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Looking for simplicity in complex groundwater-surface water interfaces: A "simple" approach for determining hyporheic nitrate source-sink function

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Groundwater-surface water interfaces (GSIs) are characterized by complex hydrological and biogeochemical gradients that control the fate of many important ecosystem solutes, such as biologically-available nitrogen (N). However, this complexity limits our ability to predict their biogeochemical function across scales. Our research on N in GSIs strives to develop "simple" approaches that determine the biogeochemical function of stream GSIs (i.e. hyporheic and parafluvial zones), while recognizing the many sources of complexity. This research helps determine the relative role of the physical and biogeochemical controls on function across a range of temporal and spatial scales. For example, we used an advection, dispersion, and residence time model coupled with multiple Monod kinetic models to simulate the GSI concentrations of oxygen (O_2), ammonium (NH4), nitrate (NO_3), and dissolved organic carbon (DOC). These models when coupled with sensitivity analyses explored wide ranges of observed physical transport and biogeochemical kinetic conditions. These analyses revealed that GSI water residence time and O_2 uptake rate (via respiration and/or nitrification) dictates GSI function as either a source or a sink of NO_3 to surface waters. Furthermore, it showed that whether the GSI is a net NO_3 source or net NO_3 sink is determined by the ratio of the characteristic transport time to the characteristic reaction time of O_2 (i.e. the Damköhler number, DaO_2), where GSIs with $DaO_2 < 1$ will be net nitrification environments and GSIs with DaO_2 » 1 will be net denitrification environments. This coupling of the hydrological and biogeochemical limitations of N transformations across different spatiotemporal scales allowed us to explain the mechanisms behind the widely contrasting GSI functional results seen in previous field studies. Ultimately, these model results suggest that only estimates of residence times and O_2 uptake rates are necessary to predict net nitrification-denitrification function thresholds in stream GSIs. Therefore, the DaO_2 approach may be a simple approach for determining if freshwater GSIs will function as either a net source or sink of NO_3 across catchment scales.