Sediment *E. coli* as a Source of Stream Impairment

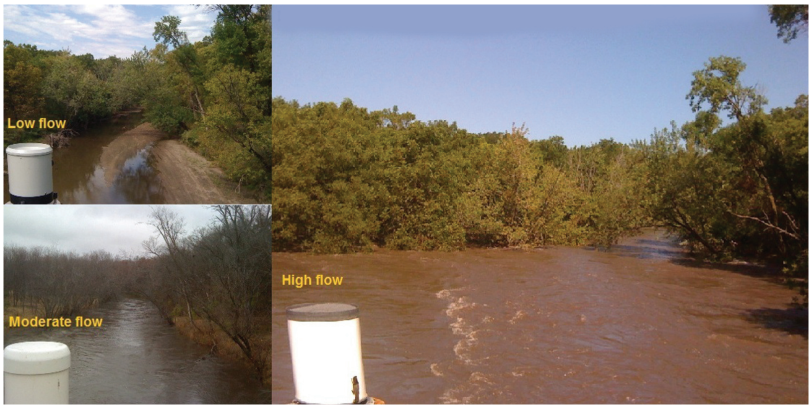
Michelle Soupir and Pramod Pandey

In the U.S., 74,863 surface water quality impairments are on the EPA's list of impaired waters, and the leading cause is high levels of pathogens or fecal indicator bacteria (FIB) in streams and lakes. To understand *E. coli* contamination in an agricultural stream, we monitored streambed sediment and the overlying water for *E. coli* concentrations over a range of flow conditions during storm events and characterized the impact of sediment *E. coli* on stream water quality. Data collected in the field were used to develop and test a model of *E. coli* resuspension that uses sediment transport theory to calculate the release of *E. coli* from the streambed sediment to the water column.

A limitation of the existing criteria

Typically, *E. coli* or enterococci are the two FIB used to detect the presence of pathogens originating from fecal contamination. More than 612,410 km of streams and 12 million acres of lakes and reservoirs are listed as pathogen impaired. High levels of pathogens or FIB in stream or lake water indicate a potential risk to human health. Ingestion of contaminated water may result in gastrointestinal illness in humans, including vomiting, diarrhea, fever, or rash. To protect public health, the ambient water quality criteria developed by the EPA in 1986 were recently revisited, and in 2012 the EPA established the new recreational water quality criteria (RWQC). The EPA's current fresh water quality criterion for *E. coli* is a geometric mean not exceeding 126 colony-forming units (CFU) per 100 mL, which corresponds to an estimated illness rate of 36 per 1,000 recreators.

These guidelines are important to protect public health, and improved modeling tools can help identify situations in which high levels of pathogens in streams can be expected. The levels of *E. coli* in streams are particularly driven by precipitation events. Our observations during high flow and normal conditions showed that the *E. coli* levels in streams change considerably within a short period. During precipitation events, fresh sources of FIB can enter a waterway through overland flow or subsurface pathways such as tile drainage. However, studies have also confirmed the presence of surviving "legacy" FIB in stream bottom sediment. These background organisms are a concern because the bottom sediment is resuspended, along with the FIB persisting in the sediment,



Flow driven water quality changes in the Squaw Creek, Iowa.

during high flow conditions. The EPA water quality standards were established based on sampling of overlying water and do not consider the presence of these legacy organisms.

The effect of legacy organisms

To get additional insight into these legacy organisms, we collected sediment and water samples in the Squaw Creek watershed near Ames, Iowa, during the first significant precipitation event of the season in spring 2013. The *E. coli* concentrations in the stream water followed a pattern similar to that of the stream flow, with *E. coli* concentrations increasing and decreasing with flow. The *E. coli* concentration varied greatly during the precipitation event, ranging from 360 to 37,553 CFU per 100 mL. These values are about 3 to 300 times greater than the EPA recommended value (126 CFU per 100 mL) and were observed within 12 hours of the precipitation event.

Because of the high flow caused by precipitation, the stream sediment characteristics changed dramatically during the study, with a decrease in the *E. coli* levels in the stream sediment corresponding to a decrease in the fraction of fine particles in the sediment. This observation is supported by previous studies, which found that *E. coli* tended to associate with cohesive particles and fine sediment.

Flow patterns in the Squaw Creek watershed are flashy, so we performed a scenario analysis to assess the impacts of a wide range of sediment *E. coli* concentrations and stream flows on the *E. coli* concentration in the overlying water. Previous researchers have observed sediment-to-water ratios ranging from 1 to 10,000, so we used this range of values along with a resuspension model that we developed earlier. At sediment-to-water *E. coli* ratios of 1 and 100, when the flow was low, the water *E. coli* load was equal to the total *E. coli* load, indicating that the sediment *E. coli* contribution was negligible at low flows.

However, as flow increased, the total *E. coli* load became considerably larger than the water *E. coli* load, indicating a significant contribution from the sediment *E. coli*. For example, for a sediment-to-water ratio of 100, the water *E. coli* load was less than 50% of the total *E. coli* load. The sediment *E. coli* contribution to the total *E. coli* load increased with flow; at high flows, resuspending *E. coli* dominated the total *E. coli* load. In addition, as the sediment-to-water ratio increased, the resuspending *E. coli* load also exceeded the water *E. coli* load at lower flows.

Future considerations

While our study and other studies are advancing current understanding of legacy *E. coli* in stream sediment, many questions remain as to how this information should be incorporated into total maximum daily loads (TMDLs) and watershed management plans. Few watershed-scale water quality models include FIB resuspension as an in-stream process. Stakeholder groups are anxious to implement management practices to improve water quality, but few strategies exist for mitigation of sediment-associated FIB.

ASABE member Michelle Soupir, Associate Professor, Department of Agricultural and Biosystems Engineering, Iowa State University, Ames, USA, msoupir@iastate.edu, www.public.iastate.edu/~msoupir.

ASABE member Pramod Pandey, Assistant Specialist/Microbiologist, Department of Population Health and Reproduction, University of California-Davis, USA, pkpandey@ucdavis.edu.

Further reading

Bai, S., & Lung, W. S. (2005). Modeling sediment impact on the transport of fecal bacteria. *Water Research, 39*(20), 5232-5240.

EPA. (2012). 2012 recreational water quality criteria. Washington, D.C.: U.S. EPA. Retrieved from www.epa.gov/wqc/microbial-pathogenrecreational-water-quality-criteria

EPA. (2015). Causes of impairment for 303(d) listed waters. Washington, D.C.: U.S. EPA. Retrieved from https://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T#causes_303d

Pandey, P. K., & Soupir, M. L. (2013). Assessing the impacts of streambed sediment on total *E. coli* load over a range of flows. *Journal of the American Water Resources Association, 49*(6), 1261-1269.

Pandey, P. K., & Soupir, M. L. (2014). Assessing linkages between *E. coli* levels in streambed sediment and overlying water in an agricultural watershed in Iowa during the first heavy rain event of the season. *Transactions of the ASABE, 57*(6), 1571-1581.

Pandey, P. K., Soupir, M. L., & Rehmann, C. R. (2012). A model to predict resuspension of *E. coli* from streambed sediments. *Water Research, 46*(1), 115-126.