Hydrologic controls on the fate of fertilizer nitrogen: Influence of groundwater-stream connectivity

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Elevated concentrations of nitrate (NO_3^-) in groundwater are common in the Atlantic Coastal Plain, USA, due to application of chemical fertilizers to agricultural fields. Much of the nitrogen (N) load to the Chesapeake Bay is first stored in groundwater before being discharged to coastal waters through base flow in streams. Biogeochemical reactions occur to varied extents in the streambed sediments through which groundwater discharges to gaining streams. In one low-relief stream on the Eastern Shore of Virginia, denitrification in streambed sediments removed 70-90% of the NO_3^- from groundwater [1]. This research explores hydrological and geochemical characteristics that may limit the potential for similar behavior in other streams.

Four streams with annual N flux of 3-7 kg NO_3^- per ha were studied to elucidate hydraulic and biogeochemical properties. Hydraulic head measured in piezometers installed 60, 100, 150 cm below the sediment-water interface was directed upward with groundwater rising 4-20 cm higher than the stream-surface elevation. Sediment cores were collected, and porewater and sediment were extracted at 10-cm intervals. Hydraulic conductivity was measured using small falling-head permeameters, organic matter (OM) content by ignition, and NO_3^- concentration by ion chromatography. Although draining a geologically uniform region, sediment varied physically and chemically among streams. Hydraulic conductivity had a strong inverse relationship to OM content. Combining hydraulic head with conductivity, we found the longest residence time of groundwater to be associated with OM-rich intervals that controlled upward flow rates. NO_3^- concentration had a weak inverse relationship to OM, but concentration in the porewater was low overall. The stream with the most conductive sediments had the highest NO_3^- concentrations. For three streams, NO_3^- exceeded levels in porewater suggesting that upstream surface-water conditions were an unquantified and influential factor in determining stream NO_3^- concentration even in strongly gaining streams.

[1] Gu, C., G. M. Hornberger, A. L. Mills, and J. S Herman. 2008. Influence of stream-groundwater interactions in the streambed sediments on NO_3^- flux to a low-relief coastal stream. *WRR* **44**, W11432, doi: 10.1029/2007WR006739.