Impact of Human Activity on Groundwater Dynamics (Proceedings of a symposium held during the Sixth IAHS Scientific Assembly at Maastricht, The Netherlands, July 2001). IAHS Publ. no. 269, 2001.

Modelling nitrate transport in deep aquifers: comparison of model results and field measurements

GERARD J. M. UFFINK
National Institute of Public Health and the Environment (RIVM), PO Box 1, 3720 BA Bilthoven, The Netherlands
e-mail: gerard.uffink@rivm.nl

Abstract The nitrate distribution in deep aquifers is being studied. Simulations were carried out for a study area in the east of The Netherlands (40×30 km^2). Model results are compared with data from the Groundwater Quality Monitoring Network. Based on preliminary runs modifications in the model are proposed. In a second series of runs these modifications are evaluated. A major factor is the vertical nitrate distribution. The steep vertical concentration gradients shown by the field data can only be simulated if vertical dispersion is reduced to the level of molecular diffusion. Several set-ups of the denitrification parameter are considered.
Key words nitrate; nitrate modelling; particle tracking technique

INTRODUCTION

During recent decades intensive animal husbandry has led to a significant rise of groundwater nitrate levels in the Netherlands. A National Groundwater Monitoring Network was installed during 1979–1984 to monitor the groundwater quality. The network provides information on present conditions, but to evaluate today's policy one must predict future changes in the nitrate content. Models are needed for prediction. Recently, a groundwater transport model (LGMCAD) has been developed at the National Institute of Public Health and the Environment (RIVM). The aim of the present study is to test the functioning of this model.

MATERIAL AND METHODS

Study area

The study area, known as "The Achterhoek", is located in the east of The Netherlands and covers an area of 40×30 km^2. The aquifer system consists of Pleistocene sandy layers that vary with considerably in thickness. Along the eastern boundary it ranges from 10 to 30 m, while in the northwest the thickness reaches 220 m and more. Some semi-pervious clay layers separate the aquifers in the western part of the area. Where the clay layers are absent the system acts as a single phreatic aquifer.

Flow and transport model

For groundwater heads and groundwater velocities the transport model relies on the LGM flow model (National Groundwater Model of The Netherlands). LGM is a finite element model for a multi-aquifer system (Kovar *et al.*, 1992). In the present study the groundwater flow is treated as a stationary system under the assumption of constant surface hydraulics and constant groundwater recharge from excess rainfall. The solute transport model (LGMCAD) is based on a *particle tracking* technique using a random walk to account for dispersion (Uffink, 1990, 1999). The advantage of this technique is the absence of numerical dispersion even for small dispersivity values.

Source of nitrate

Input for the transport model is the flux of nitrate leaching out of the unsaturated zone. Leaching rates for the area have been obtained by model studies (Van Drecht, 1993). Boumans & Van Drecht (1998) completed the data using a statistical analysis. Spatial variation due to differences in land use and crop type is also taken into account. The leaching rates mentioned above refer to various moments in time from 1950 to 1995.

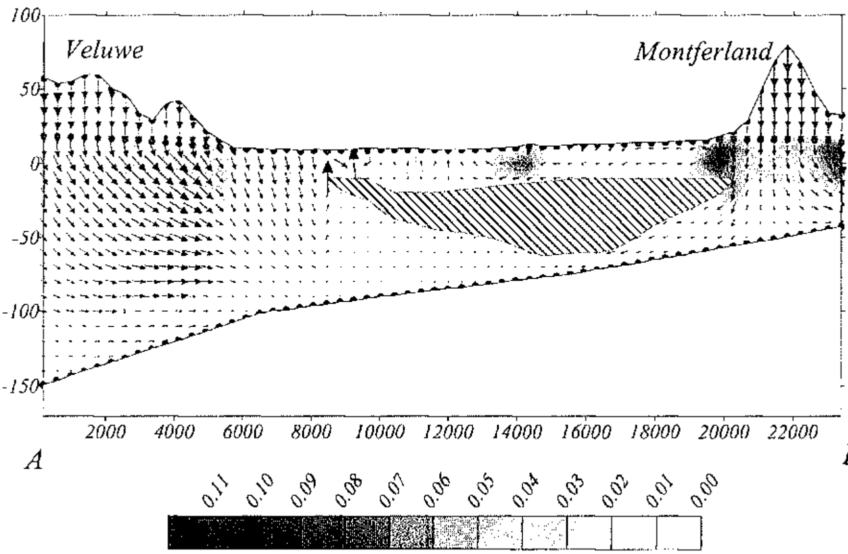

Fig 1 Shades of grey: calculated nitrate concentrations (in g l^{-1}) for 1995. Vertical axis: depth in metres NAP (standard Dutch reference level). Horizontal axis: distance in metres. Dots: phreatic surface.

RESULTS

Denitrification is modelled by first-order kinetics using the half-life time, T_{50}. Simulations have been carried out for various values of T_{50} ranging from 2–10 years. In some cases T_{50} was held constant over the area, while in others this parameter was varied spatially. The latter variation is based on the assumption that nitrate-reducing capacity increases close to the clay layers and near the valleys of rivers and brooks, due to the presence of organic material. Comparison of the first series of model results and field data indicated that vertical mixing by transverse dispersion was highly overestimated by the original model. Several modifications of the model were considered and tested. The most successful modification was the reduction of vertical dispersion to the level of molecular diffusion. Similar results are found in the international literature (Rajaram & Gelhar, 1991) and were reported in earlier field studies in the Netherlands (Maas, 1980; Uffink, 1990). As an illustration of the model results, a vertical cross section is included (Fig. 1). In our study the best fit between model results and measurements was obtained for T_{50} between 3 and5 years. This value is locally reduced to $T_{50} = 1$ year in a 5 m thick zone above and underneath the clay layers and in a 500 m wide strip on both sides of rivers and streams.

REFERENCES

Boumans, L. J. M. & Van Drecht, G. (1998) Nitrate in shallow groundwater in sandy areas in The Netherlands (in Dutch). *RIVM report 714801015*. Bilthoven, The Netherlands.

Kovar, K., Leijnse, A. & Gan, B. S. (1992) Groundwater model for The Netherlands. Mathematical model development and user's guide. *RIVM Report 714305002*. Bilthoven, The Netherlands.

Maas, C. (1980) Macrodispersion. Results of studies at Bergambacht and Remmerden (in Dutch). *Report Hyh 80-9, National Institute for Water Supply*. Voorburg, The Netherlands.

Rajaram, H. & Gelhar, L. W. (1991) Three-dimensional spatial moments analysis of the Borden tracer test. *Wat. Resour. Res.* 27(6), 1239–1251.

Uffink, G. J. M. (1990) Analysis of dispersion by the random walk method. PhD Thesis. Delft University of Technology, The Netherlands.

Uffink, G. J. M. (1999) LGMCAD, a solute transport module of the groundwater model for the Netherlands. User's manual. *RIVM Report 711401006*. Bilthoven, The Netherlands.

Van Drecht, G. (1993) Modelling of regional scale nitrate leaching from agricultural soils, The Netherlands. *Appl. Geochem.* Suppl. issue 2, 175–178.