PROJECT SUMMARY

Title: A Basin-Scale Denitrification Budget for a Nitrate Contaminated Wisconsin Aquifer: A Study at the Groundwater/Surface Water Interface

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Investigators:
Bryant A. Browne, Associate Professor of Water & Soil Resources, University of Wisconsin – Stevens Point; George J. Kraft, Director and Professor, Central Wisconsin Groundwater Center, University of Wisconsin – Stevens Point; David Saad, United States Geological Survey, Water Resources Division, Madison, Wis.

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Background/Need:
Nitrate is a pervasive and increasing groundwater contaminant in Wisconsin. Many studies have found that nitrate is relatively conservative in groundwater. However, others have shown that nitrate can be transformed to nitrogen gas (denitrified) when reducing conditions are encountered along a groundwater flowpath (e.g., within riparian soil). Inadequate knowledge of groundwater denitrification hinders the development and application of accurate mass balance models for management of nitrate pollution.

Objectives:
The goal of this study was to achieve a better understanding of groundwater denitrification as a basin-scale control of nitrate concentrations and export from Wisconsin basins.

Methods:
The quantity and quality of groundwater discharging to the Little Plover River in Central Wisconsin was measured using a network of miniature wells at the groundwater/surface water interface (0.6 m beneath the streambed, distributed at 60-meter intervals over 10 km of headwater stream channel). Sampling surveys of all sites (n=160) were conducted in the summers of 2000 and 2001. A subset of sites (n=30) comprising a downwelling/upwelling sequence was sampled periodically. The concentration and load of denitrified-N carried into each 60-m stream segment via groundwater were quantified from the concentration of dissolved nitrogen gas (N_2) in excess of atmospheric equilibrium. Total groundwater nitrate was estimated from the sum of dissolved nitrate-N and excess N_2-N gas.

Results and Discussion:
For the average stream segment, 22 percent of groundwater nitrate-N (nitrate-N + denitrified-N) was discharged to surface water as excess N_2 gas (denitrified N). Higher denitrified N percentages were associated with low dissolved oxygen and high dissolved organic carbon of shallow (e.g., riparian soil) groundwater flowpaths. Lower denitrified N percentages were associated with indicators of deeper groundwater flowpaths (e.g., low DOC). Summed across all stream segments, the cumulative loads of denitrified N and nitrate-N were 45 kg/day and 157 kg/day, respectively, representing a basin-wide denitrification rate of 22.1 percent. Extrapolated

to an annual basis and expressed in terms of basin yield, these data indicate that approximately 57 kg/ha/yr were leached to groundwater as nitrate-N, of which 44 kg/ha/yr were released to surface water as nitrate-N. The remaining 13 kg/ha/yr were released to surface water as excess N_2-N (10 kg/ha/yr) or were transformed to excess N_2-N as surface water recharged groundwater in downwelling stream segments (3 kg/ha/yr).

Conclusions/Implications/Recommendations:
This study provides an aquifer-wide estimate of denitrification (13 kg/ha/yr) for a moderately thick (50-200 ft) surficial aquifer typical of many glacial/alluvial aquifers in agricultural settings in Wisconsin. Our results show that the transformation of NO_3^- to N_2 gas is quantitatively significant for the nitrate budget of agriculturally impacted aquifers. Approximately 22.1 percent of the total nitrate recharge to the aquifer (57 kg/ha/yr) was transformed to N_2 gas in groundwater. Groundwater denitrification appeared to be electron donor-limited in partially oxygenated intermediate and regional groundwater flow from remote upland recharge areas. Nitrate concentrations introduced by agricultural activity probably exceed the electron donating capacity of dissolved species in these flow systems. This suggests that increased loadings of nitrate to groundwater in the upland recharge areas will not be further offset or mitigated by biological nitrate removal via denitrification. In contrast, groundwater denitrification appeared to be nitrate-limited in a DOC-rich, local groundwater flow system associated with the near-stream environment. The near-stream, local groundwater flow system appeared to have additional capacity to buffer the stream's nitrate load against further increases in nitrogen loadings within the LPR landscape.

Because the annual recharge of the LPR aquifer is mostly derived during the rapid infiltration of coarse texture upland soils, intermediate and regional groundwater flow systems, which dominate the discharge to the LPR, carry low amounts of DOC to fuel the respiratory consumption NO_3^- by denitrifiers and have O_2 levels that potentially inhibit the activity of denitrifiers. Thus, our findings for the LPR basin may represent a lower-bound index of aquifer-wide denitrification. Similar studies should be performed in other basins to determine how basin characteristics (e.g., soils and geomorphology) affect aquifer-wide denitrification and further work should be done to clarify in what environments most denitrified N is generated (e.g., near-stream environment vs. intermediate and regional flowpaths).

This study contributes to a body of evidence that groundwater denitrification can substantially affect the load of nitrate delivered to aquifer-fed streams and that groundwater denitrification is an important factor controlling the collective release of N to large river systems from small agricultural basins.

Related Publications: none yet submitted

Key Words: nitrate, aquifer denitrification, groundwater/surface water interface, excess nitrogen gas.

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