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E. coli Resuspension During an Artificial High-flow Event in a Small First-order Creek

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Stream, pond, and lake sediments can serve as environmental reservoirs for *E. coli*, including pathogenic strains. Substantial increases in *E. coli* concentrations observed in stream water during rainfall events are often attributed exclusively to runoff from agricultural fields, pastures, and riparian areas. However, this increase can, to various extents, be caused by the resuspension of *E. coli* from sediment. The separation of runoff vs. sediment *E. coli* sources is not possible based exclusively on creek water sampling during natural rainfalls. The objectives of this work were (a) to create and monitor an artificial high-flow event that would cause *E. coli* concentration changes solely due to resuspension and settling, (b) to develop a model of *E. coli* transport in creek water as affected by resuspension and settling.

The study site, at the USDA-Beltsville Agricultural Research Center, is in the mid-Atlantic coastal plain of Maryland. The site contains a small first-order stream that is instrumented with four stations for monitoring stream flow and bacteria concentrations. The creek runs within a riparian corridor of variable width from about 65 m at its narrowest point, to more than 100 m. The creek bed is from 100 to 150 cm wide.

Prior to the high-flow experiment, the creek sediment was grab-sampled weekly for 2 months for *E. coli* concentrations at three locations downstream from stations 1, 2 and 4. Time and sample position across the creek were not significant factors affecting *E. coli* concentrations in sediment; location along the creek was a significant factor. Initial *E. coli* concentrations in top 1 cm (just prior to flow) averaged 4500, 2500, and 500 cell per g of sediment at locations 1 and 2 and 4, respectively. The *E. coli* concentrations in sediments decreased exponentially with depth by about one order of magnitude per 2 cm.

The artificial flow event was created by releasing 80 tons of tap water on a tarp-covered stream bank at 11 m above the station 1 at a rate of 60 L per second in four equal allotments separated by 1, 3, and 1 min break intervals. The initial flow in the creek was insignificant. Both rising and falling limbs of the hydrographs became less steep as the water pulse moved along the creek; the break intervals were not discernible in hydrographs at stations 2, 3 and 4. Bacteria breakthrough concentrations at all stations were typical for the advective-dispersive transport concept, and had the long tails indicative of low rates of settling caused by re-entrainment of the sediment and *E. coli* associated with it. The tail concentrations were far above the regulatory threshold for *E. coli* concentrations indicating microbiological impairment.

The *E. coli* mass balance computations showed that net *E. coli* resuspension rates (resuspension minus settling) upstream from station 1, and at the 140 m reaches between stations 1 and 2, and 2 and 3, were 15000, 6000, and 1500 cell per sq. m per sec, respectively. These rates could be crudely estimated as the total amount of bacteria in the top 1 cm sediment layer released within an hour. The bacteria concentrations in sediment samples from reaches approximately 2 hours after flow event initiation were smaller than before the event; this decrease compared favorable with the abovementioned resuspension rates. Although hydrographs at stations 2, 3 and 4 were quite similar, the net *E. coli* resuspension rate at the 350-m reach between stations 3 and 4, was -1500 cell per sq. m per sec, while the *E. coli* concentrations in sediment below station 4 did not change significantly.

Sediment texture varied along the creek. Sediment was predominantly sandy upstream from station 1, and between stations 1 and 2, while the amount of silt and clay gradually increased from station 2 to 4. Sediment bacteria con-

centrations were smaller in those parts of the creek bottom having a finer texture, and the net *E. coli* resuspension rate decreased. The differences in resuspension could be explained by the stronger association of bacteria with silty and clay sediment particles as compared with sandy particles. We have observed this previously with soils. Relatively small bottom roughness causes smaller bed shear stress could be another reason for the texture-dependent *E. coli* resuspension.

Overall, bottom sediments, as *E. coli* reservoirs, released bacteria in substantial numbers during the artificial high-flow event. Bacteria resuspension and settling rates were affected by the sediment texture. The observations in this work indicate that artificial high flow events can provide useful information on these rates in small creeks, and that the calibration of the convective dispersive transport model of suspended *E. coli* is apparently the technique of choice for obtaining this information.