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Potential Health Hazards of Roadside Springs: Results from Central New York

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Abstract: Across the United States, groundwater springs adjacent to roadways have been developed as unregulated drinking water sources. We attempted to address two basic questions: 1) why do people collect water at these springs; and 2) is the water safe to drink? We conducted a study during 2015-2019 of seven springs in central New York State that included a survey of 199 users and analysis of the water for common dissolved constituents and bacteria. The survey of water users showed that over 70% of respondents use the springs at least multiple times per month for drinking water and the majority collect more than five gallons per visit. More than 80% of the users live farther than three miles from the springs and a recurring reason for drinking the spring water is that the taste is better than the water available at their homes. However, all the springs at some point tested positive for total coliform bacteria and all but one tested positive at least once for fecal coliform bacteria, meaning that 86% of the springs at some point did not meet U.S. municipal drinking water standards. None of the measured dissolved constituents exceeded drinking water standards, but one spring that exhibited elevated nitrate is downslope from a small cattle operation which may be affecting nutrient values in the water. Most of these springs appear to be fed by shallow, unconfined aquifers that are susceptible to contamination from nearby land uses that are not readily apparent from the roadside collection locations.

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

Access to safe, clean water is a global requirement for healthy and sustainable societies. In the United States, advancements in providing sanitary municipal water are a major reason for the overall improvement in human health and a reduction of water-borne diseases in the past century (Cutler and Miller 2005). Much of this progress can be attributed to the passage of the Safe Drinking Water Act (SDWA) of 1974. This law, and its amendments in 1986 and 1996, created enforceable standards for municipal drinking water to reduce contaminants posing risks to human health, and requires the protection of drinking water sources. As a result, the majority of U.S. citizens have access to clean municipal water, although these regulations do not pertain to the approximately 40 million people that rely on private wells (Johnson et al. 2019).

Despite this progress, a recent survey of U.S. residents on perceptions of tap water showed that slightly more than 50% were not totally confident that their municipal water supply or their private well water is safe (Water Quality Association 2019). This lack of trust can lead some consumers

Research Implications

- Roadside springs pose potential health risks to users.
- Roadside springs can be fed by shallow, unconfined aquifers that are susceptible to contamination.
- The presence of total and fecal coliform bacteria in a single spring can vary over time so multiple analyses are needed to fully assess contamination.
- Users of roadside springs appear to be influenced mainly by organoleptic and aesthetic properties such as taste compared to their available tap water at home.

to buy bottled water (Hu et al. 2011). In the U.S., 78% of residents regularly consume bottled water (Water Quality Association 2019). An alternative to tap or bottled water is unregulated roadside or community springs. These can be broadly defined as "improved" springs located near a public roadway where the water flow has been channeled into a pipe, allowing easy water collection. Roadside springs are not monitored or regulated by state or governmental institutions although some have use-at-your-own risk warning signs that are placed by local governments or landowners. As a result, water from the springs has the potential to contain dissolved constituents or host micro-organisms that can pose threats to human health. Our understanding of roadside spring use and water quality is not well documented and only recently have there been any published studies (Swistock et al. 2015; Westhues 2017; Krometis et al. 2019; Patton et al. 2020). There has been at least one parasitic outbreak linked to a spring in upstate New York (Bedard et al. 2016). These studies indicate that roadside springs can pose potential threats to human health yet are the preferred source of water for some people.

In central New York State, as in many other rural regions of the United States, roadside springs are used as drinking water sources. Some of these springs seem quite popular based on the authors' seeing people filling multiple large containers and reviewing findaspring.com, a wiki website that collects the locations of roadside springs globally. In this study, we attempted to answer several overarching questions about these roadside springs:

- What is in the water?
- Does drinking the water pose a hazard to human health?
- What are the reasons people have for collecting water at these sites?

Site Descriptions

The project began with observations of people gathering water at two springs close to the authors' institution. Field measurements and sampling of these two springs began in 2014 and, in 2017, five more springs were located either by word of mouth or from findaspring.com. The sites (Figure 1) are described as follows.

Lisle Spring

The Lisle spring (Broome County) consists of a bifurcated PVC pipe that is embedded into a wooded hillslope of glacial till on the south side of the Dudley Creek Valley. A large pull-off allows easy vehicle access from NY 79. Satellite imagery shows that about 500 meters to the south and upslope, the topography flattens and there are several houses, a sawmill, and a small cattle operation with agricultural fields and a manure lagoon. The imagery history (Google Earth) shows that the manure lagoon was installed between 2015 and 2017.

DiRisio Spring

The DiRisio spring (the name comes from findaspring.com) is located on NY 38 about 200 meters south of Port Byron (Cayuga County). At the site, a black PVC pipe is embedded into the west side of a hill that appears to be glacial till of the Mapleton Formation (Kozlowski et al. 2018) and is possibly the eroded flank of a drumlin. Satellite imagery shows the area upslope is mostly forested with some agricultural fields 300-400 meters to the east. A sign from the Cayuga County Health Department warns that the spring is not regulated and "the water may not be safe to drink."

Reservation Spring

This is one of two springs we studied in the Tully Valley of Onondaga County. The spring is on Onondaga Nation land on Gibson Road west of Onondaga Creek. Water flows from an iron pipe protruding from a small hill that appears to be composed of stratified glacial sediment (Pair 2016) on the northern side of the road. Upslope to the north is forest cover and to the west there are several houses and agricultural fields. About 1 kilometer west is a steep escarpment of the Tully Valley with a "losing" stream that is likely the recharge source of the unconfined aquifer that feeds this spring (W. Kappel, pers. comm. 2021).

Nichols Road Spring

The Nichols spring is located near the western end of Nichols Road (Onondaga County) in the Tully Valley. The spring is a black plastic pipe installed in an excavation into a small hill of

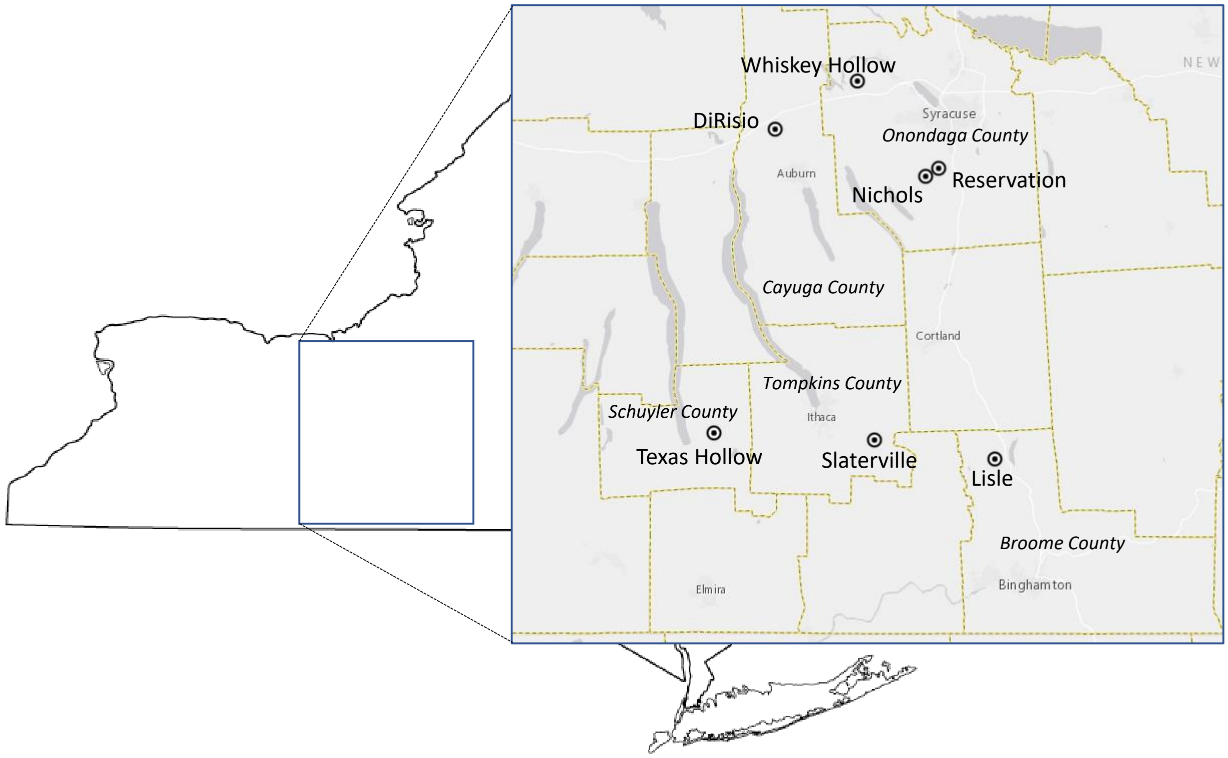

Figure 1. Map of central New York State showing the locations of the seven roadside springs in this study.

glacial sand and gravel that is partly cemented. The satellite imagery shows the area upgradient to the south is mostly forested with agricultural fields about 300 meters from the spring.

Whiskey Hollow Spring

This spring is in the forested Whiskey Hollow Nature Preserve (Onondaga County) and is part of the Central New York Land Trust. An east-west road follows the hollow, which has steep hillslopes on the northern and southern sides. A single PVC pipe is embedded into an outcrop of carbonate-cemented glacial gravel on the northern slope. These cemented gravels (Aber 1979) are the low permeability layer that creates this spring (W. Kappel, pers. comm. 2021). Satellite imagery shows the area uphill to the north is forested, but there are several tilled agricultural fields 400-500 meters upslope where the topography flattens.

Texas Hollow Spring

This spring is located on Texas Hollow Road (Schuyler County) and consists of two PVC pipes (separated by ~10 meters) placed on the west side of the road into a hill. The hill appears to be made of glacial sediments. Water seeps from the hill and flows across the soil surface before being channeled into the pipes. Satellite imagery shows the area uphill is forested, but there are agricultural fields within 500 meters upslope to the west where the topography flattens, and a cattle operation is located 1.2 kilometers to the west.

Slaterville Springs Artesian Well

This is the one artesian well in our study and is located next to the Caroline Town Hall in the village of Slaterville Springs (Tompkins County). An iron pipe protrudes from the ground and a sign advises to "use at your own risk." The land use around the site is a mix of forest, agricultural fields, and dwellings. The well was drilled 86 feet deep into a confined aquifer of sand and gravel overlain by fine, glaciolacustrine sediments (Miller 2009). The aquifer supplies the nearby Town Hall building as well as approximately 200 households, several apartment complexes, two mobile home parks, a school, and several farms. Based on chlorofluorocarbon and tritium concentrations, Miller (2009) estimated that the water in the aquifer has a residence time of about 50 years.

Methods

On-Site Water Collection and Measurement

Springs were visited on an opportunistic basis during the spring, summer, and fall with Lisle and Slaterville studied from 2015-2019 and the others from 2017-2019. At each site, water temperature and electrical conductivity were measured using an Extech EC400 meter (FLIR Commercial Systems, Nashua, NH). Flow rate was calculated by measuring the time to fill a liter bottle. Water samples for dissolved ion analysis were collected in 125 mL acid-washed, low-density polyethylene (LDPE) bottles that were rinsed three times with the sample water before collection. Samples for fecal coliform analysis were collected in sanitized 1 L LDPE bottles. All samples were placed in a cooler during transportation back to the lab where they were stored in a refrigerator until analysis.

Dissolved Ions

All samples were analyzed for common anions (chloride, nitrite, nitrate, phosphate, and sulfate) using a Dionex ICS-900 ion chromatograph at Ithaca College. Analytical methods are based on Pfaff et al. (1997). Samples from four of the springs were analyzed at Cornell University for common dissolved metals (Ca, Mg, Na, K, and Si) using inductively-coupled plasma optical emission spectroscopy. A deionized water blank was included in the analyses for quality control.

Bacteria Testing

Total coliform screening tests were conducted throughout the test period using Lamotte 5850 water test kits (Chestertown, MD). Glass vials with growth media tablets were filled onsite and incubated in the lab for 48 hours, after which they were interpreted as either positive or negative. We did not clean or sanitize the supply pipe which could result in a positive total coliform test from the supply pipe and not necessarily from the environment upstream from the pipe. Quantitative fecal coliform testing was conducted at Lisle and Slaterville from 2016-2019 and at the other sites from 2017-2019. Water samples for fecal coliform testing were analyzed within 24 hours of collection. Each sample was measured in triplicate using a membrane filtration technique (USEPA 2002) in which an aliquot of 100-300 mL of water was passed through a sterile 45 micrometer membrane under vacuum. Filter membranes were placed in sterile petri dishes on an absorbent pad that had been saturated with 2.2 mL of m-FC agar growth media. All petri dishes were incubated for 24 hours at 44.5 (±0.2)°C. After the incubation period, fecal coliform colonies were counted and reported as colony forming units (CFU) per 100 mL. Two times during summer 2019, sites that tested positive for fecal coliform bacteria were further tested for *Escherichia coli* (*E. coli*) using the same membrane filtration technique and m-ColiBlue24 (Hach) growth media and incubated at 35°C.

User Perceptions and Data

To assess the reasons why people use the springs and to gather relevant information, a sheltered box with a voluntary questionnaire was placed at Slaterville and Lisle springs in September 2015, for two weeks each. The questionnaire (Table 1) was printed on cards and participants placed the completed card in a locked collection box. The survey plan was accepted by the Ithaca College Institutional Review Board (#0216-11).

Results and Discussion

Springs are generally described as locations where groundwater discharges at the ground surface and they can be classified into several types (Kresic 2010). Slaterville is the only location in this study that is a flowing artesian well. The other sites can be classified as gravity springs or seeps at the base of hills composed of unconsolidated glacial sediments. Given their proximity to the land surface, the water from these springs likely originates in shallow, unconfined aquifers. These differences can lead to variations in the water chemistry, presence of bacteria, and ultimately the potential threat to consumers.

Spring Water Chemistry

Table 2 summarizes the range of values from the detected dissolved ions samples (a complete dataset of all the measurements is available from the corresponding author). Nitrite and phosphate were not detected in any of the samples. The composition of the artesian Slaterville spring is within the range reported in Miller (2009) and has a relatively low dissolved concentration. All locations varied in terms of dissolved load composition relative to one another. The springs with the highest dissolved concentrations, including sodium and chloride, are Reservation and Nichols. These sites are in the Tully Valley, an area known for mudboils that can contain brackish water likely derived from the salt layers in the regional bedrock (Kappel et al. 1996). At these two sites chloride can vary widely over time, but it is not clear if the source is from road salt or derived from the brackish water.

Nitrate is very soluble and tends to be the dominant form of nitrogen in water. As a result, it can move quickly into surface runoff and percolate into groundwater. Nitrate can occur naturally in water from wildlife, the decomposition of organic matter, and atmospheric deposition. As water passes through the subsoil, nitrate tends to

Table 1. User survey questions and answer options from 199 respondents in September 2015.

Question 1	**Question 4**
How often do you collect water here?	**Does your home have municipal water or well?**
This is my first time coming here	I have municipal water
I come here every so often, a few times a month	I have a well, which supplies my water
I frequently fill up here, multiple times a week	Other
Question 2	**Question 5**
What do you use this spring water for?	**How much do you normally collect here?**
Drinking	Usually only a water bottle full
Household use	1-3 gallons
Storage or surplus water	3-5 gallons
Question 3	5-10 gallons
How far do you travel to get here?	10+ gallons
Less than 2-3 miles	**Question 6**
More than 3 miles	**Is this your primary source of drinking water?**
How many miles or minutes?	Yes
	No

Table 2. Minimum and maximum values of discharge, temperature, and measured dissolved components spring data.

Location	Discharge (lpm)	Temp (°C)	Cl^-	NO_3^--N	SO_4^{2-}	Na	K	Mg	Ca	Si
Lisle	32-48	7.2-15	7.4-11.3	5.3-3.4	9.8-13	4.4-4.9	0.6-0.7	12-13	69-84	3.6-4.4
DiRisio	3.7-14	9.2-15.4	1.6-12	1.2-2	5.4-33	NA	NA	NA	NA	NA
Reservation	15-25	8.7-13.5	112-205	2.4-1.3	26-31	113-123	1.5-1.6	23-24	109-112	4.1
Whiskey Hollow	15-17	9.4-14.7	3.7-11	2.1-2.9	15-31	NA	NA	NA	NA	NA
Nichols Rd	17-28	9.3-16	33-235	1.3-1.9	10-33	25-28	1.5-1.6	21-22	104-107	3.4-3.5
Texas Holl.	6.2-20	8-18	0.7-1.8	0.1-0.2	11-17	NA	NA	NA	NA	NA
Slaterville	2.9-4.6	7-18	1.7-3.4	BDL	15-21	5.5-6.3	0-0.7	6.2-7.0	36-44	6.2-7.4

BDL= below detection limit; NA = not analyzed.

attenuate through denitrification processes (Rivett et al. 2008; Huno et al. 2018). Excess nitrate in water is that which is above background levels due to human activities. The dominant sources of excess nitrate in groundwater are agricultural activities, such as the application of synthetic fertilizers (e.g., ammonium nitrate), and animal manure (Puckett 1994; Nolan et al. 1997; Di and Cameron 2002; Williams et al. 2015). Domestic wells in agricultural areas tend to have higher nitrate concentrations compared to public supply wells and surface water (Mueller and Helsel 1996). Shallow groundwater beneath agricultural areas has higher nitrate concentrations compared to deeper aquifers away from agricultural areas (Burow et al. 2010).

In order to evaluate if the nitrate levels in the roadside springs are in excess of background levels, a threshold needs to be established. The median value for nitrate as nitrogen (NO_3-N) in central New York State groundwater is 0.32 mg/l (Reddy 2014), but this can represent water taken from deeper wells and/or confined aquifers and may not represent background levels for shallow springs. Panno et al. (2006) proposed a nitrate threshold for spring water to be 2.5 mg/l NO_3-N, and that anything above that can be attributed to anthropogenic input. Using this threshold, the Lisle spring consistently shows anthropogenic nitrate input and this is most likely due to the animal operation and agricultural fields uphill from the site. Whiskey Hollow also registered two of four measurements at or above 2.5 mg/l NO_3-N and the agricultural fields ~500 m uphill from the spring could be the source of this. The other sites did not have nitrate levels above the background threshold. The lack of measurable nitrate at the Slaterville artesian spring could be attributed to the confining layer of clay and silt that would prohibit the percolation of nitrate from nearby agricultural fields and septic systems (Miller 2009) or it could be due to denitrification in the low oxygen conditions of the deeper aquifer.

When compared to the United States Environmental Protection Agency's (USEPA) Maximum Contaminant Levels (MCLs) (USEPA 2018) for drinking water, none of the measured dissolved constituents exceeds the standards, including the nitrate concentrations at Lisle and Whiskey Hollow, which are below the 10 mg/l MCL. The Tully Valley springs (Nichols and Reservation) have maximum chloride concentrations of 235 and 205 mg/l, respectively, which approaches the chloride MCL of 250 mg/l. The previously published manganese level at Slaterville of 0.183 mg/l (Miller 2009) exceeds the USEPA secondary drinking water standard of 0.05 mg/l – this can affect taste and color but does not pose a human health hazard at these levels. Manganese is common in groundwater and almost 7% of samples from principal U.S. aquifers have concentrations exceeding 300 mg/l (DeSimone et al. 2015). Unfortunately, we did not have the resources to determine manganese concentrations of the spring water.

Bacteria and Pathogenic Organisms

Pathogenic micro-organisms in groundwater lead to millions of people globally becoming ill every year (Murphy et al. 2017). These pathogens include viruses, bacteria, and protozoans such as *Cryptosporidium parvum* and *Giardia*. Therefore, untreated natural springs pose a potential hazard, as evident from the 2009 outbreak of *Giardia duodenalis* in Rensselaer County (New York) (Bedard et al. 2016). Testing water for the presence of viruses and protozoans can be time consuming and expensive, but testing for bacteria is relatively easy. While many bacteria do not pose a threat to human health, the USEPA considers coliform bacteria to be a useful indicator organism for the presence of other pathogens.

There are a broad range of coliform bacteria types found in soil and in the gastrointestinal systems of organisms. All the springs in this study were tested often for total coliform bacteria (summarized in Figure 2) and all sites at some point had a positive result. The Slaterville spring only had one positive test (September 2018) out of a total of 23 over a four-year span and this coincided with 12.6 cm of rainfall in the area from the remnants of Hurricane Florence – the average amount for the entire month is 9.4 cm (Northeast Regional Climate Center 2020). The excess precipitation may have led to surface or near-surface water infiltrating the well casing. The MCL for total coliforms is no more than 5% samples positive in a month (USEPA 2018) but this is not relevant, considering that we generally did not test multiple times in any given month. The exception is the Lisle spring, tested four times in November of 2015, where 75% of the samples were positive for total coliform.

Fecal coliform bacteria are a subgroup of coliform bacteria that specifically reside in the gastrointestinal systems of warm-blooded animals. Federal guidelines mandate that no fecal coliform bacteria be present in municipal drinking water (USEPA 2018). Table 3 shows the results of the quantitative fecal coliform testing. The one time that the Slaterville spring tested positive for total coliform, it also tested positive for fecal coliform bacteria, although at a relatively low 2.3 CFU/100 mL. All other sites, with the exception of the Reservation spring, at some point tested positive for fecal coliform and failed to meet federal drinking water standards. *E. coli* is the most common fecal coliform bacteria and, although most *E. coli* strains are non-pathogenic, some strains, such as *E. coli* O157:H7, pose a serious health risk to humans (Jamieson et al. 2002). The sites were tested twice (June and July 2019) for *E. coli*: Nichols tested positive once and Texas Hollow tested positive both times. The low nitrate at Texas Hollow suggests little input from the nearby agricultural operation and the contamination from fecal bacteria is more likely from where the water flows about 10 m across the land surface before entering the supply pipe.

Our bacteria results are similar to the findings of two other studies of roadside springs. Testing of 21 springs in five Appalachian states (Virginia, West Virginia, North Carolina, Kentucky, and Tennessee) (Krometis et al. 2019) found that 99% of the sites

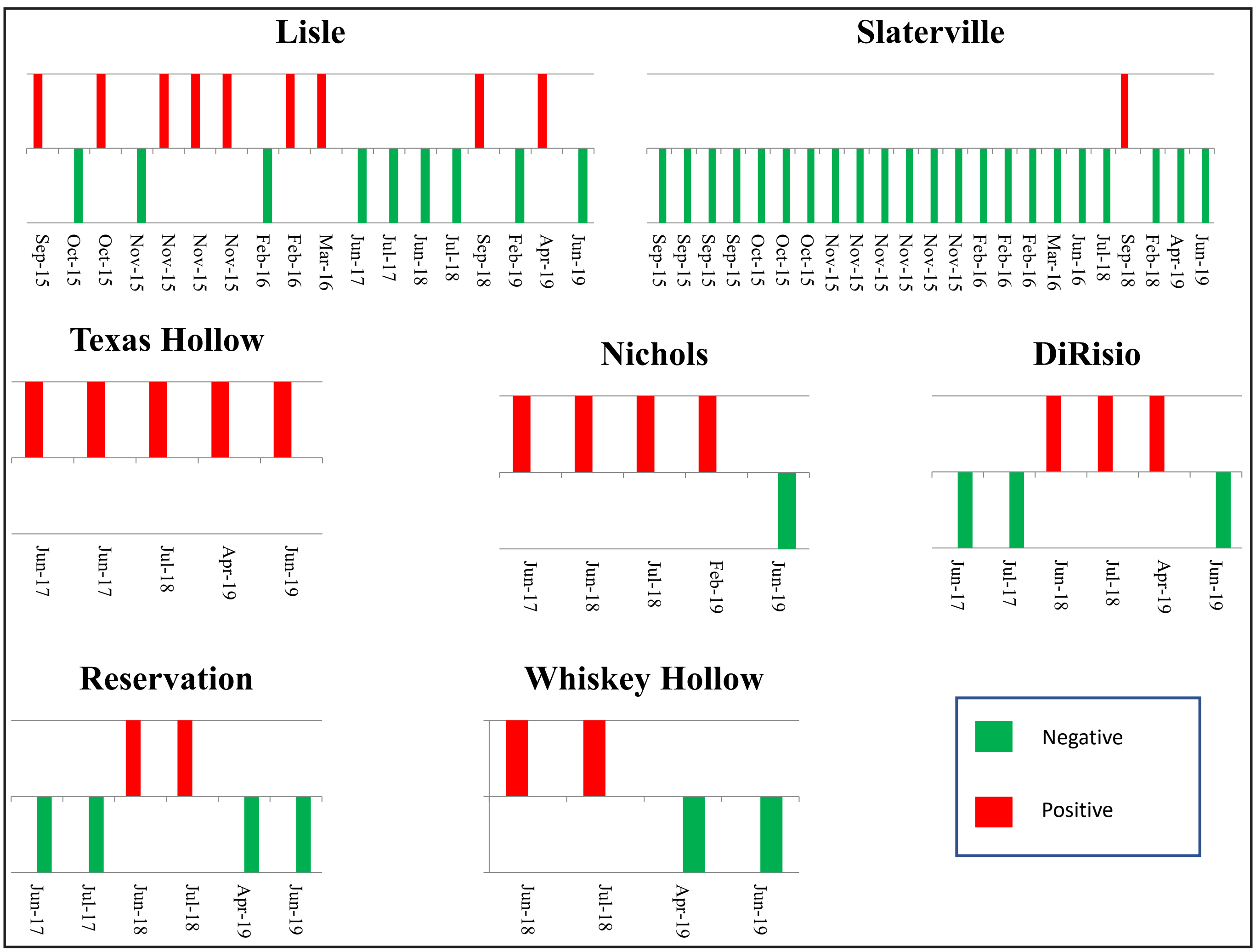

Figure 2. Compilation of the total coliform testing for the roadside springs in central New York. Red lines are positive (bacteria present) and green are negative (no bacteria present).

tested positive for total coliform bacteria and 81% of the sites tested positive for *E. coli* at least once. Swistock et al. (2015) found that 90% of the 37 roadside springs tested in Pennsylvania in 2013-2014 failed one or more health-based drinking water standards. The following year, testing of ten of those Pennsylvania springs detected bacteria, as well as the presence of both *Giardia* and *Cryptosporidium* cysts. While we did not test for any other pathogenic micro-organisms, a user of a spring in our study did contact the authors (through our informational website) to ask about *Cryptosporidium* testing because they had been diagnosed with it. Of course, this does not prove that the spring was the source of the infection, but it does indicate that testing of other pathogens at our sites may be warranted.

The combined results of our study and those referenced above demonstrate that 90% or more of roadside springs contain pathogenic micro-organisms, which is much higher than the 15% of household groundwater wells in the U.S. and Canada (Hynds et al. 2014). While there is the potential that a positive total coliform test was from the unsanitized supply pipe, the presence of fecal coliform bacteria means that the water has been contaminated by feces of warm-blooded organisms. It is generally accepted that as water passes through subsoil and into deeper strata, there is a natural attenuation of micro-organisms. Determining the survival and transport of enteric organisms such as fecal coliform bacteria into and through surface and groundwater is complex and beyond the scope of this project – the reader is referred to several papers that review this topic (e.g., Jamieson et al. 2002; John and Rose 2005; Bradford et al. 2013). Fecal coliform bacteria can come from natural organisms but can also be introduced into groundwater through agricultural practices, such as the application of animal manure to fields (Oun et al. 2014), or from residential septic systems (Lusk et al. 2017). The apparent susceptibility of the roadside springs to microbial contamination could be attributed to the water coming from shallow, unconfined aquifers or, in the case of Texas Hollow, water that has been in contact with the ground surface. Depending on the local geology, well water tends to come from deeper sources with lower susceptibility to pathogens.

User Survey

The survey resulted in 78 responses from Slaterville springs and 121 responses from Lisle (summarized in Figure 3). All respondents said that they use spring water for drinking. Almost all respondents (>96%) were regular visitors to both sites, and the proportion that visited at least weekly was 31% for Lisle and 49% for Slaterville springs.

Table 3. Fecal coliform results (colony forming units per 100 ml).

Date	Lisle	DiRisio	Whiskey Hollow	Texas Hollow	Nichols	Reservation	Slaterville
10/4/16	5.3						
11/17/16	4.8						
6/1/17				63			
6/29/18		15.5	44.6				
7/14/18		ND	ND		35	ND	
8/21/18	2.7	ND	3.8	25.5	ND		
9/30/18							2.3
4/21/19	ND	2	ND		13.4	ND	ND
6/19/19	ND	ND	ND	5.5	ND	ND	ND
7/11/19	ND	11.7	ND	27	ND	ND	ND

Values represent the average of the three replicate analyses for each date. ND = not detected.

The amount of water collected differed between the two sites, with 44% collecting 10 or more gallons per visit at Lisle compared to 8% at Slaterville. Anecdotally, this is reflected in the observation by the authors that visitors at Lisle often had five-gallon carboys. This difference could be due in part to the relatively lower discharge rate at Slaterville of 2.9-4.6 liters per minute (lpm) compared to Lisle with 32-48 lpm; a five-gallon carboy would take about 30 seconds to fill at Lisle.

The majority of respondents (62% at Lisle and 81% at Slaterville) also claimed that the springs were their primary source of drinking water. A little more than half of all respondents had a well at their home and 31-44% had municipal tap water. We were interested in how far users traveled to gather water from the springs, and the combined surveys from both Slaterville and Lisle indicated that 83% of respondents live more than three miles from the springs. We filtered out the surveys from people that had visited for the first time or that visited only occasionally, and we found that some regular (weekly) users traveled up to 30 miles each way. As an example, one user who lives 20 miles away and collects 40 gallons several times per week stated that "all water in the house must come from here."

Most of the respondents wrote comments to explain why they collect water at the spring. A common theme was that the spring water tastes good and their water at home does not – either because of a well with a sulfurous smell or the chlorine used to disinfect municipal water. Some representative comments were:

- *My water has iron - doesn't taste great, leaves stains.*
- *I live half a mile from here and have a spring in my front yard. However, my water tends towards sulfur. I think water should be free and people need to stop buying plastic water bottles.*
- *I trust it. I like it. Feels right.*

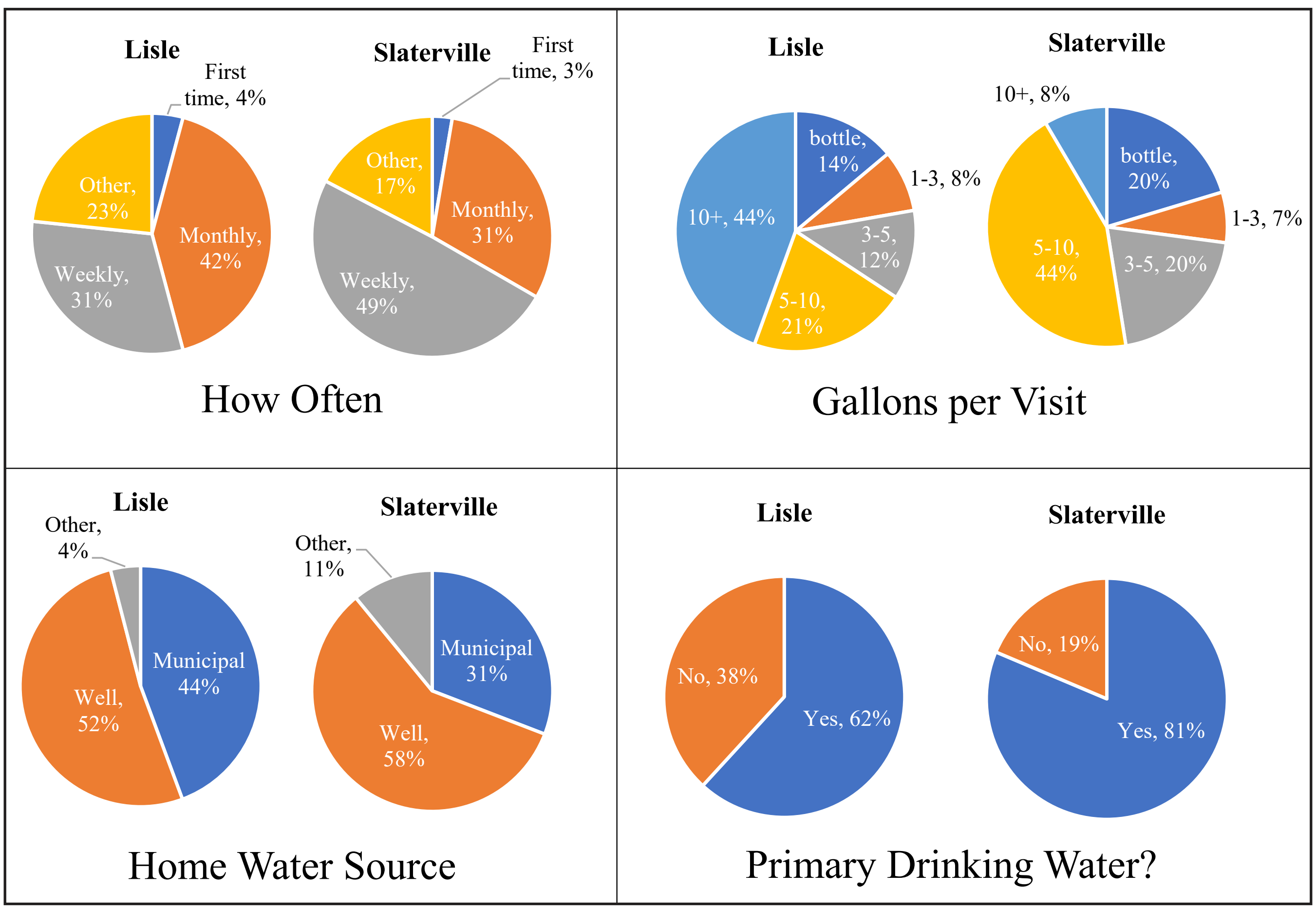

Figure 3. Results from the 2015 user survey from the Lisle and Slaterville springs.

- *So delicious, no odor, no chemicals and smells and horrible taste like the Ithaca city water that comes out of my tap.*
- *It's pure spring water clean and I do not trust any other municipal or urban source!*
- *I have been stopping here for over 50 years. Special ritual, nostalgia. I would stop here on the way to my grandmother's house as a kid.*

Our survey results are similar to the few other published studies on this topic. In the survey of the Appalachian region, Krometis et al. (2019) reported that the majority of respondents said that taste was a primary reason to collect spring water (66%) and that "quality/health" was a motivating factor. Similar to our observations, respondents in that study did not trust their water at home. A survey of roadside spring users in Indiana (Westhues 2017) reported that users generally considered spring water as "pure, natural, and good for those who consume it." Westhues (2017) further found that some water users considered any additions from natural sources preferable to elements added to municipal tap water. A survey of over 1,000 Pennsylvania residents (Swistock et al. 2015) found that 30% had consumed water from a roadside spring and 12% consumed water every year from a roadside spring, mostly because of the taste and perception that it is natural.

Some of the comments from our survey indicate that those on well water have problems with organoleptic and aesthetic properties, such as hydrogen sulfide (rotten egg) odors or staining from iron. Patton et al. (2020) surveyed homeowners near roadside springs in three Appalachian states (Kentucky, Virginia, and West Virginia) with in-home well water, and reported that over 80% of those surveyed did not trust their tap water for aesthetic reasons. The aesthetic properties of the water from the springs in our study are excellent: the water is clear, cold, and has no undesirable taste or odor. One can understand why the users with poor-quality well water would choose the springs if their decisions are based on taste, smell, and appearance. With the exception of the Slaterville artesian well, the water from the roadside springs in this study comes from near-surface, unconfined aquifers that have low turbidity because of the filtering of suspended sediment during the recharge process as surface water passes through soil and subsoil. In addition, we would not expect that this water had a long residence time in the aquifer compared to the artesian well water. A longer residence time in a confined, low oxygen aquifer could lead to higher dissolved metals and microbial generation of hydrogen sulfide. However, the shallow aquifers can have pathogenic micro-organisms and their presence has no effect on the organoleptic properties of spring water.

The users that have tap water from a regulated municipal water system appear to have slightly different reasons for drinking spring water. These center on a general lack of trust of municipal water and/or a dislike of the taste and smell of chlorine added for disinfection. Perceptions of water quality from treated municipal water sources are complex. They are commonly influenced by properties such as taste and odor but can also be a function of race, culture, income, and education level (Doria 2010; Pierce and Gonzalez 2017; Javidi and Pierce 2018; Weisner et al. 2020). We did not gather the demographic data necessary to assess the role of these variables, but we do suggest that this should be included in any future work.

Conclusions

Our study of seven roadside springs from 2015-2019 in central New York State demonstrated that each spring has its own hydrological and geochemical characteristics. In general, the chemistry of the water did not vary much at a given site and none of the dissolved species we measured exceeded federal municipal drinking water health standards. However, the presence of fecal bacteria was detected at all but one of the springs, which exceeds the drinking water standards and could signify the presence of other pathogenic micro-organisms. With the exception of the one artesian well at Slaterville, the other springs appear to be fed by shallow, unconfined aquifers that may be susceptible to contamination from nearby agricultural fields and domestic septic systems that are not readily apparent from the spring water collection outlet. The survey of water users showed that over 70% of respondents use the springs multiple times per month for drinking water and the majority collect more than five gallons per visit. More than 80% of the users live more than three miles from the springs and a recurring reason for drinking the spring water is that the taste is better than the water available at their homes. Taken together, our survey results combined with the other studies indicate that the choice to use roadside springs comes from several factors, dominated by the organoleptic and aesthetic factors (taste, smell, and color) as well as mistrust of well water and municipal tap water.

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