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Attempting to link hydro-morphology, transient storage and metabolism in streams: Insights from reactive tracer experiments

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In-stream transient storage zones, including the hyporheic zone and vegetation beds, can be hotspots of biogeochemical processing in streams, enhancing ecosystem functions such as metabolism and nutrient uptake. The spatio-temporal dynamics and reactivity of these storage zones are influenced by multiple factors, including channel geomorphology, substrate composition and hydrology, and by anthropogenic modifications to flow regimes and nutrient loads. Tracer injections are a commonly employed method to evaluate solute transport and transient storage in streams; however, reactive tracers are needed to differentiate between metabolically active and inactive transient storage zones. The reactive stream tracer resazurin (Raz), a weakly fluorescent dye which irreversibly transforms to resorufin (Rru) under mildly reducing conditions, provides a proxy for aerobic respiration and an estimate of the metabolic activity associated with transient storage zones.

Across a range of lotic ecosystems, we try to assess the influence of stream channel hydro-morphology, morphologic heterogeneity, and substrate type on reach (10^3 m) and sub-reach (10^2 m) scale transient storage, respiration, and nutrient uptake. To do so, we coupled injections of Raz and conservative tracers (uranine and/or salt) at each study site. The study sites included: vegetated mesocosms controlled for water depth; vegetated and un-vegetated sediment-filled mesocosms fed by waste-water effluent; a contrasting sand- vs. gravel-bedded lowland stream (Q = 0.08 m^3/s); and a series of upland streams with varying size (Q = 0.1 - 1.5 m^3/s) and prevalence of morphologic features. Continuous time-series of tracer concentrations were recorded using in-situ fluorometers and EC loggers. At the stream sites, time-series were recorded at multiple downstream locations in order to resolve sub-reach dynamics. Analyses yielded highly variable transport metrics and Raz-Rru transformation between study sites and between sub-reaches within stream sites. Higher Raz-Rru transformation rates were typically observed in smaller streams, in sub-reaches with higher prevalence of morphologic features known to promote hyporheic exchange, and in mesocosms with higher water depth, vegetation density and retention time. However, relationships between transformation rates and common metrics of transient storage were not consistent among study cases, indicating the existence of yet unrealized complexities in the relationships between water and solute transport and metabolism. Further insights were also gained related to the utility of Raz and improved tracer test practices.