Comparison of storm-event transportation trends on Nitrate in Chloride in a low-gradient stream within Central Illinois

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Nitrate ($\text{NO}_3^-$)

- $\text{NO}_3^-$ is sourced from fertilizers whose usage has increased over the past 80 years[1]

- With ever growing food demands, we can infer that $\text{NO}_3^-$ usage will continue to increase.

- High concentrations of $\text{NO}_3^-$ in surface waters are exacerbated by tile drainage, preventing subsurface flow and $\text{NO}_3^-$ removal[2]
NO$_3^-$ affect on Ecosystems

- Excess anthropogenic NO$_3^-$ in surface waters are responsible for resulting in algal blooms leading hypoxia$^{[3-6]}$

- The 16,000 km$^2$ Gulf of Mexico hypoxic zone is primarily attributed to anthropogenic NO$_3^-$ sourced from the Midwestern United States$^{[7-9]}$

- The Illinois River contributes 19% of the total NO$_3^-$ load to the Gulf of Mexico hypoxic zone$^{[3-6]}$

- These hypoxic zones deteriorate ecosystems, leading to fish kills and benthic organism mortality$^{[9-10]}$
NO$_3^-$ affect on Human Health

- National and Illinois EPA regard NO$_3^-$ as a Primary National Drinking Standard$^{[11-12]}$

- NO$_3^-$ limit for both National and Illinois EPA is 10 mgL$^{-1}$ as (NO$_3^-$-N)$^{[11-12]}$

- Consumption of excess levels of NO$_3^-$ can lead to:
  - Methemoglobinemia in infants and young children$^{[13]}$
  - The formation of nitrosamines attributed to gastric cancer$^{[14]}$
Hyporheic Zone (HZ) role in $\text{NO}_3^-$ cycling

- HZ is an important area of surface-subsurface interaction within streams & rivers\textsuperscript{[15-22]}

- Within the HZ denitrification can take place due to microorganisms who break $\text{NO}_3^-$ down into $\text{N}_2\text{O} (g)$ and $\text{N}_2 (g)$\textsuperscript{[23-24]}
  - This reaction is anaerobic or low dissolved oxygen (DO)\textsuperscript{[23]}
  - Requires high amounts of dissolved organic matter (DOM)\textsuperscript{[23]}

- Furthermore plant uptake can occur predominantly from benthic stream algae\textsuperscript{[25-26]}
Storms Impact on NO$_3^-$ in streams

- During storm events, stream stage increases as does the area of surface-subsurface exchange and the volume of the HZ$^{[27-29]}$
  - DOC remains constant$^{[28]}$
  - DO increases$^{[27]}$

- However, it remains to be studied how NO$_3^-$ behaves during elevated stream stage and whether or not stream banks play a crucial role in NO$_3^-$ removal and retention.

- Using Chloride (Cl$^-$), as a conservative tracer, we will compare its transport during storm events to that of NO$_3^-$. 
Objective

• If we measure that the behavior of $\text{NO}_3^-$ and $\text{Cl}^-$ concentrations during storm events are similar, then we can infer that transport during this time is conservative.

• If $\text{NO}_3^-$ and $\text{Cl}^-$ transport timing and amplitude of change differs may indicate that denitrification and uptake during storm events.
Questions

1. How do concentrations of $\text{NO}_3^-$ and $\text{Cl}^-$ change in response to storm events within the stream, hyporheic zone, and bank storage?

2. Are $\text{NO}_3^-$ and $\text{Cl}^-$ transported similarly in a low-gradient system?

3. Are $\text{NO}_3^-$ and $\text{Cl}^-$ transported similarly during different storm events?
Methodology

Sample Preparation

Weather Monitoring

Field Sample Collection

Well Sampling

Water Parameters

Ion Chromatograph Analysis

Mixing Model

using Weather.gov to monitor weather events

Take place over 24-hour storm event

Occur every 2-hours during event
Study Site

- T3 study site is a tributary of Evergreen Lake Watershed ELW) (105.45 km²)
  - ELW primary land cover is cultivated crops of 77.6%
  - ELW secondary land cover is developed land of 13.3%
- T3 stream is a modified low-gradient stream fed by tile drainage.
Study Site

- Silt-Clay layer is 1 meter in depth composed of organic-rich alluvium.
- Unconsolidated sand-gravel layer ~ 1.25 meters in depth.
- Compacted glacial till sits beneath.
- Stream bed composed of sandy-gravel-silt-clay layer ~50 cm in depth.
Field Sampling

• Sampling from 10, 30, and 50 cm depths in the stream and vertical HZ zone.

• 14 samples will be collected in total per rotation.
  • monitoring of pH, temperature, DO, and specific conductivity.

• Sample rotation will take place every 2 hours, with maximum monitoring duration lasting 24 hours.
Analysis

All samples will be analyzed in the Laboratory for Environmental Analysis (LEA) on a Dionex Ion Chromatograph, primarily measuring concentrations of $\text{NO}_3^-$ and $\text{Cl}^-$.

Will utilize a two-end member mixing model between Surface Water (SW) and Ground Waters (GW) to infer Stream Bank Concentrations of $\text{Cl}^-$ [30] in order to determine $\text{NO}_3^-$ mixing [30]

$$\%_{\text{SW}} = \frac{\left(C_{l_{\text{HZ}}} - C_{l_{\text{g}}}ight)}{\left(C_{l_{\text{s}}} - C_{l_{\text{g}}}ight)}$$

$$\text{NO}_3 - N = \%_{\text{SW}} \times (N_s - N_g) + N_g$$
Expected Results

[Graph showing nitrate and chloride levels over time with stream stage and hyporheic zone data]

- Nitrate: Chloride
- Stream Stage
- Stream Bank
- Hyporheic Zone
- Surface Water

Time (hours): 0 2 4 6 8 10 12 14 16 18 20 22
Stream Stage (meters): 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
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References


Questions