Groundwater Pollution in an Agricultural Catchment on Sandstone: Evaluation of Water and Nitrogen Losses from Soils

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Abstract In order to quantify the effect of specific farming practices on the nitrate concentrations of the Luxembourg Sandstone aquifer, water movements and nitrogen fluxes were analysed at the field and catchment scale. The studied site is a moderate cropped area in eastern Luxembourg. Soils are of sandy, loamy and clayed types. Meadows (56%) and cereals (30%) cover most of the catchment. A first step simulations was executed with the SOIL-SOILN model. Results are compared with the mesured values. Soil analyses show important variations of mineral nitrogen concentrations related to the agricultural practices. Nitrogen leaching in the soils under fields cultivated with cereals is significantly higher than under meadows. Nitrogen concentrations vary over a large range in the soil pore water and depend on the type of culture, the cultivation practices and rainfall.

Keywords: Agriculture, Nitrogen, Nonpoint source pollution, Modeling, Soil model, Nitrogen model,Groundwater

INTRODUCTION

In agricultural regions, nitrogen leaching from arable land contributes to the contamination of groundwater resources. In the Grand-Duchy of Luxembourg, the Luxembourg Sandstone aquifer is the most important source of groundwater. It provides 8.10^3 m^3 of potable water daily. Actually, 1% of the population is supplied with water having nitrate concentrations above 50 mg NO_3/l and 20% of the population with nitrate concentrations between 25 and 50 mg/l (Ministère de l'Environnement, 1994 & 1997). Concerns about increasing nitrate concentrations have prompted actions to decrease nitrate input from agricultural land (Oeko-Fonds, 1998; Chambre d'Agriculture, 1998).

METHODOLOGY

In the present study, environmental management principles integrating heterogeneity in soils and agricultural practices were applied to an agricultural catchment in Luxembourg. The experimental site is located at Hersberg, 20 km north-east of Luxembourg (49°45'N, 06°20'E). The region has a mean annual precipitation of 795 mm (Altrier: 1961-1990). Meteorological data (precipitation, air temperature, air vapour pression, wind speed and solar radiation) were recorded with an automatic weather station at the experimental catchment. The soil consists of sand, loam and clay deposits, covering a 55 m thick sandstone. Six fields were selected to study nitrate movements as a function of different land use and farming practices. Plots were then equipped with ceramics cups and tensiometers. Drainage water from each plot was sampled weekly or biweekly. Tension water was measured at the same time. The concentrations of NO_3-N were determined by ion chromatography. Two coupled simulation models SOIL (Jansson, 1991) and SOILN (Johnsson et al., 1987) were used to calculate the water and nitrogen budget and estimate the nitrogen inputs to the ground water table. These models describe water flow and nitrogen transformations and transport in soils. The soil water and heat model provides driving variables for the soil nitrogen model such as infiltration, runoff, evaporation, water flow between layers and soil water content. The soil nitrogen model includes the major processes determining inputs, transformations and outputs of nitrogen in soils. Preliminary simulations were realised in order to estimate the influence of various parameters on water and nitrate fluxes. Soil profiles were divided in several layers down to a maximum depth of 152 cm. To estimate the impact of crops on the nitrate concentrations, several crop rotations were simulated with SOILN for different types of soil.

RESULTS AND CONCLUSION

Results from thirty months of field monitoring are presented. The water tensions measured in the field and those calculated by the SOIL model are compared. Water balances in six soil situations were calculated. Deep water losses were estimated. According to these results, soils of the catchment can be divided in two main soil classes. For the SOILN model, nitrogen concentration predictions are reasonably well estimated. During fall and winter periods a peak in nitrate leaching is observed because of the excess rainfall and the absence of nitrogen uptake by the plants. Differences in nitrogen concentrations under the six crop situations are observed. They underline the different environmental impacts of crops and meadows and the influence of the agricultural practices. The parameters generated by these simulations are used to model the nitrogen fluxes in all the areas of the catchment having the same soil and crop characteristics. This approach provides an estimation of the amount of nitrogen lost to the aquifer.

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