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.

Relationship between the nitrate attenuation zone and groundwater flow in a typical hillslope–wetland plot in Japan

SEIICHIRO IOKA, NORIO TASE & KUNIYUKI TOYAMA
Institute of Geoscience, University of Tsukuba, Ibaraki 305-8571, Japan
e-mail: tase@atm.geo.tsukuba.ac.jp

Abstract More than 100 piezometers were installed in 0.01-ha hillslope–wetland plot in the Tsukuba upland (Japan) to investigate in detail the three-dimensional distribution of nitrate concentrations and groundwater flow. Nitrate is attenuated at the hillslope–wetland interface, where groundwater flow is upward. However, the decrease of nitrate concentration is not remarkable in the thick sand and gravel layer and the thin surface soil layer. Dissolved N_2O concentrations and denitrification rates (activity) are correlated.

Key words attenuation zone; denitrification rate; dissolved N_2O; groundwater flow; interface between hillslope and wetland; Japan; nitrate

INTRODUCTION

It has become clear that riparian zones and wetland play an important role in the attenuation of nitrate in groundwater. However, the role of the hydrological cycle in nitrate attenuation in this buffer zone is not yet clearly understood, mainly due to the very complicated hydrogeological conditions (Mengis *et al.*, 1999). Therefore, there has been little quantitative evaluation and modelling of the nitrogen cycle in the buffer zone. Cey *et al.* (1999) showed that groundwater nitrate decreased when groundwater flow became downward at the interface between an agricultural field and the riparian zone. In contrast, Hedin *et al.* (1998) indicated the possibility that upward flow of groundwater to riparian sediments might induce nitrate attenuation. These research projects indicate that further studies on the relationship between groundwater flow and nitrate distribution in buffer zones are still necessary.

The purpose of this study is to clarify the relationship between groundwater flow and the distribution of nitrate concentrations at an interface between a hillslope and a wetland in Japan.

STUDY SITE AND METHODS

The study area is located about 15 km northwest of Lake Kasumigaura, Ibaraki Prefecture. The uplands and hillslope of the study area are farmed and the valley bottom (wetland) is used for rice cultivation, i.e. a rice paddy (Fig. 1).

The geology of the site consists of five layers. The top layer is a soil which covers the entire slope and thickens towards the valley bottom. The soil is underlain by a clay layer in the upper part of the slope. Beneath the surface soil (lower slope and wetland)

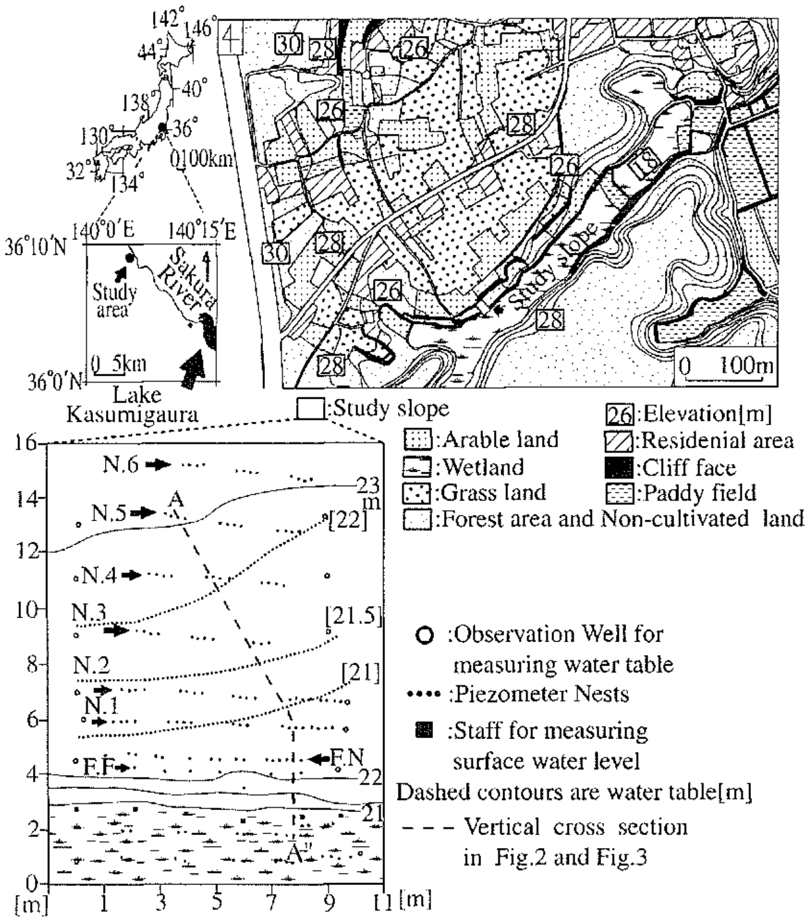

Fig. 1 Map showing the location, landform, and land use of the study area, the location of piezometers and observation wells at the hillslope–wetland plot, and water table elevations on 1 August 2000.

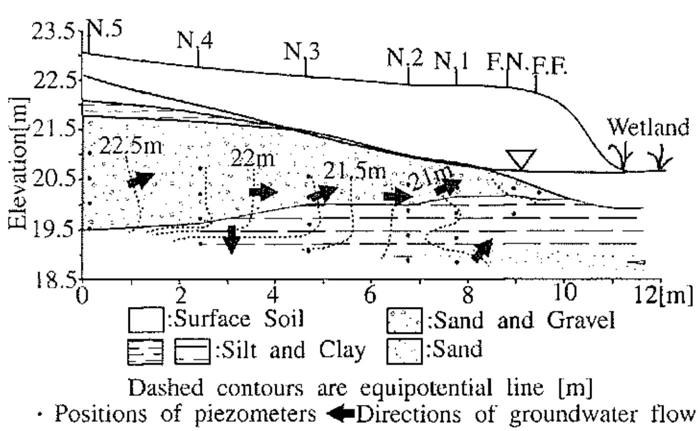

Fig. 2 Geological cross-section and water table.

or the clay layer (upper slope), is a sand and gravel layer which is thickest under the upper slope and thins towards the wetland. The sand and gravel is underlain by a silt and clay layer confining a deeper sand layer (Fig. 2).

The hillslope–wetland plot was instrumented along eight transects, which are almost parallel to the slope; more than 100 piezometers with depths from 2 to 3.5 m were installed (Fig. 1). Since August 2000, the groundwater samples have been collected from the piezometers using a polyethylene tube and syringe. Electrical conductivity and pH were measured in the field. Cations and anions were analysed using an ICP (inductively coupled plasma) and an ion chromatograph, respectively. Alkalinity was determined by titration. To evaluate denitrification, N_2O dissolved in the groundwater, and denitrification rate or activity of sampled soils, were measured by gas chromatography and using the method of Yoshinari *et al.* (1976), respectively.

RESULTS AND DISCUSSION

The water table as shown in Fig. 2 correlates with the landform. The nitrate and N_2O concentrations, and denitrification rate along the cross-section of A–A" (Fig. 1), and the nitrate concentrations along each transect from N.3 through to F.F. are shown in Fig. 3. The groundwater flow in the sand and gravel layer is mainly horizontal from the hillslope towards the wetland, but in the silt and clay layer is downward. However, groundwater flow is vertically upward downslope of the N.1 transect. The nitrate concentrations in the silt and clay layer decrease with depth, which may be due to decreased penetration or the hydraulic barrier (lower permeability) of the strata (Cey *et al.*, 1999). In addition, nitrate concentrations decrease downslope of the N.1 transect in each strata, and are relatively greater in the thick sand and gravel layer compared to the other strata. For the F.F transect, nitrate concentrations are low at all the piezometers. The dissolved N_2O is correlated with the denitrification rate, but there are some significant departures along the cross-section and within some transects, which are being investigated.

CONCLUSIONS

The nitrate attenuation occurs not in the bottom valley or wetland itself, but within a narrow zone at the foot of the slope. The nitrate attenuation zone is located in the lower slope below the N.1 transect where groundwater flow is predominantly upward to the wetland. The decrease of nitrate concentration is not remarkable in the thick sand and gravel layer or the thin surface soil layer. The dissolved N_2O gas concentrations and the denitrification rates (capacity) are correlated but their relationship with nitrate concentrations needs to be studied further.

Acknowledgement This research was partly supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture, Japan (no. 11555135).

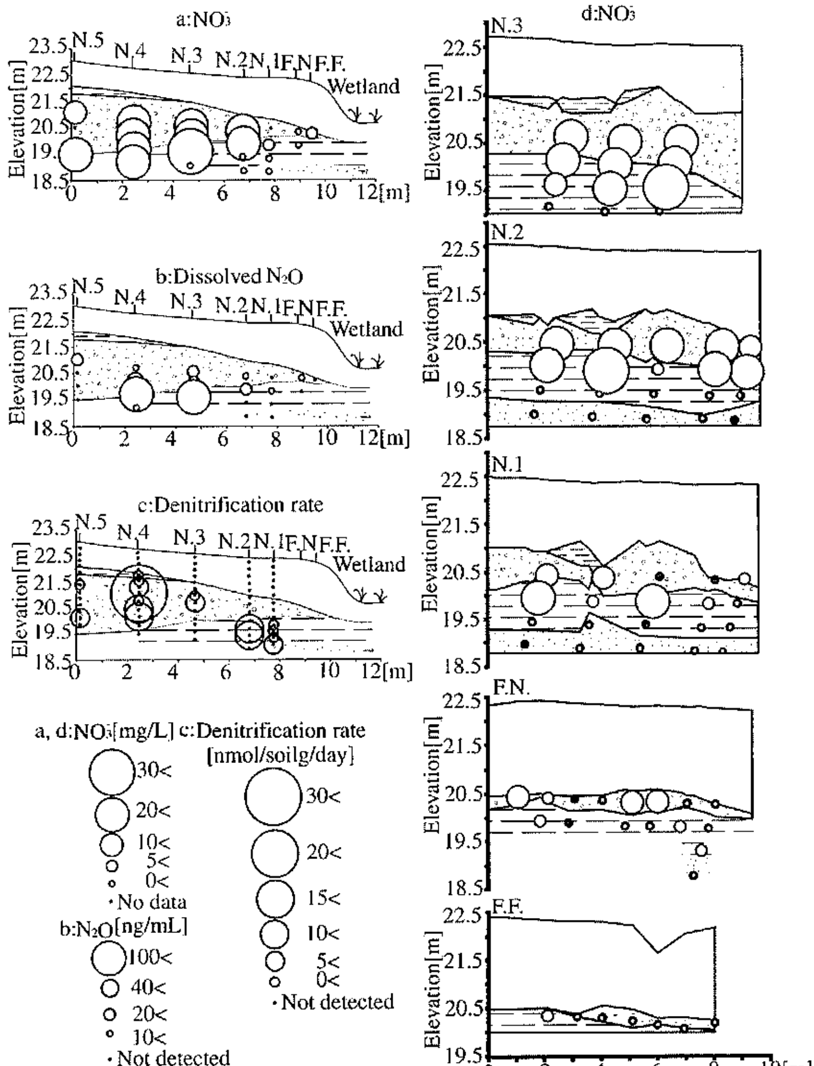

Fig. 3 Nitrate concentrations, N_2O concentrations, and denitrification rates along the transect A–A" (Fig. 1) of the hillslope-wetland plot.

REFERENCES

Cey, E. E., Rudolph, D. L., Aravena, R. & Parkin, G. (1999) Role of the riparian zone in controlling the distribution and fate of agricultural nitrogen near a small stream in southern Ontario. *J. Contam. Hydrol.* **37**, 45–67.

Hedin, L. O., von Fischer, J. C., Ostrom, N. E., Kennedy, B. P., Brown, M. G. & Robertson, G. P. (1998) Thermodynamic constraints on nitrogen transformations and other biogeochemical processes at soil–stream interfaces. *Ecology* **79**(2), 684–703.

Mengis, M., Schiff, S. L., Harris, M., English, M. C., Aravena, R., Elgood, R. J. & MacLean, A. (1999) Multiple geochemical and isotopic approaches for assessing groundwater NO_3^- elimination in a riparian zone. *Groundwater* 37(3), 448–457.

Yoshinari, Y. & Knowles, R. (1976) Acetylene inhibition of nitrous oxide reduction by denitrifying bacteria. *Biochem. Biophys. Res. Commun.* 69, 705–710.