outreach and prevention. The aim of a

good outreach program is good stewardship, which encompasses (but may not be limited to) maintenance to prevent contamination and periodic water testing to detect contamination and prevent exposure. Workshop participants suggested the concept of "building an infrastructure for stewardship," referring to movement beyond solely the water infrastructure of pipes and pumps to development of information resources, collaborative relationships between water and health agencies, well testing laws and regulations, evaluation research, and community-level programs and outreach that will support private well owners in proper maintenance, testing, and remediation of their wells.

Discussion of outreach was linked to development of a better understanding of the people using private wells (demographic data needs) and their willingness to get their water tested and treated, if necessary (including motivations for and/or barriers to testing and treatment). These types of information will be essential to building a good outreach program that will support stewardship.

2.5.1. Population demographics

Designing effective outreach and communication involves developing an understanding of the target audience (Lang et al., 2001). Drawing on their collective experiences, participants noted that there are diverse populations relying upon private wells, representing the full spectrum of socioeconomic statuses and including all racial, ethnic and tribal groups. Despite this, needs remain with regard to demographic data to characterize populations using private well water. For example, questions about household water supplies were last asked in the 1990 Decennial Census (U.S. Census Bureau, 2011). More recently, household water supply questions were incorporated into the American Housing Survey, though this survey reports limited demographic data (U.S. Census Bureau, 2015). The lack of detailed demographic information for private well users creates a data gap that may impair planning and implementation of outreach programs.

Vanderslice (2011) reviewed the existing literature on drinking water infrastructure and environmental disparities. Of the few studies examining this issue, some identified specific populations where a substantial fraction lack piped water (e.g. Mexican-American communities along the US-Mexico border and American Indian and Alaska Natives); and others who were relying on contaminated groundwater (Hispanic residents of the Yakima Valley in Washington and migrant labor camp residents) (Vanderslice, 2011). Considering the issue of disparities, state agencies can potentially access disparities-targeted funding for water testing and treatment. While helpful in theory, this advice to utilize disparities-targeted funding is predicated on well user demographic data that at the present time are not widely available.

2.5.2. Motivations or barriers to testing and treatment

Workshop participants reported ambiguity with regards to how they should proceed following the acquisition of private well testing results. Information on what motivates a well owner to complete recommended treatment options and conversely, what barriers exist for those who do not pursue treatment will be very important to know to improve uptake and adoption of treatment. Participants reported that comprehensive information on the quality, effectiveness and longevity of different treatment options is also lacking.

2.5.3. Training and outreach resources

Other factors identified as important for delivering an effective outreach program included a trained, local workforce familiar with groundwater science. Public health officials at the workshop notes that training of environmental health workers and sanitarians is lacking in areas that are critical to good outreach, particularly knowledge of groundwater science and risk communication skills.

Several participants were engaged in private well outreach programs of varied design, leading to a discussion about the value of assembling a tool-kit of outreach approaches; and also, for research to identify the most successful outreach approaches. Many divisions of CDC have developed toolkits supporting outreach around various topics including water, such as issuance of drinking water advisories (CDC, 2013). Other examples of CDC toolkits include Social Media Tools, Guidelines and Best Practices (CDC, 2015b) and Capacity Building for Diabetes Outreach (National Diabetes Education Program, 2008). Other programs addressing environmental health issues may serve as models for private well outreach and treatment, such as existing programs for indoor radon detection and abatement.

Another theme related to outreach and stewardship was the potential for funding citizen science to address gaps in information gathering related to both private well vulnerability and testing. Citizen science refers to a range of activities that engage the public in scientific discovery such as collecting, analyzing or reporting data on real-world questions, often in collaboration with scientists (Cornell University, 2015; National Science Foundation, 2015). Given the limited regulatory standards for private well testing, the individual nature of well ownership, and the need for increased public awareness and engagement, citizen science could play an important role. Some states in the Mid-Atlantic region have voluntary "Master Well Owner" programs that could serve as a foundation for citizen science efforts (Penn State College of Agricultural Sciences, 2012; Virginia Master Well Owners Network, 2015).

2.6. Discussion summary

The various topics of the workshop discussion can be arrayed around the concept of "building an infrastructure for stewardship" to support well owners in maintaining their water supply. Well owner demographics and community-specific information will help sanitarians plan outreach programs. Outreach workers will need appropriate training to ensure confidence and impart the requisite knowledge necessary to engage well owners during program implementation. Data on wells and potential contaminants developed and organized within a context of the underlying science will be key information that an outreach worker will need to inform the well owner. Contaminant data and an understanding of the types of wells in an area will help an agency prepare the necessary testing capacity to meet community needs. Protecting the well and preventing exposure will depend on having an evidence base on effective treatments and preventive measures. A completed infrastructure for stewardship will link the well owner with knowledgeable agency personnel, information, and technical resources to foster appropriate well testing, maintenance, and treatment to ensure safe drinking water.

3. Recommendations

The workshop resulted in 16 recommendations that will facilitate private well protection efforts at CWH and across the spectrum of environment and health agencies concerned with groundwater and drinking water. The types of activities recommended to prevent potential health problems from contaminated private wells are rooted in the core functions of public health (Institute of Medicine, IOM, 1988). The core functions of public health (assessment, policy development and assurance) were developed by a committee of the Institute of Medicine to help galvanize and organize a fragmented public health community around a well-defined set of activities (IOM, 1988). Protecting private drinking water wells faces similar challenges of a fragmented regulatory system with multiple agencies concerned and active in the field. In presenting the workshop recommendations using the core functions as a structure, we hope to stimulate within the environmental health science and practice communities a coordinated effort on behalf of those reliant on private wells for drinking water.

Among the recommendations there was an emphasis on assessment activities to address data needs across all of the topics discussed. Recommendations related to policy development include investments in research and training efforts. Assurance activities recommended included evaluations of household water treatment systems and dissemination

of information. A number of "overarching" recommendations were made that will support program work across all assessment, policy development and assurance activities.

3.1. Key recommendations from the expert panel

3.1.1. Assessment: support water testing, health and outreach-related assessments

3.1.1.1. Methods. Development of innovative screening tests and methods for commercial laboratories as well as test kits for well owners should be encouraged, perhaps through a challenge program.

3.1.1.2. Information needs

- Identify and assess emerging contaminants and recurring chemical mixtures of interest
- Synthesize the state of knowledge regarding private well stewardship and maintenance practices that are best suited for addressing emerging contaminants
- Promote strategic use of existing data and develop and disseminate a standard database of private well and well user information
- Conduct studies to characterize health burden(s) from chemical exposures from consuming unregulated drinking water, and model related costs and benefits of investments in private well testing and treatment
- Develop descriptive and predictive approaches for modeling of contaminant intrusion and contamination processes and translate results for training, outreach, and prevention

3.1.1.3. Outreach

- Conduct research to better characterize users of unregulated water with regard to demographics, socioeconomics, knowledge, attitudes and practices
- Develop a needs assessment tool for outreach workers incorporating demographic and other factors to aid in the design of effective programs

3.1.2. Policy development: evaluate interventions and outreach strategies, develop trainings

- Implement effective outreach and intervention strategies to encourage well owner engagement and well stewardship
- Develop training materials that incorporate the complexities of private well and groundwater issues and support environmental health professionals in conducting outreach and health promotion intervention

3.1.3. Assurance: identify effective treatments, build outreach capacity, provide information

- Identify effective and practical household water treatment systems and make the information widely available
- Increase state and local capacity for private well programs, especially with regard to ongoing, longitudinal monitoring programs

3.1.4. Overarching: raise awareness and enhance engagement to protect private wells

- Develop and implement a national engagement strategy to raise awareness of private well issues among public health leaders
- Develop and maintain collaborations between CWH and US EPA, the Association of Public Health Laboratories, US FDA, USGS, Consumer Product Safety Commission, stakeholder groups and non-governmental organizations
- Bridge knowledge gaps between water scientists and environmental health professionals to build partnerships and foster evidence-based practice
- Address water-related health disparities

4. Discussion and conclusions

To inform the future work of CDC's Clean Water for Health program, we convened a diverse group of scientists and public health practitioners at a workshop to consider current and emerging concerns for drinking water sourced from private wells. The expert panel provided recommendations for CWH covering a wide-range of activities including specific data needs and research project ideas, and ways to enhance public health capacity.

Ensuring clean water for private well users is not solely the responsibility of any one agency or program. Workshop participants emphasized that collaboration among many actors is required to assess and respond to private well contamination issues. A number of the recommendations relate to developing and improving partnerships and collaborations among agencies as well as environmental health practitioners and scientists engaged in private well issues.

A number of limitations must be acknowledged. The workshop was focused on chemical contaminants to align it with the CWH program mission (NCEH, 2012); pathogenic microorganisms, which are not covered by the program mission, were not an area of focus. We note, however, that good stewardship and well maintenance can reduce and prevent both chemical and microbial contamination in many cases. Workshop resources were such that only a single in-person meeting was possible. Johns Hopkins investigators conducted outreach to agencies and public health stakeholder groups to enhance the reach of the project overall. Finally, the extent to which CWH can implement the workshop recommendations will depend on program resources.

The results of this workshop support improvements in the nation's drinking water infrastructure in important ways. First, enhancing the work of CWH on federally unregulated drinking water is a critical need. While EPA lists protecting America's waters as one of its current strategic priorities (USEPA, 2014), the drinking water aspects focus on public water supplies and not private wells. Second, the recommendations provided here include actions that go beyond those stated in the NCEH strategic plan (CDC, 2014) and, if implemented, will ensure progress towards the NCEH goal of safe drinking water for those reliant on private wells.

Acknowledgements

The authors thank the participants for offering their time and advice at the expert panel workshop. This work was supported by the Centers for Disease Control and Prevention contract number 200-2014-M-59797.

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