Reach-scale isotope tracer experiment to quantify denitrification and related processes in a nitrate-rich stream, midcontinent United States

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ABSTRACT: We conducted an in-stream tracer experiment with Br and ^{15}N-enriched NO_3^- to determine the rates of denitrification and related processes in a gaining NO_3^- -rich stream in an agricultural watershed in the upper Mississippi basin in September 2001. We determined reach-averaged rates of N fluxes and reactions from isotopic analyses of NO_3^-, NO_2^-, N_2, and suspended particulate N in conjunction with other data in a 1.2-km reach by using a forward time-stepping numerical simulation that included groundwater discharge, denitrification, nitrification, assimilation, and air-water gas exchange with changing temperature. Denitrification was indicated by a systematic downstream increase in the d15N values of dissolved N_2. The reach-averaged rate of denitrification of surface-water NO_3^- indicated by the isotope tracer was approximately 120 $\pm$ 20 μmol m^{-2} h^{-1} (corresponding to zero- and first-order rate constants of 0.63 μmol L^{-1} h^{-1} and 0.009 h^{-1}, respectively). The overall rate of NO_3^- loss by processes other than denitrification (between 0 and about 200 μmol m^{-2} h^{-1}) probably was less than the denitrification rate but had a large relative uncertainty because the NO_3^- load was large and was increasing through the reach. The rates of denitrification and other losses would have been sufficient to reduce the stream NO_3^- load substantially in the absence of NO_3^- sources, but the losses were more than offset by nitrification and groundwater NO_3^- inputs at a combined rate of about 500-700 μmol m^{-2} h^{-1}. Despite the importance of denitrification, the overall mass fluxes of N_2 were dominated by discharge of denitrified groundwater and air-water gas exchange in response to changing temperature, whereas the flux of N_2 attributed to denitrification was relatively small. The in-stream isotope tracer experiment provided a sensitive direct reach-scale measurement of denitrification and related processes in a NO_3^- -rich stream where other mass-balance methods were not suitable because of insufficient sensitivity or offsetting sources and sinks. Despite the increasing NO_3^- load in the experimental reach, the isotope tracer data indicate that denitrification was a substantial permanent sink for N leaving this agricultural watershed during low-flow conditions.