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Water Scavenging from Roadside Springs in Appalachia

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Abstract: Significant challenges in the provision of safe drinking water and appropriate, effective sanitation remain in the United States, particularly among communities with few financial resources and/or situated in challenging terrain. Though previous formal research is limited, anecdotal reports suggest that some households in Appalachia may rely on untreated, unregulated roadside "springs" as a primary source of potable water. This effort monitored the water quality at twenty-one of these springs in Central Appalachia and identified potential motivations for this behavior through volunteer surveys in order to better define community challenges and to establish communication for future outreach. The majority (>80%) of spring samples collected were positive for *E. coli,* indicating a potential risk of exposure to waterborne pathogens; measured concentrations of metals and nutrients were generally in accordance with USEPA recommendations for drinking water. Survey respondents generally had a piped source of in-home water available yet primarily collected the water due to "taste" and "quality/health" and used it directly for drinking. Multiple respondents included extra written information indicating that they either did not trust their in-home water source or considered it unreliable. Collectively these results suggest that these roadside springs do serve as a regular source of household water for some communities though they generally do not meet federal drinking water standards. Future efforts are encouraged to work with local municipal water authorities to rebuild community trust and/or to determine whether on-site treatment at these springs is practicable.

Keywords: *drinking water quality, springs, rural health, environmental health*

The United States currently reports near 100% access to drinking water but there is increasing recognition that significant issues of water quality and equity remain unsolved (World Bank 2015). Recent high profile failures in municipal safe drinking water systems (e.g., Flint, MI and Charleston, WV) (Katner et al. 2016; Thomasson et al. 2017) have drawn attention to the vulnerability of populations reliant on aging infrastructure and/or systems with limited financial resources. Systematic analyses of drinking water quality violations reported to the USEPA under the Safe Drinking Water Act (SDWA) have also revealed potential issues of environmental justice. Most recently, a 2017 national analysis of municipal systems serving more than 10,000 homes indicated that the prevalence of health-based drinking water violations was significantly correlated to both race/ethnicity and poverty, i.e., poorer communities with higher numbers of black or Hispanic residents were more likely to have drinking water that did not consistently meet national health standards (Switzer and Teodoro 2017).

Past examinations of potential drinking water contamination exposure disparities have largely focused on urban drinking water systems. These systems serve the majority of the United States population and due to SDWA monitoring and reporting requirements, data on elevated levels of contaminants of human health concern are publicly available. However, an estimated 15 million U.S. households are reliant on private drinking water systems such as groundwater wells (CDC 2018). As these systems fall outside the auspices of the SDWA, monitoring water quality and maintenance of system function are solely the responsibility of the individual homeowner. Multiple studies suggest that contamination at the system point of use by fecal indicator bacteria such as coliform and *E. coli* is quite common for these homes (Allevi et al. 2013) and lower income households reliant on private systems are more likely to have drinking water that is fecal indicator bacteria positive (Smith et al. 2014). The presence of fecal indicator bacteria in drinking water from private wells has been linked to elevated prevalence of acute and/or chronic gastroenteritis (Denno et al. 2009; Wallender et al. 2014; DeFelice et al. 2016). In addition to an elevated risk of exposure to infectious waterborne microorganisms, water from these systems can also contain elevated concentrations of toxins such as heavy metals. Pieper et al. (2015) reported that up to 20% of household water samples from private wells and springs submitted to a state extension program in Virginia contained lead above the 15 ppb limit recommended by the USEPA, with 1% of samples containing levels over 97 ppb.

In the Central Appalachian Coalfields in the eastern United States the challenges inherent in providing homes with reliable safe drinking water are exacerbated by poverty and unique topographical challenges. Of particular interest to this work are those homes in the region without reliable in-home access to safe drinking water and/or appropriate sanitation. Despite decades of investment, there remain regions of West Virginia and Kentucky where up to one in ten homes lack complete indoor plumbing (Krometis et al. 2017). Incomplete or inadequate household plumbing can result in makeshift solutions that potentially expose residents to elevated levels of water quality contamination, but, because they circumvent regulations, are difficult to locate or quantify. For example, low population densities generally preclude the development of centralized wastewater treatment, but because of the thin soils and karstic geology of the region, septic systems are often inappropriate or prone to failure. Consequently, some residents simply "straight pipe" their household wastewater, i.e., all grey and blackwater is simply piped to an open-air ditch and directed into nearby surface water (Banks et al. 2005; Cook et al. 2015; Lilly et al. 2015). The discharge of untreated wastewater is technically illegal, but this not uncommon strategy is not formally inventoried by water quality or public health managers. Recent estimates suggest up to two-thirds of homes in McDowell County, WV (Lilly et al. 2015) and 3,000 homes in Letcher County, KY (Glasmeier and Farrigan 2003) straight-pipe their sewage to local streams. Not surprisingly, streams receiving straight-piped sewage contain elevated concentrations of fecal indicator bacteria, at times detectable for miles beyond the initial discharge (Cantor et al. 2017)

This ambient contamination of environmental waters is of particular public health concern given that many homes reliant on private systems do not employ treatment (Smith et al. 2014), and that households without in-home access to acceptable drinking water may rely on these waters to meet their needs. Although some homes that either do not have indoor plumbing or perceive their drinking water to be contaminated may meet their drinking and cooking needs with bottled water, this can be quite expensive and represent a significant portion of total household income (McSpirit and Reid 2011). Other homes may therefore rely on roadside or "spout" springs, i.e., piped surface or groundwaters freely available at a public location. Very little is known about typical use of these sources, the quality of this water, and the motivations for collecting water at these locations. Swistock et al. (2015) collected water samples from 35 roadside springs in Pennsylvania and reported that 91% of samples were positive for total coliform and 32% were positive for *E. coli*. A parallel survey of attendees at Pennsylvania Extension workshops indicated that over 30% of the >1,000 attendees had used a roadside spring for drinking water, though only a small number of these attendees were regular users (i.e., <3% used the water at least once a week) (Swistock et al. 2015). In an interdisciplinary effort aimed at inventorying Appalachian water access and disaster preparedness, Arcipowski et al. conducted extensive surveys of 30 homes in eastern Kentucky and sampled 16 local surface water access points used for drinking water and/or recreation (Arcipowski et al. 2017). All sites but one were positive for fecal coliform, and 11 sites exceeded the Kentucky surface water standard of 200 MPN fecal coliforms/100 mL. Households without in-home piped water indicated that they were at times dependent on some of these sources for potable water. Of those homes surveyed, 17% did not have an indoor toilet. Though the remaining 83% reported use of a septic system, the researchers observed straight-piped wastewater entering these surface waters, which represents a potential source of contamination of water collection points.

This present effort aimed to conduct a preliminary investigation of water quality at public water collection points ("spout springs") located in the Central Appalachian region and to determine the motivations of regular spring users. This work is designed to lay a foundation for future outreach efforts and to better define the remaining challenges that render provision of safe drinking water in rural communities in the United States difficult. Explicitly defining these rural environmental health challenges will allow for comparison with more urban issues in the provision of safe drinking water to determine potential common solutions.

Methodology

Spring Selection

Between 2016 and 2018, a total of 83 samples were collected at 21 separate spout springs in five states (Virginia, West Virginia, North Carolina, Kentucky, and Tennessee). Given the considerable travel distances required to reach some of these spring sites, the total number of samples collected at each spring varied from 1 to 13 samples over this time frame. Spring sites were located using the public website www.findaspring.com, discussions with local public health offices, and community word-of-mouth. All springs were publicly accessible, i.e., they were directly adjacent to a public road or on public land. At some springs there was occasional makeshift signage (e.g., a sign tied to a tree) indicating that water quality was not monitored, or suggesting boiling prior to use.

Sample Collection and Analysis

Water was collected on-site at each spring and tested for conductivity, pH, and temperature via a YSI Quattro Pro (YSI Inc., Yellow Springs, OH). On all sampling trips, an additional sample was collected in a pre-sterilized polypropylene bottle and transported to Virginia Tech on ice for bacteriological analysis. Samples were analyzed promptly upon return to the lab via the Colilert defined substrate method for total coliforms and *E. coli* (www.idexx.com, Westbrook, MN). Additional funding during the second year of the project facilitated collection and analysis of samples for inorganic metallic ions. Samples were collected at 19 of the 21 springs (samples from one spring were lost in analysis; a neighbor adjacent to another spring requested no more sampling, which we honored although the spring was on public land). These samples were collected in a separate acid-washed sterile bottle and analyzed via ICP-IMS according to Standard Methods 3030D and 3125B (APHA/AWWA/WEF 1998). Nitrate and fluoride concentrations were determined via Standard Methods 4500-NH and 300, respectively (APHA/AWWA/WEF 1998).

Household Survey

Pre-addressed and pre-stamped short surveys were left at 12 spring locations identified as having interesting water quality results, convenient access, and/or active user communities (Figure 1). Surveys consisted of four short multiple-choice questions (Table 1) crafted to determine typical rates of use (question 1); types of use (question 2); potential alternative sources of water (question 3); and motivations (question 4). Questions were designed to be short, direct, and at a middle-school or below reading level given low rates of regional literacy (Shaw et al. 2004). Survey design, collection, and analysis were approved by the Virginia Tech Institutional Review Board (IRB#16-910). Upon receipt, surveys were coded within a Microsoft Access database. As respondents could select more than one option for multiple choice questions, each category was coded as a "1" (checked) or "0" (unchecked). Comments for "other" categories and/or marginalia were recorded verbatim.

Results and Discussion

Water Quality at Springs

All samples except for one (99%) were positive for total coliform bacteria, sometimes at very high

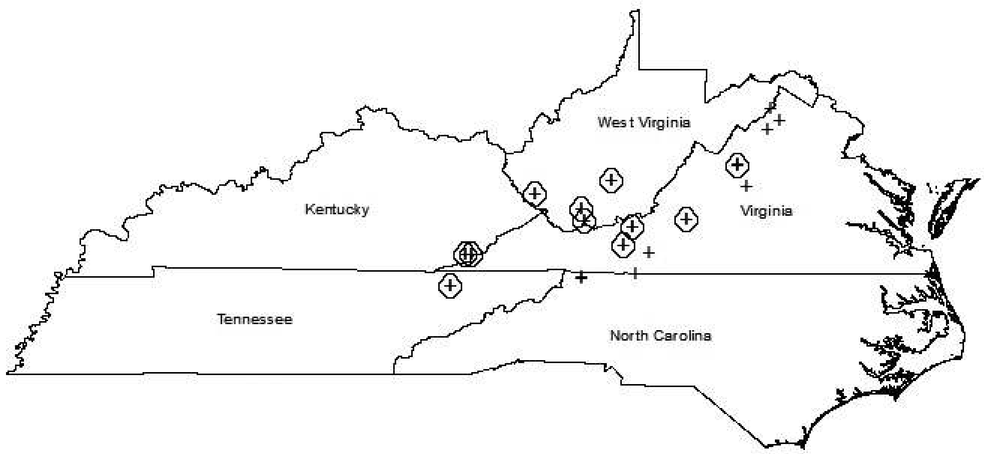

Figure 1. Spring locations for water quality sampling. Surveys were left at circled sites.

Table 1. Spring use survey questions.

How often do you collect water at this spring?
□ Once a day
□ Once a week
□ Once a month
□ Other:______________________________
What do you use the spring water for? (Check all that apply)
□ Drinking
□ Brewing beer
□ Cooking
□ Washing
□ Other:______________________________
What kind of water do you have at home?
□ City/municipal water
□ Well water
□ Cistern water
□ Other:______________________________
Why do you collect spring water?
□ Taste
□ Easy (convenient)
□ Quality/health
□ Price
□ Other:______________________________

levels (Table 2). Current USEPA standards for municipal drinking waters mandate that coliforms be entirely absent (USEPA 2018). It is not surprising however, that coliforms were present in spring samples as this bacterial family includes many species naturally present in soil (Leclerc et al. 2001), and these waters are wholly untreated and not subject to disinfection. Perhaps of greater concern is the finding that 86% of all samples were positive for *E. coli*, and 17 different springs (81% of springs) were positive for *E. coli* at least once during sampling (Table 2). The presence of *E. coli*, a specific species of coliform, is considered indicative of direct fecal contamination and potential human health risk (Paruch and Mæhlum 2012). Detection of *E. coli* in municipal waters would not only be in violation of the associated USEPA SDWA standard, but would trigger a local boil advisory to safeguard the public health.

Spring water samples were largely in accordance with SDWA standards for municipal waters for the remaining water quality targets, with the exception of two springs that exceeded the guidance level for sodium at least once, two springs that exceeded the secondary maximum contaminant level (SMCL; for taste and aesthetics) for manganese at least once, and six springs that exceeded the SMCL for aluminum at least once (Table 3). The current sodium guideline (20,000 ppb, i.e., 20 mg/L) is specifically designed to accommodate individuals following a low-salt diet based on a physician's recommendation; it is therefore worth noting that

Table 2. Bacteriological spring water quality results (* = spring with usage survey results).

Spring #	State	Samples Collected (#)	Total coliforms: % Positive	Total coliforms: Concentration Range (MPN/100 mL)	*Escherichia coli*: % Positive	*Escherichia coli*: Concentration Range (MPN/100 mL)
1*	VA	4	100	23 - 39	25	0 - 7
2*	VA	6	100	21 - 908	67	0 - 71
3	VA	2	100	24 - 159	50	0 - 1
4	VA	1	100	159	100	3
5	VA	3	100	299 - 417	33	0 - 33
6	VA	3	100	81 - 292	100	5 - 22
7*	VA	4	100	27 - 505	100	1 - 18
8	NC	2	100	57 - 2,419	0	0
9	NC	2	100	20 - 74	0	0
10	NC	2	50	0 - 134	0	0
11*	VA	3	100	17 - 60	67	0 - 1
12*	VA	13	100	295 - 2,149	100	1 - 583
13*	WV	9	100	15 - 438	67	0 - 4
14*	WV	5	100	1 - 24	20	0 - 2
15	VA	6	100	1 - 195	17	0 - 1
16*	KY	1	100	6	0	0
17*	WV	5	100	3 - 6	20	0 - 1
18	VA	1	100	1,413	100	26
19*	TN	1	100	28	100	3
20*	KY	1	100	2,203	100	14
21*	WV	6	100	87 - 1,230	83	0 - 113

several common chronic illnesses that are often partially treated with a low salt diet, including heart disease, are notably higher in this region of Appalachia (Krometis et al. 2017). The origin of the high sodium level has not been confirmed, though the natural geology of this region is characterized by ancient sea water trapped in sediments at the time of deposition which can then be released via groundwater ion exchange (Heath 1983). In addition, a survey respondent stated that s/he believed that spring 13 (which had the highest recorded sodium levels) was actually the outfall of a flooded underground mine. The respondent still collected this water for drinking regularly and did not note a poor or salty taste.

Motivations for Water Collection at Springs

In total, 35 surveys were returned. The number of surveys returned varied from one to seven per spring. The majority of respondents indicated that they collected the water directly for drinking (86%), with 63% indicating that they visited the spring at least once per week. This is noteworthy, as many of these sites are not located near communities

Table 3. Maximum observed concentrations of inorganic ions at each spring (ppb). Comparable standards are USEPA maximum contaminant levels for municipal drinking water unless otherwise noted. Values in exceedance of these standards are in bold. (“BD” = below detection limit; “ND” = sampling not done for this spring).

Spring #	NO_3-N	Fe	Mn	Pb	As	F	Na	Cu	Se	Cd	U	Al
1	0	25.7	0.7	0	0	110	934	0	BD	0	0.2	13
2	190	23.8	1.4	0	0	30	6,100	0.1	0.4	0	0	10
3	20	19.7	0.7	BD	BD	30	1,397	BD	BD	0	0	12.9
4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
5	BD	18.5	2.7	BD	BD	30	871	0.3	0	0	0.1	17.5
6	2,230	9.4	2	0.3	0	40	4,970	1.1	0.5	0	0.3	4.3
7	3,210	29.9	0.7	0	0	30	5,082	1.2	0.2	0	0.3	13.1
8	980	61.4	3.1	BD	BD	50	5,468	0	BD	0	0	12.6
9	40	16.3	0.4	BD	BD	30	1,491	BD	BD	0	0	9.5
10	BD	12.8	37.7	BD	0.4	70	6,598	BD	BD	0	0	5.2
11	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
12	290	75.5	3.9	0	0.1	30	1,078	0.1	0.2	0	0.1	49.2
13	160	265	43.2	0.1	0.4	150	**198,400**	0.8	2.9	0	0.6	**72.6**
14	790	70.6	**1,903**	2.6	0	150	2,491	3.4	0.7	0.3	0.1	**1,808**
15	30	82	2	0	0.1	70	2,595	0.4	0.2	0	0.1	**50.3**
16	150	104.8	39.4	0.1	0.2	270	**93,840**	0.3	0.4	0	0	8.9
17	220	85.1	0.5	0	0	60	8,064	0.6	3.4	0	0.1	49.3
18	600	103.2	2.9	0.4	0	20	2,631	0.1	0.2	0	0	**100.2**
19	350	5.9	0.9	0	0.2	10	644	0.1	0.5	0	0.2	3.7
20	460	55.7	**166.4**	0.1	0	80	6,443	0.4	0.6	0.2	0	**313.9**
21	90	192.2	2.9	0.2	0	70	16,200	0.5	0.9	0	0.1	**168.1**
Standard	10,000	300ǂ	50ǂ	15	10	4,000	20,000*	1,300	50	5	30	50 - 200ǂ

ǂSecondary maximum contaminant level (SMCL)

*USEPA guidance level for low-salt diets and so would require some time and planning to reach. This also represents a slightly different population than that identified by Swistock et al. (2015), which primarily inventoried occasional spring users. Of those responding, 48% indicated they had municipal water at home, 40% were dependent on a well, and two listed "other". One respondent was dependent on a cistern s/he filled regularly with spring water. This was an intriguing finding, as it was initially hypothesized that regular spring users might not have in-home water as described by Arcinpowski et al. (2017)'s work in rural Kentucky. The respondents to this survey largely had in-home water sources but preferred spring water. The majority indicated that taste was a primary reason to collect spring water (66%), with 57% also selecting "quality/health" as a motivating factor.

Somewhat surprisingly, many of the respondents included substantial marginalia or even short letters accompanying their returned surveys. These comments provide additional subtlety to the short survey responses and suggest important areas for future research and outreach or community education efforts. For example, it appears many of the respondents simply do not trust their home water source, given responses such as:

> *The well water we have is not good to drink or cook with.*

> *Too many times we don't get notified if there is a boil advisory…They have also been cited with chemical violations (not enough or too much) and we don't hear about them til after the fact.*

> *City water is toxic.*

> *I have had the honor of being raised on well and spring water…I love good old mountain spring water and truly believe it's better than any nasty, chlorine tasting city water.*

However, some respondents indicate that they are reliant on this water as their only option:

> *People cannot afford their water bills.*

> *The president of the water system didn't bring the water meter in the yard. We can't afford to dig a ditch from the yard to water meter that [sic] about 300 feet from the house.*

> *When our old water system for [X] fails, we often used this water source.*

> *When there is a dry season or when our pump went out in our well, we collected gallons and gallons of this spring water to get us through.*

Potential education and outreach efforts to spring users would differ substantially based upon these users' stated motivations for collecting and drinking spring water, as well as the actual quality of their in-home water source. The perception that spring water is more "natural" or pleasant-tasting was also cited by Swistock et al. (2015) in their survey of roadside spring users. Water taste can vary greatly amongst individuals, and is a poor indicator of most contaminants. However, perceptions such as poor taste or changes in color can be critical in an individual's decision to have their drinking water tested or seek a different source (Imgrund et al. 2011; Kreutzwiser et al. 2011; McSpirit and Reid 2011; Wedgworth et al. 2014). It is critical for local physicians, extension agents, and health departments to emphasize that taste or appearance alone is not a sufficient indicator that water is safe to drink. Future work should investigate whether this messaging is most effective if conveyed via simple roadside signage, extension publications, or more targeted community messaging.

Given local reports of municipal water infrastructure challenges and frequent violations of the SDWA by some treatment plants, for some communities these springs may present less risk than in-home drinking water (Kounang 2018; Pytalski 2018). For example, a cursory review of SDWA violations in McDowell County, WV, where one of these springs is located, lists 3,613 violations by the county's 25 municipal water plants since 2008 (https://www3.epa.gov/enviro/facts/sdwis/search.html). Simultaneously, residents in Appalachia often have higher water utility rates than national averages (Hughes et al. 2005). It is likely extensive investment in local infrastructure coupled with a substantial public outreach campaign would be required in these areas to rebuild the public trust in point-of-use drinking water.

Limitations

Though the results presented here are at times compelling, it is important to make several key limitations explicit. First, it is likely that spring water quality varies considerably based on climatic conditions and seasonality, especially given the karstic geology of the region; many of these "springs" may be re-emergent surface water or heavily influenced by surface water contamination (White 2018). Second, respondents were self-selected: those who responded were likely interested in the springs, comfortable with providing their information and opinions, and had the time and capacity to respond. Though their experiences and responses echo those reported in previous research efforts reported in Pennsylvania (Swistock et al. 2015) and current reports in popular media (Kounang 2018), these findings should not at this point be considered representative of their communities as a whole.

Future Needs

It is certainly striking to learn that some rural Americans find unregulated and untreated environmental waters preferable to the water from their tap, given the current assumption that the United States has near universal access to clean water. Appalachia is not the only rural region of the United States with struggles in providing residents safe drinking water and adequate sanitation (Gasteyer and Vaswani 2004; Izenberg et al. 2014; Wedgworth et al. 2014). Recent national analyses suggest that rural drinking water systems are more likely to report health-based SDWA violations (Allaire et al. 2018) as well as failures to adequately monitor and report water quality (Rubin 2013). A critical need when assessing the relative impacts of these failures is an investigation of whether substandard drinking water quality results in measurable adverse health outcomes. The previous Pennsylvania roadside spring study cited anecdotal health provider reports of elevated incidence of waterborne diseases such as giardiasis in individuals who use roadside springs (Swistock et al. 2015), but there have been no epidemiological studies reporting on the impacts of exposure to chronically noncompliant municipal drinking water in this region. Regardless, local physicians and health departments should be aware of this potential risk, and the means by which these communities attempt to avoid these risks by seeking out waters they perceive as healthier. Systematic door-to-door surveys should be used to determine water and sanitation challenges in rural regions in order to create sustainable communities with adequate infrastructure, and point-of-use water quality checks should be used as a means to simultaneously educate local citizens and identify contaminants of concern.

Conclusions

This effort demonstrated both that roadside springs are used as a source of potable household water by some households in Appalachia and that water from these springs is frequently contaminated by fecal indicator bacteria, suggesting a potential health risk. These results are currently being used to design and implement a household study to determine whether the in-home water of regular spring users is of comparatively better or worse quality than that observed for their spring, and to more intentionally examine how perceptions of water quality drive behavior. In addition, Cooperative Extension materials are being planned to provide these data and information on local springs to the public. Given survey responses, it appears many of these springs are culturally significant and may also meet a real need when other sources are unavailable. Consequently, it may prove most effective in some communities to work to develop simple treatment and/or water quality protection plans at spring collection sites rather than solely discouraging their use.

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