Modelling two-phase transport of groundwater age tracers ($^3H/^3He$, CFCs and SF_6)

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Introduction

Groundwater age tracers ($^3H/^3He$, CFCs and SF_6) rely on the conservative transport of dissolved gases in groundwater.

Reactions between contaminants and the subsurface may produce gases that form a gas phase below the groundwater table. A gas phase below the groundwater table obstructs the conservative transport of groundwater age tracers and ordinary methods to interpret groundwater age tracers are no longer valid.

In this study, we used a numerical two-phase flow model to study the reliability of groundwater age tracers in degassed groundwater and assessed the accuracy of an analytical method to interpret degassed $^3H/^3He$ data [*Visser et al.*, 2007].

Modelled processes

(1) Denitrification of agricultural pollution produces large amounts of N_2 below the groundwater table in Noord-Brabant, the Netherlands.
(2) N_2 forms a gas phase and groundwater is degassed.
(3) Groundwater age tracers re-partition between the aqueous and gas phase.
(4) Gas flow and groundwater flow separate the gas from the water phase and end the conservative transport of tracers.

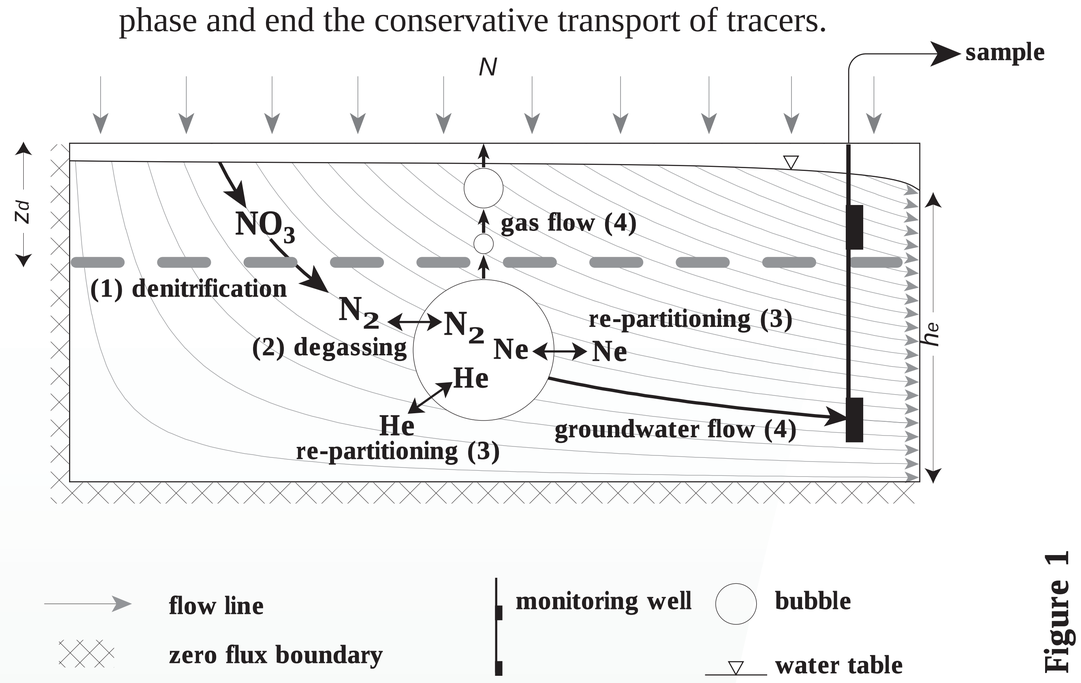

Figure 1

Methods

We used a two-phase groundwater flow and transport model [STOMP, *White and Oostrom*, 2000] to simulate the degassing of groundwater. We used model results to gain a better understanding of how to interpret degassed groundwater age tracers.

We manually calibrated a 2D model for each monitoring location to $^3H/^3He$ and TDG measurements. We adjusted recharge rate N, east boundary drainage level h_e and degassing depth z_d (Figure 1).

Data

We used a data set of 31 samples from 14 multilevel groundwater quality monitoring wells in the province of Noord-Brabant, the Netherlands. Measurements included:

- head
- total dissolved gas pressure (TDG)
- ^4He and Ne (indicating degassing)
- ^3H and ^3He
- CFC-11, CFC-12, CFC-113, SF_6

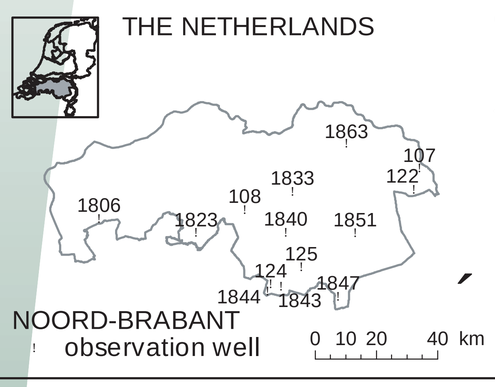

Figure 2

Results

- We were able to reproduce most of the variability in the amount of degassing (ΔNe), the ^3H and $^3He^*$ concentrations and $^3H/^3He$ age.
- Differences between modelled and measured CFC concentrations were caused by degradation of CFCs in anoxic environments.
- Most of the variability of SF_6 concentrations was caused by degassing and not by groundwater age. (Figure 3)

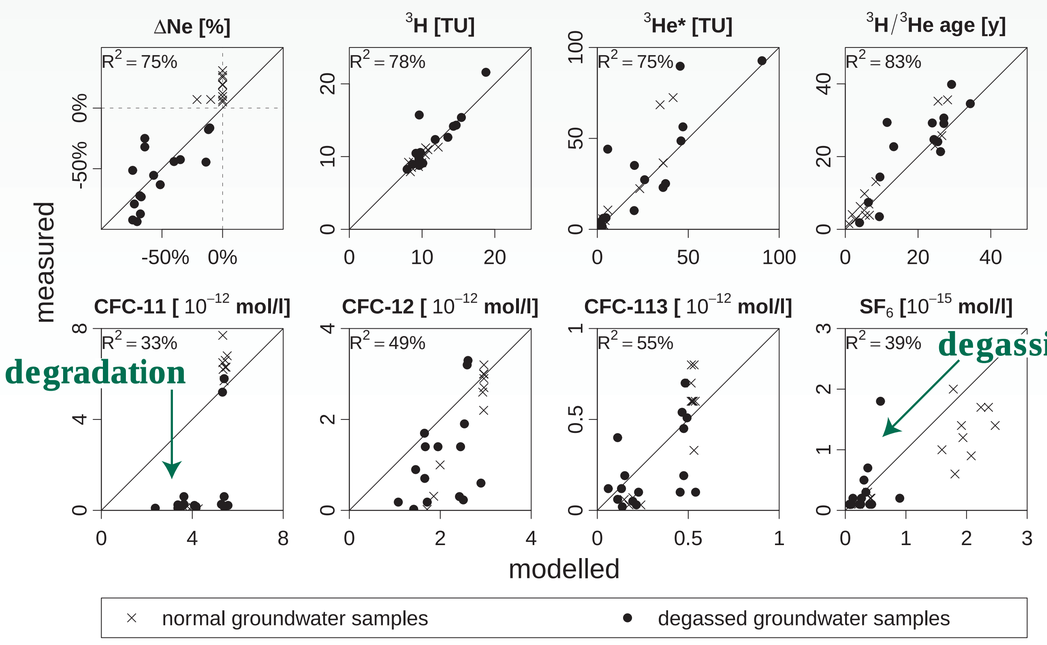

Figure 3

$^3H/^3He$ accuracy

We derived groundwater ages from modelled $^3H/^3He$ ratios in normal and degassed groundwater and compared them with actual groundwater ages.

The RMSE of the residuals between the $^3H/^3He$ ages of degassed groundwater and actual model ages was 1.43 year, which was only slightly larger than that of normal groundwater (1.33 year). (Figure 4)

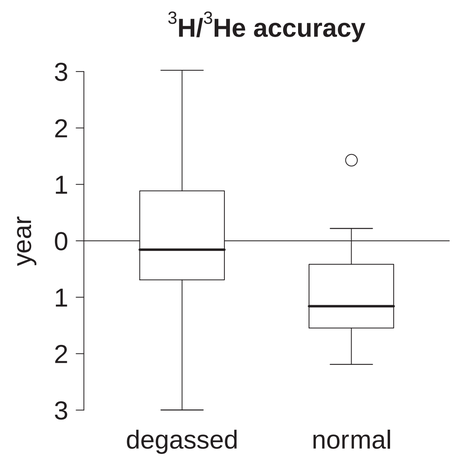

Figure 4

Conclusions

A manually calibrated numerical two-phase flow and transport model was successfully used to assess the reliability of age tracers in degassed groundwater.

- STOMP is capable of simulating the degassing of groundwater and re-partitioning of groundwater age tracers, providing a useful tool to interpret age tracers in degassed groundwater.
- Simulations showed that CFCs and SF_6 are not reliable groundwater age tracers under anoxic and degassing conditions.
- The accuracy of $^3H/^3He$ ages of degassed groundwater is close to that of normal groundwater.

References

Visser, A., H. P. Broers, and M. F. P. Bierkens (2007), *$^3H/^3He$ dating of groundwater degassed by denitrification*, Water Resources Research, accepted.

White, M. D., and M. Oostrom (2000), *STOMP Subsurface Transport Over Multiple Phases: Theory Guide*, Pacific Northwest National Laboratory, Richland, USA.

Acknowledgements

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