

ATTENUATION OF NITRATE IN THE SUBSURFACE ENVIRONMENT OF A LOWLAND DAIRYING CATCHMENT

STENGER, R¹; BARKLE, G², WALL, A¹; CLAGUE, J¹

¹ Lincoln Environmental Research, LVL, Hamilton, New Zealand,
stenger@lvlham.lincoln.ac.nz, 07-858-4844, Fax 07-858-4841

² Aqualinc Research Limited, Hamilton, New Zealand

Introduction

The ongoing expansion and intensification of dairy farming has the potential to further increase the contamination of ground and surface waters with nutrients. Land use impacts on surface water quality in the Toenepi dairying catchment have been investigated since 1997 (Wilcock et al., 2006). To improve the understanding of processes occurring during the transport of nitrogen from the land surface to the stream, in 2002 we initiated additional research on the nitrogen dynamics in the vadose zone - aquifer continuum (Stenger et al., 2008).

Catchment characteristics

The Toenepi catchment is situated in a long-established dairying area near Morrinsville, Waikato, in the North Island of New Zealand. It comprises low rolling downlands along most of the catchment boundaries, while the central corridor alongside Toenepi Stream and the catchment outlet form part of the alluvial plains.

Well-drained Typic Orthic Allophanic Soils occur on easy rolling to rolling slopes and account for approx. half of the catchment area. Less well drained Typic Orthic Granular Soils occur in approx. 40% of the catchment. These soils are overlying older strongly argillised Pleistocene volcanic ash beds ('Hamilton Ash'). Typic Recent Gley Soils, which have developed from recent alluvium on river flood plains and are characterized by a naturally high water table, are found in the remaining catchment area. Their subsoils are predominantly sandy and consist of cross-bedded sands and gravelly sands with occasional lenses of peat, silts and clays (Wilson, 1980).

In 2003, 18 of the 24 farms in the catchment were dairy farms, with the balance being drystock farms and a horse stud. The average stocking rate of all dairying land was 3.1 cows ha⁻¹, ranging from 2.5 to 4.3 cows ha⁻¹ on individual farms. Annual N fertiliser application on the dairy farms varied from 28 to 227 kg N ha⁻¹, with an average of 99 kg N ha⁻¹ for the dairying land.

Results and discussion

NO₃-N concentrations in the shallow groundwater monitored from December 2002 to December 2004 were generally very low in spite of the reasonably high land use intensity on the dairy farms. Approximately 80% of all samples analysed had nitrate concentrations below the ANZECC trigger value for eutrophication of surface water (0.44 mg NO₃-N L⁻¹). These unexpectedly low nitrate concentrations suggested that substantial nitrate attenuation may be occurring in this lowland catchment.

Heterotrophic denitrification is the most likely reason for the particularly low nitrate concentrations found in shallow groundwater underlying the Gley Soils. These poorly drained soils are characterised by high water contents and thus poor aeration in close proximity to the

root zone of the pasture, where microbial activity is greatest and organic matter is most abundant.

However, similarly low groundwater nitrate concentrations were also observed at several sites under well drained Allophanic Soils. Subsequent monitoring of NO₃-N concentrations (30, 60, 90, 120, 155cm depth) at a site with well drained Allophanic Soil showed a consistent pattern of decreasing NO₃-N concentrations below 90cm depth throughout the whole monitoring period of 15 months. Examination of that profile suggested that denitrification occurring below the root zone was the most likely reason for the decreasing NO₃-N concentrations. While the top 80 cm of the profile consisted of well drained reddish-brown soil, redox-mottling due to periodically occurring reducing conditions was evident from approx. 80 – 130 cm depth. The predominantly greyish colours of the clay found below 130 cm depth indicated more persistent reducing conditions due to longer periods of saturation. Visual inspection of additional borehole samples confirmed that reducing conditions deeper in the vadose zone could also explain the unexpectedly low groundwater NO₃-N concentrations observed under well drained soils in other parts of the catchment.

Accordingly, the combination of field (e.g. dissolved oxygen) and laboratory parameters (e.g. dissolved Mn and Fe) analysed in 2007 on groundwater samples from representative sites throughout the catchment demonstrated that some degree of reducing conditions existed in the majority of sites being monitored.

Apart from one well, NH₄-N concentrations were $\leq 0.15 \text{ mg L}^{-1}$, indicating that dissimilatory nitrate reduction to ammonium (DNRA) and abiotic nitrate reduction to ammonium were not relevant pathways for nitrate reduction in this catchment. Heterotrophic and/or autotrophic denitrification are thus considered to be responsible for the low nitrate concentrations observed in the shallow groundwater. This hypothesis is currently being tested with further experimental work in the catchment.

Independent of the exact processes involved, it is apparent that nitrate reduction below the root zone is widespread in this catchment. Estimates of NO₃-N leaving the root zone of the pasture, as provided by nutrient budget models like OVERSEER[®], are thus not sufficient to evaluate the effect of leaching losses on ground and surface waters in catchments such as this, where nitrate reduction can occur below the root zone.

References

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