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Flume experiments elucidate relationships between stream morphology, hyporheic residence time, and nitrous oxide production

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The hyporheic zone is a potentially important producer of nitrous oxide, a powerful greenhouse gas. The location and magnitude of nitrous oxide generation within the hyporheic zone involves complex interactions between multiple nitrogen species, redox conditions, microbial communities, and hydraulics. To better understand nitrous oxide generation and emissions from streams, we conducted large-scale flume experiments in which we monitored pore waters along hyporheic flow paths within stream dune structures. Measurements of dissolved oxygen, ammonia, nitrate, nitrite, and dissolved nitrous oxide showed distinct spatial relationships reflecting redox changes along flow paths. Using residence times along a flow path, clear trends in oxygen conditions and nitrogen species were observed. Three dune sizes were modeled, resulting in a range of residence times, carbon reactivity levels and respiration rates. We found that the magnitude and location of nitrous oxide production in the hyporheic zone is related to nitrate loading, dune morphology, and residence time. Specifically, increasing exogenous nitrate levels in surface water to approximately 3 mg/L resulted in an increase in dissolved N2O concentrations greater than 500% (up to 10 μg/L N-N2O) in distinct zones of specific residence times. We also found, however, that dissolved N2O concentrations decreased to background levels further along the flow path due to either reduction of nitrous oxide to dinitrogen gas or degassing. The decrease in measurable N2O along a flow path strongly suggests an important relationship between dune morphology, residence time, and nitrous oxide emissions from within stream sediments. Relating streambed morphology and loading of nitrogen species allows for prediction of nitrous oxide production in the hyporheic zone of natural systems.