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Quantifying the nitrate removal capacity of the riparian zone in an agricultural catchment

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High nitrate concentrations in streams and groundwater occur in many agricultural catchments and pose serious threats for the ecological quality of aquatic habitats and drinking water quality. Countermeasures are directed at lowering the input of nitrogen to catchments but due to the long residence time of nitrate in groundwater, these measures will take decades to show an effect. Until then, other strategies are necessary to lower stream nitrate concentrations. Using the nitrate removal capacity of riparian zones by denitrification can be one effective option to minimize the export of nitrate from soil water and groundwater into surface waters.
Here we present a study in an agricultural headwater catchment in Northeast Bavaria that has been exhibiting high nitrate concentrations (50-80 mg L-1) in shallow groundwater and streams for many years. The streams in this catchment are primarily artificial ditches that collect the water from the extensive drain tile system beneath the agricultural fields. This headwater catchment is part of the Perlenbach catchment, which is still a habitat of the endangered freshwater pearl mussel. Various mitigation measures to control the export of nutrients and sediments into the Perlenbach have been implemented in recent years but in our experimental headwater catchment nitrate concentrations have remained high. Our experimental work has focused on characterizing the seasonal dynamics of nitrate concentrations in the ditches and shallow groundwater and on investigating the nitrate removal capacity of the riparian zone. We installed a network of nine shallow groundwater wells in the riparian zone that were sampled regularly over a period of six months from late winter into summer. With increasing flow distance through the riparian zone, average nitrate concentrations in shallow groundwater dropped by 95% to values generally below 2.5 mg L-1. However, nitrate concentrations in the surface waters remained around 50-60 mg L-1 with little seasonal variation. We also used the wells to perform push-pull tests and quantified reaction rate coefficients of nitrate removal of 0.03 h-1 and a removal rate of 0.7 mg L-1 h-1. Based on our results we suggest a conceptual model of nitrate flow pathways into the surface waters of the agricultural headwater catchment and present next steps for the design of a technical nitrate removal installation.