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Issues Associated with the Use of Untreated Roadside Springs as a Source of Drinking Water

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Abstract: Roadside springs are prevalent across Pennsylvania, but little information has been available about their public use or their suitability as a drinking water source. Penn State Extension conducted research to document roadside spring use and drinking water quality between 2013 and 2015. A survey of over 1,000 Pennsylvania residents found that 30% have consumed water from a roadside spring and 12% consume water every year, mostly because they perceive the water as natural with a good taste. A synoptic survey of 37 springs in 2013-2014 found that more than 90% failed one or more health-based drinking water standards. A more intensive follow-up study in 2014-2015 on ten of the 37 roadside springs found that they consistently failed drinking water standards throughout the year, including some presence of both *Giardia* and *Cryptosporidium* cysts. Total coliform bacteria were found to be a better indicator of the overall microbiological drinking water safety of these springs than *Escherichia coli* bacteria when only a single sample is collected. The frequent use of roadside springs along with poor drinking water quality represent a significant health risk that needs to be addressed in public health education programs.

Keywords: *groundwater, education, bacteria, Giardia, Cryptosporidium*

Groundwater springs are common across Pennsylvania accounting for more than 20% of the private household drinking water supplies in many northern and western counties of the state (U.S. Census Bureau 1990). Similarly, roadside springs occur frequently along local and state roads where road cuts have intersected shallow groundwater aquifers. Some roadside springs simply include a road pull-off to access a natural spring while others have been extensively improved to include parking lots, plumbing, and detailed stone walls, all to improve public access for collection of spring water.

Studies of roadside springs are generally lacking, but one Pennsylvania study of household springs found that they were much more likely to have bacterial contamination than drilled or dug water wells (Sharpe et al. 1985). A 1990 report by Pennsylvania state government included basic testing of several popular roadside springs in northeastern Pennsylvania (Pennsylvania General Assembly 1990). The cursory study of these springs concluded that roadside springs may not meet state drinking water standards (PA DEP 2006). The report recommended that a detailed inventory and testing of roadside springs was needed along with educational efforts to assist in curbing risks associated with consumption of drinking water from these unprotected water supplies. Many municipalities and other owners of road right-of-ways responded by installing signs at road springs warning of their unsafe drinking water, but most signs have been defaced or destroyed by visitors to the springs.

In recent years, Penn State Extension water resources specialists have experienced an increased number of referrals from physicians with patients using home or roadside springs. These patients reportedly experienced various gastrointestinal illnesses including giardiasis and cryptosporidiosis. Data from the Pennsylvania Department of Health (2013) also reported that

giardiasis is most prevalent in many of the same counties where household springs are most common (U.S. Census Bureau 1990).

Little research has been done on roadside springs because they are unregulated drinking water sources and their public use is poorly understood. More data on the use of roadside springs along with more detailed water quality data are needed to better quantify the health risks associated with these water supplies and target public education efforts.

Penn State Extension developed a roadside spring project from 2013 to 2015 to gather additional information about roadside springs. The focus of the project was to quantify the following:

1) Drinking water quality from many roadside springs across the state.
2) The approximate public drinking water use of roadside springs.
3) Public awareness about the risks associated with consuming water from untreated roadside springs.

Methods

Statewide Roadside Spring Testing

Between April 2013 and May 2014, seven Penn State Extension water resources specialists collected single water samples from 37 roadside springs located in 21 counties across Pennsylvania (Figure 1). The spring locations were focused in western and northern Pennsylvania where trained water resources Extension educators are located and where the density of springs is highest. Project staff also took photos of each spring and noted if other people were present collecting drinking water from each spring. These 37 roadside springs were selected based on recommendations from district offices of the Pennsylvania Department of Transportation and various local government officials who own and maintain road right-of-ways.

Water samples were collected and transported on ice to the Penn State Agricultural Analytical Services Laboratory within 24 hours as required for testing. Eighteen parameters were analyzed including total coliform bacteria, *E. coli* bacteria, pH, total dissolved solids (TDS), nitrate-nitrogen, aluminum, arsenic, barium, copper, lead, iron, manganese, sulfate, chloride, alkalinity, corrosivity index (LSI), total suspended solids (TSS), and hardness using standard methods (APHA, AWWA, WEF 1998). The Penn State water laboratory is accredited by the Pennsylvania Department of Environmental Protection. Sample results below detection limits were converted to 50% of the detection limit for statistical analyses. Bacteria results above the maximum detection limit of 201 colonies per 100 mL were reported as 201 colonies.

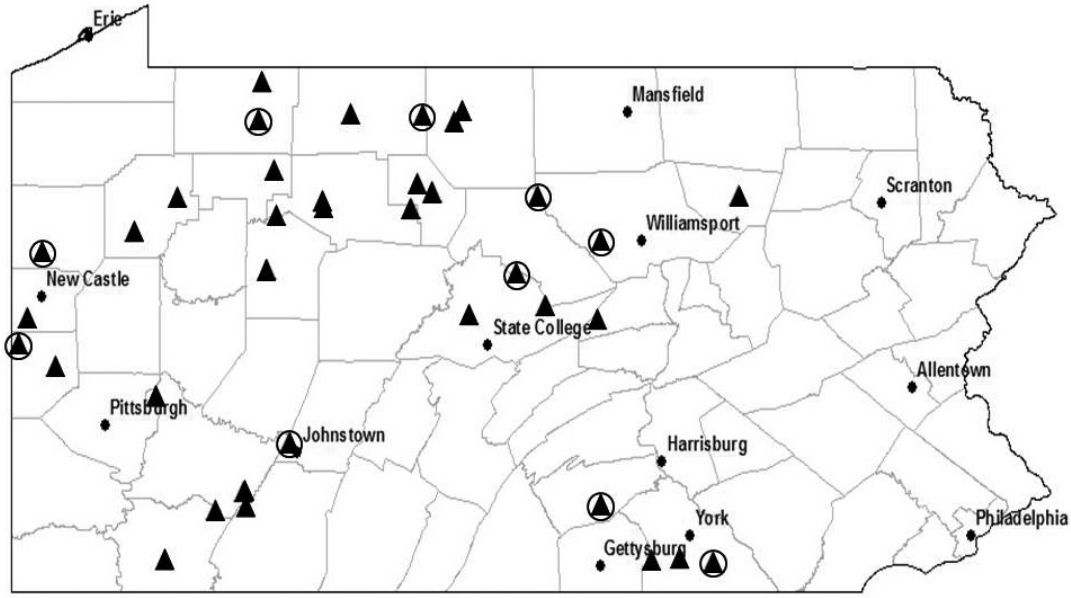

Figure 1. Location of the 37 roadside springs sampled once in 2013-2014 (all triangles) and the ten springs that were selected for additional seasonal sampling in 2014-15 (circled triangles).

Seasonal Roadside Spring Testing

The initial testing identified 12 (32%) of the 37 roadside springs that represented an especially large risk due to the presence of *E. coli* bacteria. From these 12 springs, ten that were most convenient for project staff to sample were selected for more detailed testing between June 2014 and March 2015. The locations of these ten springs are denoted in Figure 1.

Each of these springs were visited by the project staff in June 2014, September 2014, December 2014, and March 2015 to collect water quality samples. All samples were kept on ice and transported to the Penn State Agricultural Analytical Laboratory within 24 hours of collection for analysis of the same chemical and microbiological parameters that were completed in the initial survey. During each sample collection visit, project personnel documented the flow of each roadside spring in gallons per minute (gpm) by measuring the number of minutes required to fill a two to five gallon bucket. The number of visitors collecting drinking water (if any), was also noted during each site visit.

During the March 2015 sample collection visit, an additional sample was collected from eight of the springs for analysis of protozoan (*Giardia* and *Cryptosporidium*) cysts or oocysts. Only eight springs were included in this testing due to cost limitations. These same eight springs were also tested for protozoan cysts in October 2014, but no other water chemistry samples were collected at that time. March and October were selected for protozoan testing to include the typically wettest and driest seasons of the year in Pennsylvania. Samples for cyst enumeration were collected into 10 liter cubitainers and shipped overnight on ice to the Analytical Services laboratory in Williston, Vermont. *Giardia* and *Cryptosporidium* were quantified in each sample using EPA Method 1623.1. This testing included one matrix spike sample for each water sample collected from a source. *Giardia* and *Cryptosporidium* results were reported in cysts or oocysts per liter.

Roadside Spring Use Survey

Several anonymous survey questions were added to standard evaluations used at various Penn State Extension educational workshops and displays at events in 2014 and 2015 to estimate the statewide use of roadside springs. These workshops focused on rural drinking water, pond management, stormwater, pesticide certification, irrigation management, groundwater education, gardening, or other topics. Attendees were asked two questions including their frequency of roadside spring use and their reasons for using water from roadside springs. Most responses were collected informally using remote electronic response cards incorporated into PowerPoint presentations, or on paper slips.

Public Outreach

Given the extent of public use of roadside springs, public outreach and extension were an important outcome of this research. Results from the study were compiled into research reports as well as a short fact sheet for distribution to the public at Extension events and through websites. News releases were also prepared for written, online and media outlets. The project investigators presented results from this study at a variety of Penn State Extension water resources workshops, webinars, and events across the state. A short post-program evaluation was provided to all attendees to determine if they learned new information about roadside springs and if they intended on taking actions such as testing of roadside springs or avoiding their use for drinking water. Public outreach did not include the installation of signs at roadside springs due to the past experience with the destruction or removal of signs noted by other agencies and municipalities controlling access to roadside spring sites.

Results and Discussion

Statewide Roadside Spring Testing

Water quality in the 37 springs was typical of shallow groundwater in Pennsylvania, characterized by slightly acidic and soft water with low concentrations of most chemical constituents (Table 1). The major aesthetic issue for most springs was corrosive water and low pH which exceeded drinking water standards in 89% and 40%, respectively, of the roadside springs. These would only be a concern if the water was improperly stored in a container capable of

dissolution by corrosive water. Concentrations of other aesthetic pollutants like iron, manganese, sulfate, and chloride were very low in most springs (Table 1) and only rarely exceeded drinking water standards (Figure 2) which would explain the public perception of good tasting water.

Nearly all of the springs contained levels of total coliform bacteria above the health-based safe drinking water standard and 34% contained unsafe levels of *E. coli* bacteria indicating fecal sources of contamination (Figure 2). One spring also contained unsafe levels of lead which may have resulted from corrosion of a metal pipe installed to assist with collection of water. Concentrations of nitrate-N, arsenic, barium and copper were all very low (Table 1) and no springs exceeded safe drinking water standards for these parameters (Figure 2).

Use of Roadside Springs

Public use of many roadside springs was apparent during the initial visits to the 37 springs in 2013. People were found collecting drinking water from 10 of the 37 springs (27%) when project staff randomly visited the springs to collect initial water quality samples. The informal survey of attendees at educational workshops provided better information on the overall use of roadside springs.

A total of 1,035 attendees at 56 Penn State Extension workshops in 2014-2015 were asked the two questions about their use of roadside springs. Responses were distributed across the state including northcentral (312), northeast (173), northwest (41), southcentral (287), southeast (156), and southwest (66).

Overall, 30% of the respondents indicated that they had consumed water from a roadside

Table 1. Water quality statistics from 37 roadside springs in Pennsylvania (2013-2014). All results are in mg/L except bacteria (colonies per 100 mL), pH, and corrosivity (LSI index).

Parameter	Mean	Standard Deviation	Minimum	Maximum	MCL*	Type of MCL
Coliform bacteria	83.5	14.2	<1	>201	<1	Health
E. coli bacteria	7.8	5.7	<1	>201	<1	Health
Arsenic	<0.003	0	<0.003	<0.003	<0.010	Health
Barium	0.0297	0.0035	0.0069	0.0858	<2.0	Health
Lead	0.0034	0.0019	<0.003	0.0678	<0.015	Health
Nitrate-N	0.81	0.24	<0.50	6.168	<10.0	Health
Copper	0.0030	0.0004	<0.005	0.0120	<1.0	Health
pH	6.78	0.14	5.06	7.88	6.5 to 8.5	Aesthetic
TDS	102.2	30.5	20	866	<500	Aesthetic
Chloride	13.6	6.9	<5.0	239.9	<250	Aesthetic
Sulfate	21.1	8.5	0.451	292.1	<250	Aesthetic
Iron	0.045	0.014	<0.05	0.416	<0.30	Aesthetic
Manganese	0.011	0.003	<0.001	0.101	<0.05	Aesthetic
Corrosivity	-2.39	0.28	-5.46	0.98	Non-corrosive	Aesthetic
Aluminum	0.03	0.01	<0.01	0.22	<0.20	Aesthetic
Alkalinity	42.1	11.2	1.9	263.4	-	None
TSS	0.70	0.19	0	4	-	None
Hardness	63.5	21.9	5.2	663.7	-	None

*Maximum Contaminant Level (MCL) = state drinking water standard (PA DEP, 2006). Aesthetic standards are set for taste, smell, staining, residues, corrosion, etc.

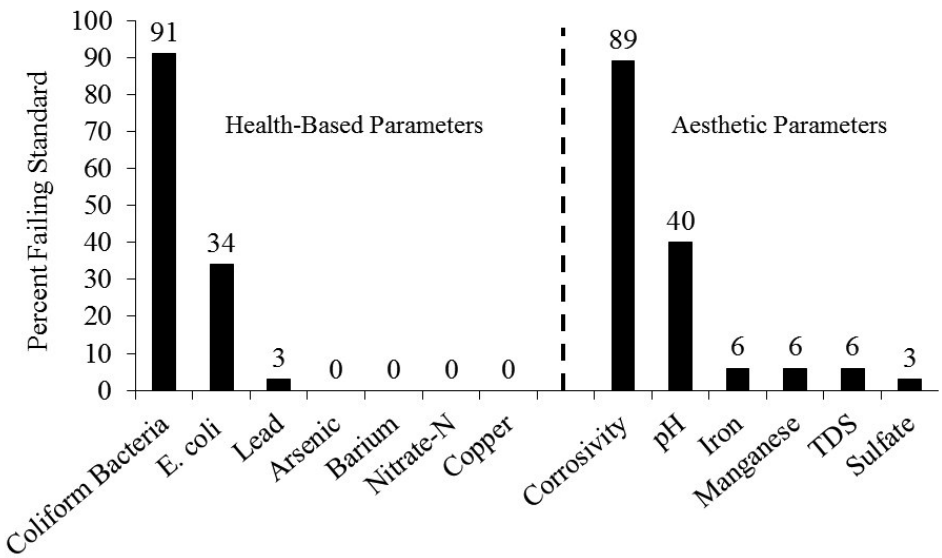

Figure 2. Percent of 37 roadside springs that failed to meet various health-based and aesthetic drinking water standards.

spring at least once in their lifetime, while 69% had never consumed roadside spring water. The remaining 1% gave no response. Of the 30% who had consumed roadside spring water, 18% collected water infrequently (12% every few years, 6% annually), while 12% collected spring water regularly (4% every few months, 5% monthly and 3% weekly).

The most common reasons for consuming water from roadside springs cited by respondents were the perceived "natural" condition of the water (42%) and the good taste of the water (41%). Other reasons for using roadside spring water included the proximity of a spring to a camp or seasonal home (20%), the overall convenience of accessing a roadside spring (12%), and as a replacement for their contaminated home drinking water (10%). An additional 15% of respondents indicated "other" uses for roadside spring water including water for household or garden plants, water for aquariums, and drinking water while hiking or biking.

Seasonal Roadside Spring Testing

Seasonal water quality among the ten roadside springs was consistent (Table 2) and agreed with the overall data from the larger set of 37 springs tested in 2013 (Table 1). Stable water quality across seasons agreed with the relatively constant flows which were typically less than 10 gpm in each spring (Table 2). More importantly, the safety of roadside springs as drinking water sources was found to be consistently poor across all four sampling periods as evidenced by the percent that exceeded various drinking water standards (Table 2). Coliform bacteria and *E. coli* bacteria were the most prevalent drinking water problems found in the springs. Higher bacteria concentrations were generally observed in March and June, presumably due to wetter and warmer conditions promoting surface water infiltration into roadside springs. Counts of coliform bacteria in roadside springs were highest in June 2014, then declined though fall and winter before beginning to increase again in March 2015.

Results from the two samples collected in October 2014 and March 2015 from eight of the roadside springs for enumeration of protozoan cysts are shown in Table 3. Seven of the eight springs (88%) contained *Giardia* cysts or *Cryptosporidium* oocysts during one or both of the sample times, but the concentrations of cysts were generally low (below 10 per liter). It is important to note that the presence of *Giardia* cysts and *Cryptosporidium* oocysts reported may overestimate the general occurrence in most roadside springs since these sites were specifically selected for testing based on the prior occurrence of *E. coli* bacteria. Data analysis shows that the hypothesis that *E. coli* bacteria may indicate a higher risk of protozoan parasites in roadside springs is questionable.

Table 2. Mean water quality concentrations in ten roadside springs in each season. All results are in mg/L except flow (gallons per minute), bacteria (colonies per 100 mL), pH, and corrosivity (LSI index). Percentages indicate the percent of springs that failed drinking water standards where applicable.

Parameter	June 2014	September 2014	December 2014	March 2015
Flow (gpm)	9.5	3.4	5.3	10.4
Coliform bacteria	>201 (100%)	169 (100%)	87 (100%)	110 (100%)
E. coli bacteria	20 (50%)	19 (50%)	1 (30%)	5 (40%)
Arsenic	<0.003	<0.003	<0.003	<0.003
Barium	0.018	0.018	0.016	0.017
Lead	0.002	0.001	0.001	0.001
Nitrate-N	0.91	0.77	0.93	0.95
Copper	<0.005	<0.005	<0.005	<0.005
pH	6.85 (20%)	7.12 (10%)	6.99 (30%)	7.14 (10%)
TDS	117 (10%)	144 (10%)	125 (10%)	118 (10%)
Chloride	11.4	12.2	10.8	10.8
Sulfate	39.7 (10%)	48.1 (10%)	44.8 (10%)	35.3 (10%)
Iron	0.10 (10%)	0.07 (10%)	0.08 (10%)	0.10 (10%)
Manganese	0.003	0.003	0.003	0.003
Corrosivity	-2.2 (80%)	-1.74 (80%)	-1.97 (80%)	-1.82 (80%)
Aluminum	0.05	0.03	0.04	0.10 (20%)
Alkalinity	43	54	50	44
TSS	2	1	2.1	1.7
Hardness	83	102	94	76

Coliform and *E. coli* bacteria results from the March 2015 sample were compared since they were collected at the same time as the March protozoan samples. While coliform bacteria were present in all samples in large numbers and were generally higher in springs that contained protozoan cysts, *E. coli* bacteria were absent from several springs that contained protozoan oocysts (Table 3). Conversely, several springs that had protozoans during both sample time periods did not test positive for *E. coli* bacteria and the one spring that did not have protozoans during either sample period did test positive for *E. coli* bacteria (Table 3). Further comparison of protozoan results to bacteria results from the entire year produced similarly confusing results. The Warren County spring that contained protozoan cysts but no *E. coli* during March 2015 tested positive for *E. coli* in all prior sample periods. However, the Centre County spring which was the only spring to not test positive for protozoans in either sample, tested positive for *E. coli* in 80% of samples from the spring, with values as high as 165 colonies per 100 mL. These results generally agree with Wilkes et al. (2009) who found that relationships between indicator bacteria like *E. coli* and parasite oocysts/cysts were overall weak and site specific.

Water testing for *Giardia* and *Cryptosporidium* is prohibitively expensive for the public making correlations to a less-expensive and widely available water quality indicator critical. While *E. coli* is a good indicator of bacterial safety of drinking water, it appears to be a poor indicator of the presence of protozoan parasites in roadside springs. Coliform bacteria were a stronger indicator of protozoan cyst presence, but these bacteria were also present in significant numbers in all springs. Even though *E. coli* bacteria was a

Table 3. *Giardia* cyst and *Cryptosporidium* oocyst occurrence (cysts or oocysts per L) in samples collected from eight roadside springs in October 2014 and March 2015 in comparison to bacteria concentrations in March 2015.

	October 2014		March 2015			
County Location of Spring	***Giardia***	***Cryptosporidium***	***Giardia***	***Cryptosporidium***	**Coliform bacteria (#/100 mL)**	***E. coli* bacteria (#/100 mL)**
Lycoming	5.28	5.01	0.09	0	62	0
Centre	0	0	0	0	59	5
McKean	0	0	6.49	2.23	>201	0
York	5.7	6.36	0	0	>201	0
Beaver	0	0	6.29	4.26	>201	8
Warren	4.07	4.71	6.75	6.93	50	0
Cambria	6.32	6.05	0	0	32	2
Cumberland	0	0	6.82	5.57	>201	0

poor indicator of protozoan cysts in single samples collected in March 2015, more research is needed to determine if springs that never test positive for *E. coli* can still contain protozoan cysts.

Public Outreach

The results from this study have important health implications for residents collecting drinking water from untreated roadside springs. The research results were distilled into a short website and fact sheet (http://extension.psu.edu/natural-resources/water/drinking-water/cisterns-and-springs/roadside-springs) for the public which has had 780 website visits in just four months. Project investigators also presented the research results to 1,619 attendees at 56 different extension programs. Educational programs were also targeted to important stakeholders including township road managers and public health officials. Of the 1,619 total attendees, 887 (55%) participated in a survey and 845 (95%) indicated that they had learned new information about roadside springs. More importantly, 690 (78%) were planning on taking some action to change their use of roadside spring water.

In addition to workshop presentations, project investigators prepared various news releases which were widely carried by newspapers and radio stations across the state. A statewide webinar on the project was also presented live or via recording to 253 participants. The recorded webinar and supporting materials can be viewed at http://extension.psu.edu/natural-resources/water/webinar-series/past-webinars/a-study-of-roadside-springs-in-pennsylvania.

Summary and Conclusions

Results from this study show that roadside springs are a routine source of drinking water for about 10% of the rural Pennsylvania population. Another 20% indicated that they use roadside springs occasionally for drinking water. Consumers of roadside springs most often point to perceived natural pureness and good taste as the main reasons for collecting spring water. While roadside springs generally provided aesthetically pleasing drinking water, nearly all fail health-based drinking water standards and many contain *E. coli* bacteria and/or parasitic *Giardia* cysts and *Cryptosporidium* oocysts. All springs containing parasitic cysts contained at least 32 colonies of total coliform bacteria per 100 mL, but *E. coli* was found to be a poor indicator of the presence of parasitic protozoans when only a single sample is collected. Temporal variations in both *E. coli* and protozoan cyst concentrations in individual springs showed that single instances, where they were absent, did not ensure those organisms are absent year round.

These results suggest that untreated roadside springs can present a significant health risk and

are largely unsuitable as drinking water sources. Total coliform bacteria appear to be the most conservative indicator of drinking water quality in roadside springs. Residents considering the use of a roadside spring for drinking water or other household purposes should, at a minimum, have the water tested through a state accredited laboratory for total coliform bacteria to ensure its safety, bearing in mind that microbial quality varies over time. In addition to bacteria problems, most roadside springs had slightly soft and acidic water, a combination that produces corrosive water that is aggressive toward metals and other materials. Because most roadside springs have very corrosive water, it is critical that this water only be stored in containers approved for drinking water storage.

Given the prevalence and rural location of many roadside springs along with the associated health risks, this project dedicated significant resources to ensure public education including online resources, workshops, and news media. More research and outreach impact analyses are needed in areas of Pennsylvania where roadside springs are commonly used as drinking water sources and structures such as pipes may give the illusion of a safe water supply. The results may be applicable in other states with similar groundwater geology and usage of roadside springs.

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