Transport and Removal of Nitrate in Agricultural Headwater Streams

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Introduction

Peterson et al. (2001) observed that forested headwater streams with low nitrate concentrations (<0.6 mg N L-1) have short nitrate uptake lengths (<1 km). On the other hand, Royer et al. (2004) determined that agricultural headwater streams, with higher nitrate loading (0.5-10.8 mg N L^{-1}), have much longer uptake lengths (>200 km). Our ongoing study is examining two types of headwater streams (agricultural/urban and forested) that receive flashy hydrology and high nitrate loading (Figure 1). Our objective is to determine which abiotic (i.e., discharge, depth, velocity) and/or biotic (i.e., limiting nutrients) factors control nitrate uptake lengths in these headwater systems.

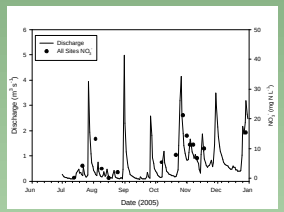

Figure 1. Hydrograph from a nearby USGS gaging station and average water column NO_3^- concentrations (mg N L^{-1}) from the study reaches.

Site Locations

We have identified five paired, 50-meter reaches (one agricultural/urban reach and one forested reach) along five headwater streams (n = 10) in the Upper Sugar Creek Watershed in Northeast Ohio (40°51'42"N, 81°50'29"W).

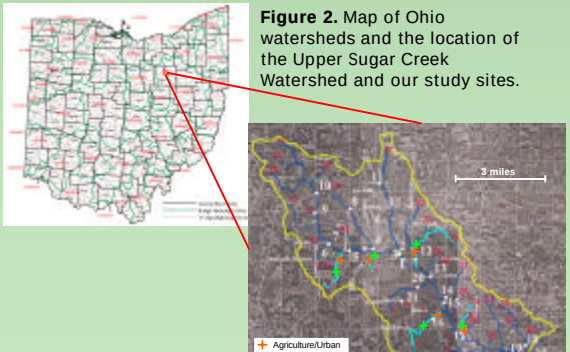

Figure 2. Map of Ohio watersheds and the location of the Upper Sugar Creek Watershed and our study sites.

Methods

- Average velocities for each reach were calculated via Rhodamine WT injections and measured in situ with a YSI 6600 (Figure 3)
- Denitrification was measured by the acetylene inhibition method on sediment slurries (Figure 4)
- Samples were measured as follows: N_2O with a ECD detector on a Shimadzu GC-14A, NO_3^- with a Lachat QuikChem 8500, sediment C and N content with a CE Instruments CHN Analyzer, and DOC with a Dohrmann-Rosement Total Carbon Analyzer
- Nitrate removal was measured via a nitrate uptake length ($S_{w,dn}$; Figure 5) and was calculated with the following equation: $S_{w,dn} = vh/(U/C)$ where v = velocity, h = water column height, U = aerial denitrification rate, C = concentration of NO_3^-

Figure 3. YSI 6600 probe measuring Rhodamine WT in a headwater stream.

Figure 4. Example of a sediment slurry in a media bottle. Gas samples were stored in 3 mL vials until processed.

Results

	Discharge (m^3 s^{-1})	[1]Travel Time (s)	[2]Time of Dispersion (s)	DOC (mg C L^{-1})	Total Carbon (%)	NO_3^- (mg N L^{-1})	$S_{w,dn}$ (km)
Ag/Urban	9.76 ± 0.81 x 10^{-3}	9.25 ± 5.62 x 10^2	0.99 ± 0.99	2.93 ± 1.15	3.38 ± 0.68	7.62 ± 6.32	2.1 ± 4.8 x 10^5
Forest	8.40 ± 0.93 x 10^{-3}	1.88 ± 1.56 x 10^3	1.81 ± 0.97	2.85 ± 1.18	3.53 ± 1.00	8.56 ± 7.11	0.8 ± 2.0 x 10^5
p-value	*0.418	*0.093	0.078	0.698	0.689	0.760	*0.9315
Summer	6.78 ± 8.69 x 10^{-3}	1.69 ± 1.58 x 10^3	1.33 ± 1.00	3.46 ± 1.39	3.75 ± 0.91	4.44 ± 4.94	8.0 ± 9.2
Fall	1.14 ± 0.82 x 10^{-2}	1.11 ± 0.75 x 10^2	1.47 ± 1.13	3.06 ± 0.64	3.16 ± 0.68	11.74 ± 6.07	2.9 ± 4.8 x 10^5
p-value	*0.103	0.311	0.758	0.421	0.118	0.009	<0.001

All results are mean ± 1 standard deviation; [1]Travel Time = reach length/average velocity; [2]Time of Dispersion = cross sectional area/dispersion coefficient; *Data was log

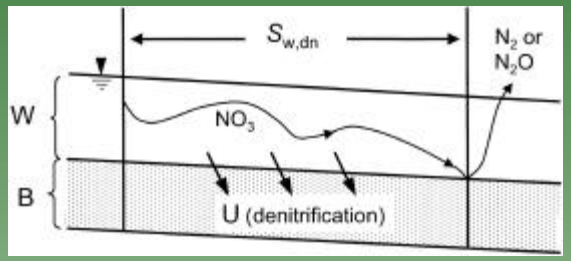

Figure 5. Conceptual diagram of a stream that consists of the water column (W) and the benthic sediments (B). The uptake length ($S_{w,dn}$) in this case is entirely dependent upon denitrification (taken from Royer et al., 2004).

Preliminary Conclusions

To date, we have collected data from the summer and fall of 2005 and still have over a year remaining in our study. The preliminary results show that forested headwater streams have longer travel times and greater mixing. However, the overwhelming nitrate loads from the surrounding watershed negates this hydrologic data. Consequently, there is not a significant difference between nitrate removal in agricultural/urban and forested streams. Only during summer, in periods of low discharge and low nitrate concentration, does either stream type appear to remove a substantial amount of nitrate. Overall, the data suggest that agricultural watersheds with fragmented areas of forested riparian stream is not enough to stimulate significant nitrate removal.

References

Peterson, B.J., et al. 2001. Control of nitrogen export from watersheds by headwater streams. Science 292:86-90.

Royer, T.V., Tank, J.L., and M.B. David. 2004. Transport and fate of nitrate in headwater agricultural streams in Illinois. Journal of Environmental Quality 33:1296-1304.

Acknowledgements

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