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Hyporheic nitrogen dynamics in gravel bed rivers

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Streams often suffer of excessive nitrogen inputs from agricultural and urban areas. These inputs are the major responsible of streamś eutrophication and may be a source of nitrous oxide an important greenhouse gas formed during same hyporheic processes. Consequently, hyporheic exchange, which mixes surface and pore waters, affects both fluvial and terrestrial ecosystems and its inclusion in nutrients and contaminant transport model is necessary. In general, in-stream water continuously exchange between stream and sediment through the p̈umpingm̈echanism, which stems primarily from near-bed pressure gradients. Alternate zones of high (downwelling) and low (upwelling) pressure induce a complex flow pattern within the hyporheic zone with in-stream and pore waters entering the stream and the sediment, respectively. In the present work, we focus on the export of ammonium (NH_4^+), nitrate (NO_3^-) and their fate within the streambed of gravel bed rivers with alternate bars. We model hyporheic exchange with analytical solutions of the intra-gravel flows induced by streambed morphology and the fate of the inorganic compounds of nitrogen with a set of transport equations coupled with first order kinetics. Transport is solved by particle tracking, assuming negligible local dispersion and temperature dependant reaction rate coefficients. Through a Lagrangian approach we present the transport equation in term of hyporheic residence time, which is the controlling parameter of both retention and nitrification-denitrificaton processes. We investigate the important factors controlling the export of ammonium, nitrate, and production of nitrogen gases by the hyporheic zone. Our results show that the hyporheic zone acts as a sink of ammonium to an extent that depends on the nitrification rate but it may act as a source or a sink of nitrate. Additionally, it can influence the emission of nitrogen gases (N_2 and N_2O), depending on the ratio between ammonium and nitrate concentrations in the stream and on the biomass uptake. Moreover, stream morphology discriminates whether the hyporheic zone is source rather than a sink of these inorganic nitrogen species . Nitrification processes dominates in small steep streams because of the short residence time, while denitrification plays a major role in low-gradient large streams. Additionally, emissions of nitrogen gases increase with water temperature in small steep streams, but not with alluvium depth, because the hyporheic flow occurs primarily near the surface. On the other hand, the emission of nitrogen gases increases with both temperature and alluvium depth in low-gradient streams.