RESEARCH TRIANGLE
ENVIRONMENTAL HEALTH
COLLABORATIVE

2015 Environmental Health Summit
Safe Water From Every Tap

Representing Expert Discussions/Recommendations

Abstract

The Safe Water from Every Tap workshop organized by the Research Triangle Environmental Health Collaborative convened more than 100 participants from county health departments, state and federal governments, universities, industries, and non-profit organizations. The focus of this environmental health summit was to develop actionable strategies to assure safe drinking water for all North Carolina residents. Through this two-day workshop, participants determined that in order to improve drinking water quality for residents reliant on private wells and other sources not regulated under the Safe Drinking Water Act, efforts need to:

1 Characterize the population to identify barriers to water quality testing, and examine the feasibility and challenges associated with extending community water services,

2 Coordinate public and private water systems data to document water quality and determine data needs,

3 Update and expand private well regulations in North Carolina, and

4 Improve communication tools and resources through personal and web interfaces.

One immediate action recommended throughout the conference was the coordination of the GW-1 Well Construction Records, GW-30 Well Abandonment Records, the Private Drinking Water Well Sampling dataset, and county-level mapping of municipal water and sewer lines. Organization of these readily available datasets would provide new insights into private system water quality conditions and variability, spatial distribution of private systems, and feasibility of extending community water services. Based on this effort, resources can be developed tailored to the private system population that encourage behavioral changes through social marketing and online platforms. Improving and ensuring safe drinking water quality is essential to protecting public health for all North Carolina residents.

Introduction

Access to clean, safe drinking water is paramount to public health. In 1974, the U.S. Congress promulgated the Safe Drinking Water Act (SDWA), which authorized the U.S Environmental Protection Agency (USEPA) to establish and enforce the regulation of waterborne contaminants in municipal water systems.[1] Between 1976 and 2006, the U.S. Centers for Disease Control and Prevention (CDC) reported that the rate of annual waterborne disease outbreaks has declined in populations serviced by municipal water utilities.[2] Unfortunately, these public health advancements have not been observed in private wells and other sources not regulated under the Safe Drinking Water Act, as the rate of annual waterborne disease outbreaks in these systems has increased.[2] These systems, referred to as '*private water systems*', have fewer than 15 service connections and serve fewer than 25 individuals at least 60 days each year.[3,4] As system maintenance and water quality monitoring are solely the responsibility of homeowners, studies report that 20-58% of systems exceed at least one SDWA health-based standard.[5-8] With approximately 47.8 million residents (15% of the U.S. population) reliant on private systems, the lack of federal oversight of these systems is often considered a gap in the SDWA.

North Carolina has one of highest levels of reliance on private water systems in the United States (Figure 1) and has enacted private well regulations that outline construction standards and sampling requirements after completion of a new well.[9] Despite these efforts, water quality from private systems in North Carolina is still not to the level of protection offered by community water systems.[10,11] Therefore, to identify strategies to improve water quality for residents in North Carolina relying on private systems, the Research Triangle Environmental Health Collaborative convened a summit titled "Safe Water from Every Tap" on October 26-27, 2015. The Research Triangle Environmental Health Collaborative is a non-profit organization with a mission of enhancing global environmental health by promoting candid conversations about emerging environmental and health issues. This summit provided an opportunity to identify public health concerns related to consumption of water from private systems and to determine actionable objectives that could remediate and/or alleviate these problems. This paper serves to: (1) provide a review of water quality and health challenges associated with private water systems in the United States; (2) describe the summit approaches used to generate recommendations addressing water quality issues in North Carolina; (3) examine the cross-cutting water quality challenges identified by conference participants; and (4) report the specific recommendations developed by the conference work groups.

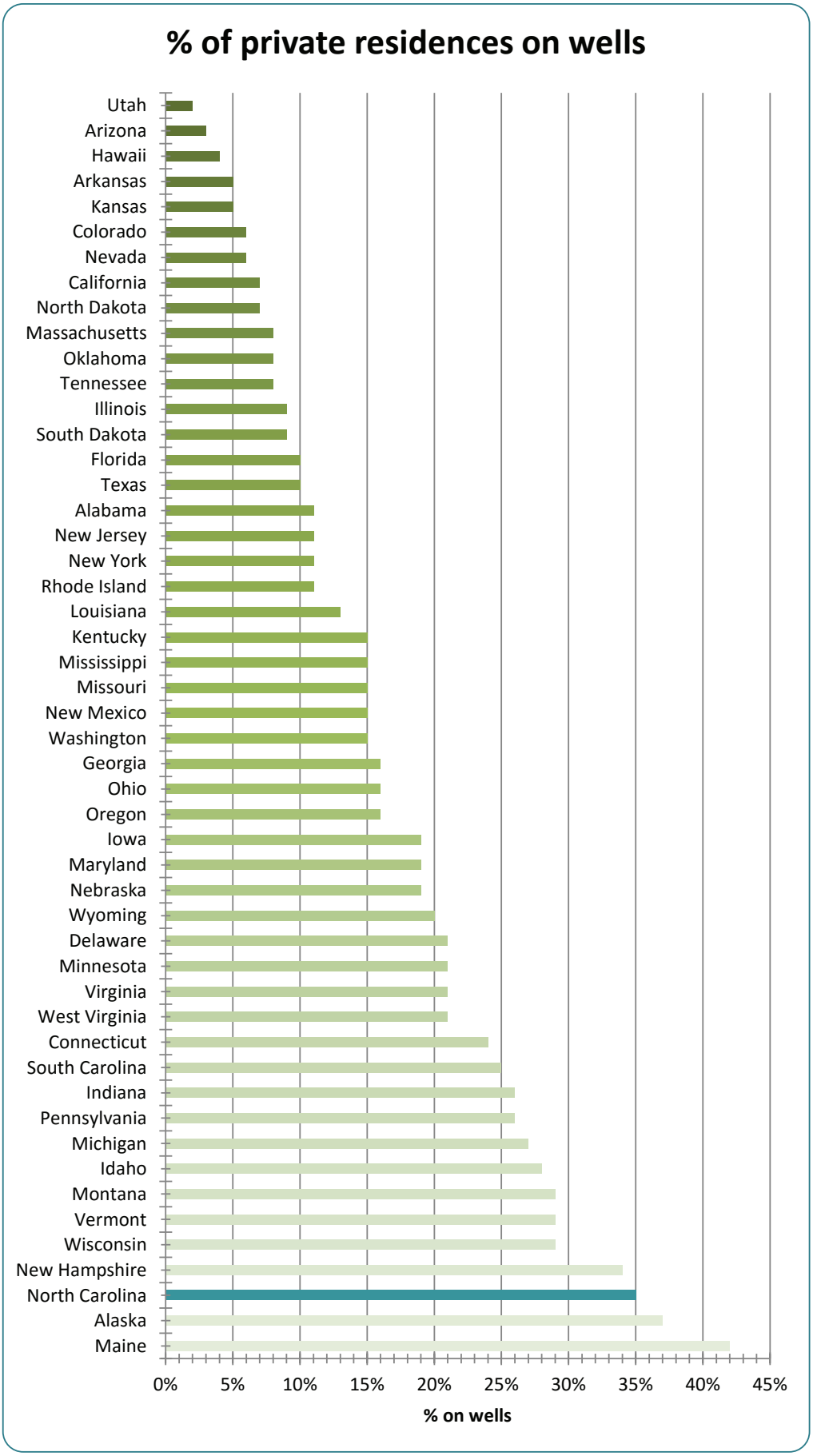

Figure 1. Percent of state population reliant on private water systems that are not regulated at the federal level[12]

National Overview Of Private Water Systems

Private water systems are constructed in areas where community water services are not available, which can be peri-urban neighborhoods bordering metropolitan areas but not within the bounds of community water services or remote rural regions miles from access to water service. Unfortunately, there is substantial uncertainty regarding the population reliant on private systems, and estimates differ based on year and reporting agency.[3,12-14] Although the number of households served by community water systems is known because residents receive water bills, the boundaries and extent of water services may not be readily accessible and/or available. Despite this lack of information, research characterizing water quality at local and state levels continues to highlight numerous water quality challenges for private systems users.

Water Quality in Private Systems

With the promulgation of the SDWA, Congress mandated a one-time national survey of rural water conditions, which was the first and only national assessment of private systems and water quality at the point-of-use.[15] Between 1978 and 1979, the USEPA surveyed 2,654 households connected to private wells, intermediate systems (2-14 service connections), and community water systems in 400 rural counties. Total coliform bacteria were the most prevalent contaminant as 42% of private wells and 78% private non-well systems (e.g., springs, cisterns) tested positive. Furthermore, the USEPA observed that bacterial contamination was associated with lower income and education households. Waterborne metals due to the corrosion of plumbing components were measured in 265 households and an estimated 9.2% of rural households exceeded the SDWA lead threshold at the time of 50 µg/L. Overall, the USEPA concluded that households connected to community water systems had better observed water quality compared to households reliant on private systems.

Recent evidence suggests that there has not been substantial improvement in private water quality in the last four decades. Recent state and national surveys report that 20-58% of private systems exceed at least one SDWA health-based standard.[5-8] Surveys report high prevalence of microbial contamination as 18-46% of systems tested positive for total coliform bacteria.[5-8] The occurrence of waterborne metals is of growing concern as state studies report that 12-19% of systems have lead concentrations above the SDWA lead action level of 15 µg/L, and 12% have copper concentrations above the copper action level of 1.3 mg/L.[5,8,16] In addition, studies highlight that private system users are at greater risk of waterborne lead exposure than residents connected to a municipal system.[11] Although the understanding of water quality disparities is still limited, higher rates of microbial contamination were observed in lower income households, which suggests that other disparities in water quality may exist.[17] However, this trend was not observed for waterborne lead concentrations, which could be attributed to the manufacturing processes of common plumbing components.[8] Recent research has revealed that racial disparities exist in access to municipal water service on the fringes of North Carolina cities and towns.[18,19] In fringes areas of Wake County, NC, the likelihood of being excluded from community water service increased as the proportion of African Americans living in a census block increased.[18]

Challenges for Improving Private Systems Water Quality

With up to 42% of residents in some states reliant on private water systems (Figure 1),[12] correcting water quality issues is imperative in protecting public health. The lack of progress since the 1970s may be attributed to the barriers in advocating and assisting these communities. Major barriers in improving private system water quality include: (1) insufficient characterization of the population reliant on private systems and associated water quality, (2) gaps in regulations at the local, state, and federal levels, (3) lack of financial and technical assistance for long-term operation and maintenance of private systems, and (4) low awareness and insufficient

understanding of the health consequences associated with consumption of contaminated private system water.

Data characterizing private system population and water quality

When reviewing private system studies, it is important to understand the scope of the survey and the population sampled. At land-grant colleges and universities, Cooperative Extension programs may provide low-cost drinking water quality testing to homeowners reliant on private water systems. These sampling campaigns collect thousands of samples, but participation in water quality testing is wholly voluntary. Sampling packages can range from $50 to $130,[20-22] which may hinder participation; studies have noted the sample populations are often highly skewed as participants are often affluent.[8] Several states mandate water testing with the completion of a new well and/or real estate transaction.[9,23] These efforts result in extensive databases, but samples are not randomly selected and may not represent the entire population reliant on these systems.

Private water quality can also vary greatly based on construction practices, local groundwater quality, and homeowner treatment practices. Although only 3% of private systems in Virginia had fluoride concentrations above 2 mg/L, this exceedance rate increased to 12% when focusing on wells in the Coastal Plain.[24] In North Carolina, 2.4% of private wells exceeded the SDWA health-based standard for arsenic (10 µg/L), but average arsenic concentration in some regions were as high as 20.1 µg/L, which was predominately in the central part of the state.[25] Spatial variations were observed when evaluating nitrate concentrations in private systems in the Midwest as well as variation by system type, with shallower systems having higher rates of contamination.[26] Therefore, in order to begin addressing water quality concerns, a better understanding of the population reliant on private systems and associated water quality is essential.

Private well regulations

Without oversight at the federal level, states are responsible for developing and enacting regulations that address private systems. All states except Alaska and Pennsylvania have enacted legislation to minimize anthropogenic contamination risk by requiring specific drilling practices such as hiring a licensed well driller, specifying construction methods that maintain well integrity, and outlining allowable locations for wells.[9,27-29] However, these state regulations do not require that private systems comply with the SDWA maximum contaminant levels that are mandatory in municipal water systems, nor do they require routine monitoring of systems. Evidence suggests that these regulations can decrease contamination risks; studies have attributed higher rates of bacterial contamination to the absence of construction techniques designed to minimize surface water contamination such as sanitary well caps and grouting.[5,30-34] However, construction practices cannot prevent the supply of contaminated groundwater.[35] Moreover, state and local well regulations generally apply only to new well installations or repairs to existing wells; wells constructed prior to enactment of these regulations are still in use throughout the country and may be constructed to much lower quality standards. Therefore, without regular monitoring and long-term maintenance, which is not required in state private well regulations, exposure to contaminated water is still very possible.

Long-term operations and maintenance

Private water quality is often neglected unless noticeable quality issues or illness arises. Not surprisingly, water quality testing rates among private system homeowners are low.[5,7,8] In New Hampshire, lack of participation in water testing was due to the following reasons: (1) knew to test but did not do so, (2) did not know how to participate, (3) were satisfied with the aesthetic characteristics of their water, (4) did not have health problems associated with their water, and (5) expense of testing.[36] Without participation in testing, it is not surprising that only half of private system homeowners surveyed had installed treatment devices.[5,8,37] These devices were most often water softeners and sediment filters, which correct aesthetic water quality

characteristics, but do not address health-based contaminants. A study in Arizona observed that the installation of household treatment devices in rural water systems was higher in more affluent and higher education households.[37] The authors also noted that household treatments resulted in both decreases and increases in waterborne contamination, which further stresses the importance of education and training in operation and maintenance for private system homeowners.

Health Implications of Private Water System Contamination

With elevated rates of waterborne contaminants observed in private systems, epidemiological studies have reported increased health risks for private system users.[2,38,39] The Wisconsin Department of Health investigated several cases of infant methemoglobinemia, which were attributed to the consumption of well water containing nitrate concentrations 2-3 times the maximum contaminant level of 10 µg/L.40 Naturally occurring arsenic has impacted numerous wells throughout the United States,[25, 36] and has resulted in adverse health outcomes such as lung cancer and high blood pressure.[41,42] Consumption of well water with E.coli contamination has been linked to cases of acute gastrointestinal illness (AGI).[43] Despite these studies, research examining the burden of disease attributable to drinking water from contaminated private systems in the United States has been minimal. DeFelice et al. (2016) observed that of the 7% of emergency department visits per year for AGI in North Carolina attributable to drinking water consumption, 99% were associated with microbial contamination in private well water.[10] Studies in Canada have also identified an increased risk of AGI associated with contaminated well water.[44-46] Uhlmann et al. (2009) observed that AGI rates were 5.2 times higher for individuals reliant on private wells compared to individuals connected to municipal systems.[45] Murphy et al. (2015) estimated that 103,230 cases of AGI per year may be attributed to the presence of pathogens in drinking water from private and small community water systems.[46]

Workshop Methods

In order to identify strategies for decreasing public health risks associated with private water system contamination, the Research Triangle Environmental Health Collaborative summit convened more than 100 leading experts representing rural residents, private well owners, environmental justice advocates, municipal officials, public health practitioners and local health departments, state and federal agency representatives, and water utilities (Figure 2). The agenda was developed by a planning committee around four interdisciplinary work group themes: (1) Community Education, (2) Good Governance and Policy, (3) Pollution Prevention, and (4) User-Friendly Technology. These topics were chosen through consensus of the planning committee following discussions of the nature of the private well user communities, a review of existing North Carolina programs and regulations for protection of private well users and groundwater quality, and challenges in reaching out to private well

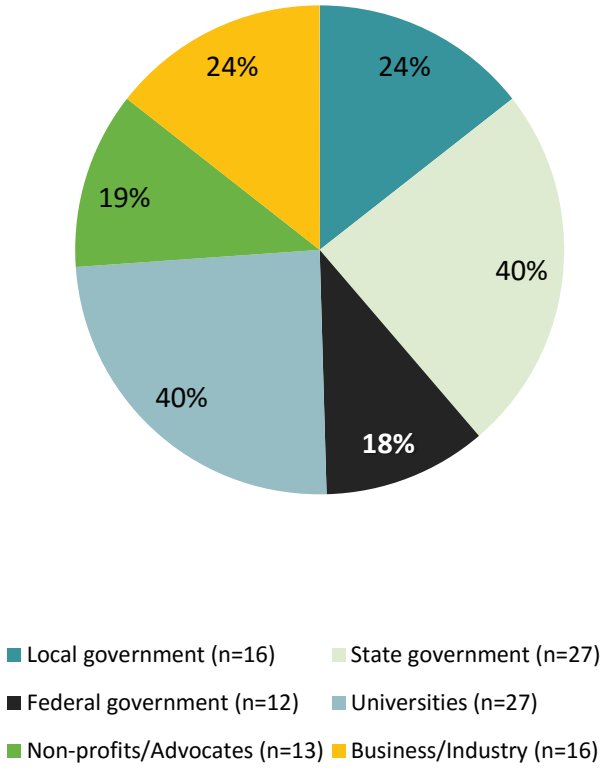

Figure 2. Percent of participants from each sector

users. To promote collaboration and discussion as well as focused group dialogue, participants registered for a work group and continued in the track throughout the summit.

The summit was structured in 3-4 hour increments of plenary and work group sessions (Figure 3). The Monday morning plenary session consisted of thought-provoking presentations and a panel discussion related to the summit theme of drinking water quality and pertinent regulations within the United States. During the afternoon work group session, participants organized into their appropriate work group to define the problem associated with their work group theme and identify challenges associated with correcting these problems. After this three-hour session, all participants reconvened to present their findings to the broader groups to solicit feedback and promote conference-wide group dialogue. Tuesday had a similar structure with a morning plenary session addressing paths to water innovation followed by two work group sessions to brainstorm solutions and prioritize actions. The brainstorming session was structured on developing ideas to solve the challenges identified on Monday while the group prioritized the solution developed in the brainstorming to provide final recommendations and actions.

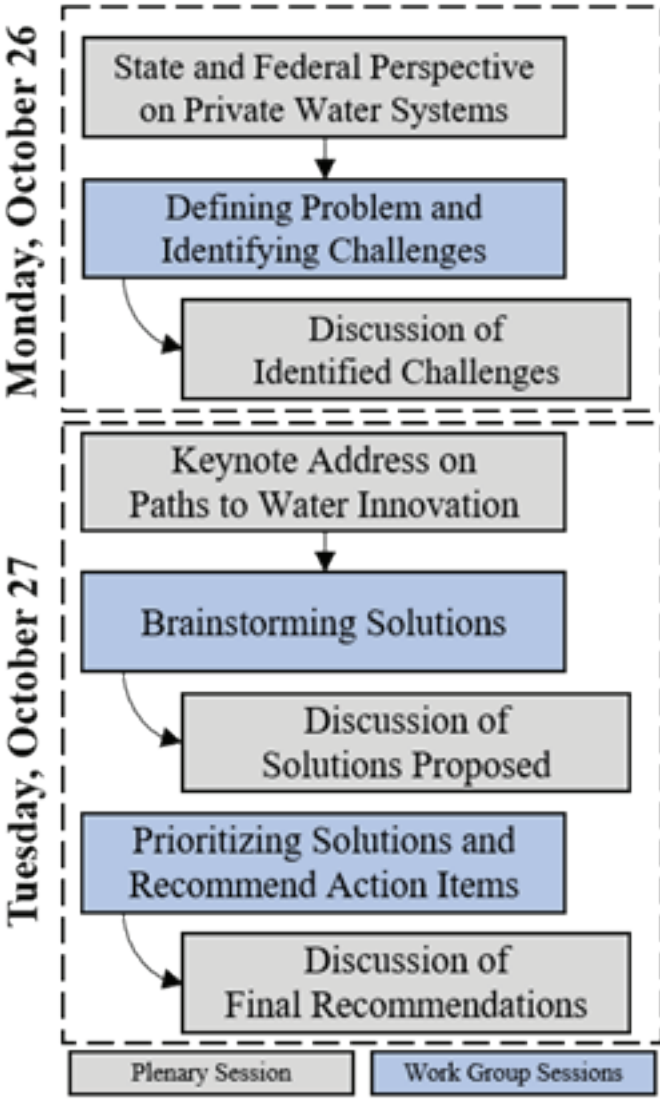

Figure 3. Schedule of conference sessions

Workshop Recommendations

At the end of the two-day summit, each work group developed a list of recommendations to address water quality challenges in North Carolina. Through the development of these actionable efforts, several cross-cutting themes emerged:

1 **Characterizing the private system population** to identify barriers to water quality testing, and examine feasibility and challenges associated with extending community water services

2 **Coordinating data about public and private water systems** to document water quality in private systems and identify data needs

3 **Updating and expanding private well regulations** in North Carolina

4 **Improving communication tools and resources** through personal and web interfaces

Characterize the private system population

In North Carolina, the U.S. Geological Survey estimated that 3.5 million residents are reliant on private systems with the highest concentrations of residents in the most densely populated counties (i.e., Forsyth, Guilford, Mecklenburg, and Wake).[47] Although 105,000-275,000 residents are using private systems in these counties, these residents only account of 30% of the counties' total population. Between 83-85% of residents are reliant on private systems in small counties such as Caswell and Ashe that have approximately 20,000 residents. While private systems are common in rural regions, these statistics highlight that private systems are present in more urban settings. Furthermore, there is also a unique subset of low-income and minority communities lacking community services even though they border or are surrounded by neighborhoods with full municipal services. In the southeastern United States, some of these communities are a legacy of the era of government-sanctioned racial segregation.[48] Evidence in North Carolina suggests that low-income and minority communities in these fringe areas are more likely to be denied access to municipal services.[18,19,49]

In order to begin addressing water quality issues, the work groups determined that there needs to be a better understanding of the population reliant on private systems. Readily available county and state-level data could aid in characterizing private water quality, developing resources about system maintenance and monitoring, educating the greater population, and examining the likelihood (e.g., financial, legal, logistical) of extending municipal services to private system residents. However, one of the main limiting factors has been and continues to be the minimal funding allocated to support research and community outreach.

Coordinate public and private water systems data

Studies characterizing private water systems in North Carolina document high rates of microbial and chemical contamination.[11,50,51] Between 2009 and 2013, 35.7% of newly constructed wells in North Carolina tested positive for total coliform bacteria, and 1.37% tested positive for E. coli.[10] In comparison, only 0.42% of community water systems in North Carolina tested positive for total coliform bacteria, and 0.01% tested positive for E. coli.[10] With higher rates of microbial contamination, it is not surprising that 7.3% of emergency room visits for acute gastrointestinal illness were attributed to consumption of microbial contaminated well water compared to 0.05% for municipal systems.[10] While these assessments and statistics are powerful and support the need for additional research, such data sources are not well coordinated and are not readily accessible for analysis.

The work groups discussed that existing

data sources have not been evaluated due to a shortage of personnel and funding. Information developed from these data could be instrumental in providing an initial understanding of the population reliant on private systems, and findings could inform state policies and provide justification for funding.

Update and expand private well regulations

To protect groundwater quality and the health of private homeowners, the North Carolina Department of Health and Human Services oversees private well regulations:[9] (1) NC Well Construction Standards (15A NCAC 2C .0100) establishes minimum well construction standards; (2) Rules for Permitting and Inspecting of Private Water Supply Wells (15A NCAC 2C .0300) requires permitting and inspection of private drinking water wells; and (3) Private Water Well Sampling (15A NCAC 18A .3800) mandates microbial and inorganic water quality testing be conducted within 30 days of a new well construction. As a result of these regulatory programs, wells are being properly grouted, sealed, and protected, and homeowners are more aware of water quality. However, there are no long-term requirements for routine maintenance and monitoring. Furthermore, it is the responsibility of the local health departments to implement and enforce state rules effectively, and stringency may vary due to resource challenges. Local health departments may also provide notice and information of known sources of contamination located within 1,000 feet of a proposed well to residents.[52] In addition, local health departments will educate residents about recommended optional and required water testing, the limitations of these testing efforts, and minimum drinking water standards recommended for private wells.

The work groups reviewed regulations in other states and discussed the possibility of incorporating the medical and real estate sectors into routine testing. The medical community could be engaged, and health-based concerns related to drinking water could be integrated into conversations with medical professionals. For example, doctors working with pregnant women could inquire about their drinking water source and recommend or prescribe water testing for private systems. However, it is important to consider the funding source for this testing (e.g., Medicaid, private insurance) and the likelihood these agencies would cover this cost. Another avenue to require private system testing could be before real estate transactions or leasing of property. This is currently a practice in New Jersey, where water quality testing is required and results must be disclosed. Test results are also reported to the state, which has resulted in the development of a statewide database and provided insight into private water quality.[23] These approaches could be incorporated in regulations in North Carolina and other states to increase awareness and water testing of private systems.

Improve communication and resources

Lack of accessible resources for homeowners was identified as a critical need. Although there are numerous outlets for accessing information, data sources are not always aimed at private system residents. Therefore, after characterizing the population, efforts could target community outreach. The working groups emphasized the need for technical assistance grants to support education of communities affected by environmental contamination. There are several states that have developed platforms to provide user-friendly information and resources such as New Hampshire's Be Well Informed and Pennsylvania's Drinking Water Interpretation Tool.

These tools aim to provide information and resources for interpreting water quality results. Users enter their measured water quality parameters and the site generates a unique interpretation. These websites state whether the parameters were above or below the Safe Drinking Water standards and provide links for more information. The New Hampshire tool also provides information about possible treatment options and discusses the adverse health effects of each parameter. These tools provide much needed assistance for homeowners attempting to understand their water quality results. These

efforts are essential for public health messaging but need to be written for the target audience. Roy et al. (2014) highlighted that consumer confidence reports (CCRs) distributed by municipal water systems are written at levels beyond the recommended 6th–7th grade level for public health communications, which limits the comprehension of public health material.[53]

Specific Work Group Recommendations

The identifed cross cutting themes were developed from the unique recommendations of each work group that specifically focused on their assigned themes. This section describes the recommendations developed.

COMMUNITY EDUCATION

The discussion of the community education group centered on water testing and considered hardships from the homeowner point of view. The group concluded that testing cannot be viewed as a final solution and that lack of knowledge and financial resources are barriers to testing for homeowners. To begin increasing community education through outreach, the group proposed the following three recommendations:

Develop a statewide working group to consolidate available data related to the quality of groundwater and private wells.

- All readily available data that is relevant to characterizing private systems should be collected and coordinated. These data sources may include: GW-1 Well Construction Record, GW-30 Well Abandonment Record, the Private Drinking Water Well Sampling dataset, and county-level mapping of municipal water and sewer lines. When there are gaps in the current data sources, such as data on wells constructed before 2008, door-to-door efforts in targeted communities may be necessary. In order to combine these data sources, collaboration between several agencies is necessary. These agencies should include, but not be limited to: Division of Public Health, Department of Environmental Quality, Center for Geographic Information and Analysis, Rural Center, universities, well owners, counties, and non-profits. This effort should also engage with various decision makers, including politicians, elected and appointed leaders, representatives from the medical community, and realtors. This effort should be coordinated with the efforts of local health departments, though it is important that the burden of this effort does not fall to county level officials because there is not sufficient manpower and funding.

Apply marketing techniques to encourage homeowners to maintain and routinely test their well water.

Social marketing is an approach that can be used to develop activities aimed at influencing behavior to encourage change that benefits individuals and communities. These techniques could be used to understand motivations and barriers that limit system operation and maintenance among private system residents.

Short-term recommendation:

- Target new parents and health care providers with the message of knowing the status of their well water, which may include water quality and treatment needs. Other communication channels that were discussed included: prenatal classes, Women, Infants, and Children (WIC) program, obstetrics and gynecology offices, and child care providers. In addition, universities and design firms could be consulted as resources.

Long-term recommendation:

- Identify other target audiences such as residents of older homes, grandparents, and Medicare recipients. Social marketing campaigns could be developed that communicate how to test and interpret water quality results, and how to access available community resources. This campaign could use local media outlets to inform the public and reach out to community support networks such as health care, faith-based, Cooperative Extension, Watershed Stewardship Network, and Master Well Owner Network.

Develop online resources to help homeowners obtain and understand information about potential water quality problems in their private systems.

- The NC Division of Public Health should develop a website at which private system residents can enter test results and learn about contamination and available remediation options. This resource should be accessible to the public and user friendly. Other states have similar products that can serve as models such as the Penn State Drinking Water Interpretation Tool or the New Hampshire Department of Environmental Services Be Well Informed Guide. Along with assisting residents, a parallel version could be developed specifically for health departments. This would promote peer-to-peer problem solving as neighboring counties often face similar challenges.
- North Carolina should create a network of professionals that provides information and training on private system issues. This group could host workshops and presentations on private system issues and encourage participation with continuing education credits. A webinar platform would facilitate communication among agencies and universities while minimizing travel and financial burdens. This network could be linked to the CDC's Private Well Community of Practice, which hosts bimonthly webinars highlighting cutting-edge research addressing water and health problems in private systems throughout the United States.

GOOD GOVERNANCE AND POLICY

The good governance and policy group explored the drivers and barriers to extending municipal services from a legal and financial approach and discussed regulations that could assist residents in regions where service extensions are not feasible. Major challenges to extending services include the limited understanding of the locations and demographics of population reliant on private systems. In addition, the group discussed potential mechanisms for assisting private system owners in areas where extending municipal water services is not possible. Therefore, to assess the feasibility of extending sewer and water lines to peri-urban communities and to improve options and support available to private system users in rural and peri-urban areas, the group proposed the following five recommendations:

Characterize areas underserved by community water and sewer service, and determine the legal and financial barriers of extending services.

- Authorize and fund a study to identify areas underserved by community water and sewer service. This effort would define the population that needs to be served and where line extension is not a practical solution. Furthermore, the effort would consider the pros (e.g., access to safe water, improved health) and cons (e.g., financial costs, stormwater impacts) of extending community water services or other means (e.g., responsible management entity) to assist underbounded residents and businesses.
- A preliminary state-wide cost analysis of the capital costs of service extensions should be completed, and areas in need of service extension should be prioritized. Existing and potential innovative options for financing capital costs of service extensions should be identified as there may be a state-wide need for supporting water and sewer bills in low-income communities. This analysis should also examine the feasibility of

establishing third party options to administer the funds and mechanisms to help low-income communities afford monthly water and sewer bills. In addition, this effort should evaluate the legislative changes to annexation necessary for municipalities to extend services and assess secondary impacts of infrastructure extension (e.g., changes in impervious surfaces, economic development, public health).

Characterize groundwater and private well water quality across the state

- Additional support and resources should be allocated to the Department of Environmental Quality in order to compile the readily available data for public use and to enable viewing on a public mapping viewer of contaminated site locations. With this updated assessment of data available, data gaps necessary to determine high-risk areas and contamination should be identified and steps taken to fill those gaps through monitoring, modeling, and other practices.
- Based on the data collected, effective fact sheets and training materials on naturally occurring versus anthropogenic sources of contamination should be developed and distributed to target, vulnerable populations.
- The 74% of the state population that is connected to municipal water service should be educated about private water systems and the importance of protecting water quality. This effort will help advocate the need for ongoing support for private water quality testing and resources.[54]

Update and expand private well standards in North Carolina.

- Conduct a legislative study of issues related to existing standards for private wells and assess the adequacy of staffing resources to track issues and provide technical assistance for local health departments in addressing private well issues. Ensure sufficient staff in DHHS and DEQ to develop regulatory solutions to problems of private water quality and to respond to the to develop regulatory solutions to problems of private water quality and to respond to the rule review requirements of House Bill 74.
- The existing standards for construction materials required should be reevaluated to ensure that well components do not introduce additional contaminants and products selected are suitable.
- Furthermore, additional regulations could pertain to the establishment of operating permits for private wells on rental properties and follow-up private well monitoring requirements such as requiring monitoring at the time of sale.
- Additional consideration should be given to create safe-harbor regulations for low-income homeowners so they are not at risk of property condemnation if well contamination/septic tank contamination is discovered. The state should fund sufficient government staffing to implement legislation and assure compliance for well and groundwater programs.

Develop programs to support private system owners in routinely testing and maintaining their wells.

- Conduct a study of options for promoting the development of affordable private well contract maintenance services, in which private system users pay subscription fees for routine maintenance and testing of their well water and for assistance in installing and maintaining remediation systems where contamination is identified. The study should include an analysis of options for providing financial assistance to low-income private system users, in order to afford the costs of such services.

Implement environmentally sustainable technologies in livestock production farms.

- Identify multiple benefits (e.g., economic, job creation, industry expansion, and greenhouse gas emissions reductions) of waste-reduction technologies in livestock farms, updating the benefits assessment from 2003.[55]
- Identify incentives, such as cost sharing, to implement environmentally sustainable technologies in livestock farms.

POLLUTION PREVENTION

The pollution prevention group reviewed the current state of contamination in private systems and well regulations with a focus on how to prioritize efforts to decrease contamination risks. The participants emphasized the need to empower homeowners to identify potential sources of contamination of their water. The group developed three recommendations:

Prevent future contamination of new drinking wells.

- Create an interactive mapping system showing current sites of contamination. This site could be modeled after DEQ's Source Water Assessment Program (SWAPInfo 2.0), which provides proximity of known potential contaminant sources to public drinking water. This site could distinguish between surface water sites and groundwater sites and list potential contaminant sites (e.g., agricultural operations, pollution incidents, landfills).
- Support and encourage different agencies to create their own differentially corrected GIS layer for potential contamination sources and store the layers at a clearing house location where the public can access the layers.
- Enforce monitoring and permitting on all well construction, including irrigation wells. These data could be developed into a database documenting water quality and systems characteristics for newly constructed and existing wells. This dataset could also be incorporated into the interactive mapping system to provide additional information about potential contaminant sites.

Develop private drinking water online resources for consumers.

- Create interactive software to assist homeowners in interpreting their drinking water results. Through this proposed website, users would be able to enter their water quality parameters, and an interpretation of water quality would be generated. This site could assist users in selecting appropriate treatment units and provide a spatial distribution of contaminants. In addition, the site could include a list of state accredited water testing labs and prices for each lab to provide multiple avenues for water quality testing. This platform could be modeled after the previously discussed New Hampshire Be Well Informed site and Pennsylvania Drinking Water Interpretation Tool.
- Incorporate source water assessment reports for public water systems, especially smaller utilities, in outreach efforts and newly developed software that are targeting educating private well users. These reports delineate catchment area, identify potential sources of contamination, and determine susceptibility for contamination. The NC Drinking Water Watch Program could be used as a template.

Integrate pollution and exposure prevention in future research efforts.

- Encourage agencies and collaborate with industries to fund special programs focused specifically on harmonizating and combining state and county level data and GIS analyses to understand contaminant trends and correlations. This would require creating a consistent method of collecting and analyzing data
- Incorporate drinking water test kits into K-12 education programs and combine data into one state-wide interactive dataset.

USER FRIENDLY TECHNOLOGY

The User Friendly Technology work group began its efforts by reviewing data availability and identifying current challenges related to the installation of treatment in private systems. This effort transitioned into a discussion of monitoring as a means to identify risk of contamination and prioritization of technologies that are most effective in removing contaminants and easiest to implement. To identify technologies that would remediate water quality challenges in private systems, the group proposed the following three recommendations:

Promote the development and use of appropriate low-cost point-of-use water treatment technologies.

- Leverage industry and government to promote the development of lower-cost point-of-use treatment methods effective in removing the most commonly encountered contaminants in private water systems. Federal and state agencies should consider establishing grant programs to support the development of low-cost, consumer-focused remediation tools.
- Develop a comprehensive catalog of currently available, easily used point-of-use treatment technology. Consideration should be given to products currently on the market as well as products developed at academic institutions. The NSF International Standard 61 criteria could continue to be used for product evaluation. In addition, a publicly accessible decision tool to help homeowners select treatment options should be developed and made readily available, perhaps on the web site of the NC Division of Public Health.

Promote the development and use of low-cost, user-friendly tools for monitoring private system water quality.

- Programs should prioritize investments to support the development of on-line continuous monitoring methods. These devices could be mounted on well head or connected at the pressure tank. Data collection could aid in improving operation and maintenance. In addition, remote monitoring could support the development of improved low-cost contract well testing and maintenance programs.
- Develop a user-friendly decision tool to help private system owners select appropriate monitoring tools.
- Leverage mobile health clinics or other outreach services to collect and analyze samples. This effort could be coupled with resources and information about interpreting results and developing actionable strategies to correct water quality.

Improve access to data on private system water quality.

- Leverage existing agencies such as US EPA's Drinking Water Mapping Application for Protecting Source Waters (DWMAPS) for information about public information on nearby small systems. This information could be integrated into publicly available open source mapping tools and frameworks, which was suggested in the Pollution Prevention group discussion.
- Increase awareness of private systems during real estate transactions by requiring private well testing before a real estate transaction, which is not currently required in North Carolina. However, states such as New Jersey could serve as a model to develop legislation.[23]

References

1. *Understanding the Safe Drinking Water Act*; EPA 816-F-04-030; U.S. Environmental Protection Agency: Washington, D.C., 2004; http://www.epa.gov/ogwdw/sdwa/pdfs/fs_30ann_sdwa_web.pdf.

2. Craun, G. F.; Brunkard, J. M.; Yoder, J. S.; Roberts, V. A.; Carpenter, J.; Wade, T.; Calderon, R. L.; Roberts, J. M.; Beach, M. J.; Roy, S. L. Causes of outbreaks associated with drinking water in the United States from 1971 to 2006. *Clin. Microbiol. Rev.* **2010**, *23*, (3), 507–528.

3. U.S. Environmental Protection Agency Public drinking water systems programs. http://www.epa.gov/dwreginfo/information-about-public-water-systems (accessed January 2, 2016).

4. Center for Disease Control and Prevention Private Water Systems. http://www.cdc.gov/healthywater/drinking/private/ (accessed January 20, 2016).

5. Swistock, B. R.; Clemens, S.; Sharpe, W. E.; Rummel, S. Water quality and management of private drinking water wells in Pennsylvania. *J. Environ. Health* **2013**, 75, (6), 60-66.

6. DeSimone, L. A., *Quality of water from domestic wells in principal aquifers of the United States, 1991–2004;* U.S. Geological Survey: Reston, VA, 2009; http://pubs.usgs.gov/sir/2008/5227/.

7. Knobeloch, L.; Gorski, P.; Christenson, M.; Anderson, H. Private drinking water quality in rural Wisconsin. *J. Environ. Health* **2013**, 75, (7), 16-20.

8. Pieper, K. J.; Krometis, L.-A. H.; Gallagher, D. L.; Benham, B. L.; Edwards, M. Incidence of waterborne lead in private drinking water systems in Virginia. *J. Water Health* **2015**, 13, (3), 897-908.

9. *North Carolina Administrative Code Title 15A: Well Construction Standards*; North Carolina Department of Environment and Natural Resources: Raleigh, NC, 2009.

10. DeFelice, N. B.; Johnston, J. E.; MacDonald Gibson, J. Reducing Emergency Department Visits for Acute Gastrointestinal Illnesses in North Carolina (USA) by Extending Community Water Service. *Environ. Health Persp.* (In-press).

11. Maas, R. P.; Patch, S. C. *Lead contamination of North Carolina domestic tapwater: prevalence, risk factors, and control measures*; Technical Report #90-003; UNC-Asheville Environmental Quality Institute: Asheville, N.C., 1990.

12. Maupin, M. A.; Kenny, J. F.; Hutson, S. S.; Lovelace, J. K.; Barber, N. L.; Linsey, K. S. *Estimated use of water use in the United States in 2010*; Circular 1405; U.S. Geological Survey: Reston, VA, 2014.

13. U.S. Environmental Protection Agency Private drinking water wells. http://www.epa.gov/privatewells/about-private-water-wells (accessed January 2, 2016).

14. Kenny, J. F.; Barber, N. L.; Hutson, S. S.; Linsey, K. S.; Lovelace, J. K.; Maupin, M. A. *Estimated use of water use in the United States in 2005*; Circular 1344; U.S. Geological Survey: Reston, VA, 2009.

15. Francis, J. D.; Brewer, B. L.; Graham, W. F.; Larson, O. W.; McCaull, J. L.; Vigorita, H. M. *National statistical assessment of rural water conditions*; U. S. Environmental Protection Agency: Washington, D.C., 1982.

16. Swistock, B. R.; Sharpe, W. E.; Robillard, P. D. A survey of lead, nitrate and radon contamination of private individual water systems in Pennsylvania. *J. Environ. Health* **1993**, 55, (5), 6-12.

17. Smith, T.; Krometis, L. H.; Hagedorn, C.; Benham, B.; Lawrence, A. H.; Ling, E.; Ziegler, P.; Marmagas, S. W. Associations between fecal indicator bacteria prevalence and demographic data in private water supplies in Virginia. *J. Water Health* **2014**, 12, (4), 824-834.

18. MacDonald Gibson, J.; DeFelice, N.; Sebastian, D.; Leker, H. Racial disparities in access to community water supply service in Wake County, North Carolina. *Front. Public Heal. Serv. Syst. Res.* **2014**, 3 (3), Article 6.

19. Naman, J. M.; MacDonald Gibson, J. Disparities in Water and Sewer Services in North Carolina: An Analysis of the Decision-Making Process. *Am. J. Public Health* **2015**, 105(10), 1–7.

20. Virginia Household Water Quality Program Well Water Testing: Drinking Water Clinics. http://www.wellwater.bse.vt.edu/clinics.php (accessed Feb 3, 2016).

21. Penn State College of Agricultural Sciences Agricultural Analytical Services Lab. http://agsci.psu.edu/aasl/water-testing/drinking-water-testing (accessed Feb 2, 2016).

22. Colorado State University Soil, Water and Plant Testing Laboratory. http://www.soiltestinglab.colostate.edu/documents/water_pricelist.pdf (accessed Feb 2, 2016).

23. New Jersey Department of Environmental Protection *Private Well Testing Act Program: well test results for September 2002–April 2007*; Department of Environmental Protection: Trenton, NJ, 2008; http://www.state.nj.us/dep/pwta/pwta_report_final.pdf.

24. Pieper, K. J.; Krometis, L. H.; Benham, B. L.; Gallagher, D. L. Simultaneous influence of geology and system design on drinking water quality in private systems. *J. Environ. Health* **2016**, *In-press*.

25. Sanders, A. P.; Desrosiers, T. A.; Warren, J. L.; Herring, A. H.; Enright, D.; Olshan, A. F.; Meyer, R. E.; Fry, R. C. Association between arsenic, cadmium, manganese, and lead levels in private wells and birth defects prevalence in North Carolina: a semi-ecologic study. *BMC Public Health* **2014**, *14*, (1), 955.

26. Richards, R. P.; Baker, D. B.; Creamer, N. L.; Kramer, J. W.; Ewing, D. E.; Merryfield, B. J.; Wallrabenstein, L. K. Well water quality, well vulnerability, and agricultural contamination in the midwestern United States. *J. Environ. Qual.* **1996**, 25, (3), 389-402.

27. *Bedrock (Artesian, Drilled) Well Design*; WDDWGB12; New Hampshire Department of Environmental Services: Environmental Fact Sheet, 2010; http://des.nh.gov/organization/commissioner/pip/factsheets/dwgb/documents/dwgb-1-2.pdf.

28. Virginia Department of Health *Private Well Regulations*; Richmond, VA, 1992.

29. Tomlinson, C. *Private well guidelines*; Department of Environmental Protection, Bureau of Resource Protection: Commonwealth of Massachusetts, 1989.

30. Bickford, T. M.; Lindsey, B. D.; Beaver, M. R. *Bacteriological quality of ground water used for households supply, Lower Susquehanna River Basin, Pennsylvania and Maryland*; Water Resources Investigation Report 96-4212; U.S. Geological Survey: Lemoyne, PA, 1996.

31. Zimmerman, T. M.; Zimmerman, M. L.; Lindsey, B. D. *Relation between selected well-construction characteristics and occurrence of bacteria in private household-supply wells, south-central and southeastern Pennsylvania*; Water Resources Investigations Report 01-4206; U.S. Geological Survey: New Cumberland, PA, 2001.

32. Gonzales, T. R. The effects that well depth and wellhead protection have on bacterial contamination of private water wells in the Estes Park Valley, Colorado. *J. Environ. Health* **2008**, 71, (5), 17-23.

33. Exner, M. E.; Spalding, R. F. Ground-water contamination and well construction in southest Nebraska. *Groundwater* **1985**, 23, (1).

34. Wojcik, D.; Weiss, D. Cooperative water quality testing and vulnerability factors for private rural wells in central. J. Environ. Health 1996, 58, (8), 16.

35. Swistock, B. R.; Sharpe, W. E. The influence of well construction on bacterial contamination of private water wells in Pennsylvania. *J. Environ. Health* **2005**, 68, (2), 17-22.

36. Borsuk, M.; Rardin, L.; Paul, M.; Hampton, T. *Arsenic in Private Wells in NH: Year 1 Final Report*; CDC Grant #1U53/EH001110-01; Dartmouth College: Hanover, NH, 2014.

37. Lothrop, N.; Wilkinson, S.; Verhougstraete, M.; Sugeng, A.; Loh, M. M.; Klimecki, W.; Beamer, P. I. Home Water Treatment Habits and Effectiveness in a Rural Arizona Community. *Water* **2015**, 7, 1217-1231.

38. Wallender, E. K.; Ailes, E. C.; Yoder, J. S.; Roberts, V. A.; Brunkard, J. M. Contributing factors to disease outbreaks associated with untreated groundwater. *Groundwater* **2014**, 52, (6), 886–897.

39. Lee, S. H.; Levy, D. A.; Craun, G. F.; Beach, M. J.; Calderon, R. L. Surveillance for waterborne-disease outbreaks--United States, 1999-2000. *MMWR* **2002**, 51, (8), 1-47.

40. Knobeloch, L.; Salna, B.; Hogan, A.' Postle, J.; Anderson, H. Blue babies and nitrate-contaminated well water. *Environ Health Perspect* **2000**, 108(7), 675-678.

41. Zierold, K. M.; Knobeloch, L.; Anderson, H. Prevalence of Chronic Diseases in Adults Exposed to Arsenic-Contaminated Drinking Water. *Am. J. Public Health* **2004**, 94(11), 1936-1937.

42. Wen Liu-Mares, W.; MacKinnon, J. A.; Sherman, R.; Fleming, L. E.; Rocha-Lima, C.; Hu, J. J.; Lee, D. J. Pancreatic cancer clusters and arsenic-contaminated drinking water wells in Florida. *BMC Cancer* **2013**, 13(11).

43. Raina, P. S.; Pollari, F. L.; Teare, G. F.; Goss, M. J.; Barry, D. A. J.; Wilson, J. B. The relationship between E. coli indicator bacteria in well-water and gastrointestinal illness in rural families. *Can J Public Health*, **1999**, *90*(3), 172-175.

44. Raina, P. S.; Pollari, F. L.; Teare, G. F.; Goss, M. J.; Barry, D. A.; Wilson, J. B. The relationship between E. coli indicator bacteria in well-water and gastrointestinal illnesses in rural families. *Can. J. Public Health* **1999**, 90, (3), 172-175.

45. Uhlmann, S.; Galanis, E.; Takaro, T.; Mak, S.; Gustafson, L.; Embree, G.; Bellack, N.; Corbett, K.; Isaac-Renton, J. Where's the pump? Associating sporadic enteric disease with drinking water using a geographic information system, in British Columbia, Canada, 1996-2005. *J. Water Health* **2009**, *7*, (4), 692-698.

46. Murphy, H. M.; Thomas, M. K.; Schmidt, P. J.; Medeiros, D. T.; McFadyen, S.; Pintar, K. D. Estimating the burden of acute gastrointestinal illness due to Giardia, Cryptosporidium, Campylobacter, E. coli O157 and norovirus associated with private wells and small water systems in Canada. *Epidemiol Infect.* **2015**, 13, 1-15.

47. U.S. Geological Survey, Estimated Use of Water in the United States County-Level Data for 2010. In 2014.

48. Aiken, C. S. Race as a Factor in Municipal Underbounding. *Ann. Assoc. Am. Geogr.* **1987**, 77, (4), 564-579.

49. MacDonald Gibson, J.; DeFelice, N.; Sebastian, D.; Leker, H. Racial disparities in access to community water supply service in Wake County, North Carolina. *Frontiers in Public Health Services and Systems Research* **2014**, *3*, (3).

50. Barros, N. *Elevated lead levels in private wells, western NC, 2013*; The EpiNotes Newsletter; North Carolina Department of Health and Human Services: Raleigh, NC, 2014.

51. Heaney, C.; Wing, S.; Wilson, S. M.; Campbell, R. L.; Campbell, D.; Hopkins, B.; O'Shea, S.; Yeatts, K. Public infrastructure disparities and the microbiological and chemical safety of drinking and surface water supplies in a community bordering a landfill. *J Environ Health* **2013**, *75*, (10), 24–36.

52. General Assembly of North Carolina. *Provisions of the Law Related to Local Government*; Session Law 2015-246 House Bill 44; Raleigh, NC, 2015. http://www.ncleg.net/EnactedLegislation/SessionLaws/PDF/2015-2016/SL2015-246.pdf.

53. Roy, S.; Phetxumphou, K.; Dietrich, A. M.; Estabrooks, P. A.; You, W.; Davy, B. M. An evaluation of the readability of drinking water quality reports: a national assessment. *J Water Health* **2015**, 13, (3), 645-653.

54. Sanders, A. P.; Messier, K. P; Shehee, M.; Rudo, K.; Serre M. L.; Fry R. C.; Arsenic in North Carolina: public health implications. *Environ. Int.* **2012**, 38(1), 10-16.

55. Murray, B. C.; Van Houtven, G. L.; Deerhake, M. E.; Dodd, R. C.; Lowry, M. I.; Yao, C.; Miles, A. M.; Bowman, E. J.; Bruhn, M. C.; Game, J. L.; Phaneuf, D.; Sommer, A.; Yang, J.-C.; Patil, S.; Guthrie, S. A.; Cajka, J. C.; Coburn, J. B. *Benefits of adopting environmentally superior swine waste management technologies in North Carolina: an environmental and economic assessment*; 08252.000 RTI International Research Triangle Park, NC, 2003.

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