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Fate of polar trace organics in the hyporheic zone

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The hyporheic zone (HZ) is often considered to efficiently remove polar trace organic compounds (TrOCs) from lotic systems, mitigating potential adverse effects of TrOCs on ecosystem functioning and drinking water production. Predicting the fate of TrOCs in the hyporheic zone (HZ) is difficult as the in-situ removal rate constants are not known and the biogeochemical factors as well as hydrological conditions controlling the removal efficiency are not fully understood. To determine the in-situ removal efficiency of the HZ for a variety of TrOCs as a function of the biogeochemical milieu, we conducted a field study in an urban river near Berlin, Germany. Subsurface flow was studied by time series of temperature depth profiles and the biogeochemical milieu of the HZ by concentration depth profiles. These results, in conjunction with a 1D advection-dispersion transport model were used to calculate first-order removal rate constants as well as Damkoehler numbers of several polar TrOCs. For the majority of TrOCs investigated, removal rate constants were strongly dependent on redox conditions, with significantly higher removal rates observed under suboxic (i.e. denitrifying) compared to anoxic (i.e. Fe and Mn reducing) conditions. Compared to previous studies on the fate of TrOCs in saturated sediments, half-lives within suboxic sections of the HZ were relatively high, attributable to the site-specific characteristics of the HZ in a stream dominated by wastewater treatment plant effluent. For nine out of thirteen investigated TrOCs, concentrations decreased significantly in the HZ with relative removal percentages ranging from 32% for primidone to 77% for gabapentin. Damkoehler numbers further indicated that, depending on the TrOC, removal efficiency of the HZ is either limited by transport or by compound specific removal rates. For many TrOCs, removal efficiency decreased drastically as redox conditions became anoxic. For the majority of compounds investigated here the HZ indeed acts as an efficient bioreactor that is capable of removing TrOCs along relatively short flow paths. Depending on the TrOC, removal capacity may be enhanced by either increasing the magnitude of groundwater-surface exchange fluxes, by increasing the total residence time in the HZ or the exposure time to suboxic zones, respectively.