Biogeochemical Hotspots: Role of Small Water Bodies in Landscape Nutrient Processing

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Increased loading of nitrogen (N) and phosphorus (P) from agricultural and urban intensification has led to severe degradation of inland and coastal waters. Lakes, reservoirs, wetlands, and streams retain and transform these nutrients, thus regulating their delivery to downstream waters. While the processes controlling N and P retention are relatively well-known, there is a lack of quantitative understanding of how these processes manifest across spatial scales. We synthesized data from 600 sites across the world and various lentic systems (wetlands, lakes, reservoirs) to gain insight into the relationship between hydrologic and biogeochemical controls on nutrient retention. Our results indicate that the first-order reaction rate constant, k [T-1], is inversely proportional to the hydraulic residence time, τ [T], across six orders of magnitude in residence time for total N, total P, nitrate, and phosphate. We hypothesized that the consistency of the relationship points to a strong hydrologic control on biogeochemical processing, and validated our hypothesis using a sediment-water model that links major nutrient removal processes with system size. Finally, the k-τ relationships were upscaled to the landscape scale using a wetland size-frequency distribution. Results highlight the disproportionately large role of small wetlands in landscape scale nutrient processing, such that for the same wetland area removed, the nutrient removal potential lost is larger when smaller wetlands are lost. Our study highlights the need for a stronger focus on small lentic systems as major nutrient sinks in the landscape.