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Archiv

Nitrogen degradation in a shallow groundwater-stream system of a lowland catchment (Saxony-Anhalt)

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1. Introduction

Diffuse nitrogen pollution in ground and surface waters is of concern especially in regions with intense agricultural activities. Observed nitrogen loads in surface waters often do not reflect the actual input situation. This apparent retention of nitrogen can be explained by various chemical transformations and hydrological processes in soil, groundwater and surface water. The quantification of these processes and their interactions was investigated by using isotope hydrology and mathematical process modeling.

2. Material and Methods

The investigations were carried out in the "Schaugraben" catchment located in the north of Saxony-Anhalt. The study site is a Pleistocene lowland catchment of 20 km², with mainly agricultural use.

Nitrogen sources and dominating in-stream turnover processes were identified by natural isotopic abundances of nitrate and DIC. Therefore stream and seepage water as well as shallow groundwater was analysed. N-turnover in soilwater and shallow groundwater was examined through field scale tracer experiments. For theese experiments 15N-nitrate was used as a reactive tracer and bromid as a conservative tracer.

In-stream N-turnover was investigated in a newly developed in situ benthic flow chamber. Conventional benthic chambers do not allow assessing the effect of flow velocities on denitrification rates. To ensure a laminar flow above the sediment surface in the 20*30 cm chamber, water was pumped in a closed cycle through the system by means of a peristaltic pump. To determine the denitrification rate water was enriched with $^{15}NO_3^-$. Nitrate fluxes into the sediments lead to the generation of $^{29}N_2$ and $^{30}N_2$ within the sediment (NIELSEN, 1992). From the generated N_2 isotopes the denitrification rate was calculated.

The complete nitrogen transport from the soil through the shallow groundwater and into the surface water drainage system was simulated by loose coupling of suitable models describing water fluxes and nitrogen turnover in soil and groundwater. The soil-water and nitrogen model mRisk-N was developed combining basically the soil water storage model SIMPEL (HÖRMANN, 1998) and the analytical soil-nitrogen model RISK-N (GUSMAN & MARINO, 1999). The model was used to calculate groundwater recharge and nitrate leaching as input data for subsequent groundwater modelling. Groundwater flow is simulated using Modflow (MCDONALD & HERBAUGH, 1988), groundwater solute transport is simulated with RT3D (CLEMENT, 1997). A specific reaction-module was developed to simulate various chemical processes in groundwater, such as degradation of organic matter by oxygen, nitrate, sulphate or pyrite oxidation by oxygen and nitrate, including the various denitrification reactions. In-stream processes are simulated with the river compartment module of AQUASIM (REICHERT, 1994).

3. Results

Nitrogen degradation in the unsaturated soil zone doesn't occur. The spatial distribution of nitrate concentrations in the uppermost groundwater layer is consistent with the spatial distribution of N-leaching from the soil. The surface near groundwater zone shows quiet high degradation-rates, hence nitrogen input will be degraded after short distances. In a broad band along the drain channels nitrate is completely removed. In these areas, the content of soluble organic matter is considerably higher than in the rest of the catchment, allowing for an effective removal of nitrate.

A comparison to observed nitrate concentrations and natural isotopic abundances in the Schaugraben drain channel suggests that groundwater contribution can not be the only source of nitrate to the surface water system. A significant contribution of other sources, such as drain flow and direct inputs of nitrate through fertilization, needs to be taken into account in order to explain elevated nitrate concentrations during winter.

Within a stream section nitrogen input as well as nitrogen degradation processes occur . In-stream degradation can be identified as a dominating process only in warm and dry periods in summer. Experiments with benthic-flow-chamber show higher in-stream nitrogen degradation than nitrogen degradation calculations based on stream nitrogen load measurements.

4. Conclusions

Conventional nitrate monitoring investigations do not allow the identification of in-stream denitrification processes in the study site, since there is continuous nitrate input into the stream system. In general, neither the nitrate input nor the nitrate degradation is known. This leads to an underestimation of both processes.

The distributed modelling approach and the implementation of a full reactive groundwater transport model allow the study of spatial and geochemical interactions at the catchment scale. The heterotrophic as well as the autotrophic denitrification will cause a reduction of reactive pools and thus should carefully be considered as an integral part of sustainable management strategies.

The overall share of in-stream denitrification of total nitrogen degradation on the catchment scale still remains unclear. For the interactions between terrestrial and in stream nitrogen turnover a coupling of a reactive transport groundwater model and a surface water quality model is required, implementing hyporheic zone processes.

5. Literature

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