Water Resources Graduate Program

Hyporheic Denitrification in an Upland Agricultural Stream: a ^{15}N Tracer Study

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H11B-0746

Ecosystem
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Introduction

Stream-groundwater (hyporheic, HZ) interactions are critical to understanding the transport and fate of nutrients, such as nitrogen, through catchments. However, the connections between HZ biogeochemeical and physical transport conditions that control nutrient dynamics are poorly understood. We used whole-stream steady-state ^{15}N-labeled nitrate ($^{15}NO_3$) and conservative tracer (Cl) additions to investigate the hydraulic and physiochemical factors controlling denitrification (Figure 1) in the HZ of an upland agricultural stream.

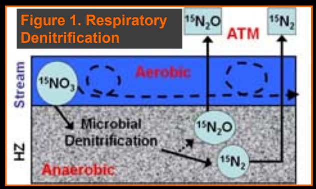


Figure 1. Respiratory Denitrification

Study Site

- We investigated a HZ of a lateral gravel bar located within the 300 m study reach of Drift Creek, Marion County, OR, USA (Figure 2)
- Drift Creek is a 3rd-order, upland agricultural, pool-riffle stream with coarse sediment (boulder to fine sand), slope of 0.007, and regionally high background NO_3 (~0.3-0.5 mg/L).

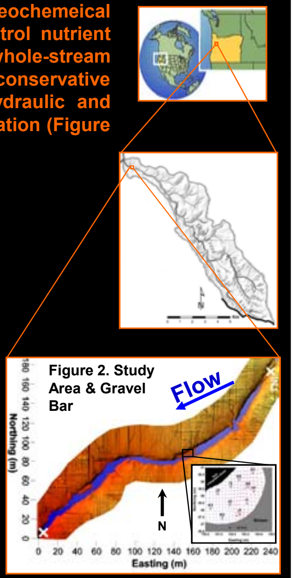
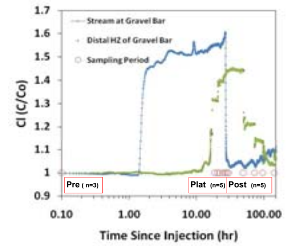


Figure 2. Study Area & Gravel Bar

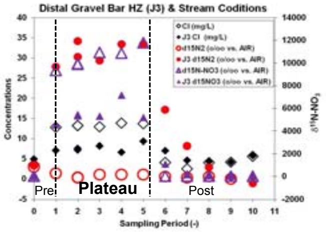
Methodology

- **Instrumented HZ:** well network (n=11), wells screened from 20-40 cm bgs to capture lateral HZ flowpaths across gravel bar.
- **Tracer Experiments:** whole-stream steady-state ^{15}N-labeled nitrate ($^{15}NO_3$) and conservative tracer (Cl) injection [similar to LINXII] to bring the instrumented HZ to equilibrium conditions.
- **Sampling:** measured solute concentrations relevant to the denitrification process ($^{15}NO_3$, $^{15}N_2(g)$, as well as $^{14}NO_3$, DOC, DO, Cl), and hydraulic transport parameters (head, flow rates, flowpaths, and residence times) of the reach and along instrumented HZ.
- **Sampling Regime:** Sampled during 3 phases of the injection: pre (n=3), plateau (n=5), post/recession (n=5). Plateau results are representative of the steady-state conditions and are the focus of this presentation.

Results & Discussion



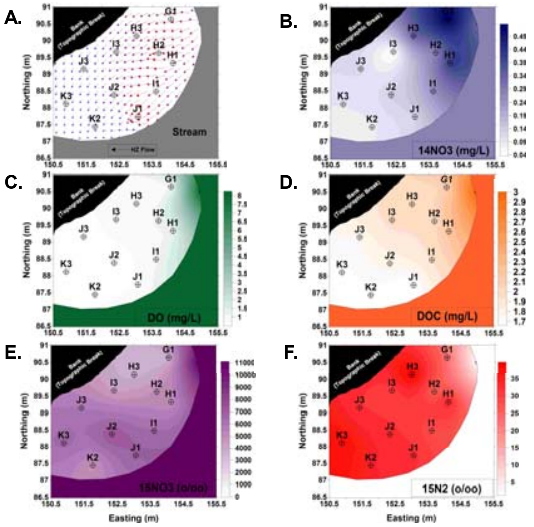
- Figure 3. Reach and a representative HZ well (J3) Cl breakthrough curve and sampling events .



- Figure 4. Comparison between Cl and ^{15}N species in stream and HZ well (J3). Note $^{15}N_2$ enrichment only in the HZ.

Plateau Denitrification Conditions in Space

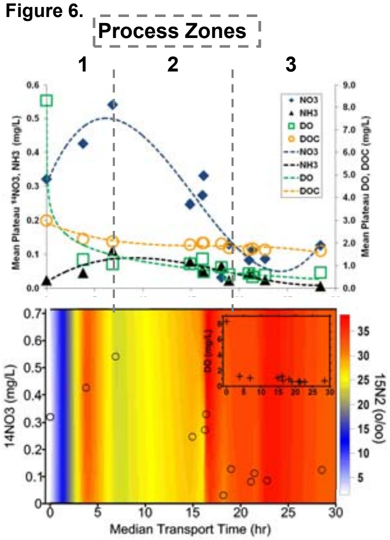
Figure 5



- HZ exchange was observed across the entire gravel bar with flowpath lengths up to 6.1 m and corresponding mean residence times greater than 21.5 hr (Figure 3A & 5A).
- Along HZ flowpaths from gravel bar head to distal well, $^{14}N\text{-}NO_3$ decreased from 0.34 to 0.02 mg/L (Figure 5B), DO declined from 8.31 to 0.59 mg/L (Figure 5C), and DOC dropped from 3.0 to 1.7 mg /L (Figure 5D).
- Rates of the $^{14}NO_3$, DO, and DOC removal were greatest in the first 2 m of the flowpaths but removal continued across the entire gravel bar. Conversely, the surface water chemical and nutrient conditions were more uniform across the length of the reach (N-NO_3: 0.31-0.34 mg/L, DO: 8.1-8.5 mg/L, DOC: 2.8-3.4 mg/L).
- $^{15}N_2$ was produced across the entire gravel bar HZ in all 11 wells) (Figure 5F).

Denitrification Conditions During HZ Transport

Figure 6.



HZ residence time is important to understanding denitrification processes in this gravel bar.

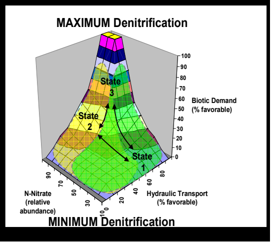
- The denitrification product, $^{15}N_2$, is produced within transport times <4 hrs but does not peak until >22hrs (Figure 6).
- NO_3 increases with transport times <6 hrs suggesting concurrent nitrification and denitrification during transport.. Increases in NH_3 and simultaneous consumption DO and DOC suggests nitrification via ammonification of a dissolved organic nitrogen sources (Figure 5B & 6).
- For transport times >6 hrs, most DO is consumed, DOC is depleted, and NO_3 continues to decrease indicating that denitrification dominants these times.

- This HZ contains multiple process domains that dictate nitrogen regulation and are related to physical transport times (Figure 6):

Zone 1: Nitrification > denitrification
Zone 2: Denitrification > nitrification
Zone 3: Denitrification >> nitrification

Conclusions

- $^{15}NO_3$ tracing confirmed that the removal of the NO_3 along the HZ flowpaths was primarily due to denitrification as $^{15}N_2$ was produced across the entire gravel bar HZ.
- These findings demonstrate that the HZ is an active sink of nitrogen in this system.
- <u>Overall</u>, results support our hypothesis that HZ denitrification is an important nitrogen sink in mid-network streams with significant NO_3, because denitrification in these systems will be less limited by HZ biogeochemical and physical transport conditions compared to streams above and below them in the network.



Acknowledgements: Support for this project was provided via National Science Foundation (NSF) grant EAR-041240 to RH, SMW, and MAB and DGE-0333257 to JPZ. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. Special thanks to: LINXers Linda Ashkenas and Suzanne Thomas for advising JPZ on stable 15N handling, Marshall Otter of MBL's Stable Isotope Laboratory for analyzing 15N samples, and Cam Jones/Kathryn Motter of CCAL and OSU IWW Collaboratory for help with analyzing general water chemistry.