Geophysical Research Abstracts
Vol. 21, EGU2019-7017, 2019
EGU General Assembly 2019

Factors controlling nitrate export from a groundwater-dominated agricultural catchment: Insights from a multitracer study

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Multitracer observations (hydrochemistry, dissolved nitrogen excess, δ^{18}O and δ^{2}H of water, tritium, δ^{15}N, δ^{18}O and δ^{17}O of nitrate, δ^{11}B of borate) were performed during a three years period (summer 2014 – summer 2017) in surface waters and groundwaters of the Kocinka River catchment in southern Poland. This study, conducted in the framework of the BONUS SOILS2SEA project (www.soils2sea.eu), was part of an effort to work out new strategies aimed at reducing agricultural nitrate export from catchments based on understanding of local conditions.

The Kocinka catchment is underlain by an important fissured-karstic aquifer supplying drinking water to ca. 300 thousands inhabitants of Częstochowa city and its surroundings. Nitrate concentrations in the aquifer exceed in some of its parts, the 50 mg/L drinking water standard. Contrary to previous assessments, stable isotopic signatures of nitrate and borate point not to domestic wastewater but to agriculture being the main source of groundwater nitrate. Observations of dissolved nitrogen excess indicate that nitrate reduction potential in the groundwater system is limited. Furthermore, numerical model of nitrate transport calibrated with tritium data predicts that average travel times of nitrate from source to discharge areas are of the order of tens of years.

Longitudinal patterns of nitrate and tracer concentrations, as well as hydrometric observations reveal that deep groundwater dominates streamflow and nitrate fluxes in the Kocinka River and its tributaries. Downstream changes in nitrate concentrations reflect primarily various nitrate levels in groundwaters discharging from subsequent parts of the aquifer. A through-flow pond located in the upper reach of the Kocinka significantly reduces nitrate concentrations in the river, especially during warm periods of the year. However, nitrate flux is quickly replenished further downstream by groundwater inflows. In-stream reduction of nitrate concentrations (by 10 – 20%) could be observed only in the lower, semi-natural reach of the Kocinka, where the river does not drain groundwater and where the river channel is well-connected to the hyporheic and riparian zones.

Results of the study have important implications for agricultural nitrate management in the catchment. Reduction of nitrate loads to the Kocinka River from groundwater could be achieved only by a radical decrease of nitrogen surplus with consequences for agriculture profitability. Moreover, the time lags in groundwater nitrate transport will considerably delay effects of mitigation actions aimed at reduction of nitrate leaching from agricultural soils. Nitrate removal in ponds or small reservoirs appears to be the only viable solution for the reduction of nitrate export from this catchment.