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The role of the benthic-hyporheic zone in controlling nitrous oxide emissions along two stream networks draining watersheds with contrasting land use

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Nitrous oxide (N_2O) is a potent greenhouse gas responsible of stratospheric ozone destruction. Denitrification in stream ecosystems occurs within the benthic layer at the sediment-water interface and within subsurface environments such as the hyporheic zone and results in N_2O production that could be eventually emitted to the atmosphere. Here, we quantify the role of benthic and hyporheic zones as sources of N_2O gas and explore the dependence of emissions from stream morphology, flow hydraulics, land use and climate using a recently-developed fully analytical framework. Variations in N_2O emissions within and among catchments of contrasting land use can be explained with a new denitrification Damköhler number (Da_D) that accounts for denitrification processes within both benthic and hyporheic zones. For initial model development, we found a strong relationship between Da_D and stream N_2O emissions using field data collected from multiple headwater streams (i.e., LINXII project) from different biomes draining contrasting land use. We then tested its generality by comparing N_2O emissions predicted with Da_D to those measured using a synoptic sampling campaign in two stream networks draining contrasting land use: Manistee R (Michigan, USA) and Tippecanoe R (Indiana, USA). Our dimensionless analysis shows that the effect of land use disappears after making the emissions dimensionless with respect to the nitrogen load. Reliable predictions of N_2O emissions at the stream network scale can be obtained from a limited amount of information, consisting in relatively easy to obtain biogeochemical and hydromorphological quantities.