E. COLI IN FLOWING WATERS

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I. Why is *Escherichia coli* (*E. coli)* being monitored? What is the concern?

Fecal pollution (from excrement of humans or animals) in the environment is of concern for many reasons, not least of which is human health risks and disease control. Other concerns related to fecal pollution of our natural waters include potential changes in the nutrient status of water, introduction of antibiotic resistance and chemical contaminants, changes in the ecological condition of waters, and degradation of natural resources on which rural economies depend.

People are concerned that the land application of swine effluent (pig excrement) will increase *Escherichia coli* in Big Creek and consequently, the Buffalo River, the first National Scenic River in the U.S. This document aims to provide better understanding of

1) what is involved in *E. coli* monitoring;
2) what the numbers mean;
3) some limitations in interpreting values; and
4) provide a context for further research that may be needed to better interpret the *E. coli* numbers being measured in flowing waters such as Big Creek and Buffalo River.

II. What is *E. coli*? Why and how is it used as an indicator?

E. coli is a species of bacteria from the coliform group - bacteria that are rod-shaped, gram negative, non-spore forming facultative anaerobes, commonly found in the feces of humans and warm blooded animals. *E. coli* occurs in human intestines - many strains with no ill effects, although certain *E. coli* cause serious human illnesses. Thus, while many *E. coli* do not harm us, there are important variants that do. There are also other species of bacteria, viruses, and other small organisms that cause disease, which if present in fecal sources polluting our waters, can make humans sick. Depending on whether *E. coli* survive as long in the environment as these other pathogens, *E. coli* may or may not adequately warn us about a disease causing agent in our waters. To date, *E. coli* is the most reliable test we have, although other indicators and tests are being investigated.

E. coli cannot be seen in streams by the human eye. Thus, it is important to determine if there is a problem of elevated *E. coli* numbers by careful water sampling and using U.S. Environmental Protection Agency (EPA) standardized methods. *E. coli* is counted in water because of the extensive studies and relationships established between the presence of *E. coli* and the number of human illnesses occurring from contact with the water (e.g. swimming) containing the bacteria. From these relationships, there have been upper limits established for bacterial numbers that correspond to the acceptable risk of people getting sick from exposure to water containing them.

Water quality standards for *E. coli* are established by the state in Arkansas Department of Environmental Quality (ADEQ) Regulation 2 (see Table 1). The *E. coli* numbers must remain below a threshold in a specified number of total samples collected. The exact upper limit that is allowed depends on the designation of the waterbody and time of year (primary or secondary contact season). *Primary*

Table 1. Upper limits for *Escherichia coli* counts defined in Regulation 2 of the Arkansas Department of Environmental Quality (ADEQ) as specified by contact season and waterbody designation for both single samples and geometric mean.

Contact season	Water designation	Limit of *E. coli* (MPN/100mL)	
		Single sample[1]	Geometric mean[2]
Primary (May 1-Sept. 30)	Extraordinary Resource Water Ecologically Sensitive Waterbody Natural & Scenic Waterway Lakes Reservoirs	298	126
	All other water	410	NA[3]
Secondary (Oct. 1-April 30)	Extraordinary Resource Water Ecologically Sensitive Waterbody Natural & Scenic Waterway Lakes Reservoirs	1490	630
	All other water	2050	NA

[1] No more than 25% of samples from no less than 8 samples per contact season may exceed the limit

[2]Geometric mean is calculated from at least 5 samples collected within 30 days at evenly spaced time intervals during that 30-day period

[3]Not applicable

contact recreation is a designation given to a waterbody where full body contact occurs and occurs from May 1 through September 30. The ADEQ also designates any stream with a watershed (e.g. drainage basin in the landscape) exceeding 10 square miles and those with smaller watersheds on individual cases (i.e. after site verification) for primary contact recreation. *Secondary contact recreation* designates waterbodies where activities such as boating, fishing, and wading take place and occurs from October 1 through April 30.

E. coli is measured in samples of water collected strictly following EPA guidelines. The measurement of *E. coli* starts within 8 hours of collection. This method provides an estimate of *E. coli* presence in the sampled water that is the most probable number (MPN) of *E. coli*. Using an EPA method provides numbers that are theoretically comparable to other labs using the same method. The MPN depends on growing bacteria in the laboratory in "culture" and is an approach used routinely in microbiology. This measurement is subject to high variability because of the nature of environmental bacteria; thus, variability in the data in *E. coli* counts from streams is not unusual. For this reason, it is important to establish background levels of *E. coli* in any water resulting from various wildlife, human (e.g., septic tanks, sewers), and agricultural (e.g. pig, chicken, cattle) sources.

E. coli thresholds are lower in late spring through summer (primary contact season) when more people are expected to be in contact with streams and lakes. More stringent limits also apply to Extraordinary Resource Waters (e.g., Buffalo River), Ecologically Sensitive Waterbodies, and Natural Scenic Waterways. During the primary contact season (May 1- Sept. 30), we do not want *E. coli* to exceed 298 MPN/100 mL, and during secondary contact season (Oct. 1 – Apr. 30) *E. coli* counts should not exceed 1490 MPN/100 mL in single samples.

III. How does the *E. coli* measurement "fit" into the context of the landscape?

While monitoring one bacterial species to assess the biological quality of water may seem simple, determining the actual ecological condition of a system is complicated. Measurement of *E. coli* is an indicator for potential fecal pollution and potential pathogen problems, but by itself, does not identify the source(s) of the bacteria.

E. coli is present in intestines (and feces) and is not supposed to grow in the environment; thus, the presence and abundance should indicate pollution and be directly related to human and animal sources. However, because *E. coli* is in many different animals (e.g. human, wildlife, agricultural) and because of the different pathways that bacteria may travel throughout the environment before ending up in water where we can measure it, the presence of *E. coli* does not identify the source of pollution.

IV. Why is *E. coli* monitoring important and why is it complicated?

There are many of factors that affect whether *E. coli* survives in the environment, for how long, and whether it moves to other locations. *E. coli* is adapted to living in intestines. After deposition from an animal, cells have to survive rapidly changing environmental conditions (e.g. temperature and moisture), exposure to harmful UV rays in sunlight, outcompete other organisms, and avoid predators. All these factors make it difficult to estimate how long *E. coli* will survive in lagoon, soil, and river environments. However, there is evidence that *E. coli* can persist in soil and sediments.

V. What are the numbers?

E. coli is measured weekly in Big Creek upstream and downstream of the C&H Farm, Mt. Judea, Newton County, Arkansas. Water sample collection for *E. coli* analysis began Sept 12, 2013, prior to manure from C&H Farm application to fields, either in fields adjacent to or distant from Big Creek. Manure application began in 2014 to fields distant from Big Creek, and then adjacent to Big Creek in March 2014. So far in the period following manure applications by C&H Farms (Jan 2 through May 19, 2014), no trends in *E. coli* with time or between sampling locations are apparent (Table 2).

The Table 2 data are detailed in the Big Creek Research and Extension Team Quarterly Reports and demonstrate the week-to-week variability in *E. coli* at upstream and downstream sites. The *E. coli* counts are expected to continue to be variable. Clearly, it is important to quantify the variability in *E. coli* concentrations long-term in order to determine if changes occur as a result of C&H operation.

The MPN is expected to increase with increases in flow, and the recent installation of a USGS gauge to measure flow will allow for the determination of the relationship between measured flow in

the stream and *E. coli* concentrations. Because of the dangers during high flows, most contact recreation is expected during base flow, and thus sampling during base flow may provide more meaningful data.

Table 2. Geometric mean of *E. coli* (and range of sample MPN) before (Sept 12 - Dec 17, 2013) and after manure applications began on the C&H Farm (Jan 2 - May 19, 2014).

C&H location	Before any manure application	After manure application
	Sept. 12 - Dec. 17, 2013	Jan. 2 - May 19, 2014
	(MPN/100mL)	
Upstream	82 (6 – 4080)	83 (ND[a] – 921)
Downstream	111 (5 – 3500)	39 (ND – 1553)

[a]Not detected.

Regulation

Arkansas Pollution Control and Ecology Commission # 014.00-002 2014. Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas as revised, effective March 24, 2014. Arkansas Department of Environmental Quality (ADEQ). Available at http://www.adeq.state.ar.us/regs/files/reg02_final_140324.pdf. Last accessed 20 Aug 2014.