Using a catchment-scale model to predict spatio-temporal evolution of water quality and assess watershed vulnerability

C. Vautier, Université de Rennes 1, France
T. Babey, Université de Rennes 1, France
T. Kolbe, Swedish University of Agricultural Science, Sweden
J-R. de Dreuzy, Université de Rennes 1, France
J. Marçais, Université de Rennes 1, France
A. Gauvain, Université de Rennes 1, France
B.W. Abbott, Brigham Young University, Utah, USA
T. Labasque, Université de Rennes 1, France
L. Aquilina, Université de Rennes 1, France
G. Pinay, IRSTEA Lyon, France

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The evolution of ground- and surface water quality is a key-point for future generations and its prediction is crucial to advise public policies. In agricultural areas, the matter of nitrate legacy is of major concern, yet there is a lack of quantitative estimations of future nitrate budgets in streams and aquifers. We propose a prospective approach to predict the spatio-temporal evolution of the nitrate load in an agricultural catchment, and identify the main factors affecting water vulnerability to pollution.

Our work is based on a three-dimensional groundwater flow model of a 35 km² catchment located in Brittany, western France. The model was developed using FEFLOW and calibrated with atmospheric tracer data (CFCs) collected in 16 wells over the catchment [1]. Denitrification activity was further inferred using reactive tracer data (NO$_3^-$, O$_2$, N$_2$ excess). We simulate several scenarios of future nitrate inputs and evaluate resulting concentrations in the aquifer and in the streams over the next decades. This approach allows us to characterize the aquifer resilience by quantifying its recovery time after a decrease in nitrate inputs. More generally, it enables to assess the time lag between a change in agricultural practices and the return to low nitrate concentrations in the watershed.

The key factors controlling the vulnerability to nitrate pollution are identified by performing a sensitivity analysis on the predictions. We test the effect of several parameters (lithology, topography, spatial and temporal distribution of nitrate inputs and reactivity) on the evolution of nitrate concentrations in the aquifer to assess their respective roles on the aquifer vulnerability.

This study focuses on a particularly well-characterized catchment, where multiple data have been collected and computed since many years (CFC, NO$_3^-$, O$_2$, N$_2$, stream discharge, etc.). To test the applicability of our approach to less-instrumented sites, we analyze the sensitivity of the predictions to quantity, quality and localization of data. In a perspective of upscaling predictions, we aim to end up with a simple method of assessing vulnerability to nitrate pollution in areas where little information is available.

We believe that this type of approach could be a valuable tool for hydrogeologists as well as decision-makers working in agricultural areas.

References