Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.37841

Capturing Slow Versus Rapid Flow Paths using Nitrate Isotopes in a Kentucky Karst Watershed

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Karst ecosystems generate additional complexity in nutrient transport and tracing. In these systems water, and the nutrients and pollutants they might carry, can circumvent “slow” infiltration through soil and bedrock and be transported to local waterways with little mixing. This direct connection between precipitation and runoff can limit denitrification and increase potential nutrient loads. Additionally, variability in precipitation event duration and intensity impacts the dominance of these slow and rapid flow paths. Knowing the likelihood and source of nutrient pollution in storms is critical for determining ideal remediation and prevention mechanisms.

Camden Creek in Kentucky, our study location, has an extensive history of nutrient-dynamic research within a karst agroecosystem. Nutrients in this system are sourced by a mix of agricultural land uses, including both synthetic fertilizer usage and significant manure generation. Previous research has shown that nutrient transport is likely controlled by storm events, seasonal variability, subsurface transport, and land use.

In this study, we utilize the stable isotope ratios of nitrate ($\delta^{15}N_{NO3-}$ and $\delta^{18}O_{NO3-}$) to constrain the sources and flow paths of nutrients during both seasonal shifts and a range of precipitation events. Nitrate isotope ratios can differentiate the system's dominant sources, particularly synthetic fertilizer, manure, and atmospheric nitrate via precipitation. Preliminary results of storm event nitrate isotope ratios show the significant influence of precipitation on nitrate isotopic compositions. We observe more positive $\delta^{15}N$ and $\delta^{18}O$ values during a storm event compared to baseline conditions. Storm $\delta^{15}N$ values suggest a predominant contribution from agricultural runoff, likely mobilized by increased surface flow and infiltration. Concurrently, $\delta^{18}O$ values indicated an influx of atmospheric nitrate from direct precipitation and rapid surface runoff. These shifts in isotope signatures during storm events support a blending of sources via dynamic mixing.