Communication

A Call to Broaden Investment in Drinking Water Testing and Community Outreach Programs

Jason A. Hubbart [1,2,3,*] and **Kaylyn S. Gootman** [1]

1   Institute of Water Security and Science, West Virginia University, Agricultural Sciences Building, Morgantown, WV 26506, USA; kaylyn.gootman@mail.wvu.edu
2   Division of Plant and Soil Sciences, Davis College of Agriculture, Natural Resources and Design, West Virginia University, Agricultural Sciences Building, Morgantown, WV 26506, USA
3   Division of Forestry and Natural Resources, Davis College of Agriculture, Natural Resources and Design, West Virginia University, Agricultural Sciences Building, Morgantown, WV 26506, USA
*   Correspondence: jason.hubbart@mail.wvu.edu; Tel.: +1-304-293-2472

Abstract: Ensuring access to safe drinking water is a challenge in many parts of the world for reasons including, but not limited to, infrastructure age, source water impairment, limited community finances and limitations in Federal water protections. Water quality crises and the prevalence of impaired waters globally highlight the need for investment in the expansion of drinking water testing that includes public and private water systems, as well as community outreach. We provide justification including a case example to argue the merits of developing drinking water testing and community outreach programs that include drinking water testing and non-formal education (i.e., public outreach) regarding the importance of drinking water quality testing for human well-being and security. Organizers of drinking water testing programs should: (1) test drinking water quality; (2) develop drinking water quality databases; (3) increase public awareness of drinking water issues; (4) build platforms for improved community outreach; and (5) publish program results that illustrate successful program models that are spatially and temporally transferrable. We anticipate that short-term and intermediate outcomes of this strategy would improve access to drinking water testing, facilitate greater understanding of water quality and increase security through inclusive and equitable water quality testing and outreach programs.

Keywords: water quality; drinking water; community outreach; urban communities; metropolitan communities; rural communities; public water systems; private water systems; public health; water security

1. Introduction

Access to safe drinking water is essential to human health, a basic human right and a critical component of effective public health policy [1]. The United States has a long history of ensuring access to safe drinking water starting with the passage of the Safe Drinking Water Act (SDWA) in 1974 [2], which authorizes the use of national drinking water standards to protect against health effects from naturally occurring and anthropogenic contaminants [3]. In other countries, there are also many complex issues related to access to safe drinking water. These challenges are often exacerbated by reduced public confidence in safe natural sources of drinking water as well as increasing costs of processed (e.g., bottled) water [4–6]. Many countries are enacting policies that improve conditions. For example, in the European Union countries, Directive 2020/2184, pertaining to the quality of water used for human consumption, was ratified in 2020 [7]. This set of progressive policies is greatly advancing how drinking water is controlled and maintained. Similarly, globally, increasing household connections to water supplies and greater community participation in sanitation interventions appear impactful towards reaching the 2015 Sustainable Development Goals [8,9]. An example of this is the efforts to improve water

service delivery in northern Ghana with stakeholder engagement and the application of continuous quality improvement methods, including safe water storage, improved the microbial quality of consumed household water [10]. Despite progress, ensuring safe drinking water access and availability has become increasingly challenging for municipal and private water systems in the United States and elsewhere, given the increasing and competing demands of contemporary society and the prevalence of poor water, sanitation and hygiene globally [11,12].

Stressors to municipal water systems include, but are not limited to, aging infrastructure, impaired source waters and strained community finances [13,14]. In the United States alone, communities have been impacted by recent cases of impaired municipal drinking water quality. For example, the 2014 crisis in Flint, Michigan, exposed up to 98,000 residents to elevated lead levels, disinfection by-products and *Escherichia coli* (*E. coli*) bacteria [15–17]. Additionally, interruptions to potable water supplies have negatively impacted large communities by limiting their access to safe drinking water. Other examples include the 2014 Elk River chemical spill in West Virginia, USA [18]; the harmful algal blooms on Lake Erie, USA, that contaminated drinking water supplies from Ohio, USA, to Ontario, Canada [19]; widespread water supply disruptions throughout Texas, USA, in the aftermath of Winter Storm Uri in 2021 [20], or Hurricane Irma in 2017 that decimated many Caribbean island water resources [4].

In the United States, approximately 13% of households rely on private water systems for their drinking water [21]. These water systems are very often not regulated (or audited) [3,22]. This is important because various microbial pathogens and chemical contaminants, including (but not limited to) naturally occurring arsenic, may be found in higher concentrations in domestic wells [23–25]. Although many private wells supply high quality drinking water [26], the number of contaminated wells in the United States is rising [27]. Additionally, many well owners do not perform or pay for recommended drinking water quality testing due to limited knowledge about drinking water testing and high testing costs [27,28]. Moreover, detailed information on private well water contaminants and safety across the United States is not readily available [3,21]. Consequently, not only is information unavailable to best support individual stakeholders, but insufficient well water data exist to enable the assessment of where private water supply infrastructure improvements are needed most.

While regulatory mechanisms, including water quality testing, are often in place to ensure safe drinking water to homes and workplaces that are connected to municipal systems, limited domestic well water quality data and the growing risk of municipal water contamination necessitate expanded drinking water testing, regardless of the water source [3,6,14,29]. Drinking water testing can serve as an effective management strategy to ensure access to safe, high quality drinking water from municipal and private systems, thereby providing a mechanism to improve public health while also providing direction, by means of stakeholder feedback, for where water infrastructure may be most greatly needed [22,30]. For example, Swistock et al. [31] conducted a study in 2007 to sample drinking water from privately owned wells in Pennsylvania, USA. Over 40% of the sampled wells failed at least one health-based drinking water standard and 76% of those well owners took at least one action to correct or manage the problem. It follows that, if routine water testing at the point of consumption became more common throughout the United States and elsewhere globally, including developed and developing countries, consumers would be able to make more informed drinking water-related decisions, which would result in increased localized problem mitigation strategies and solutions.

Drinking water quality (and therefore security) in agricultural lands may be at as great, or greater risk than drinking water sources from other land-use practices. There is a great need for development of a culture for drinking water testing in these locations. This is important given that agricultural practices that often include land clearing (e.g., removal of forests) and fertilizer application are common sources of nutrient and sediment pollution [32,33]. For example, excess nutrients, such as nitrogen and phosphorus, are

linked to eutrophication, which, in turn, can result in lower water dissolved oxygen, thereby worsening overall water quality through a variety of means [34,35]. Sediments are known to transport toxic contaminants and pathogens, as well as heavy metals and polycyclic aromatic hydrocarbons (PAHs) that may alter the effectiveness of ecosystem functions, alter water column light penetration and bury habitats via excessive sedimentation [36]. Thus, drinking water quality in areas with greater agricultural activity may be at risk; however, increased drinking water quality data at the point of consumption are needed to identify high risk critical source areas for drinking water in agricultural lands [37].

Providing access to drinking water testing is an important first step for educating consumers and for diagnosing drinking water quality problems [28,38]. In practice, potential public health concerns, such as waterborne disease outbreaks, could be traced to source(s), if drinking water testing was expanded to the points of consumption, and prevented, if increased testing encouraged changes in practices that positively impact water resources [3,39,40]. Waterborne disease outbreaks from aquatic fecal pollution result in unsafe water quality for many beneficial uses and account for approximately 10% of the annual global disease burden, including approximately 1.4 million child deaths each year. This surprising figure exceeds the mortality of malaria, measles and AIDS combined [41,42]. Given these unexpected figures of mortality for fecal pollution alone, it is surprising that more measures are not taken to standardize drinking water security education, testing and reform.

Promoting drinking water testing education is a vital component of any initiative designed to mitigate water quality or public health problems [24,43]. It is through this process that cultures, habits (i.e., drinking water testing) and outcomes change. Previous research studies demonstrated that community outreach is a critical component to improve drinking water quality [44] and public perceptions can contribute to improvements in water resource management [39,45,46]. It is accepted that providing meaningful drinking water quality information is an effective method to increase individual knowledge and may result in more point of consumption drinking water testing [28,30]. Direct outcomes of increased drinking water education and testing include a more informed population that would take preventative actions to decrease the likelihood of future drinking water quality problems and increase the likelihood that drinking water contaminants are mitigated before they can negatively impact public health and result in higher health care costs [22,38,47].

2. A United States Appalachian Region Case Study

Drinking water in the United States is often withdrawn from surface waters and groundwater [48]; however, drinking water sources vary in quantity and quality depending on location [49,50]. In the United States, the Federal government, State governments and, sometimes, local water districts share responsibilities to uphold drinking water standards for the public [51]. At the Federal level, most regulations fall under the Safe Drinking Water Act [2,49]. This arrangement of policies to secure public drinking water safety is not uncommon globally, so we present it here accompanied by a case study and application. Our case study is the state of West Virginia, USA, a state with a distinct water resources history [52] and widespread reliance on public (e.g., municipal water) and private (e.g., wells, springs, cisterns) drinking water supplies [50].

West Virginia's water resources include more than 31,000 stream miles, over 135 managed impoundments and groundwater from six major aquifers [52,53]. A 2016 assessment showed that more than 60% of the state-managed water resources are classified as having impaired water quality, under the Clean Water Act, Section 303(d) [52,54]. This figure is higher than the national impairment estimates of 46% and 21% for stream miles and freshwater bodies, respectively [55]. Water quality violations in West Virginia include, but are not limited to, mercury, polychlorinated biphenyls (PCBs), low oxygen, nitrogen, bacteria, metals and acidity [52]. Many of these contaminants are directly related to statewide land-use patterns, including agricultural practices, historic and contemporary natural resource extraction practices and industrial activities [21,56,57]. Contaminated source waters,

including surface water and groundwater, require more intensive and often expensive treatment and are associated with higher acute and chronic health risks [58].

Additional water resource stressors, such as urbanization [59] and the increasing demand for freshwater supplies [60], further complicate water resource management throughout West Virginia and the greater Appalachian region. Currently, comprehensive information on public and private drinking water quality are limited for West Virginia [21,22,56,61]. The impacts of public water system violations, including (but not limited to) agricultural practices, natural resource extraction, industrial activities and domestic waste systems, which include septic drain fields and straight piping, on drinking water are unknown [57,61–64]. Mining practices have been shown to adversely impact surface and groundwater quality in West Virginia and may contribute to the contamination of drinking water supplies [21,56]. A recent study by Hendryx et al. [64] showed that, from 2001 to 2009, West Virginia counties with mountaintop coal mining operations were more likely to have significant public drinking water quality violations but noted incomplete sampling and thus limited scope (inconclusive) of findings. McAuley and Kozar [65] studied West Virginia groundwater quality and found that mining practices, in addition to agricultural practices and the presence of chemical industries, were linked to contaminated groundwater throughout the state [53]. Concentrations of several constituents linked to coal mining, including sulfate, iron, manganese and total dissolved solids, were significantly higher in wells adjacent to mined areas [65].

Approximately 42% of the population relies on private wells for drinking water in West Virginia; thus, the risk of well contamination impacting public health is a major concern. This figure is more than three times higher than the national average [50,52], but representative of many other regions globally that rely on private well water or experience similar land-use pressures. A review of municipal drinking water violations from June 2016 to May 2019 showed that much of West Virginia, including rural and urban communities, received increased drinking water violations during that time [50]. Communities that rely on private drinking water systems are also susceptible to water quality problems; however, there are no federal testing requirements for these drinking water sources. It is clear that, in West Virginia, there is a need for drinking water testing at the point of consumption for public and private water systems, as poor surface and groundwater quality persist throughout the entire state [65]. The prevalence of potential drinking water quality risks throughout West Virginia presents an opportunity to launch an outreach-based, residential drinking water testing program that would promote water testing and drinking water education. Although drinking water quality concerns vary by community, region and country, drinking water challenges (e.g., source water protection, finances, infrastructure and public health) throughout West Virginia are similar to many Appalachian communities and regions with similar water- and land-use histories. Thus, West Virginia may be a model location to implement and learn from drinking water testing and community outreach programs. By testing drinking water at the point of consumption from public and private water systems, a drinking water testing and community outreach program would promote equitable access to safe drinking water in urban and rural communities while supporting state and national public health initiatives, as well as serving as a model for similar emergent programs [11,16].

3. Increasing Drinking Water Security with Drinking Water Testing and Community Outreach Programs

Given challenges of this fundamental global issue, we propose that drinking water testing and community outreach programs should be broadly invested and should include free or reduced-cost drinking water testing where possible. In addition, non-formal education (i.e., public outreach) regarding the importance of drinking water quality testing for human well-being and security must be included to broaden testing for all people to increase citizen awareness and provider responsibility and to advance drinking water testing as a cultural imperative.

Objectives for new programs should minimally include the following: (1) testing drinking water quality; (2) developing a drinking water quality database; (3) increasing public awareness of drinking water issues; (4) building a platform for improved community outreach; and (5) developing a drinking water testing and community outreach model that can be implemented in other regions. This final objective implies that the process and outcomes of program development should be published and made available to a global community. Lacking that learned insight, emergent programs may be more bound to repetition of potential failures. Emergent programs should simultaneously develop a culture of community outreach through workshops to increase public awareness about the importance of drinking water testing. Workshops should provide participants with free or reduced cost drinking water testing, the support required to interpret their individual test results and, if necessary, connections to additional needed assistance.

To help organize the sequence of steps to satisfy these objectives, we provide a logic model (Figure 1) that should be considered for any emergent drinking water testing and community outreach program. A logic model is a conceptual tool for planning and evaluation that describes program components and what the program would do [66]. The model is broadly applicable to any location where people have drinking water concerns and addresses the fundamental issue of lack of drinking water quality data availability at points of consumption [67].

Programmatic inputs should at least include a program leader, staff or volunteers, community engagement, a method of conducting drinking water quality testing and analyses, educational materials, local water resource information and additional support, but may differ with each unique situation (Figure 1). As per the World Health Organization (WHO) guidelines for drinking water quality, preventative integrated management practices include collaboration from multiple agencies and stakeholders to ensure drinking water safety [1]. Program collaborators may come from a range of professional, governmental, nongovernmental and private institutions, including, but not limited to, national agencies (i.e., environmental protection agency), water supply managers (i.e., local municipality) and surveillance (i.e., public health authorities) agencies [1]. The complexity and breadth of specific program inputs varies with specific community needs and known drinking water quality issues. All materials should be relevant to the community and region where the program is being offered. Free or reduced-cost water testing for participants is not required but should be considered, as free or low-cost drinking water quality testing increases the likelihood of participation and of reaching desired program outcomes [27,38]. We do recognize that there are costs associated with providing drinking water testing, which may be difficult for some programs. Grant funds, sponsorship, collaboration with an established certified laboratory and public–private partnerships may present ways to subsidize program drinking water testing. Additional opportunities may exist to collaborate with local outreach or extension organizations. Working with community partners may strengthen the outreach aspects of the program while simultaneously broadening the messaging reach and overall impact.

Activities are designed using a workshop model in which program participants attend a meeting to learn about local water resource issues, including drinking water quality, how to get drinking water tested, how to interpret drinking water test results and learn about how to find help locating assistance for mitigation, if necessary (Figure 1). Any educational method may be used, but previous studies have shown the effectiveness of non-formal education [44,45]. All activities, regardless of size or scope, should aim to increase public awareness about the importance of drinking water quality testing. Additional workshop activities may include time for participants to ask questions/voice their concerns and for program leaders to gather information regarding local drinking water quality perceptions (e.g., survey data collection). If drinking water testing facilities or test kits are to be provided, it is important for program leaders to review the water sample collection process, test results' delivery process and results' interpretation, so participants are knowledgeable about the process. After the conclusion of the workshop and once drinking water quality

test results are delivered to program participants, program organizers should follow up with participants that may need additional resources such as mitigation strategies and local health department contact information.
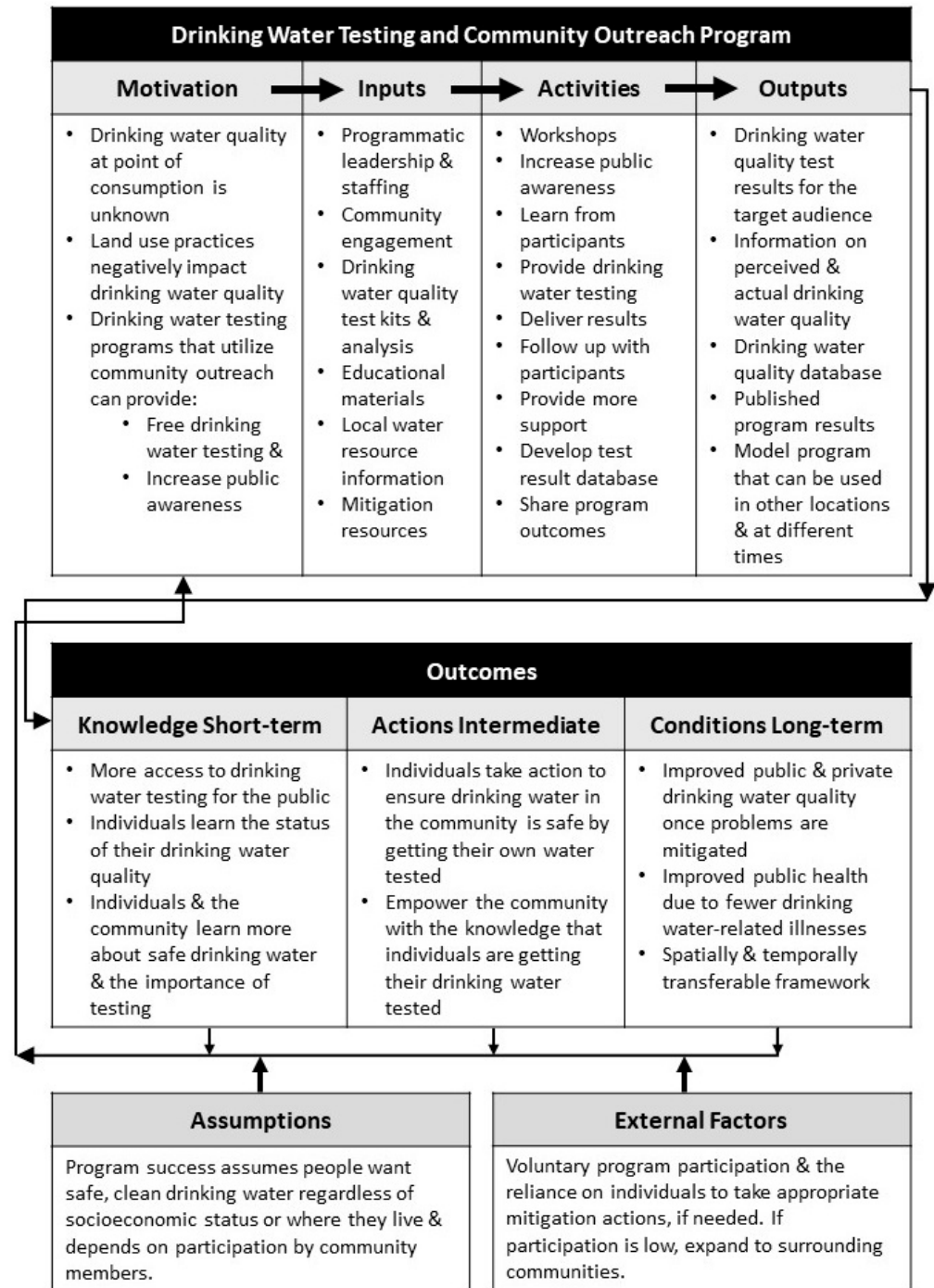

Figure 1. Many of the fundamental components of a drinking water testing and outreach program including the motivation, inputs, activities, outputs, outcomes, assumptions and external factors.

Short-term program outcomes should include a measurable change in participant knowledge [66,68] and include increased access to drinking water testing at the point of consumption, program participant learning the status of their drinking water quality and an increase in community knowledge about the importance of safe drinking water and testing, regardless of the water source (i.e., public, or private). Intermediate outcomes include actions taken by program participants ensuring that drinking water in their community

is safe by getting their own water tested, which, in turn, empowers the local community. Long-term outcomes include changes to conditions. These include improved public and private drinking water quality after problems are mitigated, improved public health due to fewer drinking water-related illnesses and a developed framework that can be transferred to their communities and regions. This last condition is critical for ensuring program objectives are met, as a spatially and temporally transferable outreach program has a better chance at improving more lives through widespread drinking water testing. Program outputs may also include drinking water quality databases and participant feedback (though surveys) pertaining to local drinking water quality perceptions and concerns (Figure 1). Program results (anonymous) should be shared with the public through a variety of forums including, but not limited to, public reports, online resources, popular press and peer-reviewed journal articles.

4. Conclusions

The success of any drinking water testing and community outreach program includes the assumption that participants want safe, clean drinking water for themselves and their communities, regardless of socioeconomic status or where they live. Herein, we provide justification, a case example and a logic (workflow) model to argue the merits of developing drinking water testing and community outreach programs that include drinking water testing and non-formal education (i.e., public outreach) regarding the importance of drinking water quality testing for human well-being and security. Although West Virginia was used as a case study to build out the drinking water testing program logic model, this workflow is intended to be adaptable to specific community and regional drinking water concerns. External factors include voluntary workshop participation and participants facilitating mitigation steps, if needed, to achieve intermediate and long-term outcomes. By testing water from public and private systems at the point of consumption, a drinking water testing program would promote equitable and inclusive access to safe drinking water, greatly advance water security and support public health initiatives [11,16]. This is of critical importance because drinking water testing programs are the best (in terms of water source type coverage), most inclusive and most equitable way to advance water security on a community-by-community basis. The workshop and community outreach model are a path forward that ensures public participation and access to water quality testing, facilitates greater understanding of water quality and supports real progress towards addressing global water security.

References

1. World Health Organization (Ed.) *Guidelines for Drinking-Water Quality*, 4th ed.; World Health Organization: Geneva, Switzerland, 2011; ISBN 978-92-4-154815-1.

2. Humphreys, E.H.; Tiemann, M. *Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements*; Congressional Research Service: Washington, DC, USA, 2014; p. 32.

3. Zheng, Y.; Flanagan, S.V. 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.* **2017**, *125*, 085002. [CrossRef]

4. Hubbart, J.A.; Stephan, K.; Petersen, F.; Heck, Z.; Horne, J.; Meade, B.J. Challenges for the Island of Barbuda: A Distinct Cultural and Ecological Island Ecosystem at the Precipice of Change. *Challenges* **2020**, *11*, 12. [CrossRef]

5. Lilje, J.; Mosler, H.-J. Continuation of Health Behaviors: Psychosocial Factors Sustaining Drinking Water Chlorination in a Longitudinal Study from Chad. *Sustainability* **2016**, *8*, 1149. [CrossRef]

6. Hamlin, C. A Science of Impurity. Available online: https://publishing.cdlib.org/ucpressebooks/view?docId=ft667nb43t;query=;brand=ucpress (accessed on 4 November 2021).

7. EU Directive (EU) 2020/2184. Available online: https://www.legislation.gov.uk/eudr/2020/2184/contents (accessed on 4 November 2021).

8. WHO/UNICEF (Ed.) *Water for Life: Making It Happen*; World Health Organization: Unicef: Geneva, Switzerland, 2005; ISBN 978-92-4-156293-5.

9. Wolf, J.; Hunter, P.R.; Freeman, M.C.; Cumming, O.; Clasen, T.; Bartram, J.; Higgins, J.P.T.; Johnston, R.; Medlicott, K.; Boisson, S.; et al. Impact of Drinking Water, Sanitation and Handwashing with Soap on Childhood Diarrhoeal Disease: Updated Meta-Analysis and Meta-Regression. *Trop. Med. Int. Health* **2018**, *23*, 508–525. [CrossRef]

10. Fisher, M.B.; Danquah, L.; Seidu, Z.; Fechter, A.N.; Saga, B.; Bartram, J.K.; Liang, K.M.; Ramaswamy, R. WaSH CQI: Applying Continuous Quality Improvement Methods to Water Service Delivery in Four Districts of Rural Northern Ghana. *PLoS ONE* **2020**, *15*, e0233679. [CrossRef] [PubMed]

11. Levin, R.B.; Epstein, P.R.; Ford, T.E.; Harrington, W.; Olson, E.; Reichard, E.G. U.S. Drinking Water Challenges in the Twenty-First Century. *Environ. Health Perspect.* **2002**, *110*, 43–52. [CrossRef] [PubMed]

12. Johnson, N.; Revenga, C.; Echeverria, J. Ecology: Managing Water for People and Nature. *Science* **2001**, *292*, 1071–1072. [CrossRef] [PubMed]

13. Benedict, K.M.; Reses, H.; Vigar, M.; Roth, D.M.; Roberts, V.A.; Mattioli, M.; Cooley, L.A.; Hilborn, E.D.; Wade, T.J.; Fullerton, K.E.; et al. Surveillance for Waterborne Disease Outbreaks Associated with Drinking Water—United States, 2013–2014. *MMWR Morb. Mortal. Wkly. Rep.* **2017**, *66*, 6. [CrossRef]

14. Allaire, M.; Wu, H.; Lall, U. National Trends in Drinking Water Quality Violations. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 2078–2083. [CrossRef] [PubMed]

15. Hanna-Attisha, M.; LaChance, J.; Sadler, R.C.; Champney Schnepp, A. 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* **2016**, *106*, 283–290. [CrossRef] [PubMed]

16. Baum, R.; Bartram, J.; Hrudey, S. The Flint Water Crisis Confirms That U.S. Drinking Water Needs Improved Risk Management. *Environ. Sci. Technol.* **2016**, *50*, 5436–5437. [CrossRef] [PubMed]

17. Pieper, K.J.; Tang, M.; Edwards, M.A. Flint Water Crisis Caused By Interrupted Corrosion Control: Investigating "Ground Zero" Home. *Environ. Sci. Technol.* **2017**, *51*, 2007–2014. [CrossRef] [PubMed]

18. Whelton, A.J.; McMillan, L.; Connell, M.; Kelley, K.M.; Gill, J.P.; White, K.D.; Gupta, R.; Dey, R.; Novy, C. Residential Tap Water Contamination Following the Freedom Industries Chemical Spill: Perceptions, Water Quality, and Health Impacts. *Environ. Sci. Technol.* **2015**, *49*, 813–823. [CrossRef]

19. Ho, J.C.; Michalak, A.M. Challenges in Tracking Harmful Algal Blooms: A Synthesis of Evidence from Lake Erie. *J. Great Lakes Res.* **2015**, *41*, 317–325. [CrossRef]

20. Busby, J.W.; Baker, K.; Bazilian, M.D.; Gilbert, A.Q.; Grubert, E.; Rai, V.; Rhodes, J.D.; Shidore, S.; Smith, C.A.; Webber, M.E. Cascading Risks: Understanding the 2021 Winter Blackout in Texas. *Energy Res. Soc. Sci.* **2021**, *77*, 102106. [CrossRef]

21. Johnson, T.D.; Belitz, K.; Lombard, M.A. Estimating Domestic Well Locations and Populations Served in the Contiguous U.S. for Years 2000 and 2010. *Sci. Total Environ.* **2019**, *687*, 1261–1273. [CrossRef] [PubMed]

22. Law, R.K.; Murphy, M.W.; Choudhary, E. Private Well Groundwater Quality in West Virginia, USA–2010. *Sci. Total Environ.* **2017**, *586*, 559–565. [CrossRef]

23. Charrois, J.W.A. Private Drinking Water Supplies: Challenges for Public Health. *Can. Med. Assoc. J.* **2010**, *182*, 1061–1064. [CrossRef] [PubMed]

24. Imgrund, K.; Kreutzwiser, R.; de Loë, R. Influences on the Water Testing Behaviors of Private Well Owners. *J. Water Health* **2011**, *9*, 241–252. [CrossRef]

25. Carlin, D.J.; Naujokas, M.F.; Bradham, K.D.; Cowden, J.; Heacock, M.; Henry, H.F.; Lee, J.S.; Thomas, D.J.; Thompson, C.; Tokar, E.J.; et al. Arsenic and Environmental Health: State of the Science and Future Research Opportunities. *Environ. Health Perspect.* **2016**, *124*, 890–899. [CrossRef] [PubMed]

26. 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*, 507–528. [CrossRef] [PubMed]

27. MacDonald Gibson, J.; Pieper, K.J. Strategies to Improve Private-Well Water Quality: A North Carolina Perspective. *Environ. Health Perspect.* **2017**, *125*, 076001. [CrossRef] [PubMed]

28. Collins, A.R.; Steinback, S. Rural household response to water contamination in west virginia. *J. Am. Water Resour. Assoc.* **1993**, *29*, 199–209. [CrossRef]

29. Kozicki, Z.A.; Baiyasi-Kozicki, S.J.S. The Survival of Mankind Requires a Water Quality and Quantity Index (WQQI) and Water Applied Testing and Environmental Research (WATER) Centers. *World Water Policy* **2019**, *5*, 55–70. [CrossRef]

30. Lucas, P.J.; Cabral, C.; Colford, J.M. Dissemination of Drinking Water Contamination Data to Consumers: A Systematic Review of Impact on Consumer Behaviors. *PLoS ONE* **2011**, *6*, e21098. [CrossRef]

31. 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*, 60–66.

32. Grathwohl, P.; Rügner, H.; Wöhling, T.; Osenbrück, K.; Schwientek, M.; Gayler, S.; Wollschläger, U.; Selle, B.; Pause, M.; Delfs, J.-O.; et al. Catchments as Reactors: A Comprehensive Approach for Water Fluxes and Solute Turnover. *Environ. Earth Sci.* **2013**, *69*, 317–333. [CrossRef]

33. Zhang, Q.; Blomquist, J.D. Watershed Export of Fine Sediment, Organic Carbon, and Chlorophyll-a to Chesapeake Bay: Spatial and Temporal Patterns in 1984–2016. *Sci. Total Environ.* **2018**, *619–620*, 1066–1078. [CrossRef] [PubMed]

34. Vitousek, P.M.; Aber, J.D.; Howarth, R.W.; Likens, G.E.; Matson, P.A.; Schindler, D.W.; Schlesinger, W.H.; Tilman, D.G. Human Alteration of the Global Nitrogen Cycle: Sources and Consequences. *Ecol. Appl.* **1997**, *7*, 737–750. [CrossRef]

35. Boesch, D.F.; Brinsfield, R.B.; Magnien, R.E. Chesapeake Bay Eutrophication: Scientific Understanding, Ecosystem Restoration, and Challenges for Agriculture. *J. Environ. Qual.* **2001**, *30*, 303–320. [CrossRef] [PubMed]

36. U.S. Environmental Protection Agency. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey*, 2nd ed.; U.S. Environmental Protection Agency: Washington, DC, USA, 2004; p. 280.

37. Strauss, P.; Leone, A.; Ripa, M.N.; Turpin, N.; Lescot, J.-M.; Laplana, R. Using Critical Source Areas for Targeting Cost-Effective Best Management Practices to Mitigate Phosphorus and Sediment Transfer at the Watershed Scale. *Soil Use Manag.* **2007**, *23*, 144–153. [CrossRef]

38. Colford, J.M.; Roy, S.; Beach, M.J.; Hightower, A.; Shaw, S.E.; Wade, T.J. A Review of Household Drinking Water Intervention Trials and an Approach to the Estimation of Endemic Waterborne Gastroenteritis in the United States. *J. Water Health* **2006**, *4*, 71–88. [CrossRef] [PubMed]

39. Bates, A.J. Water as Consumed and Its Impact on the Consumer—Do We Understand the Variables? *Food Chem. Toxicol.* **2000**, *38*, S29–S36. [CrossRef]

40. Yoder, J.S.; Blackburn, B.G.; Craun, G.F.; Hill, V.; Levy, D.A.; Chen, N.; Lee, S.H.; Calderon, R.L.; Beach, M.J. Surveillance for Waterborne-Disease Outbreaks Associated with Recreational Water—United States, 2001–2002. *MMWR Surveill. Summ.* **2004**, *53*, 1–22.

41. Mara, D.; Lane, J.; Scott, B.; Trouba, D. Sanitation and Health. *PLoS Med.* **2010**, *7*, e1000363. [CrossRef]

42. Mukherjee, M.; Gentry, T.; Mjelde, H.; Brooks, J.; Harmel, D.; Gregory, L.; Wagner, K. Escherichia Coli Antimicrobial Resistance Variability in Water Runoff and Soil from a Remnant Native Prairie, an Improved Pasture, and a Cultivated Agricultural Watershed. *Water* **2020**, *12*, 1251. [CrossRef]

43. Hudson, S.J. Challenges for Environmental Education: Issues and Ideas for the 21st Century. *BioScience* **2001**, *51*, 283. [CrossRef]

44. Paolisso, M.; Trombley, J.; Hood, R.R.; Sellner, K.G. Environmental Models and Public Stakeholders in the Chesapeake Bay Watershed. *Estuaries Coasts* **2015**, *38*, 97–113. [CrossRef]

45. Doria, M.D.F.; Pidgeon, N.; Hunter, P.R. Perceptions of Drinking Water Quality and Risk and Its Effect on Behaviour: A Cross-National Study. *Sci. Total Environ.* **2009**, *407*, 5455–5464. [CrossRef]

46. Andrew, R.G.; Burns, R.C.; Allen, M.E. The Influence of Location on Water Quality Perceptions across a Geographic and Socioeconomic Gradient in Appalachia. *Water* **2019**, *11*, 2225. [CrossRef]

47. Alzahrani, F.; Collins, A.R.; Erfanian, E. Drinking Water Quality Impacts on Health Care Expenditures in the United States. *Water Resour. Econ.* **2020**, *32*, 100162. [CrossRef]

48. Drinking Water Frequently Asked Questions (FAQs) | Drinking Water | Healthy Water | CDC. Available online: https://www.cdc.gov/healthywater/drinking/drinking-water-faq.html (accessed on 8 September 2021).

49. U.S. Environmental Protection Agency. Safe Drinking Water Act (SDWA). Available online: https://www.epa.gov/sdwa (accessed on 12 September 2021).

50. Fedinick, K.P.; Taylor, S.; Roberts, M.; Moore, R.; Olson, E. *Watered Down Justice*; Natural Resource Defense Council: New York, NY, USA, 2019; p. 52.

51. Drinking Water Quality Legislation of the United States. *Wikipedia*. Available online: https://en.wikipedia.org/wiki/Drinking_water_quality_legislation_of_the_United_States (accessed on 21 November 2021).

52. U.S. Environmental Protection Agency. How's My Waterway? Available online: https://mywaterway.epa.gov/state/WV/water-quality-overview (accessed on 12 September 2021).

53. Kozar, M.D.; Mathes, M.V. *Aquifer-Characteristics Data for West Virginia*; Water-Resources Investigations Report; US Department of the Interior, US Geological Survey: Washington, DC, USA, 2001; Volume 1, pp. 2001–4036.

54. Federal Water Pollution Control ACT. United States Environmental Protection Agency Publication November 27 2002, 234 Pages. Available online: https://www.epa.gov/sites/default/files/2017-08/documents/federal-water-pollution-control-act-508full.pdf (accessed on 21 November 2021).

55. National Water Quality Inventory: Report to Congress. United States Environmental Protection Agency (305(b) Reports). Available online: https://www.epa.gov/waterdata/national-water-quality-inventory-report-congress (accessed on 21 November 2021).

56. Chambers, D.B.; Kozar, M.D.; White, J.S.; Paybins, K.S. *Groundwater Quality in West Virginia, 1993–2008*; US Department of the Interior, US Geological Survey: Washington, DC, USA, 2012; p. 60.

57. Levêque, J.G.; Burns, R.C. Drinking Water in West Virginia (USA): Tap Water or Bottled Water—What Is the Right Choice for College Students? *J. Water Health* **2018**, *16*, 827–838. [CrossRef] [PubMed]

58. Davies, J.-M.; Mazumder, A. Health and Environmental Policy Issues in Canada: The Role of Watershed Management in Sustaining Clean Drinking Water Quality at Surface Sources. *J. Environ. Manag.* **2003**, *68*, 273–286. [CrossRef]

59. Kaushal, S.S.; Groffman, P.M.; Mayer, P.M.; Striz, E.; Gold, A.J. Effects of Stream Restoration on Denitrification in an Urbanizing Watershed. *Ecol. Appl.* **2008**, *18*, 789–804. [CrossRef] [PubMed]

60. Lookingbill, T.; Kaushal, S.; Elmore, A.; Gardner, R.; Eshleman, K.; Hilderbrand, R.; Morgan, R.; Boynton, W.; Palmer, M.; Dennison, W. Altered Ecological Flows Blur Boundaries in Urbanizing Watersheds. *Ecol. Soc.* **2009**, *14*, 789–804. [CrossRef]

61. Hu, X.C.; Andrews, D.Q.; Lindstrom, A.B.; Bruton, T.A.; Schaider, L.A.; Grandjean, P.; Lohmann, R.; Carignan, C.C.; Blum, A.; Balan, S.A.; et al. Detection of Poly- and Perfluoroalkyl Substances (PFASs) in U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants. *Environ. Sci. Technol. Lett.* **2016**, *3*, 344–350. [CrossRef] [PubMed]

62. Arcipowski, E.; Schwartz, J.; Davenport, L.; Hayes, M.; Nolan, T. Clean Water, Clean Life: Promoting Healthier, Accessible Water in Rural Appalachia. *J. Contemp. Water Res. Educ.* **2017**, *161*, 1–18. [CrossRef]

63. VanDerslice, J. Drinking Water Infrastructure and Environmental Disparities: Evidence and Methodological Considerations. *Am. J. Public Health* **2011**, *101*, S109–S114. [CrossRef] [PubMed]

64. Hendryx, M.; Fulk, F.; McGinley, A. Public Drinking Water Violations in Mountaintop Coal Mining Areas of West Virginia, USA. *Water Qual. Expo. Health* **2012**, *4*, 169–175. [CrossRef]

65. Ground-Water Quality in Unmined Areas and Near Reclaimed Surface Coal Mines in the Northern and Central Appalachian Coal Regions, Pennsylvania and West Virginia. Available online: https://pubs.usgs.gov/sir/2006/5059/ (accessed on 12 September 2021).

66. Logic Model Planning Process | National Institute of Food and Agriculture. Available online: https://nifa.usda.gov/resource/logic-model-planning-process (accessed on 12 September 2021).

67. Wu, J.; Cao, M.; Tong, D.; Finkelstein, Z.; Hoek, E.M.V. A Critical Review of Point-of-Use Drinking Water Treatment in the United States. *Npj Clean Water* **2021**, *4*, 40. [CrossRef]

68. Tomer, M.D.; Locke, M.A. The Challenge of Documenting Water Quality Benefits of Conservation Practices: A Review of USDA-ARS's Conservation Effects Assessment Project Watershed Studies. *Water Sci. Technol.* **2011**, *64*, 300–310. [CrossRef] [PubMed]